USER-CENTERED DESIGN OF AN OMNIDIRECTIONAL TREADMILL VIRTUAL REALITY EXERGAME

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ABSTRACT

Omnidirectional treadmills allow users to walk long distances with 360 degrees of freedom without fear that they will collide with objects in their real-world environment. In this paper, we discuss a user-centered design approach to the development of an omnidirectional treadmill virtual reality exergame. Our findings suggest that exergames for omnidirectional treadmills should emphasize movement objectives that encourage players to travel throughout the virtual environment.

KEYWORDS

Omnidirectional treadmill exergame, user-centered design

1. INTRODUCTION

Virtual reality (VR) technologies can immerse users in fantastic environments with a feeling of presence not possible through other mediums. Contemporary applications of VR technologies exist for areas such as product design and prototyping, education, medical training, therapy, and entertainment (Hamad and Jia, 2022). VR games have become increasingly accessible to gamers, as the availability of the equipment necessary to play these games expands. A common user task in VR applications is to navigate throughout virtual spaces (Sherman and Craig, 2018). Omnidirectional treadmills allow users to walk in virtual spaces with 360 degrees of freedom, without fear of colliding with objects in the real physical world. However, omnidirectional treadmills are not yet commonplace, and thus the design of enjoyable omnidirectional treadmill games is an area largely unexplored. In this paper, we describe our work in progress to develop a VR exergame for an omnidirectional treadmill through a user-centered design approach.

User-centered design (UCD) actively involves users in the development process, through iterative design and evaluation (Mao et al, 2005). UCD approaches can help to ensure that products are meeting user experience goals. UCD techniques have been used to develop video games for motor-impaired users (Mat Zain et al, 2015), augmented reality games for children (Oppermann et al, 2018), and exergames for seniors (Brox et al, 2017). Through use of UCD techniques, we hope to identify characteristics of omnidirectional treadmill VR exergames that make them both easy and fun for players to play, while also allowing users to meet exercise goals.

2. BACKGROUND

The concept of an omnidirectional treadmill has been around for more than two decades (Darken et al., 1997), and there exists a growing body of research exploring user interaction with them. For example, researchers have compared the use of an omnidirectional treadmill to real walking on the ground (Soni and Lamontagne, 2020; Lewis et al, 2024). Findings suggest that travel speeds tend to be slower when walking on omnidirectional treadmills than on the ground, and that walking on omnidirectional treadmills impacts gait and turning. Other researchers compared use of an omnidirectional treadmill to a uni-directional treadmill (Bashir et al, 2023), finding that subjects reported higher levels of cybersickness, required more effort, and found it more difficult when walking on an omnidirectional treadmill as compared to a uni-directional treadmill. Wehden et al (2021) explored the impacts of a VR headset and an omnidirectional treadmill on the

gaming experience. They found that while subjects reported higher levels of game enjoyment when using the VR technologies, subjects also reported higher levels of cybersickness than those who used a standard (non-VR) gaming system. There was no significant difference with respect to game enjoyment between VR gaming with only a VR headset and VR gaming on the omnidirectional treadmill; however, subjects that used the omnidirectional treadmill reported higher levels of perceived exertion. Wehden et al (2021) suggest that this finding may be significant to designers of exergames, games that players play for the purposes of both fun and exercise. Polechoński et al (2023) explored the use of ankle weights to increase physical exertion while playing a game on an omnidirectional treadmill. They report that use of ankle weights significantly increased heart rate, while not significantly affecting game enjoyment.

While previous research suggests that walking on an omnidirectional treadmill is not as natural to users as real walking (Soni and Lamontagne, 2020; Lewis et al, 2024), or walking on a traditional uni-directional treadmill (Bashir et al, 2023), omnidirectional treadmills do have potential to be useful for VR exergames (Wehden et al, 2021; Polechoński et al, 2023). However, little research has explored the characteristics of VR exergames that encourage game players to actually walk (or run) on an omnidirectional treadmill in order to receive a health benefit. The purpose of this project is to design a fun VR exergame that encourages game players to exercise by walking on the Infinadeck omnidirectional treadmill (shown in Figure 1). UCD techniques encourage involving users in software design and evaluation. Our hope is that by involving potential game players in an iterative design and evaluation process, we will develop a game that is usable, fun to play, and provides gamers with a health benefit. The remainder of this paper reports on our first iteration of designing a prototype of our game and evaluating it with potential game players.

Figure 1. The Infinadeck omnidirectional treadmill.

3. VR MECH WARS

In our game, players take on the role of a space marine wearing a mech warrior suit. Since we intend this as an exergame, players walk on the Infinadeck omnidirectional treadmill to move their mech warrior suit. We chose the concept of wearing a mech warrior suit in the game since walking on an omnidirectional treadmill might feel unnatural for users. We thought that having game players believe they are walking in a mech warrior suit while playing the game might add to the realism of the game and increase the sense of presence. To win the game, players must repair damaged terminals while defending their space station from attacking enemy robots. The game was developed using Unreal Engine 5 and the Infinadeck Experience Platform Software Plugin developed by Infinadeck Studios and available on the Unreal Engine Marketplace. As can be seen in Figure 1, users of the Infinadeck typically hold the guardrail while walking on the treadmill. Because of this, we felt it would be impractical for users to hold a controller in their hand while playing the game.

Thus, game players fix damaged terminals simply by standing near to them for 14 seconds, and target and shoot missiles at enemy robots simply by staring directly at them for one second. Figure 2 shows a screen shot of the game.

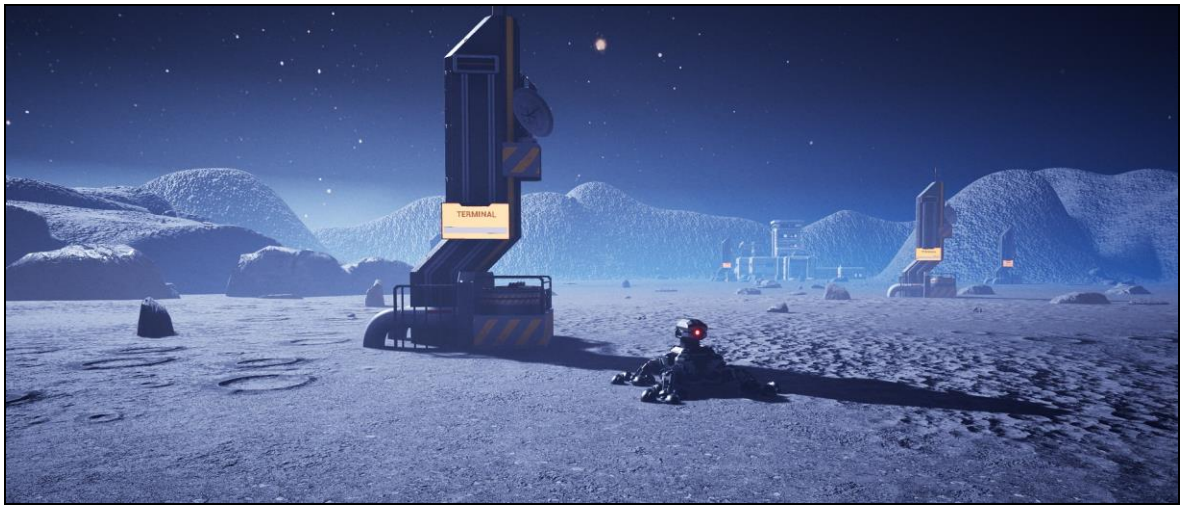

Figure 2. The VR Mech Wars game showing a terminal and enemy robot.

4. EVALUATION

Our primary goals with the evaluation of the first game prototype were to determine if the game was usable, what aspects of the game were enjoyable, and what modifications could be made to the game to motivate players to want to play longer. To evaluate the game, subjects were invited to play and provide feedback. Play sessions were designed to last less than 10 minutes, and provide subjects with an exercise experience equivalent to a leisurely walk on a treadmill. Subjects needed to find and repair six damaged terminals in order to complete the game. After playing the game, subjects then wrote their responses to the following items on an anonymous written questionnaire.

1) What was it like for you to experience an omnidirectional treadmill for the first time?
2) Did you find the game to be usable and playable? Please explain your answer.
3) Was there anything you thought you should be able to do that you were not able to do? If so, what?
4) What would have compelled you to keep playing the game longer and for more time?
5) What did you like most about the game?
6) What did you like least about the game?
7) What suggestions do you have to improve the game?

The Institutional Review Board at the authors' university approved this procedure. Twelve subjects played the game and completed at least some portion of the questionnaire. Subject responses to the items on the questionnaire were analyzed to identify general themes. Our findings are as follows.

Subjects described their first experience on the omnidirectional treadmill as "fun", and they found our game to be usable and playable. However, some subjects did comment that it was difficult to keep their "balance" on the treadmill, and they found it challenging to come to a complete stop since the treadmill was always attempting to pull them back to center. Subjects did like that this was a "new experience", "how realistic it was", and being "able to move around the world freely." Interestingly, the least liked aspect of the game was the "aim and shoot" system, as subjects found it "frustrating to have to stare down an enemy" in order to be able to shoot at it. Subjects mentioned wanting "buttons to press," and some wanted to be able to shoot lasers at robots in addition to targeting them with missiles. We designed the targeting system so that game players could keep both hands on the guardrail while playing the game, but apparently this was not intuitive and subjects found it "hard to aim and move at the same time." Perhaps our subjects were used to conventional controls more commonly found when playing first person shooter games. Subjects suggested that we develop a "backstory" to make the game more compelling, add "more objectives," and that we

provide a “map” to help them understand “where you have to go.” One subject even suggested that the game could require players to find ammunition in order to keep shooting at the robots.

In our next game prototype, we plan to decrease the amount of time that subjects must focus on a robot in order to target it, to the approximate amount of time it would take to press a button on a game controller. We hope that this will make it easier for players to target the robots while continuing to walk on the treadmill, and reduce the amount of time that subjects feel they must come to a complete stop in order to target the robots to destroy them. We also plan to decrease the amount of time that subjects must stand next to terminals in order to repair them. We had thought that subjects would target and destroy robots mostly while standing next to terminals, but in play sessions subjects attempted to target the robots while walking between the terminals. This was difficult to do, and clearly led to frustration for some subjects.

We do consider our findings to be encouraging results, as they suggest that the game was usable, subjects enjoyed moving about the game world, and that future versions of the game should focus on providing players with more movement objectives with more guidance on where to move. These findings also suggest that the game should focus less on tasks that encourage players to stop moving, such as targeting the robots and repairing the terminals. Incorporating these suggestions would likely increase the amount of exercise players perform while playing the game, since players would walk further and stop less in order to complete the game.

5. CONCLUSION

While previous research on the use of omnidirectional treadmills suggests that users find them less natural than real walking, they do support users in walking unrestricted distances in VR applications with 360 degrees of freedom. We report on the design and evaluation of our first prototype of a VR exergame for the Infinadeck omnidirectional treadmill. Findings suggest that subjects found playing our game to be fun, and that as we continue to develop the game we should focus more on movement objectives and less on targeting, since players found it difficult to walk on the treadmill and target enemies at the same time. Future versions of the game could allow players to set workout goals. Players could select their walking speed and the amount of time they want to walk. The game could then generate an environment with objectives spaced at distances requiring players to walk their selected amount of time in order to complete the game. Navigation objectives could also be placed randomly in the environment so that no two gameplay experiences are the same. This would give players more control in how the game is used to help them meet their exercising goals, and provide more variety in the gameplay experience.

One possible limitation to our findings is our sample of subjects. All of our subjects were college and university students, and thus their opinions may not reflect the general population of game players. Future evaluations should include subjects from a more diverse age range. This would help us to determine the viability of the game as an exercising tool for a variety of age groups. Future work could also focus on multiple game playing experiences over a much longer period. This would help to assess the likelihood of players using the game as an exercising tool over an extended period. Nonetheless, we are encouraged by our findings and do believe they support a general conclusion that omnidirectional treadmills have potential as devices that can be used to develop VR exergames.

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