Designing Inclusive Virtual Reality Experiences

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Abstract. Virtual Reality experiences are often touted as having the most immersive user experience possible outside of live action, yet Virtual Reality (VR) technology is often not designed to be inclusive to all users. From mild sim sickness effects to a lack of accessible controls, many users are being left out from the modern virtual reality experience. There are however tools available to the developer that will make inclusive VR design a possibility.

While many of the tools for inclusive VR experiences are physical hardware-based solution there are also what Doug Church describes as "Formal Abstract Design Tools" that are conceptual tools that can be applied in this case to allow a designer to think through making their experience design inclusive [1]. The goals of this journal paper are to provide a primer for those approaching inclusive game design. The researchers will cite current research, discuss existing accessibility forward technologies, and highlight areas that need more attention to assure a more inclusive VR experience.

Keywords: Universal Design · Inclusive design · Alternative controllers · Game design · Gamification

1 Introduction

When approaching accessible forward design, one must explore a variety of approaches, methods, and recognize past and present oversights that can occur when designing for specific communities. Though there is no "magic method" when it comes to designing for accessibility, there have been many successful utilizations of technology involving users who have disabilities. Virtual reality (VR) has been proven to be a successful tool in both rehabilitation and inclusive game design [2].

Susan Goltsman describes inclusive design as, "Inclusive design doesn't mean you're designing one thing for all people. You're designing a diversity of ways to participate so that everyone has a sense of belonging" [3]. Designs that start with assumptions that the user will have the average height, dexterity, and number of limbs as the average person are already being exclusionary. VR is a medium of which modern design patterns remain fraught with assumptions. It seems clear, however, that in many cases this could be solved by simply informing the designers that the exclusion exists and providing solutions for how to be more inclusive.

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2 Background

There is a long history of accessible design, but it wasn't until wounded veterans were returning from World War II that the United States passed a law allowing free access to government buildings, with the Architectural Barriers Act of 1968 [4]. This was followed by additional legislation and a global declaration by the United Nations [5]. Of course, while access is required, ensuring the best designed access is not always the case in the physical world, and is only amplified in the virtual.

Many researchers have found positive impacts from using VR based solutions to training those with traumatic events including stroke. Laver, et. al found positive results in 8 out of 12 tests when using VR to train stroke suffers [6]. Additionally, Jack et al. found significant improvements in hand control in stroke suffers as well as positive subjective opinions of the training [7].

Phantom-limb or other phantom sensations pain is often reported from amputee populations after the loss of a limb or other innervated body part [8]. Research has investigated the role of cortical reorganization on the initiation and magnitude of phantom limb phenomena, which result in either a painful or non-painful response [9, 10]. Studies done to investigate methods of mitigating the phenomena have examined neurological and psychological influences on the underlying drivers of the phenomena [9, 11, 12]. Work by Pucher et al. [10] correlated self-perceived body image with the coping skills that may reduce phantom-limb phenomena.

New work is leveraging immersive virtual reality (IVR) as a management tool for symptomatic patients [12]. Further studies will improve the understanding of the effectiveness and statistical correlation that may have both psychosocial and psychophysiological impacts.

3 Universal Design

According to the National Disability Authority, Universal Design is, "the design and composition of an environment so that it can be accessed, understood and used to the greatest extent possible by all people regardless of their age, size, ability or disability" [13]. They also state that these design implementations should not act for the benefit of only a minority of the population. Their mantra is, "if an environment is accessible, usable, convenient and a pleasure to use, everyone benefits." The goal with universal design is to meet all user needs and maximize accessibility to the product or system.

3.1 Accessible Design

Accessible design revolves around designing for a specific disabled community the design process. In other words, the design is focused on creating an inclusive experience for a person of a specific disability. In United States, the Americans with Disabilities Act (ADA) mandates that the design of public facilities be completely accessible to people with disabilities [14].

3.2 7 Pillars of Universal Design as Related to VR Game Design

The 7 Principles of Universal Design were developed in the late 1990s by researchers at North Carolina State University. The purpose of the Principles is to act as a guide in the development of products, places involving human interaction [15]. This is the foundation for protections of equality for differently abled users that has driven much of the progress over the past decades. However, in application there are still limitations where the intentionality of inclusion is misaligned from the execution of design that can make a meaningful inclusive experience. This can be seen in the VR environments, where simulated visuals can be customized to not be limited by traditional form. This may provide empowering experiences for differently abled users, however the hardware to participate must consider a wider distribution of abilities.

Principle 1: Equitable Use
The design is useful to people with diverse abilities. Ideally the use of virtual environments can positively enhance experience for those with both cognitive, and motor skill impairments. Unfortunately, current VR systems are designed with core users in mind. Controls often require 2 hands, the ability to stand and move for long periods of time, and the ability to manipulate complex tools with the user's hands.

Identify Potential Users
It is important to identify potential users when beginning any inclusive VR game development project. Determine if the design needs to support able bodied individuals. Determine what other individuals the project will support. Will there need to be changes made of individuals with motor, cognitive, hearing, speech, vision, or other accessibility issue. The game accessibility guidelines suggest adding key remapping, text size options, colorblindness modes, and subtitle options as the easiest features to add support for [16].

Principle 2: Flexibility in Use
The design accommodates a wide range of individual preferences and abilities. While some users will be fine with 2 hand controls not all users can support that. Additionally, even if there is no exclusion for the user many users will not have the right hardware.

Identify Potential Exclusions
As consumer level VR solutions are still in an early stage the hardware individuals bring to the VR space is varied. Supporting additional hardware configurations is important from a financial perspective for many VR ventures. VR ready games on steam will often support multiple control schemes. This includes two handed controllers, the Xbox controller, or even Keyboard and Mouse. Supporting these additional interface methods allows the user to implement their own customized solution as well.

Principle 3: Simple and Intuitive Use
Use of the design is easy to understand, regardless of the user's experience, knowledge, language skills, or current concentration level. This principle is key to good user experience regardless of user's skills and abilities. Insuring a good UX/UI experience will go a long way in developing accessible games.

Unfortunately, because VR is a new interaction platform, good standard conventions are not well established. Early First-Person Shooters (FPS) were notoriously difficult to control on game consoles until the release of Halo: Combat Evolved on the original Xbox. The tutorial on Halo taught a generation how to play FPS games. This VR ready example has yet to be established. As such it is the designer's job to continue to bring the most intuitive experience to the user they can.

Mimic Real World Interaction
Most VR controllers are an attempt at mimicking what hands can do in the real world. If your player does not interact with the real world using their hands, mimic the tools they do use. This might be a prosthetic device of one form or another, a wheel chair control stick, or other implements used in the real world to interact. The closer the interaction method is for the user is in VR to what they are comfortable experiencing in reality, the better their interaction will be.

Principle 4: Perceptible Information
The design communicates necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities. This can be accomplished through the use of Heads Up Display (HUD) messages explaining things that can't be easily seen. User guidance through good game design, lighting, environmental cues will all help aid the player. Simple options like the ability to turn on subtitles, while 4th wall breaking in VR, are a necessity for those with hearing lose. While it may seem obvious that most information provided to the player would be through a graphical interface there are other ways to build the player with perceptible information.

Audio Guidance
Audio can be used to enhance a virtual experience. It can set the mood, excite action, and build a more complete immersive experience. It can also be used to help guide low vision users through an environment. Players have used audio cues only to play games like Street Fighter, and with the rise of audio assistants like Google Home and Amazon Alexa, it can be easy to integrate an audio guide into any virtual space. This can provide a deeper connection to the environment and stimulate subtle cues that can support a wider range of abilities by providing additional reaction and planning time.

Haptic Feedback
Using the haptic feedback is becoming more common in game design. It is even possible to use haptic feedback to help guide or smooth user input. The involves providing cues to the player to warn them of potential impediments in the virtual world and may have extensions to overlaid augmented reality (AR) that bridge the gaming and physical environments.

Subtitles and Other Text Cues
While there should be a standard for videogame subtitles, there is currently is not. Developers can still implement support tools for hearing lose, color blindness, and many other common disabilities. Larger successful games like Fortnite have already done so and the additional inclusion benefits a large range of users who may have long term ability differences or simply situation limitations that could be physical, interface hardware, or of the local environment.

Principle 5: Tolerance for Error
The design minimizes hazards and the adverse consequences of accidental or unintended actions. Everyone has the experience of hitting the wrong character on their cellphone when typing a message. Luckily Autocorrect features have been improving and a close miss can be corrected to the actual word required. The old saying of "close only counts in horseshoes…" no longer needs to be the case. Devices should be able to have tolerance for uneven input and do their best to interpret user intent.

Signal Smoothing
While users with less fine muscle control may input a more erratic signal then other users, smoothing algorithms can be used to interpret the input. Using smoothing for the player may not be 100% accurate or precise to the motion recorded, but this smoother interpreted motion will provide a better experience for the player.

Sensitivity Controls
Many games will offer mouse and controller sensitivity control in the options menu. This allows users to adjust the speed of their input on their own. These controls can go a long way in making a player feel comfortable with the input in the game and can easily be implemented.

Principle 6: Low Physical Effort
The design can be used efficiently and comfortably and with a minimum of fatigue. When Wii Tennis was released players thought they needed to mimic the action of actual tennis. The advertising campaign led to this belief. Players quickly learned that they could sit and flick their wrists slightly to accomplish the same effect. This of course was great for people with low upper limb dexterity.

In the case of VR games reticles can be smoothed and targeting can be sticky, so users with unsteady hands can still track and interact with objects in the virtual space. This is similar to the ability to adjust mouse sensitivity or remap controls to adjust to user preferences. A feature to engage additional levels of ability may provide additional comfort or ease for traditionally abled users.

Eye Tracking
Eye tracking is a feature that is quickly coming to VR. The basic functionality is based on shining infrared light on the pupil and then detecting it with a camera to determine the direction the eye is looking. This is commonly used to test usability on websites, but it could also be used to move a character in a virtual space. It could be used to select items or do any number of interactive tasks. Offloading the need to use hand of foot-based controls.

Hand Tracking
Some VR hardware has hand tracking built in. This is similar to eye tracking but looks at the user's hands to determine hand location and gesture. While there are multiple solutions available one common off the shelf device is the Leap Motion controller, which can be on a table or mounted to the front of a VR headset.

Standard Controller or Microsoft Xbox Adaptive Controller
While VR appears to be next level and supports free motion either with hands or with one handed controllers. Also, the standard controller might be more readily available

and easier for some users. Microsoft recently released the Xbox Adaptive Controller which connects as a standard controller and allows for custom controls to be used by a large variety of available external button controls.

Quadstick
The Quadstick is an evolution of the Sip and Puff controller found on some wheelchair controls. The Quadstick remaps all the buttons on a standard controller to a device that can be controlled 100% with facial muscles and breath.

3D Rudder and Other Foot Controls
The 3D Rudder is a foot pad that can be manipulated with feet while sitting. It is a flat platform with the bottom part of a sphere on the bottom. As the user tilts their feet their character can traverse in the virtual environment. Other foot controls are generally button based and could come in the form of individual buttons or something more similar to a Dance Dance Revolution dance pad.

Custom Controller
In many cases there will not be the perfect device available. In this situation custom controls could be considered. This is especially true when the user has expertise in a particular device. Researchers at the University of Utah have adapted a sip and puff controller to a ski simulation. Limbitless Solutions at the University of Central Florida uses a custom controller based on their prosthetic design to support their users.

Principle 7: Size and Space for Approach and Use
Appropriate size and space is provided for approach, reach, manipulation, and use, regardless of user's body size, posture, or mobility. Users will come in all shapes and sizes. The Void experience is a large room scale VR environment, that handles this situation well. It does not require users to use their hand and shows them to the player in front of them. It also supports changing the size of the avatar to match the height of the player, and even wheelchair users will find themselves with a very short avatar while in the experience.

Some VR systems may exclude specific groups of the population. For example, inside out hand tracking is inefficient for those with limb difference. One the other end of the spectrum the Vive Room Scale tracking is less effective for wheel chair users. Each type of VR experience has its own benefits and limitations and the key moving forward will be to broaden our expectations of the user profile to increase the accessibility to the virtual environment.

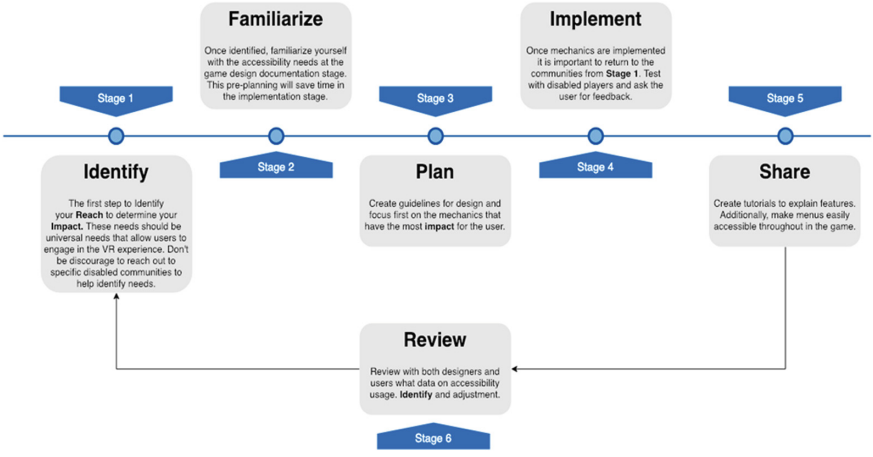
Room Scale
Of the three major types of consumer VR experiences Room Scale is the most complex. This form of VR has the user setup a complex set of tracking devices around their room and allows the player to walk freely in that space. This type of VR space is good for users with the ability to walk around in the space. Because tracking of the user and their hands is done from an external source this particular type of VR is well suited for people with limb difference. It can have trouble, however, for users in wheelchairs or with other types of lower limb mobility differences. The most common Room Scale VR system is the HTC Vive.

Front Facing
Another solution for VR is Front Facing. This type of VR has the user position themselves in front of a camera or multiple cameras. This type of VR works best if the user has no reason to turn around. The need to be positioned in front of the camera lends itself well to seated applications and can support tracking upper limb difference. It is also good for users with lower limb difference but does not provide the same level of freedom to move around found in Room Scale. The most common Front Facing VR systems are the Oculus Rift and PlayStation VR.

Inside Out
The new trend in VR is called Inside Out tracking. This type of tracking comes from inside the headset. The tracking looks for hand controllers in from of the headset. The issue with this type of tracking is it is not well suited for those with limb difference as it can be difficult to get the controller our far enough to see it. It can be better for wheelchair users as height of the tracked individual does not impact the tracking. Inside Out tracking can be found in the Oculus Go, and in the Microsoft Mixed Reality headsets.

4 The 6 Steps in Inclusive Game Design

When designing for accessibility it is important to recognize the various needs of your end user. Common accessibility needs revolving around remapping, text size, color blindness, and subtitle presentation. This gets more complex when dealing in a virtual or augmented space. Both virtual reality and augmented reality games can cover a large array of mechanics and user needs. These game mechanics could involve the user to utilize specific speech, hearing, vision, and other cognitive abilities. It is important that the designer recognizes these specifics and builds them into the design process.



When approaching a new inclusive project, it is important to follow these steps [16]:

- Identify
- Familiarize
- Plan
- Implement
- Share
- Review

4.1 Identify Potential Exclusion

Creating an inclusive experience means avoiding unnecessary hurdles that prevent users with various impairments from fully experiencing or interacting with your game. According to the Center for Disease Control (CDC), one in every four adults has some type of disability [17]. This equates to around 61 million adults in the United States alone living with a disability. These disabilities range from highest need to lowest in mobility, cognition, independent living, hearing, vision, and self-care. A survey conducted by PopCap in 2008 [18], one in five players of casual video games have an impairment related to physical, mental or developmental disability. A study in the Netherlands revealed that around 92% of people with impairments play games despite difficulties [19].

This, however, does not mean that there has been enough done to support gameplay for this population. It is the opposite. This population is so excited about games they are figuring out personal work arounds. What should be happening is they should be supported by the developers and the player communities. Unfortunately, with the current state of competitive play, users with custom controls are often discovered as cheating, and treated as lesser then others in the community they are working hard to participate with.

This can only be truly changed with a cultural shift. Both the developers and the other players must see this potential new competition as desired. Developers must champion this to the community and hopefully the community will see how inclusion makes the playing field stronger. While this might not extend to competitive gaming in the short term, this needs to be on the horizon for all involved.

4.2 Familiarize with Current Strategies

Now that we have identified select mechanics how could one approach these mechanics to develop an accessible gaming experience. Virtual Reality and Augmented Reality games often require a large need for motor skills. Designers should take in consideration the following when designing for those with limited motor skills.

Allow controls in the game to be remapped. Do no assume that the player will have the ability to utilize the out of the box control set. Furthermore, do not limit these configuration options solely to the in-game experience. Ideally all areas of the user experience including the user interface should be able to be accessed with the alternative hardware/remapping.

When considering movement in the design process, do not assume that your user will have full dexterity of motor function. It is advised to implement calibration when needed to adjust sensitivity of controls of the experience. With that said, the designer should take a minimalist approach to designing the controller layout. The controls should be as simple as possible and have the ability to have various visual and auditory customizations to create a more inclusive experience.

When designing this type of experience the importance of a simple UI cannot be overstated. Players navigating a slew of calibration screens, menus and maps can quickly became troublesome for those utilizing a single-handed controller, especially in VR. Per the motor skill discussion above, is also a need for implementation of both customizable and easily readable typefaces in the interface. There is also a need to use simple readable fonts for users with screen readers.

4.3 Plan a Custom Solution Using a Persona or a Person

This next step in designing for inclusivity is to understand your user. This can be done in a variety of ways including creating personas or working directly with your user's community. Before the development of your VR game and even before the game design document is created designers must put themselves in the role of various gamer types. Keith Knight, a wheelchair user that streams his gameplay under the name the Aerion, recommends asking these questions that should be thought about and answer in the development of every new experience [20]:

- Does the user have the ability to physically play the game?
- What equipment do I use? What equipment with those with specific disabilities need to use to experience the game?
- Will playing the game as the designer creates it physically hurt the user?
- Will the user have to program any specialized equipment?
- Can the user be competitive (if needed) within the experience?

To answer the questions listed above, many game and user experience designers often develop user personas. The User Persona is a representation of the goals and actions of a community of hypothesized users. Of course, working directly with actual users is recommended and should be prioritized.

4.4 Implement Custom Solutions

In many cases the only solution is a custom solution. This can be in form of a combination of off the shelf products organized in appropriate configurations. It can also be with truly custom piece of hardware that allows for a specific interaction to occur. The Able Gamers Foundation has begun keeping track of specific solutions that could be implemented in a series of design patterns that will provide ways designers can change their games to meet the needs of people with various forms of disabilities. The Accessible Player Experiences (APX) is available freely on their website [21]. Further information on how to implement inclusive design in games can be found in the game accessibility guidelines [16].

While sharing what works for others is a good place to start, not all disabilities are the same. Even people with the same diagnosis can have different levels of impairment. Therefore, a single lens can not be applied universally. It is important to work closely with individual users and find what works best for them. In some cases, this might require the development of completely custom hardware solutions, in others it might be as easy as modifying an existing solution. In any case it is important to share solutions back to the community.

4.5 Share with the User and the Community

It is important that discovered or created solutions are shared back with the community. When a new solution works for one user it is likely it will help others, even if their disability is not the same. Seeing game-based solutions in action will also inspire new work.

4.6 Review and Iterate

After implementing a solution testing with real users is important. Often times developers will attempt to use a surrogate population when actual users are in low supply. This can help with general usability but will not provide enough information in ensure that a solution will work and will be accepted by the actual users. It is important to get the target population represented in the research. Able Gamers can provide access to player panels made up of game players with various disabilities.

5 Conclusions

By applying the 7 principles of universal design to the development of inclusive VR experiences, all users will benefit from a more approachable and customizable experience in the long run. This will provide a more meaningful and engaging experience. It is important to identify users with potential exclusions and find solutions that can work for them directly. In many cases off the shelf solutions, like the Microsoft Adaptive Controller, can help in the process. Modularity and the ability to interface with standard ports allows for the creation of unique tools that may translate to a larger user population after initial prototyping. Developers should not shy away from custom solutions that will help individuals participate. This will only increase the potential user base VR and improve the overall market. At the same time these solutions could easily have benefits to existing users as well.

The key to inclusive design is to not to think of inclusion as a check box that needs to be satisfied, but as a method to provide multiple paths for use. This cultural change will lead to better user experiences for everyone.

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