Implementing 'The Enclosing Dark': A VR Auditory Adventure

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Abstract

Video games rely heavily on visual information, making them largely inaccessible to blind or visually impaired (BVI) individuals. To address this barrier, we explored what an accessible video game for a BVI player would look like. Through the design process of *The Enclosing Dark*, an immersive virtual reality (VR) auditory adventure game, we found that audio, haptic, user interface, and player training require special development to translate them for a non-visual environment. The pre-game training teaches the player how to understand the audio and haptic information and navigate the user interface, which is essential due to the lack of industry standards. Through initial informal user experience (UX) testing, we have identified additional areas that need further study, including the user interface voice recognition system and a standardized auditory sound dictionary for use in future accessible games. The creation of *The Enclosing Dark* suggests that it is possible to create accessible VR games and provides a foundation upon which other game designers and studios can build.

Keywords

Virtual Reality; Game Design; User Interface; Accessibility; Visual Impairment

Introduction

The Enclosing Dark: A VR Auditory Adventure is a prototype virtual reality (VR) game designed as an accessible game option for the visually impaired. To accomplish this, the game takes advantage of built-in features found in today's commercially available VR systems (e.g. Oculus Rift), specifically spatial audio and haptic feedback, to offer a unique VR experience. In this article, we summarize the design choices made during the creation of *The Enclosing Dark* and argue that the presented options can provide other game designers or studios beneficial information for the implementation of their own VR accessible games.

Background

The Enclosing Dark project began with a simple question: what would an accessible video game for a blind or visually impaired (BVI) player look like? Traditional video games rely heavily on visual information to create a game environment, engage players in the experience, and provide them with the required information to successfully navigate the game. While audio and haptic feedback can also be used in this style of video game, they are merely supplemental design elements to round out the sensory experience. While these games can be visually stunning, sighted gamers often take for granted the ability to receive visual input. As we approached the question of how to design an accessible video game, we knew we needed to find an alternative to visual information, focusing instead on incorporating different sensory inputs. While there are multiple sources of non-visual sensory information, we decided to concentrate on auditory and vibrotactile inputs (Tzovaras et al. 47). The benefit of focusing on these two sensory sources is their inclusion as built-in features of commercially available VR systems.

The Visually Impaired Gamer

Andrade et al. found that while BVI gamers wish they could experience VR, they do not believe it will be accessible to visually impaired persons. This perceived lack of accessibility has caused BVI gamers to fear that the video gamer peer group, to which they desire to belong, will become even further out of reach (8). In addition to providing BVI gamers much needed social interaction with their peers in order to reduce feelings of isolation, accessible video games also provide an important educational component. According to Archambault et al., BVI individuals benefit from the use of technology in their daily lives, whether at home, work, or school (2). Providing opportunities for BVI individuals to practice using technology in a non-threatening format like gaming will increase their comfort and proficiency with using other forms of technology. Due to this, it is important to encourage the development of accessible games rather than focusing on the perceived negative of additional design requirements for BVI gamers. Instead, game designers should relish the creative opportunity to incorporate the BVI gamer's specialized skills and abilities (i.e. highly developed senses of sound and touch) (Nordfors et al. 27).

The Enclosing Dark: A Synopsis

You don't know how long it has been since you fell, and the earth swallowed you. The darkness confuses your mind. Eyes open or closed, the view is always the same. You know you have awoken multiple times, but whether losing consciousness due to exhaustion or fear, you don't know. The only thing you know for sure is that you should be dead.

A loud growl reverberates around you.

Something has found you… You must escape!

In *The Enclosing Dark*, your adventure takes place in complete darkness. Only through auditory cues and haptic feedback are you able to traverse the invisible landscape in which you wander. Will you avoid the unseen, but heard, creatures in the dark, or will you choose to fight them head on? The choice is yours as you make your way through *The Enclosing Dark*.

Discussion

By utilizing the built-in audio and haptic systems provided by current VR systems and building a user interface and targeted in-game training, we created a virtual environment (VE) free of visual components that is fully accessible to BVI gamers.

Audio

Audio is the main source of information in *The Enclosing Dark*. It is used to provide the player with information about the VE, to become immersed in the narrative, and delivers feedback on the actions of the player's avatar. While the narrative drives the player to explore and understand why they are trapped in the dark, most of the audio information revolves around the actions of the player's avatar. From footsteps representing when the player is moving to sounds tracking rotation, we designed the audio to alert the player to any change in the VE.

Spatial Audio

Spatial audio is used to create a simulation of the natural environment by leveraging the head tracking device, which collects the player's current head position, rotation, and angle, to provide audio information through headphones built into the VR system (Picinali et al. 400). We use spatial audio to provide information on the direction of the sound in relation to the player (e.g. in front of, behind, to the left, or to the right). This allows the player to successfully navigate through the VE, building a mental map through auditory clues, and determining where the player is in relation to surrounding game objects.

Echolocation

Echolocation is another auditory system we implemented to assist the user with distance-related information in the VE. We simplified the echolocation process by tying it to the process of shooting the player's gun. The originating sound is the firing of the gun and the reflection is the sound of the bullet colliding with an object in the VE. While not truly echolocation, the result is the same. The player can use this system to determine relative distances by timing how long it takes for the fired bullet to collide with an object in the VE as well as the difference in sound volume between the originating shot and the collision.

Passive Sonar

While echolocation can provide good information about the VE, it requires the player to actively fire the gun. We did not want this to be the only navigation option available to the player, so we also implemented a passive sonar system for navigation. The sonar system constantly checks the player's distance to the walls of the VE. When the player is not at risk of colliding with a wall, the sonar system is silent. When the player gets too close to a wall, the sonar system actively pings the potential collision location.

Originally, the system checked around the player for potential collision all at once, but we found that this could result in multiple pings which tended to confuse the player (Stadler and Hlavacs 507). To combat this overwhelming amount of audio information, we changed from the 360-degree blast type system to a 360-degree rotation system, which checks one direction at a time and pauses between pings, to make sure that the user can successfully determine the direction of a potential collision.

Haptics

While not the main source of information, the use of haptics plays an equally important role in *The Enclosing Dark*. The haptic devices provide vibrotactile information to the BVI gamer and is used in conjunction with the audio input to deliver supplemental information about the VE. This is done by taking advantage of the vibration aspect of the VR system controllers. We currently use the vibrotactile information in three ways. First, it supplements the sonar audio system to increase the player's accuracy in determining the location of obstacles. Second, we use it in conjunction with the audio feedback when a player is hit by an enemy. Third, we incorporate haptics into a variety of other game objects and interactions that provide the player with additional feedback about their surroundings. In order to differentiate between each type of signal, we use a different vibration pattern to indicate to the player what information is being provided.

Haptic Patterns

The basic rumble of an electromagnetic vibration system, used in handheld VR system controllers, is traditionally used to represent when a player's avatar has been damaged or when they use a weapon. Weapon attacks tend to be a sharp short vibration at full intensity and player damage is either a long constant vibration or a pulsing vibration, once again at full vibration intensity. While these basic patterns provide information to the player, there are many instances where nuanced haptic feedback vibrations could prove useful in providing the player with additional information about the virtual environment being explored.

To create a nuanced haptic feedback vibration pattern, a custom audio file is created, which is triggered by the program's code to play the audio file through the vibration system within the controller. The lower the decibel (dB) level the less intense the vibration, while higher dB levels create a more intense vibration. We have found that dB levels below -23 tend to not be discernable and the most intense vibration is found at a dB level of zero. Anything -24 dB and below (we use -96 dB) effectively turns off the vibration causing a pause between vibration pulses. These findings provide the building blocks necessary to create custom vibration patterns.

While we use multiple custom vibration patterns throughout *The Enclosing Dark*, here are two examples of patterns we have created: a damage taking pattern, and a butterfly's wing fluttering pattern. When a player takes damage from getting too close to one of the creatures in the dark, an audio file plays, which begins with a grunt of pain and then the sound of the player's heartbeat, which starts loud and rapid, then slows, and fades over the course of ten seconds. We start with a sharp half-second pulse at 0 dB that matches the timing of the grunt. Then a half second pause at -96dB, at this point we match the vibration timing to the audio heartbeat sounds, while the dB intensity level drops at a curved roll off from -3 dB, for the first heartbeat, to -21, for the final heartbeat.

Our butterfly-fluttering pattern does not have specific auditory sounds that play in accompaniment as the soft fluttering produces no sound. Instead, if the player is very still in an area where the underground butterflies fly, a butterfly will come and land on one of their hands. To replicate this experience, we created a pattern that alternates between a very short, less than one-quarter of a second, vibration pattern that starts at -23 dB, rises quickly to -22 dB, then drops back to -23 dB followed by a -96 dB pause for one half second, which is followed by vibration that stays at -23 dB for an even shorter moment in time and then returns to -96 dB. This pattern repeats itself a total of three times before the complete vibration pattern ends.

User Interface

We allow the player to interact with the game through the VR game controllers and through voice recognition. The game controllers allow the player to navigate and interact with the VE, as well as operate the game menu. The menu system is required to access the non-game elements, like score and time.

In order to translate a typically visual game menu to an accessible menu, we implemented two methods to interact with the game menu. The first was by using the game controllers to access a menu that verbalizes the options to the player. Due to the inefficiency of navigating this system, we added the option of using voice recognition commands. We left the verbalized menu system in place due to the current unreliability of voice recognition systems, so the player can always access the game menu.

Training

Balan et al. found that providing training to interact with the VE, in terms of navigation, user interface, and building an auditory vocabulary, resulted in a better ability to successfully navigate and interact with the VE (686). To provide users this starting information, we designed a training session, which is accessed before playing the first time. The training is in a separate environment and is designed to teach the player how to interact with the different aspects of the game. Once the training has been completed the first time, it is no longer required, but is accessible through the game menu for new players or as needed as a refresher. The training focuses on navigation and interacting with the environment, introducing the spatial audio and haptic feedback mechanics that are used throughout the game.

Results of Informal User Experience Testing

As a result of our informal user experience (UX) testing, our participants found that more, non-competing auditory and tactile feedback provides for a richer, more immersive environment. Our participants also stated that the most important auditory information is connected to player movement: walking, turning, and player positioning in relation to walls and creatures. These sounds were found to provide the best auditory information to successfully navigate and explore the VE.

Additional UX feedback recommended further development on the menu system. While usable, it was not as efficient as a visual menu system and one participant was unable to get the voice recognition system to recognize any spoken commands. Finally, two participants recommended the addition of a helper object, creature, or sprite that could be used to help navigate the levels to avoid frustration when feeling completely lost in the darkness.

Future Work

Based on our UX testing, we will experiment with different verbal menu systems to create a simplified and more efficient menu system to use in non-visual VR experiences. We will also conduct research into different voice recognition systems in hopes of finding a system that better recognizes speech from users with accents or speech disabilities.

We also plan to expand upon the use of the echolocation system by applying it to the footstep sounds. This could provide additional detail and more accurate and useable information than the currently implemented echolocation system.

Additionally, we believe that in order to further the development and distribution of accessible VR games, it is imperative to create a standardized auditory sound dictionary. While in no way meant to suppress developer creativity, a standardized dictionary of auditory sounds would allow players to take the meaning of specific sounds learned in one game and apply it to other games using these same sounds. The dictionary is not meant to encompass all sounds used in the development of a VR experience, but instead would be for general sounds that are used to present common information to the player experiencing the sound. For example, sounds like explosions, rockslides, doors opening, a ringing phone, or an approaching car, would benefit from standardization, while background, ambient, or sounds specific to characters or objects of the environment would not be included in the dictionary. The standardized auditory sound dictionary would benefit BVI gamers by reducing the learning curve and increasing familiarity with the sound features of each game they play, thus improving playability and the ease with which they can switch from one game to another. With the ability to spend less time learning or relearning the meaning of sounds as they switch from game to another.

Finally, we plan to conduct studies with both sighted and BVI gamers to better understand the needs and requirements of all gamers, aiding in the development of design guidelines for the creation of non-visual, auditory-based VR games and experiences.

Conclusion

Since commercially available VR systems include hardware that provides nonvisual information to the player, through haptic feedback and spatial audio, many of the previous barriers for creating accessible, immersive VR games for the visually impaired have been removed. The techniques and hardware used in the development of *The Enclosing Dark* create a base on which improvement and advancement will provide new ways to incorporate accessibility. Within this report, we describe the implementation of auditory and tactile sensory input solutions designed to allow the visually impaired a way to explore the offerings of VR. We argue that our implementation of *The Enclosing Dark* will prove beneficial to both game designers and studios in the creation of VR accessible games and to those with visual impairments who want to join their peers in playing VR games.

Works Cited

Andrade, Ronny, et al. "Playing Blind: Revealing the World of Gamers with Visual Impairment." *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems - CHI '1*9, ACM Press, 2019, pp. 1–14. doi:10.1145/3290605.3300346.

Archambault, Dominique, et al. "Computer Games and Visually Impaired People." *Upgrade 8.2,* 2007, pp. 43–53.

Balan, Oana, et al. "Navigational 3D Audio-Based Game-Training towards Rich Auditory Spatial Representation of the Environment." *2014 18th International Conference on System Theory, Control and Computing (ICSTCC)*, IEEE, 2014, pp. 682–87, doi:10.1109/ICSTCC.2014.6982496.

Nordfors, David, et al. "A New Labor Market for People with 'Coolabilities.'" *Communications of the ACM*, vol. 62, no. 7, June 2019, pp. 26–28, doi:10.1145/3332809.

Picinali, Lorenzo, et al. "Exploration of Architectural Spaces by Blind People Using Auditory Virtual Reality for the Construction of Spatial Knowledge." *International Journal of Human-Computer Studies*, vol. 72, no. 4, Apr. 2014, pp. 393–407. doi:10.1016/j.ijhcs.2013.12.008.

Stadler, Viktor, and Helmut Hlavacs. "Blind Adventure - A Game Engine for Blind Game Designers." T*he Annual Symposium on Computer-Human Interaction in Play Extended Abstracts* - CHI PLAY '18, 2018, pp. 503–09, doi:10.1145/3242671.3242703.

Tzovaras, D., et al. "Design and Implementation of Virtual Environments for Training of the Visually Impaire." *Proceedings of the Fifth International ACM Conference on Assistive Technologies - Assets '02*, July 2002, pp. 41–48, doi:10.1145/638249.638259.