Comparing two input devices for virtual walkthroughs using a Head Mounted Display

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ABSTRACT

Selecting input and output devices to be used in virtual walkthroughs is an important issue as it may have significant impact in usability and comfort. This paper presents a user study meant to compare the usability of two input devices used for walkthroughs in a virtual environment with a Head-Mounted Display. User performance, satisfaction, ease of use and comfort, were compared with two different input devices: a two button mouse and a joystick from a gamepad. Participants also used a desktop to perform the same tasks in order to assess if the participant groups had similar profiles. The results obtained by 45 participants suggest that both input devices have a comparable usability in the used conditions and show that participants generally performed better with the desktop; a discussion of possible causes is presented.

Keywords: User study, Input devices, HMD (Head Mounted Displays), Virtual Environments (VE), virtual walkthroughs

I. INTRODUCTION

Virtual Reality (VR) platforms using Head Mounted Displays (HMDs) and trackers are important for applications such as training and simulation and frequently used for virtual walkthroughs. These HMDs may have significant advantages when compared to other displays since they may allow users to always see the virtual world as they turn their heads offering a 360º field of regard. However, not all input devices (e.g. keyboards) can be used with HMDs. In fact, choosing the appropriate input device is an important issue for a particular virtual reality application. It implies considering the tasks that need to be supported, choose the appropriate interaction techniques and map the input device to those techniques [1].

Navigation is a central task while using a Virtual Environment (VE). It is the most common interaction task in 3D interfaces, often supporting other tasks. In essence, navigation is the movement in and around an environment and

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includes travel and wayfinding. Whereas wayfinding is the cognitive component, travel is, according to Bowman, Kruijff, LaViola & Poupyrev ([1] p.136), "the motor component … the low-level actions that the user makes to control the position and orientation of his viewpoint". They contribute both to the same goals; though in simple VEs a good travel technique might be enough. Several interaction techniques can be used to perform travel tasks, but their usability often depends on the specific task. Test bed experiments have attempted to relate task type to usability of the technique [2], and various guidelines are available. Other characteristics besides users' goals should be considered in the design of a travel technique; e.g., if only short distances are to be travelled, velocity control may not be necessary, or if targets are visible, gaze-directed steering works well.

Due to its importance, we focused on travel in previous studies [3,4]; in the scope of these studies we observed and interviewed users, and logged data characterizing their performance, while doing virtual walkthroughs in a VE using a setup including a HMD with a tracker and a common (two button) mouse as input for direction (forward and backward). Throughout those studies, participants recurrently suggested that we should use instead a gamepad with a joystick as in their opinion it would be more usable. Possibly this recommendation was due to the fact that desktop walkthroughs are frequent in games generally using a combination of keyboard and mouse in PCs and joysticks from a gamepad in consoles.

The users' suggestion to replace the mouse by a gamepad joystick seemed promising in terms of usability for the following three reasons:

1 - gamepads are meant to be held with both hands while playing while mice were designed to be used on a working surface;
2 - a more intuitive mapping technique can be used with the joystick than with the mouse;
3 - many young users are very experienced in using gamepads.

Thus, it seemed that better results concerning performance, satisfaction and comfort might be possible with the gamepad joystick as compared to the mouse. This made us consider performing a new user study to tackle the following question: Will users' performance, satisfaction and comfort while using the HMD in a virtual walkthrough improve with a gamepad joystick as input device as compared to a mouse?

Empirical studies for determining appropriate input devices for specific tasks in 3D user interfaces in general is an important area of research as these interfaces continue to evolve. On the other hand, the type of input devices that can be used along with HMDs is limited given that users cannot see the physical world while using them, which makes the choice of input devices more demanding. According to Bowman, Kruijff, LaViola & Poupyrev ([1], p.133), this empirical work can be difficult due to the many variables involved, yet is important and can help designers in choosing input devices. For all these reasons we decided to organize a user study aimed at comparing the usability of a mouse and a gamepad joystick as input devices while using a HMD in a virtual walkthroughs; this paper reports on the methods and the results obtained with the collaboration of 45 young participants.

II. METHOD

To compare user performance, satisfaction, ease of use, and comfort during a walkthrough in our virtual environment while using a HMD with a tracker and two different input devices, the same virtual reality platform and VE were used as in previous studies [3,4].

Conventional evaluation methods may present limitations for 3D interfaces; there have been attempts to adapt them for use in VEs and efforts to develop structured evaluation methodologies [1,2]; nevertheless, there are some important differences to traditional user interfaces evaluation that must be taken into consideration [1,5]; for example, users wearing a HMD may be standing and cannot see the surrounding physical world, therefore the evaluator must ensure that they will not trip over cables, or bump into objects; moreover, touching or talking to the user may cause breaks in the presence, thus if presence is hypothesized to affect performance on the task under evaluation, the evaluator must take care to remain unnoticed.

II.1. Participants

We had the collaboration of 45 high school volunteer participants recruited in the scope of technology demonstrations for young people. There were 16 girls and 29 boys aged between 15 and 18 years; they were all used to computer games and all completed the walkthrough.

Due to practical constraints of the demonstration, a between-groups experimental design had to be used and thus, to tackle potential individual differences between the two groups, all the participants also navigated in the virtual environment using a desktop setup and the same variables were assessed.

II.2. Setups and travel techniques

The HMD was a i-glasses SVGA Pro with a resolution of 800x600 pixels, with stereoscopic capability, however it was used in mono, a 26º diagonal of FOV, a frame rate of 60Hz and 120Hz (in mono and stereo, respectively), an InterTrax 2 tracker from InterSense with three degrees of freedom (DOF) (roll, pitch and yaw) and a PC with a nVidia Quadro FXGo 1400 graphics card. While using the HMD, users were standing and someone was holding the cables to avoid disturbing the participants. Interaction was performed using either a standard two button mouse (swop-3 optical 3D mouse) or a mini joystick of a gamepad (XFX Executioner Dual Reflex PS2 Controller) (Fig. 1).

According to the classification of travel techniques in physical versus virtual ([1], p.189), we used a combination of physical rotation (via head-tracking) and virtual translation (via input device). Gaze-directed steering was chosen. The input device in both cases allowed only moving forward or backward.

The mappings used for the two input devices were the following:

1 - Mouse: push left button – move forward; push right button – move backwards;

2 - Gamepad joystick: tilt joystick forward – move forward; tilt joystick backwards – move backwards.

The desktop used had a 19” Wide Screen monitor with a resolution of 800x600 pixels at a viewing distance of 25”, corresponding to a 42º diagonal field of view (FOV); interaction was performed using a mouse and keyboard. In this case the travel mapping was the typical WASD (front, left, back and right) used in most First Person Shooter games.

Fig. 1. left – using the gamepad joystick; right – using the mouse (bottom); and Gamepad XFX Executioner Dual Reflex PS2 Controller (top).

II.3. Virtual Environment and tasks

As VE we used a simple scenario where users had to navigate in a maze in order to find objects. A game was chosen as it may be designed to incorporate several navigation tasks that users perform spontaneously, which can be an advantage in VE usability evaluation since users can concentrate on their tasks, not needing directions from the experimenter; moreover, a game is more attractive to volunteer users. On the other hand, a maze provides a good way to test some forms of navigation (other authors also used mazes in navigation experiments [6]). Users had to walk through the maze for 5 minutes in order to find 21 objects (Fig. 2). These objects were floating at eye level and users had only to collide with them, receiving visual and audio feedback of their success.

According to Griffiths, Sharples & Wilson [7], tests of navigation while grounded should contain simple actions such as moving forward and navigating around corners, as well as more complex manoeuvres, for instance walking through doorways (which requires correct judgement of distances between viewpoint and the doorway). Thus, our VE was designed as to compel users to perform some of those simple and complex navigation tasks.

Fig. 2. Aspect of the Virtual Environment with a floating object.

II.4. Experimental design

This study was designed to test the following main null hypothesis: users would have similar performance whether using a mouse or a gamepad joystick while navigating our VE using a HMD.

Speed and accuracy are easy to measure quantitative values, but other more subjective measures should also be considered, such as perceived ease of use, and user comfort; user-centric measures are important: if a VE causes fatigue or discomfort, it will not provide overall usability despite its performance in other areas. Thus, simulator sickness and fatigue were also considered.

A between-group experimental design was used; input device and corresponding travel technique (mouse vs. gamepad joystick) were the independent variable and performance, satisfaction, ease of use, and comfort were the dependent variables. Performance was measured through the number of caught objects, velocity, walked distance and number of collisions with the walls, as we have been doing in our previous studies. Lapointe, Savard & Vinson[8] have also used walked distance, and velocity to measured user performance in a virtual walkthrough. Satisfaction and comfort (regarding nausea, vertigo and disorientation) were assessed through a post-test questionnaire in order to avoid eliciting an increase in simulator sickness felt by users[9]. Data characterizing profile (as age, game experience) and preference were also collected through the same questionnaire. Moreover, after completing the experiment, participants were informally invited to express their opinions and suggestions.

Since we had two groups, and in order to have a “baseline performance”, all participants also performed the walkthrough in the desktop setup. Likewise, the performance, satisfaction and comfort were measured through system logging and questionnaire.

II.5. Procedure

Each participant played the game for five minutes on the HMD setup using one of the input devices and also the desktop. To avoid a possible bias on the results due to learning, fatigue or boredom, the order in which the two setups were used was varied among users, by randomly dividing them in two groups and asking users to start by a specific setup according to the group they belonged to.

This study involved several phases. First the procedure was explained to the participants and they could practice for a while; then participants used both setups while performance data were logged; finally, satisfaction and comfort data as well as preferences were obtained:

1 - The experimenter explained the complete procedure to each participant, collected his/her consent and informed that s/he could give up at any moment. The participant were allowed to practice for a while;

2 - The participant performed the walkthrough using both platforms in sequence: the HMD setup with one of the input devices (mouse or joystick) and the desktop; meanwhile, performance measures (number of caught objects, travelled distance, mean attained velocity and number of collisions with the walls) were logged and the participant observed;

3 - The participant answered; finally s/he was informally asked to make comments or give suggestions. Several questions concerning preferences, ease of use (seeing and catching object and entering and walking along the

corridors) and comfort (vertigo and disorientation) were included, as well as questions concerning profile (e.g., age, gender, experience with computer systems, and game usage) which were considered possible secondary variables.

III. Results

The 45 high school volunteer students were divided in two groups: 22 used the mouse (G1) and 23 used the gamepad joystick (G2), while using the HMD. As mentioned, to establish a reference, both groups used the desktop.

Performance data were analysed using Exploratory Data Analysis (EDA) [10], and non-parametric tests [11,12]; all performed using STATISTICA [13]. These tests were chosen due to the relatively low number of participants and lack of normality of the obtained data (confirmed by Shapiro-Wilks tests). Mann-Whitney U Tests were used for between-groups tests (e.g. testing G1_hm against G2_hj); while Wilcoxon Matched Pairs Tests were used for within-group tests (e.g. testing G1_hm against G1_d).

Figure 3 shows the box-plots corresponding to the number of objects caught by each group as using the desktop (G1_d, G2_d), and the HMD with the mouse (G1_hm) or the joystick (G2_hj). We observed that users from both groups generally caught a higher number of objects with the desktop (median=19) as compared with the number of objects caught using the HMD (median=16.5 or median=16 with the mouse or the gamepad joystick, respectively). Testing the difference between the number of objects caught by the two groups with the HMD (using either input device), we found through a Mann-Whitney U Test that it was not significant (p-value=0.18).

We also tested average velocity (Figure 4) and obtained similar results: users reached higher velocities with the desktop and no significant differences were observed between the velocity using the mouse and gamepad joystick (Mann-Whitney U Test, p-value=0.84), neither between the two groups while using the desktop (Mann Whitney U Test, p-value=0.08).

Figure 5 shows the box-plots corresponding to the number of collisions by each group using the desktop (G1_d, G2_d) and the HMD with the mouse (G1_hm) or the gamepad joystick (G2_hj). Users from both groups collided less with the walls when using the desktop as compared to when they used the HMD. Again, no significant differences (confirmed by a Mann Whitney U Test, p-value=0.97) were observed for the HMD with the mouse (G1_hm) or the gamepad joystick (G2_hj).

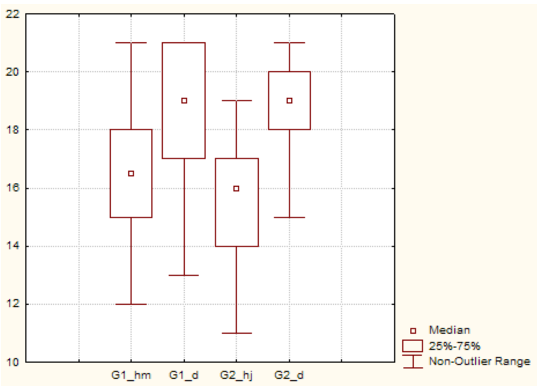

Fig. 3. Median number of objects caught by the two groups (G1 and G2) while using the mouse and the gamepad joystick with the HMD (G1_hm, G2_hj, respectively), and the desktop (G1_d and G2_d). The two groups have better performances while using the desktop and similar performance while using the HMD, with either input device.

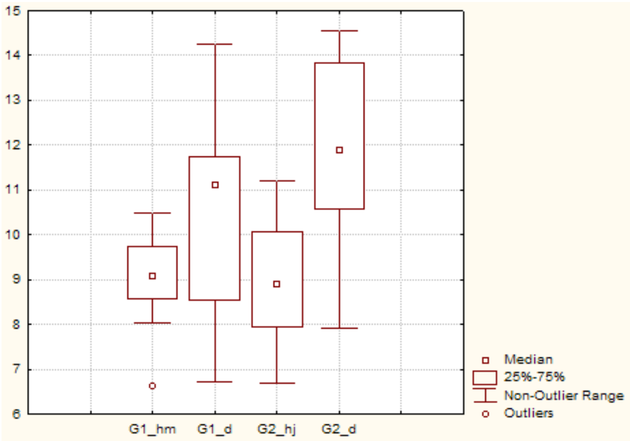

Fig. 4. Average velocity attained by the two groups (G1 and G2) while using the mouse and the gamepad joystick with the HMD (G1_hm, G2_hj, respectively), and the desktop (G1_d and G2_d). The two groups have better performances while using the desktop and similar performance while using the HMD, with either input device.

No significant performance differences between the two groups were observed when they used the desktop suggesting that the groups have similar profiles, which is important when a between-group experimental design is used, as in the present case. The three performance measures used, number of objects caught, attained velocity and number of collisions were similar for the two groups as confirmed by Mann Whitney U Tests (p-value=0.86, 0.08, 0.07 respectively); this suggests that profile differences between the two groups need not be taken into consideration in the results obtained with the HMD.

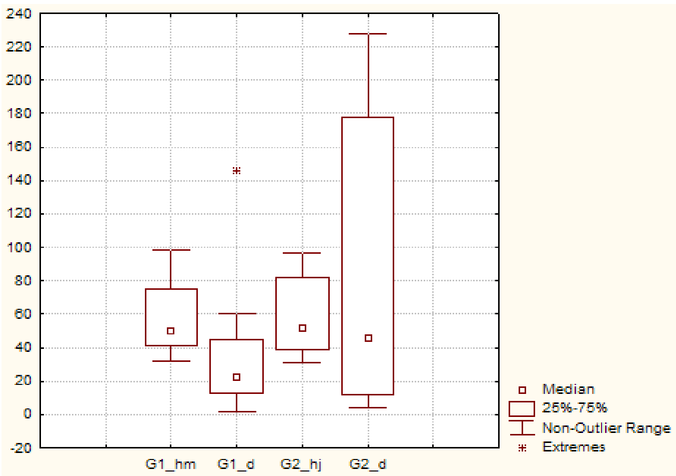

Fig. 5. Number of collisions obtained by the two groups (G1 and G2) while using the mouse and the gamepad joystick with the HMD (G1_hm, G2_hj, respectively), and the desktop (G1_d and G2_d). The two groups have better performance (less collisions) while using the desktop and similar performance while using the HMD, with either input device.

We were expecting better performances with the gamepad joystick as mentioned. Nevertheless, the results obtained confirmed yet again the fact that users generally perform better while using the desktop, being consistent with previous studies (Sousa Santos et al., 2008, 2009). In fact, the difference in number of objects caught by each group using the

HMD (with either input device), and the desktop was established as significant through Wilcoxon Matched Pairs Tests (p-value=0.002, p-value=0.00006 for group G1 and G2 respectively). Furthermore, the difference between velocity using the HMD and the desktop was also found significant according to the same type of test (p-value=0.0036, p-value=0.00004 for group G1 and G2 respectively). As for the number of collisions, the Wilcoxon Matched Pairs Test found significant the difference between the HMD and the desktop for group G1, using the mouse (p-value=0.002) and not significantly different the results for group G2, using the joystick (p-value=0.35).

All participants liked to play using both platforms (HMD with one of the input devices and desktop) and most preferred the HMD (37 of 45) over the desktop.

The answers to the questions concerning ease of use (seeing and catching objects; entering and walking along the corridors) as well as comfort (vertigo and disorientation) using the mouse (G1) and the gamepad joystick (G2) with the HMD were expressed in three level ordinal scales. For ease of use the scale was 1 – very easy, 2 – easy, 3 – not easy and for comfort it was 1 – none, 2 – some, 3 – a lot of disorientation/ vertigo.

The answers concerning ease of use were very similar for the two groups (it was very easy). Also concerning comfort the two groups gave similar answers as shown in figures 6 and 7. However, participants using the gamepad joystick reported slightly more disorientation; although, it was not statistically significant (Mann-Whitney U Test, p-value=0.22). Despite the increase of disorientation reported by the participants using the gamepad joystick (17 answers of 2-some disorientation) as compared with the participants using the mouse, the median values are the same (median=2).

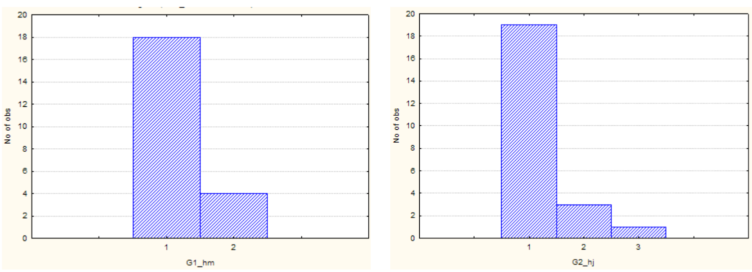

Fig. 6. Answers concerning vertigo by the two groups (G1 and G2) while using the mouse or the gamepad joystick with the HMD (G1_hm, G2_hj, respectively) in a three level scale (1- none, 2-some, 3-a lot of vertigo). The two groups gave similar answers.

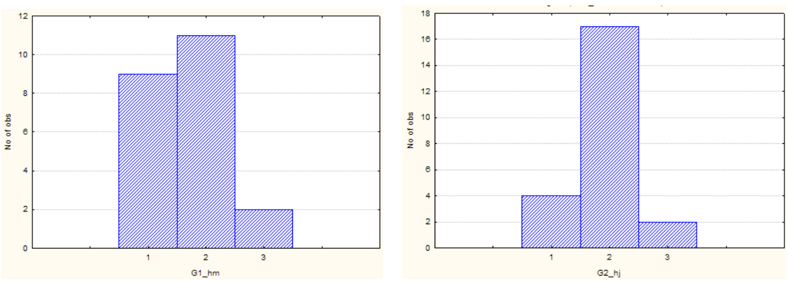

Fig. 7. Answers concerning disorientation by the two groups (G1 and G2) while using the mouse or the gamepad joystick with the HMD (G1_hm, G2_hj, respectively) in a three level scale (1- none, 2-some, 3-a lot of disorientation). Participants using the joystick reported slightly more disorientation (not statistically significant).

IV. DISCUSSION AND CONCLUSION

A user study meant to compare the usability of two input devices, a mouse and a gamepad joystick, used for walkthroughs in a virtual environment with a HMD and a tracker was presented. Participants also used a desktop to perform the same tasks in order to establish if the the groups have similar profiles, which was confirmed statistically. This study was devised to test a hypothesis concerning the influence of the input device on users' performance, satisfaction, ease of use, and comfort, while using an HMD.

While the study by Lapointe, Savard & Vinson[8] found that users had better performances in a desktop walkthrough when they used a mouse (as compared to a keyboard, a joystick or a gamepad), and the authors conjecture that this might be a consequence of the larger experience their participants had with the mouse, our results don't show any differences between the groups using the two input devices (mouse and gamepad joystick) when performing a walkthrough while using a HMD. Notice, however, that the above mentioned work studied the influence of input devices in a walkthrough using a desktop, and ours had as main goal to compare this influence while participants used a HMD; nevertheless, our results concerning the desktop setup, used just to assess if the profiles of the two groups were similar, seem to be in line with the results of Lapoint et al.

Our participants were high school students all having at least a reasonable amount of experience with joysticks from gamepads, and on the other hand, while using a HMD the mouse was not used on a surface as it can be during desktop walkthroughs. This led us to think that there was a potential joystick "advantage" as the mouse was not used in the conventional way but rather as illustrated in figure 1. It has been shown that bimanual interaction techniques may outperform the common way of using a mouse [14], and this might be another explanation for the fact that the gamepad joystick after all did not allow better performances as we were expecting. This suggests that it would be interesting to test a bimanual usage of the gamepad allowing both joysticks control the motion and let the user choose how to use them: either using one joystick to go forward and the other to move backwards, or pressing both simultaneously. The first mapping might better accommodate left-handed users.

Our results contradict what many participants in our previous studies had suggested and seemed reasonable concerning a potential usability advantage of a joystick compared to a mouse. This may illustrate the well know phenomenon that what users prefer or believe would result in a more usable user interface may not work out better [15], and reinforces the importance to perform user studies to obtain guidelines that will help designing more usable 3D user interfaces as the ones used in virtual reality [16].

This study also illustrates how to use a controlled experiment involving users and how to statistically analyze the obtained data in order to find answers to specific questions, as the ones tackled.

We deem that usability evaluation in virtual reality is still a challenge, given that the constraints of these platforms are different from the traditional ones and specific methods might be needed, namely to measure qualitative aspects as participants' perceptions concerning comfort.

Finally, this work strengthened our belief that user studies are adequate if we aim at getting insight, establishing guidelines for the development of more usable VR systems, or performing evaluation.

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