On the Use of Jumping Gestures for Immersive Teleportation in VR

Lucie Kruse1 and Sungchul Jung2 and Richard Li2 and Robert Lindeman2

1Human-Computer-Interaction, Universität Hamburg 2Human Interface Technology Lab NZ, University of Canterbury

Abstract

Virtual environments can be infinitely large, but users only have a limited amount of space in the physical world. One way to navigate within large virtual environments is through teleportation. Teleportation requires two steps: targeting a place and sudden shifting. Conventional teleportation uses a controller to point to a target position and a button press or release to immediately teleport the user to the position. Since the teleportation does not require physical movement, the user can explore the entire virtual environment. However, as this is supernatural and can lead to momentary disorientation, it can break the sense of presence, and thus degrade the overall virtual reality experience. To compensate for the downside of this technique, we explore the effects of a jumping gesture as a teleportation trigger. We conducted a study with two factors: 1) triggering method (Jumping and Standing), and 2) targeting method (Head-direction and Controller). We found that the conventional way of using a controller while standing showed better efficiency, the highest usability and lower cybersickness. Nevertheless, Jumping+Controller invoked a high sense of engagement and fun, and therefore provides an interesting new technique, especially for VR games.

Keywords: Teleportation, Virtual Reality, Locomotion Techniques, Jumping, Presence, Cybersickness, Usability, Gaze-input, Controller-input

CCS Concepts

• Human-centered computing → User studies; Virtual reality; Mixed / augmented reality;

1. Introduction

Locomotion in virtual environments (VEs) is a fundamental activity and a challenging problem in virtual reality (VR). Natural locomotion in VEs through walking in the physical space is easily enabled by six-degree-of-freedom tracking of the user’s movement in the given space. However, compared to the theoretically infinite space in VEs, physical movement is always confined to the available physical space, as well as the volume of the tracking space. To mitigate such restrictions, teleportation has been suggested as a locomotion metaphor in VR.

Teleportation was introduced as an alternative to joystick-based movement due to inducing less cybersickness [LLS18] while still making it possible to traverse large VEs in a short amount of time. In the most common implementation, users point their controller at a target position while holding down a button and upon releasing the button, they are teleported to the indicated destination immediately [BRKD16]. While using a controller is a general method for teleportation in commercial applications and games, it is unnatural because it does not match expected body movement along with the changed visual feed and thus can lead to a break of presence. Besides, it can cause the user to perform worse in orientation tasks due to the sudden location shifting [BPW03]. Physical jumping could address the problems in terms of providing a better feeling of presence and a more natural user experience [BSB11].

Additionally, jumping behavior could support hands-free teleportation as a natural trigger. Studies show that switching between hand and leg input is cumbersome and that users might even stop leg input altogether [BTF17], which is detrimental to presence and leads to users neglecting a large part of the available tracking space [LPAZF18, SNZ*20]. To address the problem, a head-direction based targeting method was used in our study, as Bolte et al. suggested in their jumper metaphor study in VR [BSB11]. However the authors did not use a real physical jump as a trigger in their experiment. Compared to the jumper metaphor, which uses an acceleration threshold in the horizontal direction to trigger a teleportation, we used a positional difference in the vertical direction with a physical jump as a trigger.

Jumping in VR has recently been investigated in several studies as well. As proposed by Hayashi et al. [HFT*19], redirected jumping has significantly higher detection thresholds for rotational, horizontal, and vertical jumps than the traditional redirected walking thresholds. Jung et al. have confirmed this study for rotational jumps [JBHL19], and thus jumping has the possibility to be used in combination with redirection. Linowes et al. developed an application where the user can physically jump to take off from the ground, fly by looking around and crouch to land [Lin18]. There also exists some hardware to investigate the user’s jumping behaviour in VR, like the cable-driven system developed by Kim et al. [KCT*17] or
the ski jumping simulation by Yoshida et al. [YUNY16]. Although these systems may induce a natural feeling while jumping in VR, not every user has access to them. Jumping can also be used as part of an exergame, as developed by Lehtonen et al. [LKK+19] and in the entertainment sector, for example in the mixed reality trampoline park “Urban Air Adventure Park” in Texas [Par]. Although there has already been some done research regarding jumping as a teleportation method, for example by Hoeg et al., who investigated user preferences [HRN+17], there are a lot of factors that have not yet been explored. We compare different techniques regarding cybersickness with the Simulator Sickness Questionnaire (SSQ) [KLBL93]. Our hypothesis is that jumping for teleportation will not induce a higher occurrence of cybersickness than conventional teleportation, except for an expected rise in exertion. Also, we test our four methods with the System-Usability-Scale (SUS) [B96] to produce comparable results, expecting the jumping methods to receive similar usability scores as the conventional methods. A third addition to previous work is a test for the feeling of presence using the Slater-Usoh-Steed Presence Questionnaire (SUPSQ) [SU94].

The contributions of this paper are as follows:

1. The development of two new teleportation techniques that are triggered by a physical jump,
2. the comparison of the two new teleportation methods to two established methods regarding cybersickness, usability and presence, and
3. the contrast of subjective opinions to objective measures regarding the different methods.

2. Related Work

Locomotion is the act of moving the virtual body around in a VE. While locomotion is important for many aspects of the experience in VR, it imposes several challenges. For one, VEs can be infinite, in comparison to the limited physical space that is available to the user. Data shows that less than 10 percent of users have a room that exceeds 3m × 3m [Roo]. In order to be able to reach all possible locations in the VE, the user’s physical movement has to be scaled or their position has to be changed in a different way. Well-known techniques to alter the user’s position include joystick movement [FRK14, FSW17, LLS18], redirected walking [RKW01, SBJ+10, SBK+08] and teleportation [BRKD16].

Using a joystick to gradually change the user’s position while a joystick is pushed in a certain direction is a well-known method from console games. While joystick movement works very well, it can cause severe cybersickness in VR. Cybersickness occurs when the visual and the vestibular senses are in conflict, which can happen if the user’s camera is moving while their physical body stands still or vice versa [LJ00, MJHL19]. Several approaches try to counterbalance cybersickness by making the walking movement seem more real [SHSL17, LBHDo06]. Redirected walking slightly alters the user’s velocity (angle and/or gain) while they are walking physically. This makes it possible to direct them to walk on a different path in the VE as compared to the physical one [RKW01, SBJ+10, SBK+08]. Since this method includes physical walking, it is seen as one of the most natural forms of locomotion [SVCL13]. Nevertheless, the amount of redirection that can be applied imperceptibly is limited, which results in the need for a room with a diameter of around 22 meters in order to make the user feel like they are walking straight ahead infinitely [SBJ+10, SBJ+08].

Teleportation is used in many commercial games, because it enables the user to use a relatively small physical space or even to stay seated. Point-and-Teleport [BRKD16] is an often used method, where the user points the controller at a target location, and is then teleported there immediately after a button is pressed or released. This is a very efficient method, but it is unnatural. Two other problems are that the Point-and-Teleport method can cause temporary disorientation, because of the sudden change of position [BPW03], and that the acquisition of spatial knowledge about the environment is reduced [LLS18].

In this paper, we explore how to enhance the feeling of presence when using teleportation. Spurgeon et al. [Spu18] have compared four different hands-free teleportation techniques to the original Point-and-Teleport: Teleportation by Voice Command, Eye Blink, Foot Stomp and Gaze Dwell. They measured efficiency, accuracy, time, learnability and likeability. Spurgeon et al. found that Point-and-Teleport, Gaze Dwell, and Eye blink were equally fast, and Point-and-Teleport and Eye Blink were the most likeable. We want to expand this study by looking at two more teleportation methods including jumping: one controller-based and the other head-direction-based. Jumping for teleportation was recently investigated by Hoeg et al. [HRN+17]. They compared three trigger methods for teleportation: A button press, jumping forward and a gesture-based trigger. For all three cases, the viewing direction selected the target position. The participants rated the three methods according to suitability, ease of use, exertion, enjoyment and ease of orientation. The only statistically significant difference was for exertion between button-press (low) and jumping input (high), which was to be expected for a physically demanding task. Wolf et al. compared three jumping methods: teleportation, scaled jumping and normal forward jumping [WRKR20]. In their scaled jumping method, the users only jumped vertically, while forward movement was added depending on their velocity. The authors found that jumping methods significantly increased motivation, immersion and presence, compared to teleportation. Furthermore, they did not lead to increased cybersickness.

Another important fact is that jumping as a trigger for teleportation is a hands-free method to navigate the VE. The user can perform manipulation tasks with their hands, while using their legs to move around in the VE. La Viola et al. stated that hands-free methods have the greatest potential for maximizing the interactivity of VEs, because the user’s hands are free to perform tasks like modelling, pointing or object manipulation [LJFK+01]. They also believed that leg-based locomotion techniques could be more natural for navigation tasks and that the load from one overloaded channel (hand input) could be transferred to a different channel (leg input) to increase task range and complexity.

3. Methods

Two of our proposed teleportation methods are hands-free, while the two other methods are a mixture of hand and leg input. A graphical explanation of the two jumping techniques is shown in Figure 2. All conditions use an invisible, slightly-bent ray, so it would not
interfere with the user’s view in the head-based conditions, and a radiating circle on the floor to indicate the target position.

3.1. Jumping with Head-direction Teleport

The first newly proposed method is head-direction based. The user selects a destination by pointing their head at a certain spot on the ground until a circle is filled completely (See Figure 1). This takes around one second. In order to avoid the Midas Touch problem [Jac93], the circle filling is reset if the user moves too far (with the threshold being 25 cm) from the original position, or if no jump is initiated within five seconds following a selection. Once the target position is locked, the user must jump upwards to initiate the teleport. The teleport is executed at the highest point of the jump, between the Up and Down phases, as described in Section 3.5.

3.2. Jumping with Controller Teleport

The second new jumping method enables the user to choose a target position with their controller and lock it by clicking the touchpad button once. A wrong goal selection can be corrected by pressing the touchpad again and selecting a new target position, or by waiting for five seconds. Once the user is ready, they can jump upwards. When they reach the highest position, they are teleported to the target position.

3.3. Standing with Head-direction Teleport

This method utilizes the user’s head direction to determine the target position as explained above. Once a selection has been locked in using the Head-direction method, the user can "concentrate to channel their powers and use the Force" as proposed by Clifford et al. [CTL17] and by tilting their head slightly downwards, they are teleported to the selected position.

3.4. Standing with Controller Teleport

Point-and-Teleport [BRKD16] is the general method that is widely used in commercial systems. We used the standard implementation by SteamVR, where the user points to a target location with a controller while keeping the touchpad pressed, and when the touchpad is released, they are teleported to the new position immediately. No correction mechanism can be used for wrongly selected areas, since the teleportation is carried out as soon as the touchpad is released.

3.5. Jump Detection

In order to detect a jump, we used an algorithm which takes into consideration the previous jump state, the current height of the head-mounted display (HMD) and the height difference between the last five frames. The initial y-value of the HMD is calibrated at the start of each condition, by making the user look slightly upwards, in order to avoid detecting false positives. The user starts in the Idle state. When their HMD is lower than the y-value of their initial position, they switch into the Ready state. Once in the Ready state, they can switch into the Up state as soon as their HMD is higher than their start position. If the user is in the Up state, and the program detects them going downwards, by comparing their position over the last five frames, they switch into the Down state. The Landing state is detected when the user's head is not higher than their initial position anymore. In a pre-test, we confirmed values for the threshold of 0.5 cm to detect differences in the movement direction and a threshold of 3 cm to detect a difference from the initial height.

![Figure 1: The selection reticle while it is filling up.](image1)

3.6. Participants

A user study with 25 students aged between 18 and 35 ($m = 24.78, sd = 5.32$) was conducted. Out of the 25 participants, 17 were female and eight were male. Participants received a compensation voucher for their time. The experiment was approved by our organization’s Human Ethics Committee.
3.7. Material
The study was developed using Unity 2019.1.0f2. It was run on a computer with a GTX 1080 Ti, using the Vive Pro headset. The average frame rate during the study was 115 frames per second. The task was to teleport from one highlighted platform to another to collect an office item floating above their head, which triggered the next target position to appear. They were asked to reach their goal as quickly and precisely as possible. The environment was a simple office scene, with a corridor and some desks on the sides (Figure 3).

![Figure 3: The office environment. We displayed distances (in meters) on the floor from the initial position of the user.](image)

We used a 2 × 2 within-subjects design. The four blocks were balanced equally using a counterbalanced measures design [Shu09] to avoid any order bias, with one additional participant receiving a randomly chosen order.

3.8. Hypotheses
We argue that the act of jumping as a trigger of teleporting in the virtual spaces is a good locomotion method for an exergame and motivates the users to do physical work. Our hypotheses are the following:

- **H₁** Physical-jumping-triggered teleportation (Jumping-Head and Jumping-Cont) will result in a higher sense of presence than the conventional approaches (Standing-Head and Standing-Cont).
- **H₂** Head-direction-based targeting methods for teleportation will result in better usability than controller-based teleportation, because they are easy to learn.
- **H₃** Physically-jumping-triggered teleportation (Jumping-Head and Jumping-Cont) will result in a higher preference than the conventional approaches (Standing-Head and Standing-Cont).
- **H₄** The study will not lead to severe cybersickness, but there will be a rise for exertion-related symptoms after the jumping conditions.
- **H₅** The traditional method (Standing+Controller) will be more efficient in terms of speed and accuracy.

3.9. Instruments and Measurements
To measure the usability of the four methods, SUS [B96] was administered after each condition. The SUSPQ [SUS94] was used to measure the participants’ feeling of presence. To measure the user preferences, we designed a simple set of five questions. Specifically, participants were asked to pick the condition that they found was the most precise, the fastest, the most natural and the most fun to use. Finally, they needed to pick the condition they would choose if they were asked to do the task again. During the study, the subject’s completion time, accuracy, number of teleportations and number of wrongly locked and then unlocked target positions to reach a goal position were measured. Completion time was measured as the time needed from the start of a new trial until the end of the trial, when the collectible item was picked up. Accuracy was calculated to be the distance between the goal position and the selected position of the teleport. We also used the SSQ by Kennedy et al. [KLBL93] to measure the participants’ cybersickness during the experiment.

3.10. Procedure
The study was conducted before the COVID-19 pandemic started. On arrival, participants filled out a consent form. They were informed about precautionary measures regarding their health, which included the hazards of jumping, but also the possibility of cybersickness. Participants had to answer some questions about their physical well-being and medical condition. If they did not meet the requirements, they were excluded from the study. In addition to the experimenter and a helper who watched the participant during the study and took care of the HMD cables, a staff member trained in first aid was present at all times to ensure the participant’s well-being.

Before putting on the equipment, the participant filled out a demographics questionnaire, followed by a cybersickness questionnaire. They were shown which buttons to use for the controller-based tasks and a demonstration of the teleportation method was shown to them. Then the users had time to get accustomed to the teleportation system and try it out in a tutorial. When they felt ready, they started the first block. Their task was to teleport from virtual platform to platform, using the proposed teleportation method, but they were not restricted in their movement within the virtual room. Upon reaching the platform, they had to collect an item by moving their controller into it and pressing the trigger button. After two seconds, the next trial was started, with a new platform appearing behind or in front of them.

Once the participant finished a block, they took the HMD off and answered another cybersickness questionnaire, followed by SUSPQ and SUS. After a break, they started their next block, with a different condition. After each block, the participant filled out all three questionnaires again. Once they completed the fourth block, they were also asked about their personal preferences regarding the specific teleportation methods, and had the opportunity to leave some additional comments. After that, they were debriefed and their questions were answered. The study took around 45 minutes, out of which around 20 minutes were spent in VR.

4. Results
The evaluation of the results was done using R. This section describes the main results in detail. Wilcoxon Signed Rank Tests were performed with continuity correction.
4.1. SSQ
Cybersickness was tested using the SSQ by Kennedy et al. [KLWL93]. The mean values can be seen in Figure 4. Testing the data for normal distribution using the Shapiro-Wilk test showed that the mean values were not normally distributed, so we used a Wilcoxon signed-rank test to test if the cybersickness scores were different before and after the experiment for each condition. Significant differences were found for Standing-Head \((p = 0.002, r = 0.626)\) and Jumping-Head \((p = 0.015, r = 0.449)\). This might be due to the fact that looking down in order to “use the force” or dwelling on a place close to the user puts a strain on the user’s neck from the heavy headset, as reported by several users. This implies that jumping methods should be used with lighter HMDs. No significant differences could be found for the other methods \((p = 0.2\) for Standing-Cont and \(p = 0.517\) for Jumping-Cont).

4.2. Usability
Usability was tested with the SUS after each condition and the results can be seen in Figure 5. Standing-Cont achieved the highest usability score with a mean of 81.5 \((sd = 11.2)\), followed by Jumping-Cont with a mean value of 72.7 \((sd = 18.48)\). Jumping-Head received a score of 71.4 \((sd = 17.58)\), and Standing-Head received the lowest score \((m = 70.5, sd = 14.27)\). A Shapiro-Wilk test showed that the data was not normally distributed \((p < 0.001)\). A Friedman test found evidence against the hypothesis that all conditions have the same usability score \((p = 0.02)\). Follow-up Wilcoxon signed-rank tests showed a p-value of \(p = 0.015\), \(r = -0.48\) between Standing-Cont and Standing-Head and a p-value of \(p = 0.025\), \(r = -0.45\) between Standing-Cont and Jumping-Head.

4.3. Presence
The SUSPQ [SUS94] was used to compare the feeling of presence for the four different teleportation methods. The questionnaire was evaluated after Usoh et al. [UCAS00]. Standing-Cont received the highest presence score with a mean of 4.83 \((sd = 1.24)\) over all questions, followed by Standing-Head \((m = 4.74, sd = 1.24)\). The two jumping methods received slightly lower scores, with a mean of 4.68 \((sd = 1.2)\) for Jumping-Cont and a mean score of 4.58 \((sd = 1.07)\) for Jumping-Head. A Shapiro-Wilk test showed that the data is not normally distributed \((p = 0.015)\). Testing the data with a Friedman test, we were unable to find evidence against the hypothesis that all conditions invoke the same feeling of presence \((p = 0.49)\). Looking at the SUSPQ Count, where the number of high numbers \((6 or 7)\) is counted, Standing-Cont and Jumping-Cont both received a mean value of 2.08 high numbers per condition. Standing-Head received a slightly lower count, with 1.92, and Jumping-Head received a SUSPQ count of 1.68.

4.4. User Preferences
The users were asked to pick the condition that they found was the most precise, the fastest, the most natural, the most fun, and which one they would choose if they had to do the task again. The results can be seen in Figure 6. According to the responses, the most precise technique \((13\) participants) and the fastest technique \((14\) participants) was Standing-Cont. Users had very mixed opinions on the most natural teleportation technique, with 13 people choosing a standing-based method and 12 people choosing a jumping-based method. Even within these methods, opinions were very balanced. Both jumping methods received the most votes for fun, with 10 votes for Jumping-Cont and 11 votes for Jumping-Head. If they would have to do the task again, 16 participants reported they would use a jumping-based method, while nine participants would choose a standing-based method.

4.5. Efficiency Tests
During the study, the time needed to complete one trial, the accuracy, the number of teleports and the number of unlocks were logged. The mean values for a single trial can be seen in Table 1. Some trials were performed without a teleport, which is why the number of teleports needed for each condition is below one. Shapiro-Wilk Tests showed no normal distribution for any of the four measures \((p < 0.001)\). Paired Wilcoxon-Signed-Rank Tests showed evidence against the hypothesis that all conditions were...
accurately (\(p < 0.001\)), except for Standing-Head and Jumping-Cont \((p = 0.205)\). Regarding the different distances, the traversal of long distances \((m = 9.026, sd = 2.767)\) needed a higher time than short \((m = 7.642, sd = 3.423)\) and medium \((m = 7.182, sd = 2.483)\) distances \((p < 0.001)\). The accuracy was calculated to be the distance between the target position and the position of the teleport. In this case, a value of zero would mean that the participant teleported to the middle of the target area. For accuracy, the only significant difference was found between Standing-Head and Jumping-Head \((p = 0.024)\). Our results could not find evidence for differences between the conditions for the number of teleports and unlocks.

### 5.3. Personal Preferences

When asked about their personal preferences, the participants stated that Standing-Cont was the fastest and most precise method. This was expected, as there is no additional step to trigger the teleport and no noise from performing a jump. Most participants stated that the jumping methods were the most fun to use and that they would choose them if they had to do the task again. While jumping is not suitable for every scenario, it might be a good option for exergames or if it fits with the topic of the content. Regarding the most natural technique, the opinions were quite balanced. In this case, it depends on the individual person, experience with VR and personal preferences. For some more experienced users, controller input is already a well-established teleportation method, while some inexperienced participants preferred the Jumping with Head-Direction teleport, since it did not require them to learn a new mapping of buttons on their controller.

### 5.4. Efficiency Tests

As expected, participants were generally faster using a controller than using their head direction. On the other hand, the accuracy and number of teleports was worse for Standing-Cont. This is due to the fact that it is such a fast method and corrections can be performed very quickly. We postulate that this led to people often choosing speed over accuracy in this condition. Regarding the different distances, it can be seen that participants needed longer for distances that were farther away. This might be due to the fact that it was harder to point at the specific position and to hold their head or the controller still when trying to aim at a far away target. This effect was especially strong for the two Head-Direction-based methods. Jumping-Head had the lowest average number of teleports. Users took more care in performing their teleports, because each single teleport took longer to execute. Especially for targets that were only one meter away from them, participants sometimes decided to just take a step forward instead of teleporting themselves onto the platform.

### Figure 6: User preferences regarding the different teleportation methods (higher is better).

![Graph showing user preferences for different teleportation methods](image)

#### Table 1: The mean time, accuracy, number of teleports and number of unlocks for each condition per trial.

<table>
<thead>
<tr>
<th>Method</th>
<th>Time (s)</th>
<th>Accuracy (m)</th>
<th>#TPs</th>
<th>#Unlocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standing-Head</td>
<td>8.06 ± 2.93</td>
<td>0.18 ± 0.37</td>
<td>0.98 ± 0.17</td>
<td>0.05 ± 0.23</td>
</tr>
<tr>
<td>Standing-Cont</td>
<td>6.86 ± 3.00</td>
<td>0.18 ± 0.22</td>
<td>0.99 ± 0.22</td>
<td>∞</td>
</tr>
<tr>
<td>Jumping-Head</td>
<td>8.67 ± 2.94</td>
<td>0.17 ± 0.27</td>
<td>0.97 ± 0.25</td>
<td>0.03 ± 0.23</td>
</tr>
<tr>
<td>Jumping-Cont</td>
<td>7.97 ± 2.92</td>
<td>0.16 ± 0.27</td>
<td>0.98 ± 0.23</td>
<td>0.07 ± 0.40</td>
</tr>
</tbody>
</table>

### 5. Discussion

In this section, we provide some interpretations and insights into the results obtained from our study.

#### 5.1. Presence

Presence scores were higher for the two standing methods, although the differences were not significant. This might be due to the implementation of the jump. Many participants suggested that using a smoother transition for the jumping teleportation could possibly enhance the feeling of presence. Although we see a trend in users feeling more present with the traditional standing methods, jumping as a trigger for teleportation can be used as an alternative or extension to the traditional controller-based teleportation method, as it keeps the illusion of presence and still receives high presence scores and a similar SUSPQ Count.

Generally, it can be seen that controller-selection was preferred compared to the Head-Direction-selection methods. In the latter, users had to wait for the circle to fill completely in order to lock the teleport position. We suppose that this waiting time resulted in a break in presence for the users. It seems like the selection method plays a fundamental role in the teleportation process.

#### 5.2. Usability

Standing-Cont received the highest score in terms of Usability. It is the most common method used in several video games. It is also easy to use for experienced participants and the fastest method, because it uses a more-unified trigger action (press to indicate, release to confirm), whereas the other techniques had separate trigger actions. Head-Direction selection took around one second to lock a position, with the additional time and effort needed to perform a trigger action afterwards. Additionally, some participants found the head tilt and picking a destination with their head difficult to perform. They reported that the Head-Direction selection sometimes felt inaccurate and hard to control, especially with the heavy HMD.
5.5. Additional Comments

Most of the participants stated that the study was fun, well designed and a good experience. Participant comments on the jumping trigger were mostly positive. One participant stated that jumping made them less dizzy, but that the system did not always notice their jumps. Nevertheless, that same participant still preferred the jumping methods over the “magic” teleportation methods. Improvements suggested by participants were different game environments, for example by letting them be a kangaroo or rabbit, and making the transition for jumping teleport smoother and faster. One participant wrote that Standing-Cont was the fastest and therefore felt more natural. Another participant also stated that it was easy to use and caused less dizziness. Other participants explained that they found the use of a controller difficult, because it “involves [the] mind” and that the press of a button is “like a sort of interruption”, whereas the use of head direction is easy. One participant stated that they found it easier to target a spot more accurately with head direction, while another one said that they found the head lock “kind of wobbly”. Two participants found it hard to keep their head straight with the helmet on or to look down when the target was too close. One participant preferred the controller-based methods because they were more confident and accurate with hand movements than head movements. No participant mentioned being exhausted or tired after the jumps, since they only did 20 jumps in total. This might be different if the users spend a longer period of time with the jumping conditions in VR.

5.6. Implications

Jumping can be used as a trigger for teleportation in certain scenarios. It was seen as a fun way to navigate through large virtual environments and the personal preferences showed that jumping for teleportation can produce engagement. In Jumping-Cont, cybersickness was not significantly higher, and some participants mentioned feeling even better after jumping. This might be due to the physical exercise they performed, as opposed to just standing around and using a controller to navigate.

5.7. Limitations

This study only tested upwards jumps. In the future, forward jumping to trigger a teleport or scaled-forward-jumping could be tested as well. However, it should consider safety issue such as collisions with objects or walls, or increased fatigue. Also, the office environment might not have been an ideal environment, since jumping is not a common thing to do there. Future studies need to investigate the effects of different environments or even larger distances. In general, the implementation of the different methods was very specific. A difference in jump detection, the ray distance or the time to lock a position could have an impact on the results. Smoother transitions for the jump teleportation, as mentioned by the participants, also need to be explored. A problem which happened sometimes during the study was that the users’ jumps were not detected properly, especially when the participants were looking towards the floor while jumping. Although this problem only happened in very few cases, this could have an influence on the perceived realism and be reflected in the presence and usability score, since this is an unexpected behavior of the game, potentially causing a break in presence. Additional trackers on the user’s feet or hip could solve this problem in the future. As we reported in Section 3.6, we observed that more female participants than male were involved in this study, though we did not intend this. Since gender is a known factor for VR experience, especially in terms of cybersickness [KKP+05,FKB+12], our sampling pool could lead to a bias. To address the gender issue, a larger number of participants with a balanced gender is needed. Furthermore, there are some ergonomic issues with the use of heavy HMD. User guidelines advise against holding the head still for a longer period of time and this led to uncomfortable feelings for some participants. Future studies should use a lighter HMD or use an actual eye tracker to facilitate the selection of a target position in the VE.

6. Conclusion

This study has shown that jumping can be used as a trigger for teleportation. Especially the controller-based method, which received high scores for presence, similar scores for usability compared to the traditional Point-and-Teleport and which did not induce significant cybersickness, can be used as alternatives. The head-direction-based methods on the other hand should be avoided as a selection mechanism. The contrast between the study data and the user comments is an interesting finding. While the data measured by questionnaires is in favor of traditional controller-based methods, user comments show that many of them prefer the newly proposed jumping methods. The traditional Point-and-Teleport method still seems like the most practical for many applications, but we believe that jumping as a trigger method can be incorporated into future games, such as exergames. Also, the positive impact of jumping on physical well-being and fun lead us to believe that Jumping-Cont can be a valid alternative to traditional Standing-Cont teleportation. These techniques can lead to a fun and engaging way to move around in virtual environments while keeping up the illusion of being present. In future work, different types of jumping styles with different selection methods, like eye blinks, a button press, or a gesture, could address some of the problems raised in this study.

References

Proceedings of the Annual Symposium on reality trampoline game. In SI3D 1
ments.

Packt Publishing Ltd, 2018. 1

(2017), ACM, p. 316–323. 2


[Roost] RoomScale.: URL: https://uploadvr.com/steamvr-usage-data-room-scale/. 2


© 2020 The Author(s)