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Development of a Directed Teleport Function for Immersive Training in Virtual Reality

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***Abstract*—Recent advances in Virtual Reality (VR) technology have contributed to the development of immersive applications for training and simulation. VR serious games can be utilized to support and supplement traditional training. In VR-based training environments, the player can make mistakes without serious consequences to gather experiences which help them to make better decisions in the future. However, it is difficult to guide the player's attention throughout the VR game, since the player has the freedom to look anywhere anytime. Thus, many game designers create linear and restrictive experiences. In this paper, we develop a dynamic story and guide the player's attention to the specific game elements. To this end, we propose a novel directed teleport function to show points of interest to the player. We evaluate the effect of the proposed function by conducting a user study among two groups of 20 participants: one group can use only the common teleport function, whereas the other group can additionally use the directed teleport function. The results of our study indicate that the directed teleport function is very effective, has a positive effect on the orientation, and is very easy to use. In particular, the directed teleport function not only helps the player to navigate through the virtual world but also reveals interesting points.**

***Index Terms*—Immersive Virtual Reality, Serious Game, 3D Storytelling, Virtual Worlds, Training, Simulations, Teleportation, Full-Body Motion Reconstruction, HTC Vive**

I. Introduction

Games and game technology are becoming increasingly important to enable immersive training in virtual environments. However, when creating such immersive virtual reality (VR) games, the game developers face a variety of challenges. For example, because the players are free to look anywhere at any moment, it can happen that they are looking somewhere else when an important event is taking place. Therefore, many game designers restrict the experience to a linear layout [1], so that the players are more likely observers of the story instead of participants. When the players cannot influence the story and feel like they are forced to follow a specific path, this will destroy immersion.

Due to recent advances in VR technology, many immersive serious games for training and simulations were developed. Serious games can be used to support or supplement training. Simulations are often provided to train specific action sequences that are not always possible in the real world because they are either too risky, too complicated or too expensive. Indeed, researchers have found that serious games have a positive impact on training results [2]. If the scenarios in the virtual environment vary, the effectiveness of the training can be increased. At the same time, the skills and knowledge acquired while playing serious games can be transferred to the real work tasks.

In this paper, we present a serious game, which considers the player's input. The game results in multiple paths, depending on the player's action, while still guiding the player's attention. We reach the player's attention through various means: (1) using a non-player character (NPC) to guide the player through the story without restricting the player's choice of action and (2) with a novel teleport function. We propose a directed teleport function, which shows the points of interest (POI) to the player. The common (traditional) teleport function teleports the player from one place to another, while the orientation of the player remains unchanged. With the directed teleport function, the designer can specify the direction the player will be facing after the teleportation. The directed teleport function serves as an indicator of exciting events and is useful for guidance. When the player sees such a point in the virtual world, he or she will gravitate towards that place.

The game designer can deploy the directed teleport function across the virtual environment to fulfill two purposes: to enhance movement in the virtual world and to improve the player's guidance. The directed teleport function can be used to explore the virtual world without continually turning and it also reduces trip hazards caused by cables attached to the headset. Furthermore, the directed teleport function can also be used to show POI to the player. In familiar VR games, the events are usually triggered when the camera view frustum intersects a specific object to ensure that the events are shown only when the player is looking at it. However, the player

Fig. 1: Top-down view of the game scene (left). The player chases the red vehicle around the block until the police car is near enough to signal the vehicle to stop in order to investigate it (right).

often does not know that at one particular position something is interesting or is distracted by something else. Thus, the player will eventually miss essential story elements. Therefore we propose the directed teleport function so that the game designer can utilize the teleport points to indicate exciting story elements, e.g., objects which the player should discover or events which are triggered as soon as the player is near enough. When a directed teleport point is deployed, the player will see interesting points and will gravitate towards them. As soon as the player teleport to the POI, he or she will be guaranteed to view the desired game event.

The paper is structured as follows. In Section II, we present selected related work. In Section III, we describe the gameplay and propose the directed teleport function. We evaluate the serious game and the proposed directed teleport function in Section IV and discuss the results in Section V. Lastly, we conclude in Section VI.

II. Related Work

A. Immersive Virtual Reality

Slater et al. [3] have drawn attention to the fact that the virtual environment should portray a storyline, in which the players can participate and modify. A story can present an alternate sequence of events. Previous work on storytelling already delivered great insights on how to create an exciting story to increase immersion. For example, the *Hero's Journey* contains several stages where a hero grows and changes during the journey until he or she faces the final battle [4]. Dörner et al. [1] discusses different forms of progression, from a simple linear layout to a more complex layout with branches or level groups and alternative endings. The most common way is a linear layout where several levels are just connected consecutively and players have to achieve all levels to win the game. A more sophisticated setup consists of multiple branches, where the players have to decide which path they want to follow. In such a game, the players will not be able to see the entire game content during one playthrough. Other types of story structure include level groups and alternative endings.

Immersion and, in particular, the presence (the sense of being there) can be furthermore improved by creating a virtual body [3]. The movements of a player should be directly mapped to the movements of the virtual body so that he or she can identify with this virtual body. To reconstruct full-body movements, a motion capture system is needed, e.g., a markerless or a marker-based. Sra et al. [5] utilize multiple Kinect devices to provide immersive VR experience where numerous players can see each other's avatar. Other researchers use a full-body capture suit to track movements [6], [7]. Furthermore, Inertial Measurement Units (IMUs) can be attached to the body to track the movements and to reconstruct a full-body avatar [8].

B. Locomotion

There are various ways to move in the VR games. The most intuitive way is natural walking in the real world, while the character moves in the same way in the virtual world. HTC Vive enables the player to physically walk around in a large area up to 15×15 feet.[1] Shewaga et al. [9] provide significant evidence that the room-scale VR configuration leads to higher immersion. When the physical area is smaller than the virtual environment, the players can teleport around large virtual worlds, e.g., by using a controller to move from one location to another instantly.

Other research publications utilize a treadmill to allow endless walking [10], [11]. Furthermore, the players can move their character forward in the game while they are walking in place (WIP) in the real world. For example, Lee et al. [12] recognize the movements (up and down) of the HMD whereas Ferracani et al. [13] use a Kinect device to recognize WIP gestures for locomotion.

Moreover, redirected walking has been proposed to allow the players to walk naturally, even though the tracking space is limited. Steinicke et al. [14] introduce an approach by redirecting the players so that they unknowingly walk in a circle. Suma et al. [15] present a technique for exploiting change

[1] https://www.vive.com/us/product/vive-pro/, last visited on January 21st, 2019

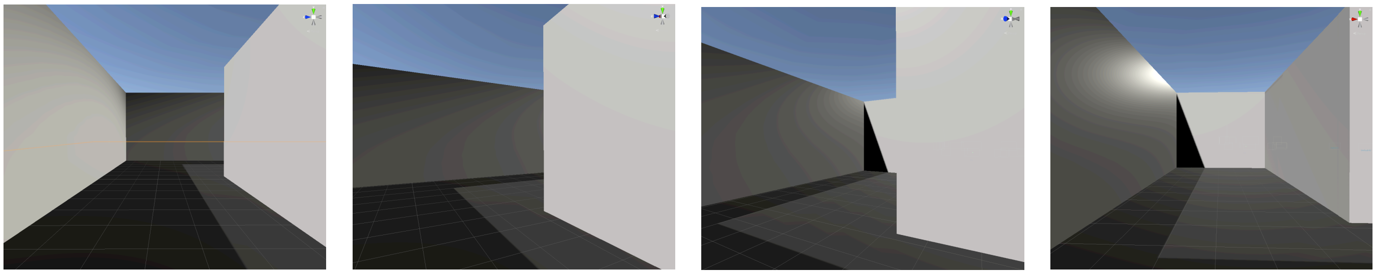
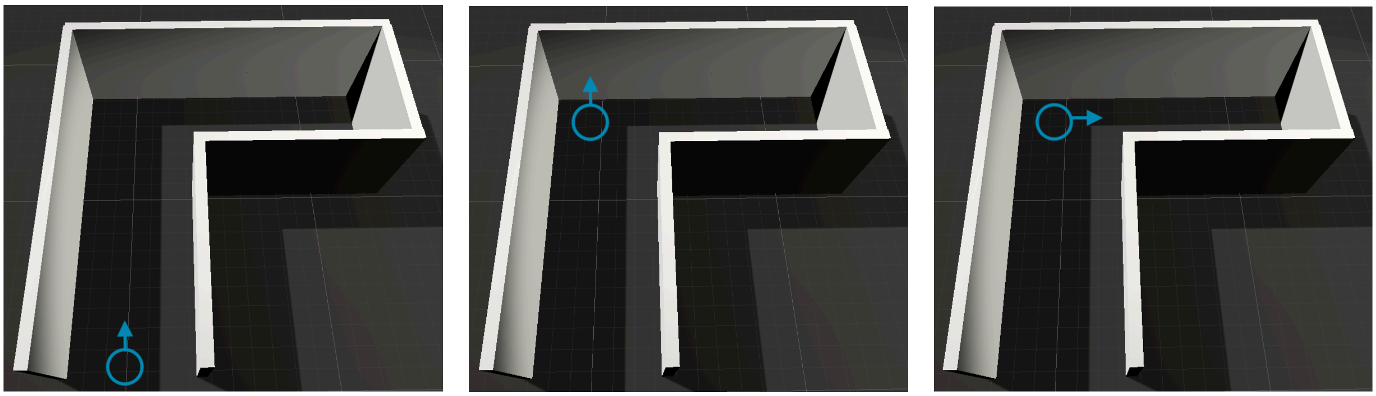


Fig. 2: Turning in real life (first-person perspective).



(a) Before teleporting (b) After common teleportation (c) After directed teleportation

Fig. 3: Top-down view of the teleport function. In the common teleport function, the player will face the wall. However, in the directed teleport function, the player is aligned directly along the corridor.

blindness to allow the user to walk through an immersive virtual environment that is much larger than the available physical workspace. Change blindness describes the inability of a person to detect changes in a scene. This blindness can be used to slightly change the virtual environment outside the players' view to redirect them in the desired direction, e.g., by replacing the doors or moving walls.

C. Training in Virtual Reality

Safe VR-based training environments allow a trainee to make mistakes without serious consequences, to gain experiences that help to avoid wrong decisions and make mistakes in the future [2]. Serious games are already being used in an extensive range of areas. Simulation-based training, such as XVR Simulations[2], Virtual Crisis Simulations[3], VSTEP Simulation[4], Serious Games Solutions[5], and MASA SYNERGY[6] are aimed at security, and safety training as well as crisis management.

Other recent studies introduced a VR approach for earthquake safety training where the players learn survival skills, e.g., to detect potential danger and to protect themselves [16]. Training and simulations are also often used in military training (e.g., America's Army [17]), for police training (e.g., ViPOL [18]), and for crime scene reconstruction [19], [20].

III. Concept

A. Gameplay

We developed a serious game (see Figure 1) to provide an immersive training environment for police officers or students in police school. The game is available online on Viveport.[7] To fulfill the training purposes and to provide the trainee with the opportunity of trial-and-error, the designed virtual environment must be interactive and less restrictive in terms of story. The game contains multiple paths with alternative endings. The story changes, depending on how the player reacts. Thus, the player has to play the game multiple times to train all scenarios.

At the beginning of the game, an experienced police officer (P-NPC, policeman non-player character) greets the player. The player and the P-NPC then get in a police car and identify a suspicious vehicle. They follow this vehicle and as soon as the police car is near enough, the player has to signal the vehicle to stop. Next, the player approaches the vehicle to investigate the driver (D-NPC, driver non-player character). The player is supposed to carry out traffic control, i.e., he or she has to check driver's license, vehicle registration paper, safety vest, first aid kit, and warning triangle.

[2]https://www.xvrsim.com/, last visited on February 15th, 2019
[3]http://www.vr-crisis.com/, last visited on February 15th, 2019
[4]https://www.vstepsimulation.com, last visited on February 15th, 2019
[5]http://www.serious-games-solutions.de, last visited on February 15th, 2019
[6]https://masasim.com/synergy/, last visited on February 15th, 2019

[7]https://www.viveport.com/apps/fb577ee0-3e85-4681-bc3a-c17b0cbf1208/VRPoliceControl/, last visited on April 18th, 2019

(a) Before teleporting

(b) After teleporting

Fig. 4: A screenshot of the game while activating the teleport function. The player sees POIs, indicated as virtual avatars facing in the direction of the teleported waypoints (left). The arrows above the virtual avatars additionally indicate the desired direction the player will take after the teleportation. For example, when the player teleports to the driver's car side, he or she will be directly facing the menu (right).

During the game, the P-NPC guides the player and can help, if the player does not know what to do or is unsure. The game consists of multiple scenarios. Either the D-NPC will be cooperative or he will be aggressive. When the D-NPC is cooperative, the player can carry out traffic control and when the player discovers a gun on the passenger seat, the player can arrest him. The D-NPC does not resist. In another scenario, where the D-NPC is aggressive, he will get out of the car and will try to shoot the P-NPC. The player can choose between different items, e.g., a gun, handcuffs, and a walkie-talkie. The player can use the weapon for defense and the handcuffs to arrest the D-NPC. Moreover, the player can use the walkie-talkie to check the driver's ID or to call an ambulance in case the D-NPC shoots the P-NPC.

B. Directed Teleport Function

We propose a novel teleport function to show POIs and to turn the player directly in the desired orientation. The directed teleport function also corresponds to the natural movement. For example, when a player approaches the corner in real life, he or she does not focus on the wall all the time. Instead, as shown in Figure 2, the player will be turning slightly to the desired position. The players' direction represents their focus and attention. To overcome this challenge when teleporting in virtual environments, we propose directed teleport function (see Figure 3). Using the common teleportation, the player is turned to the wall when teleporting to the corner (see Figure 3b). In contrast to this, using the directed teleportation, the player is directly aligned along the corridor (see Figure 3c).

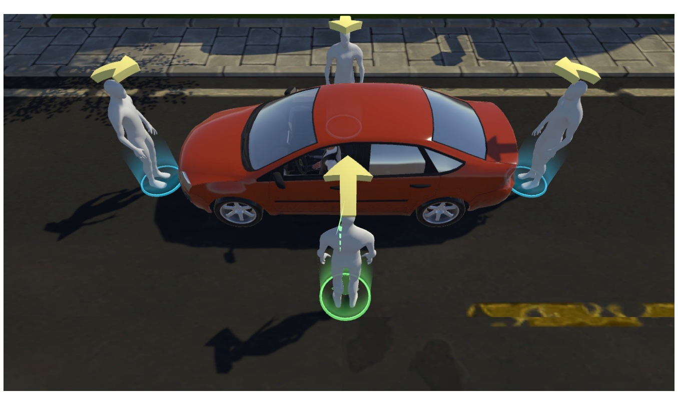


Fig. 5: Top-down view of the POIs around the car, which a player should check to finish the game successfully.

The directed teleportation technically works similar to the common teleportation. The player can activate the teleport function by pressing the touchpad on the controller. Once activated, the player can see an arced laser beam shooting from the controller and a highlighted circle indicating the position after teleportation. Additionally, a virtual avatar and an arrow above it indicate the direction after the teleportation (see Figure 4a). The player can choose the location to teleport by moving the controller while holding down the touchpad. Once the player chooses the teleport point and releases the touchpad, he or she will be instantly teleported to that location and turned to the desired rotation (see Figure 4b).

There exist four POIs around the car, i.e., the driver's car side, the passenger's side, the trunk, and the bonnet (see Figure 5). The player can directly teleport to the driver's car side to carry out the traffic control. When the player chooses to check the first aid kit, the D-NPC will get out of the car and will walk towards the trunk. The player can easily follow the D-NPC and teleport directly to the back of the vehicle. Furthermore, the player can instantly teleport to the passenger's side to open the car door and find a gun on the seat. Moreover, another teleport point reveals that there can be something interesting under the bonnet of the car.

C. Human Model

Each player can select a gender-specific avatar at the beginning of the game. We calibrate the skeleton so that motion reconstruction works independently of the body height and

Fig. 6: Examples for motion reconstruction of the full-body avatar from third-person view (left) and the corresponding player's pose (right). Note that the player can view the virtual body from the first-person view.

the position/rotation of the attached sensors. During training, the player can view the virtual body from the first-person view through a HTC Vive HMD. To reconstruct the full-body movements, the player has to hold two associated Vive controllers (one in each hand) and additionally has to wear three HTC Vive trackers (two on the feet and one on the lower back). The position and orientation of all six devices (one HMD, two controllers, three trackers) are used to estimate the full-body pose by solving the Inverse Kinematics (IK) problem [21]. As depicted in Figure 6, the motion reconstruction works well even for complicated poses, such as kneeling.

IV. Evaluation

The goal of the user study was to evaluate the influence of the proposed directed teleport function and the overall game experience of the player. The metrics for the evaluation are the player's subjective judgment of engagement, usability, and sense of embodiment.

A. Participants

We recruited 20 participants (2 females), aged between 19 and 58 (average age was 26.45) to participate in this evaluation. We split participants randomly in two groups (each group consists of 10 participants) to compare the effect of the directed teleport function. Both groups were allowed to move freely in the tracking area (2.5×2.5 meters). Since the physical space is limited, the participants intuitively used the teleport function for larger distances. The experimental group could use the directed teleport function in addition to the common teleport function. Hence, the participants in the experimental group could see the POI, e.g., around the car. The control group had only access to the common teleport function and could therefore not see the POI.

Before the participants put on the HTC Vive HMD, they were instructed about the controls, e.g., how to teleport, how to choose between the different game objects (handcuffs, a walkie talkie, and a gun) and how to interact with the objects (open a door, press a button).

B. Method

On average, the entire experiment took approximately 30 minutes (20 minutes for playing and 10 minutes for filling out a questionnaire). Because the game consists of multiple paths, each participant played the game two times. In the first playthrough, the D-NPC was cooperative and in the second round, he was aggressive.

After the play session, the participants were asked to fill out the questionnaire. We asked participants to provide basic demographic information such as age and gender. The questionnaire furthermore contained three parts, i.e., engagement, usability, and sense of embodiment. All questions consist of either five-point Likert-scale or true-false items.

1) Usability Questionnaire: For usability, we developed a questionnaire that suits our requirements to evaluate the effectiveness of the proposed directed teleport function on navigation and orientation. The questions are aimed to evaluate how easy it is to teleport in general, how easy it is to teleport when investigating the car, how easy it is to play the game, how disoriented the players get after the teleportation, and how natural it is to teleport at all.

2) Engagement Questionnaire: To measure engagement, we used a modified Game Engagement Questionnaire (GEQ) as proposed by Brockmyer et al. [22]. The questions are

Condition	**Common Teleportation**	**Directed Teleportation**
Traffic control items	100%	100%
Trunk	100%	100%
Passenger seat	90%	100%
Bonnet	10%	60%

TABLE I: The proportion of players who checked important items while investigating the car. The results show that the players are more likely to find interesting objects when using directed teleport function.

Condition	Questions	Common Teleportation		Directed Teleportation		
		MED	IQR	MED	IQR	p
Easiness Teleportation	Rate how easy it was for you to teleport. (*extremely difficult* = 1, *extremely easy* = 5)	4	1	4.5	1	0.5
Investigation	Rate how easy it was for you to teleport when investigating the car. (*extremely difficult* = 1, *extremely easy* = 5)	4	1.25	5	1.25	0.049
Disorientation	Rate how disoriented are you when teleporting. (*very disoriented* = 1, *not disoriented at all* = 5)	4	2.25	4	1	0.5
Easiness Game	Rate how easy it was for you to play the game in general. (*extremely difficult* = 1, *extremely easy* = 5)	4	1	4	0.25	0.357
Naturalness	Rate how natural it was for you to teleport around the space. (*extremely unnatural* = 1, *extremely natural* = 5)	4	1	4	1	0.5

TABLE II: Results of the usability questionnaire.

designed to measure variables such as *immersion*, *presence*, *flow*, and *absorption*. *Immersion* is typically used to describe the experience of becoming engaged in the game-playing experience and has an impact on *presence* [23]. *Presence* is defined as the player's sense of "being there" in the virtual environment [24]. Furthermore, *flow* describes the feeling of enjoyment when challenges and skills are in balance [25].

3) Sense of Embodiment Questionnaire: We asked questions about the *sense of agency* and *body ownership* as proposed by Kilteni et al. [26]. In our paper, the *sense of agency* refers to the sense of being in control of the virtual body. *Body ownership* refers to a player's sense of possessing a virtual body.

V. Results and Discussion

A. Usability Questionnaire

Our prior expectation has been that the directed teleport function not only shows POI to the players but also helps the players to teleport around the space. Based on the responses to the usability questionnaire, the directed teleport function is very effective when investigating a car. Table I shows how many participants checked particular items in either a common or directed teleportation group. Table II shows the median (MED) and Inter-Quartile Range (IQR) for both groups. We furthermore determine the significance of the results by calculating a one-tailed, two-sample t-test.

We found a significant difference between the groups in terms of investigating the car ($p = 0.035$): More than half of the players in the directed (60%) and only a minority (10%) in the common teleportation group investigated the bonnet of the car (see Table I). One player in the common teleportation function even did not check the passenger seat (and thus did not find the gun). The results show that the directed teleportation function reveals POIs to the players. Furthermore, during the evaluation, it was observed that many participants in the common teleportation group asked what they are supposed to do after they checked all documents. In this case, the supervisor encouraged the participants to investigate the virtual world. In contrast, the participants in the directed teleportation group intuitively checked the car, without asking the supervisor. The majority of the players saw the specified POIs and wanted to investigate them.

The results in Table II appear to complement the findings in Table I. The median score of the *investigation* question in the directed teleportation group is significantly higher ($p = 0.049$) than in the common teleportation group. In other words, the players could teleport around the car easier when they used the directed teleport function. Hence, these results suggest that the directed teleport function is very effective. It can help the players to navigate through the virtual world and will show interesting points to the players.

The level of *disorientation* reported by the participants was very low, without a significant difference between the groups. Whereas the orientation of the players in the common teleportation group remains the same, the orientation of the participants in the directed teleportation group will be realigned. Nevertheless, the participants were not disoriented ($\text{MED}_{\text{common}} = \text{MED}_{\text{directed}} = 4$). The results suggest that the virtual avatars facing in the direction of the teleported waypoint and the arrows above them indicate the final orientation to the players very well. Because the players intuitively understood how the directed teleport function works, they did not get disorientated.

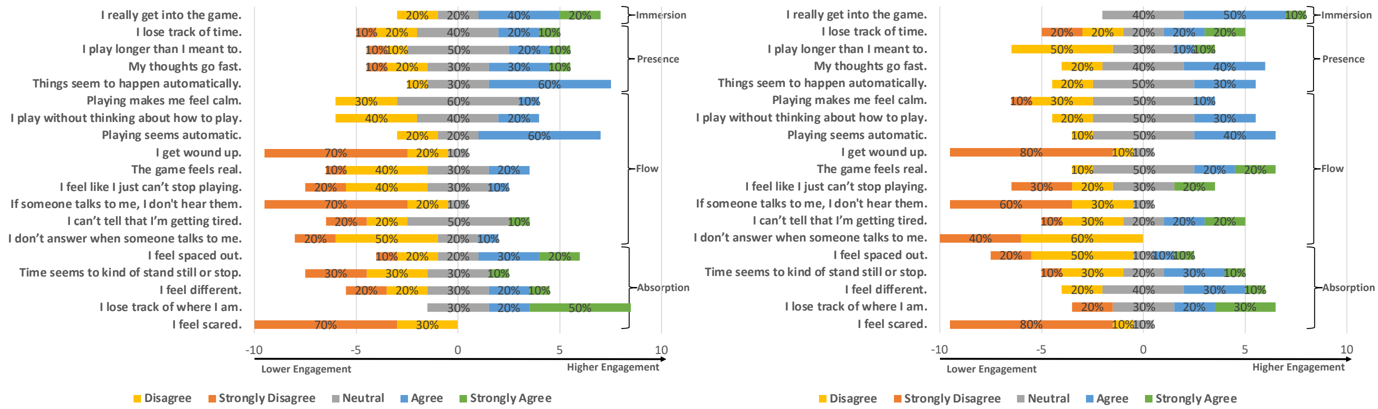
Regarding the *easiness of the teleportation function*, the median score for both groups is very high, with a slightly higher score for directed teleport group ($\text{MED}_{\text{common}} = 4, \text{MED}_{\text{directed}} = 4.5$). Similarly, both groups found it very natural to teleport around the space (*naturalness*). The results for both groups also show that the game is in general straightforward to play (*easiness game*).

B. Engagement Questionnaire

The GEQ measures a self-report of a player's potential for becoming engaged in a game. For statistical analysis, the questionnaire was scored by assigning each possible response a numerical value: *strongly disagree* = 1 and *strongly agree* = 5.

Condition	Common Teleportation		Directed Teleportation		
	MED	IQR	MED	IQR	p
Immersion	4	1.5	4	1	0.403
Presence	3	0.938	3	0.938	0.258
Flow	2.5	0.25	3	0.75	0.233
Absorption	3	2.5	3	1.5	0.361

TABLE III: Results of the GEQ categories.



(a) Common Teleport Function

(b) Directed Teleport Function

Fig. 7: Participants' engagement scores. Higher scores indicate higher engagement.

The higher scores show more engagement, whereas the lower scores indicate lower engagement while playing a game (see Figure 7). The summarized results of the questionnaire are detailed in Table III. Median scores across each category of the GEQ are similar between the group, without significant differences between them.

The results indicate that participants mostly rated the *immersion* items very high ($\text{MED}_{\text{common}} = \text{MED}_{\text{directed}} = 4$), although we could not find a significant difference between the groups. In both groups, 60% of the participants reported 'getting really into the game.' Two participants in the common teleportation group disagreed with this statement.

The median *flow* score increases in the directed teleportation group ($\text{MED}_{\text{common}} = 2.5, \text{MED}_{\text{directed}} = 3$). These results also confirm the fact that the directed teleport function shows POI to the players (see also Table I). Thus, players using directed teleportation are more likely to stay in the flow because they are guided throughout the VR game. In the directed teleportation group, 40% of participants reported that 'the game feels real' as opposed to only 20% in the common teleportation group ($p = 0.026$). Furthermore, more participants in the directed teleportation group (40%) reported 'not getting tired' in opposition to the participants in the common teleportation group (10%). We believe this is because the players using the directed teleport function do not constantly need to turn when navigating around the car. On the one hand, when the players using the common teleport function stand on the left side of the car facing the driver seat and want to teleport on the right side of the car, then they have to turn $180°$ to face the driver seat in order to open the car door. We could observe that the participants in the common teleportation group also had to step over the cable constantly to avoid stumbling over it. In general, they often had to turn in the opposite direction so that the HMD cable did not wrap around the body. On the other hand, the players using the directed teleport function do not need to turn at all, because the teleportation function aligns the players in the right direction.

In terms of *absorption*, the scores towards 'time seems to kind of stand still or stop' increases in the directed teleportation group (10% common, 40% directed teleportation group). None of the participants in the common teleportation group felt scared, whereas one participant in the directed teleportation group was unsure.

Although the results for *immersion* show high scores, *presence*, *flow*, and *absorption* items are rated relatively low. The results thus show relatively low scores in engagement on average. The median scores for *flow* increase while the median scores for *immersion*, *presence*, and *absorption* stay the same for both groups. The participants, in general, enjoyed the serious game. However, room for improvements remains.

C. Sense of Embodiment Questionnaire

The sense of embodiment questionnaire was used to measure the subjective *sense of agency* and *body ownership*. Recall that all participants could choose between two avatars (a male or a female). They were wearing a HMD so that they saw their virtual body by looking down towards their real body. The responses are displayed in Figure 8.

The main finding was that more than 80% of participants felt that they were in control of the virtual body (*sense of agency*). However, only 45% of participants had the feeling to look at their body when they looked down and had the feeling as if the virtual body was their body (*sense of body ownership*). We believe this is because the IK algorithm only estimates the full-body pose. The movements of the virtual body did not always correspond to the movements of the player. Thus, the elbow rotation of the virtual body sometimes did not match

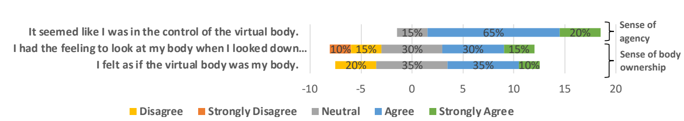


Fig. 8: Participants' sense of embodiment scores. Higher scores indicate a higher sense of embodiment.

the exact rotation of the player's elbow. Overall, the players perceived the virtual body as their own body.

VI. Conclusion and Future Work

In this paper, we introduced a novel directed teleport function which can be used in immersive VR serious games to guide the player's attention to the specific story elements. We presented the results of a user study that provided a comparison between common and directed teleportation function with respect to usability, engagement, and sense of embodiment. The results reveal that the directed teleport function is very effective, easy to use, and is very suitable to show interesting points to the players. We measured a significant difference between the control and experiment group when rating the easiness of investigating the car. Furthermore, the results of the directed teleportation group also show that the players tend to find interesting objects that are hidden and often overlooked by the players in the common teleportation group.

We believe there are several major benefits of using the directed teleport function for serious games. First, the directed teleport function can be used to reveal POI to the players. When the players see such a point in the virtual world, they become curious and will gravitate towards that place to investigate it. Secondly, the directed teleport function can be used to trigger events as soon as the player is near enough. When the players teleport to such a location, they will be directly aligned in the intended direction to see the desired game event. Lastly, the directed teleport function enhances movement in the virtual world because the players can explore the virtual environment without continually turning. Furthermore, it also reduces trip hazards caused by cables attached to the headset.

Future work will focus on improving the serious game by deploying more POI and increasing the number of scenarios to increase the engagement of the players. We also want to investigate the effects of the virtual avatar on the disorientation of the player.

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