

PhD Archer: the VR Game and the UX Analysis

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Abstract

We built an archery game with two versions: VR and PC, and conducted a user experience study on the games. Out of the 19 participants, 16 said that they enjoyed the VR version better after playing both versions. Furthermore, more than half of the players predicted that they would play better with the PC version, whereas most participants played better with the VR version.

1. Introduction

Inspired by a recent popular small game on facebook messenger, “Master Archer Game,” we decided to develop an immersive archery game, which is a virtual reality (VR) version that we call “PhD Archer Game,” as its creators are two PhD students. The motivation of providing such archery gaming experience is not just for joyful fun time for user him/herself, but also some human perception studies. To compare how users react to and perceive the 3D environment in different settings of the immersive experience, we would like to find out that if virtual reality environment really provides the better user experience in gaming that requires users to perceive physics and 3D geometry perception. On the other hand, among various immersive experience, such as analygraph, virtual reality head mounted device, and plain LCD screen but with near 3D contents, how users would succeed the best in the gaming and obtain the most joyful gaming experiences is also of our great interest.

To address these questions, we conducted a user study on top of an archery game we developed, where the participant took a pre-survey, played the 2D and the VR versions of the archery game, and took a survey. Specifically, the participant would have three arrows for targets at each of three distances, and we will analyze how the gaming environment (i.e. PC or VR) and the target distance affect the participant’s shooting performance. In this report, we present how we built the game and conducted the user study, and the interesting things the study reveals.

2. Related works

2.1. VR and archery game

Over the literature research, we have found several experimental or pioneering works that we found particularly insightful and instructional. Domenico Sammartino, for example, implemented a virtual-reality cross-bow game, which employs external motion sensors to capture the user’s behavior [1]. In his technical report, he specifically discusses that the acceptable dimensions of stereoscopic arrow should be constrained. Further, he suggests that in order to provide a realistic game experience, the game should be able to visualize the real position and pose of the cross-bow as well as the arrow itself. As a final product, Sammartino implements the archery game with Unity3D game engine and the OptiTrack system, delivering a stereoscopic-3D cross-bow game. Seo *et al.* developed several VR games, including an archery game, for rehabilitation purpose [2]. On top of their VR games, they performed a user study that includes pre and post-surveys to study subjects’ expectations and preferences on VR games.

Furthermore, in 2016 Yiran Zhao *et al.* presented a wearable device that can analyze the behaviors of the archer by using accelerometers [3]. Though this work is not for entertainment purpose, we found it useful, as it guides an approach to apply electronics to the archery. Beyond the technical papers, we have also studied several professional or interdisciplinary publications. For example, Stanislaw H. Czyz *et al.* quantitatively study the archers’ performance [4]. Specifically, they provide a score vs. target distance model, or in other words, accuracy as a function of target distance, which provides a control reference to which we can compare with our recorded user behavior.

2.2. Depth estimation

A majority of conventional depth estimation lies in single-view depth estimation and multi-view stereo rendering algorithms. Both works by Gogard *et al.* and Saxena *et al.* demonstrate how to estimate the depth of the objects and scenes in a single-view point [5, 6]. Multi-view stereo pairs can be used to construct the structure from motion and other depth estimation required tasks [7, 8]. We believe that the

multi-view stereo rendered images viewed in a VR headset will equip the users better depth estimation ability than that in single-image depth estimation using vanishing points in the PC or usual gaming settings of plane monitor.

3. The Game

3.1. Game design

The game scene is consisting of the position where the archer stands, a bulleye target the archer will be aiming for, and some additional items for decoration purpose. Figure 1 shows the scene of the shooting range from a birdview. To further enhance the game experience, we also put an arrow holder, where the archer will find another eight arrows on top of the first arrow, which is already in the bow. Also there is score display board showing the score of every attempt. The score of each attempt ranges from 0 to 10, 10 being the points for hitting the tiny central part on the bulleye, while 0 points being given if the arrow hits anywhere other than the bulleye.

Once the player finishes the first three arrows, the target will move 10 units (presumably representing 10 meters in the real worlds) away from the player, and then the player continues with another three attempts. Finally, the target moves another 10 units and the user has another three arrows, and the game ends when the ninth arrow hits. At this time, the player will have an opportunity to proceed to the target and take a look at it, as shown in Figure 2 (a); in the mean time we the user study coordinator will copy the scores shown on the display board in the scene, as shown in Figure 2 (b).

3.2. Implementation

The game was built with Unity 5.6, a powerful game engine. The scene was built on top of an archery game unity asset package, which is available from the Unity Asset Store¹. While the package provided nice item assets such as bow and bulleye target and a simple game prototype for us to start with, we added additional game logics and physics to further enhance the game experience. For example, our custom script allows the player to hold the space bar (or the trigger on the VR head set) to determine to what extent the archer wants to pull the string on the bow, setting the initial velocity of the arrow. Furthermore, we have also implemented additional physics on top of Unity's physics engine. For example, the arrow will point to the direction of its velocity once it leaves the bow. Finally, we realized that sound effects are essential for a game, and especially for a VR game that aims to mimic the real world. Therefore for we have design sound effects for several events, such as string

¹<https://www.assetstore.unity3d.com/en#!/content/60443>

pulling. Thanks to unity's built-in 3D sound system, the player can experience realistic spatial sound effects when they are playing.

3.3. Cross-platform support

Since we propose to deliver two versions, one PC and VR for user experience comparison, it is important to be able to build the game for different platforms. Fortunately, Unity conveniently provides multi-platform building, which allows the developer to switch among different build targets by simply clicking a button. Thanks to Unity, we were able to build for the Mac as well as for iOS devices. The build and installation for iOS devices were done with Xcode 8.3.3 running on macOS Sierra (version 10.12.5).

3.4. VR support

The VR support is done by using Google VR SDK for Unity², which conveniently provides head rotation API (application programming interface) and automatic setting for different VR headsets. In our implementation, we used the ViewMaster housing and an iPhone 6 as the head mounted display (HMD) instead of the Google Cardboard, as our game needs the mechanical trigger on the housing, which allows the user to "hold and shoot," whereas the Google cardboard uses a magnet as trigger, which can only send "pulse" signal.

4. The user study

4.1. Methodology

The user study for VR user experience was conducted as follows: the participant will be firstly asked to take the pre-survey questions regarding some general knowledge and background for VR and archery, the the participant will then be asked to play both the PC and the VR versions of the archery game, and finally be asked to answer the post-survey questions for our analysis. Nineteen Stanford graduate students from a variety of disciplines participated the user study. The whole process takes approximately 10 minutes for each participant. The user will receive a can of Pepsi or Mountain Dew for their participation as the reward.

4.1.1 Pre-survey

The pre-survey includes the following questions and answer choices:

Q1. How familiar are you with Virtual Reality (VR) Games, state your experience level?

A1. 0 (None) - 5 (Expert)

Q2. How familiar are you with Archery?

A2.

²<https://developers.google.com/vr/unity/>

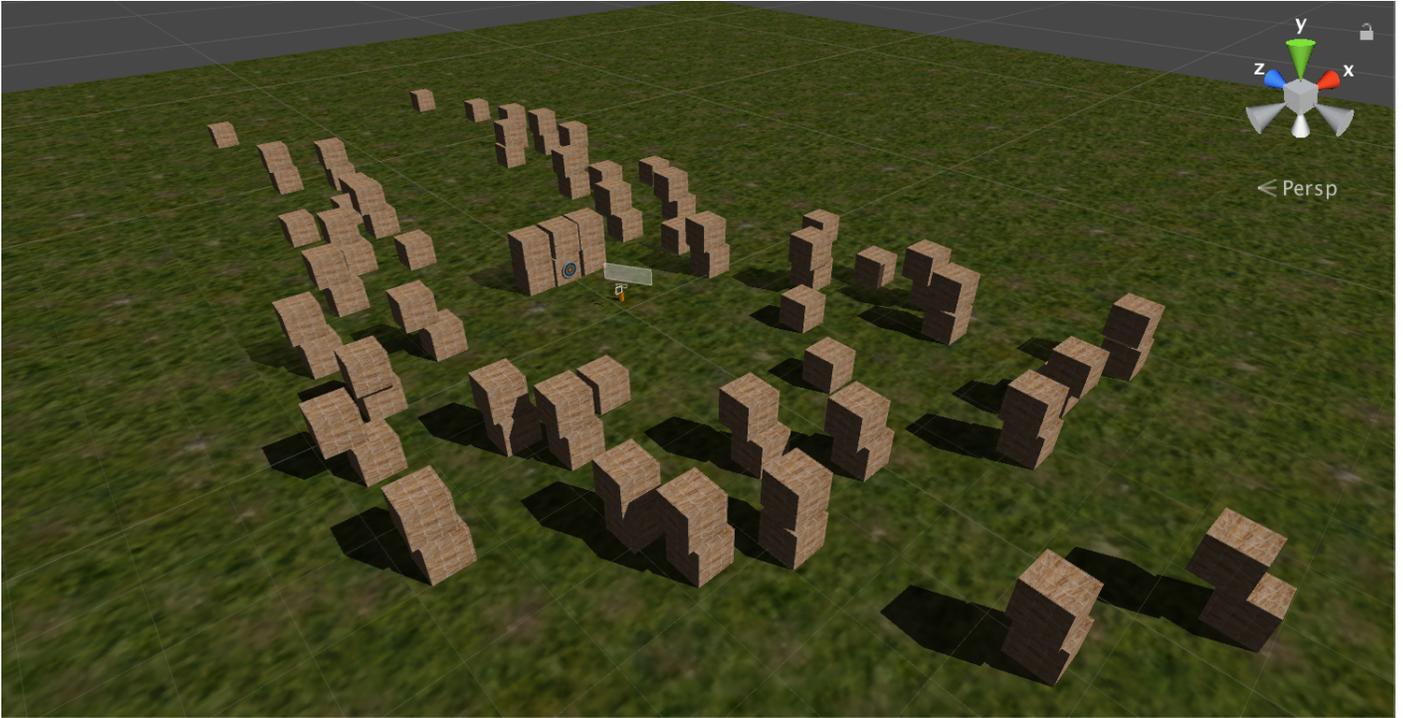


Figure 1. Birdview of the archery game scene.

1. None.
2. Have played some archery video games.
3. Have experienced real archery.

Q3. Do you think immersive experience like VR would help you estimate the depth of the target in any shooting scenario?

A3. 0 (Of course not!) - 5 (Of course yes!)

Q4. Do you think immersive experience like VR would help you estimate the depth of the target in any shooting scenario?

A4. 0 (Absolutely No) - 5 (Absolutely Yes)

Q5. We provide two versions, PC and VR, gaming experience, which one do you think you would perform better?

A5.

1. PC.
2. VR.

In Figure 4, we can see that in general people are not that familiar with virtual reality games, few of them even had no experience in any kind of VR immersive experience. Figure 5 shows that approximately one third of the users had no experience in archery games nor real archery. Another one third had experience in video archery games, and the last one third of users have real archery experiences.

We would like to know if these prior experience in archery in any form would help user achieving better performance. Furthermore, Figure 6 shows that almost 60 percents of the users suggested that they think immersive experience such as VR would help them aim the target while better perceiving the depth in the 3D surrounded world. Figure 7 suggests that almost 80 percents of the user prefer to have sound effect while enjoying the game. Interestingly, as shown in Figure 8, slightly more than a half participants predicted that they would perform better in the PC version, primarily due to higher familiarity with the PC video games. However, is this true? Do people perform better in PC version since they are not that familiar with the VR settings? This will be evaluated in Sec. 4.2.

4.1.2 Game playing

We asked the participant to play both version of the PhD Archer game, in the order of playing the PC version and then the VR version. We recorded their scores after each version was done. There are in total 3 stages, each stage we allow three arrows to be shoot, but each serves as its own independent score, i.e. the three arrows are not trial and error opportunity to obtain the optimal results. For each stage we gradually increase the distance between the target and the user and thus increase the difficulty of the aiming and accurate depth estimation.

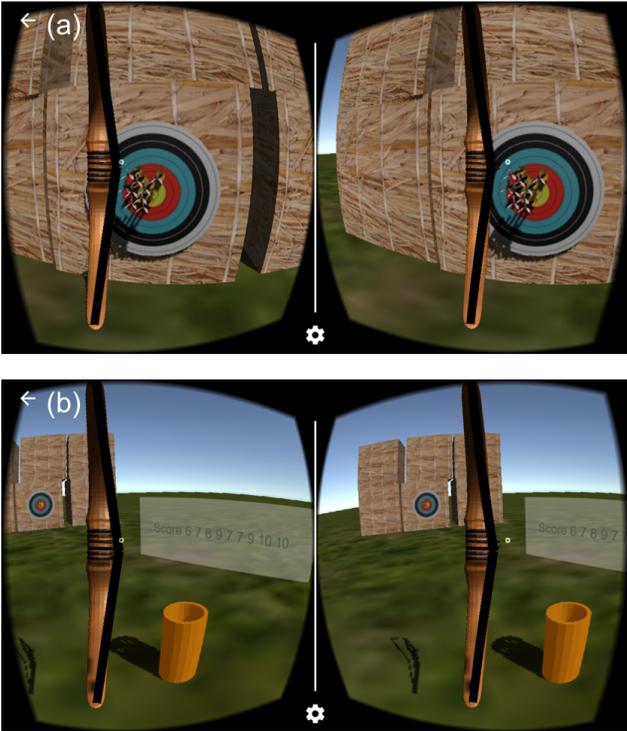


Figure 2. (a) When done shooting, the archer is able to walk to the bullseye and check the arrows on the target. (b) The score display shows the latest scores.



Figure 3. The mechanical trigger on the HMD allows the user to “hold and shoot.”

4.1.3 Post-survey

The post-survey includes the following questions and answer choices:

Q1. How familiar are you with Archery?

A1.

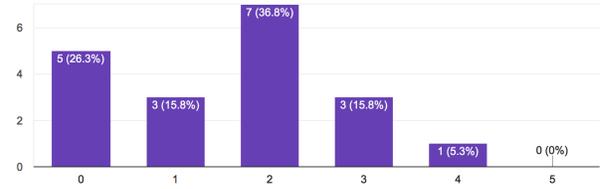


Figure 4. Users' experience of VR games.

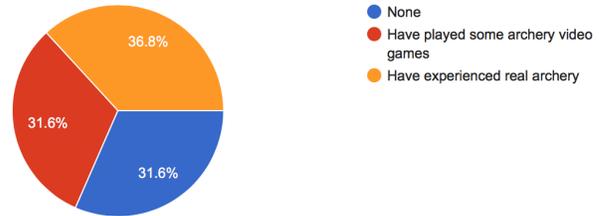


Figure 5. User's familiarity of the archery.

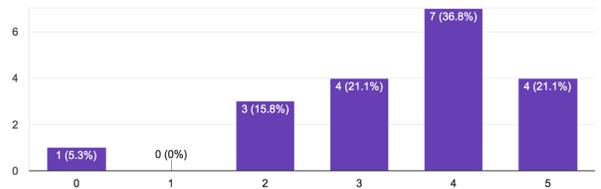


Figure 6. The pre-survey of better depth estimation for aiming with immersive experience such as VR.

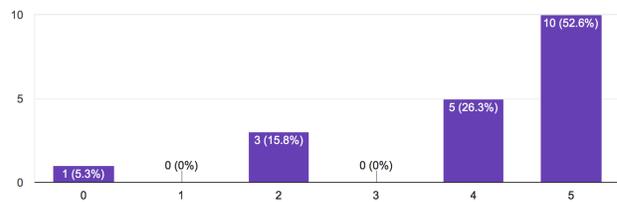


Figure 7. Pre-survey of that if sound effect will bring better user experience during gaming.

1. PC.
2. VR.
3. Both.
4. Neither.

Q2. After playing both versions, did you think immersive experience like VR, would help you estimate the depth of

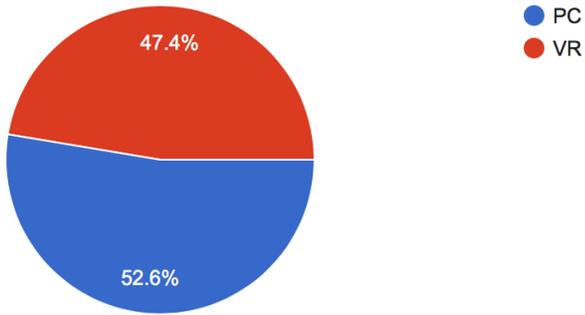


Figure 8. Users' PC vs. VR performance prediction

the target and have better aiming?

A2. 0 (Absolutely No) - 5 (Absolutely Yes)

Q3. After playing the game, did sound effect bring you better user experience in a VR game?

A3. 0 (Absolutely No) - 5 (Absolutely Yes)

Q4. How comfortable were you controlling the bow and aiming in the PC version?

A4. 0 (Terrible) - 5 (Excellent)

Q4. How comfortable were you controlling the bow and aiming in the PC version?

A4. 0 (Terrible) - 5 (Excellent)

Q5. How comfortable were you controlling the bow and aiming in the VR version?

A5. 0 (Terrible) - 5 (Excellent)

Q6. Did you feel any fatigues while playing the VR version?

A6. 0 (Completely Not) - 5 (Very Fatigue!)

Q7. Did you feel any fatigues while playing the PC version?

A7. 0 (Completely Not) - 5 (Very Fatigue!)

After playing the game, according to Figure 9, we found that more users agreed (scores over or equals to 3) that having been immersed in the virtual reality environment equip them better ability while shooting the archer by 79% to 84.3% gain. Majority of users still think that sound effect will bring them better user experiences with a slight gain in one user switched from not so sure to very sure, as shown in Figure 10. For both VR and PC versions, users expressed they were capable of comfortably controlling the aiming and the shooting, while for the PC version there are slightly more people (17 to 16) think that the PC version is more comfortable to control, according to Figure 11 and Figure 12. We attribute this to the fatigues when facing the VR environment for those novice users who had little

experience being immersed in such 3D surrounded world, as shown in Figure 14 and Figure 13. 6 out of 19 users expressed undergoing fatigues (scores over or equals to 3) when playing the VR version, while majority of users expressed 0 fatigues when playing the PC version. This suggests that more enjoyable user experience from VR comes to a compromise of undergoing more stressed experience through the VR headsets.

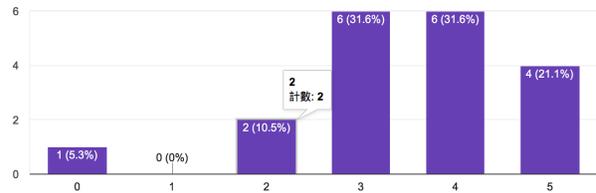


Figure 9. The post-survey of better depth estimation for aiming with immersive experience such as VR.

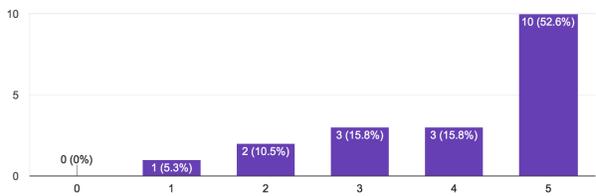


Figure 10. Post-survey of if sound effect will bring better user experience during gaming.

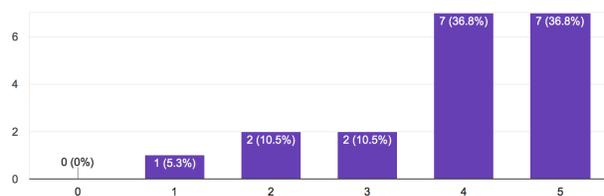


Figure 11. How comfortable were the users while controlling in the VR environment.

4.2. Further Analysis

We then performed some interesting post-analysis after gathering the data from the users. Table 1 and Figure 15 show the averaged scores from the 19 participants, categorized by the stages where the distance is near (10 m), middle (15m), and far (20m). It is obvious to see them in all stages, users perform better in VR settings than in PC settings, for

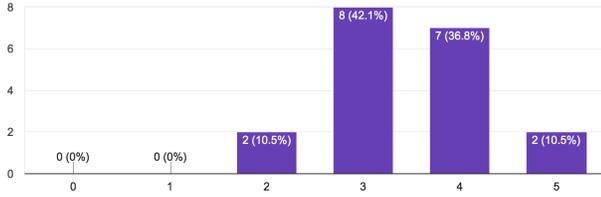


Figure 12. How comfortable were the users while controlling in the PC settings.

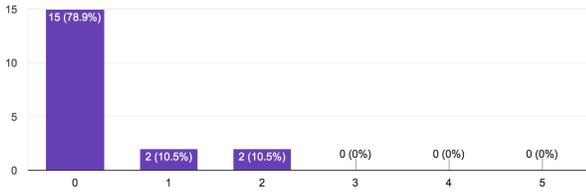


Figure 13. How fatigue were the users while playing the archery game in the PC settings.

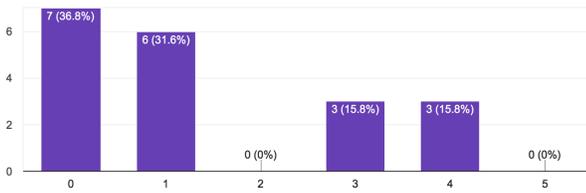


Figure 14. How fatigue were the users while playing the archery game in the VR environment.

the last stage this is even more significant. The averaged raw score of both version are 4.0 and 5.4, respectively. Observing the trend of the scores at each stage, usually the first shot achieves the lowest score, which is much more significant in the third stage, we found that the user were actually learning from failure trials, and improving their aiming by adjusting themselves to the environment. We also calculated the weighted scores proportion to the distance of each stage. The resulted weighted averaged scores are 3.5 and 4.8 for PC version and VR versions, respectively. Both scores are slightly lower than those without the weighted average. This is reasonable as the final stage is the hardest and weighted the most to showcase the ability of users being capable of estimating the depth of the target more accurately. The gain from the PC version to the VR version in the weighted scenario is 37%, which is higher than the raw averaged gain 35% (gain defined as $(\mu_{VR} - \mu_{PC}) / \mu_{PC}$, μ being raw average).

In Table 2, we notice that, surprisingly, users with little

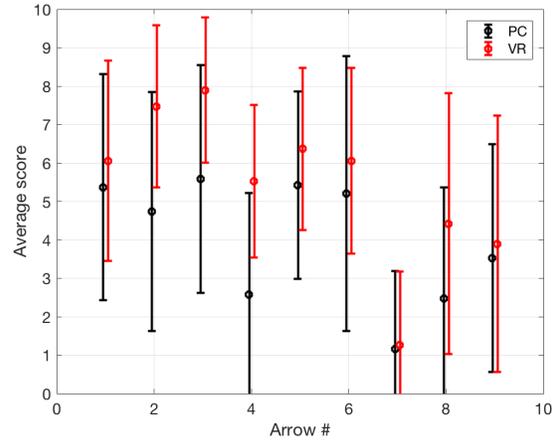


Figure 15. Players' score vs. arrow number. See Table 1 for values. Arrows 1 to 3 are aiming for a near target; 4 to 6, mid; 7 to 9, far. Errorbars indicate one standard deviation. Horizontal positions of data points and errorbars are slightly offset for better visualization.

to no archery experience, i.e., those who have none or only played video games, actually performed better than those who have real experience in archery. We attribute this to the controlling and real world environment estimation is different from that of the unity engine, which is a much more simplified world.

Figure 16 illustrates that how users predicted their performance in both PC and VR versions and how they actually performed during the game. Did their actual performances really meet their expectations? This confusion matrix suggests that 0% of users predicted they would perform better in VR setting, but actually performed better in the PC setting, while 26% of users who claimed they would perform better in PC version guessed right. On the other hand, 26% of users wrongly predicted that they would perform better in the PC version, presumably due to better familiarity of PC games, turned out to perform better in the VR environment. The left majority of 47% of users met their expectations in predicting better performance in the VR setting. We found that people tend to predict the outcomes of the performance due to their past experience and familiarity (in total 52% of users predicted they would perform better in the PC version), rather than the actual science underneath the situation.

5. Discussion

In Sec. 4.2 we report that it is obvious that most users performed better with the VR version. One might argue that there is a bias, as all of the participants played the VR version after they had played the PC one, and thus they might have been more skilled when playing the VR version. While

Table 1. Average score of each arrow (shooting attempt) over 19 participants. See Figure 15 for visualization and errorbars. Weights: 1, 2, and 3 for near, mid, far targets, respectively.

Distance Arrow #	Near			Mid			Far			Average	
	1	2	3	4	6	6	7	8	9	Raw	Weighted
PC ver.	5.4	4.7	5.6	2.6	5.4	5.2	1.1	2.5	3.5	4.0	3.5
VR ver.	6.1	7.5	7.9	5.5	6.4	6.1	1.3	4.4	4.9	5.4	4.8

Table 2. Average scores categorized by users' archery experience.

Group	PC	VR
No archery experience	3.9	5.1
Have some archery game experience	3.2	5.0
Have some real archery game experience	2.8	3.7

User's actual performance

User's prediction	PC	VR
	PC	26%
VR	0%	47%

Figure 16. Users' own prediction before playing the games vs. their actual performances.

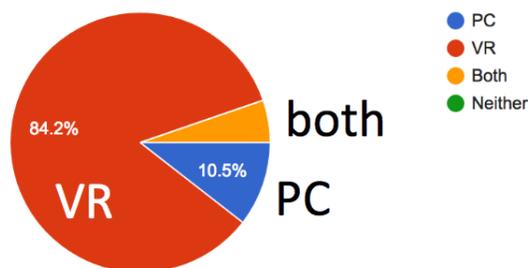


Figure 17. 16 out of 19 participants said they enjoyed the VR version over the PC version.

there is definitely a room for improvement, i.e. eliminating this bias, we argue that such order might be necessary, as we can provide instructions during the participant playing the PC version on the laptop. We also argue that the two versions are different enough, that the prior experience of playing the PC version might not contribute too much to users' better performance with the VR version.

Another thing one might argue is that we should have

been comparing with 2D and stereoscopic versions, both running on an iPhone, rather than PC vs. VR. While this is definitely a topic we should also study, we still think it is equally interesting to compare against the PC, which the users are most familiar with.

6. Future work

If we have had two more months to work on this project, we would have done the following to make the project and the user study thereof more complete. We write this section in the hope that it will be useful for the students taking the course in the future. First of all, both issues discussed in Sec. 5 are absolutely of our recommendation. Beyond that, in our original proposal, we also named analygraph, in addition to 2D rendering and VR, for the user study comparison. Further, we also proposed to study if the target were a person with an apple on top of his/her head, rather than a bulleye, would user be more serious and cautious before shooting? Another feature a future developer can do is to implement the facebook integration, as we realized that a great portion of our user study would like share their scores on their facebook wall.

7. Summary

We built a VR archery game with Unity, which works with the HMD provided in the class and an iPhone. On top of that, we further conducted a user study, where we asked participants to player both the VR game and a PC version. The user study results show that the most participants not only enjoyed the VR version better, but also performed better with VR over the PC version. We therefore conclude that VR could an ideal setting for an archery game, or even generally for first-person shooting (FPS) games.

Author contribution

Both authors conceived the whole experiment, which includes the game and the user study thereof. Po-Nan designed and programmed the game with inputs from Te-Lin. Te-Lin designed and conducted the user-study. Both authors wrote the manuscript.

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