PowerUp: An Accessible Virtual World

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ABSTRACT
PowerUp is a multi-player virtual world educational game with a broad set of accessibility features built in. This paper considers what features are necessary to make virtual worlds usable by individuals with a range of perceptual, physical, and cognitive disabilities. The accessibility features were included in the *PowerUp* game and validated, to date, with blind and partially sighted users. These features include in-world navigation and orientation tools, font customization, self-voicing text-to-speech output, and keyboard-only and mouse-only navigation. We discuss user requirements gathering, the validation study, and further work needed.

Categories and Subject Descriptors
H.5.1 [**Multimedia Information Systems**]: Artificial, augmented, and virtual realities; K.4.2 [**Social Issues**]: Assistive technologies for persons with disabilities; K.8.0 [**General**]: Games

General Terms
Design, Human Factors.

Keywords
3D, virtual worlds, accessibility.

1. INTRODUCTION
During the Fall of 2007, we were approached with the request to make a 3D Virtual World game accessible. This game, named *PowerUp*, was being created by an IBM development team and we were asked to provide accessibility options for players who might have perceptual, physical, or cognitive disabilities. As we started this work, many people questioned whether people with disabilities, particularly those who are blind, would be able or even be interested in playing a 3D virtual world game. The work reported here allows us to respond to such questions.

To begin, virtual worlds enable their users to bring a sense of 'self' into their digital space, and provide real-time interaction with other participants in a shared environment. They have the potential to teach concepts that may be difficult to grasp with traditional two-dimensional presentation and are being used, for example, in training situations to allow people to practice job situations in virtual spaces. Virtual worlds also enable social groups and communities to form around shared interests by individuals who are dispersed across the globe.

By their very nature, however, virtual worlds place high demands on the ability to utilize information in the 3D multi-sensory environment. Specifically, users must manage multiple inputs from visual and audio sources. This information presents a sensory challenge in that it often demands a high level of visual and audio acuity. It also presents a cognitive challenge as the information presented dynamically changes in response not only to the individual user's actions, but also in response to actions of other users in the world. The reading and language requirements can be difficult for those with a learning or cognitive disability and the dual mouse and keyboard requirements present problems for people unable to use one or the other of these. Despite these difficulties, virtual worlds have the potential to better include people with disabilities. To quote one of our survey participants: "Virtual worlds can empower disabled people in ways that the real world can't. Plus, as virtual worlds are digital, they're easier to be transformed to meet the disabled person's needs."

This paper describes an investigation of virtual world accessibility for users with vision disability (blind, low vision, color blind), hearing loss, cognitive disability (such as users with dyslexia or other causes of low reading proficiency), and physical limitations (that impact ability to use a mouse or keyboard). The work reported here extends our early thoughts on accessible virtual worlds [15] and provides new results from requirements gathering activities and from user testing with blind and partially sighted students. *PowerUp* was originally released in February, 2008, and an updated version is available online [12]. Discussion of the technical implementation of the game is outside the scope of this paper. We envision the value of our work as not only having made this game accessible, but also as developing requirements for building accessibility features into 3D virtual worlds.

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2. BACKGROUND
3D virtual worlds have seen an explosion of interest with the advent of applications such as Second Life. These virtual worlds, however, have their roots in games. We looked, therefore, to games to learn about approaches to accessibility in these worlds.

Efforts to make virtual world games accessible are often the result of grassroots efforts focused on a single disability group. For example, Terraformers [16] is designed to be playable without vision, while Half Life 2 and Doom CC [3] add captioning for deaf and hard of hearing players to popular mainstream games. These kinds of efforts provide evidence that virtual world accessibility for specific groups of users is possible, at least for closed game worlds [3]. In some cases, the addition of accessibility features was achieved with little impact on the project schedule [3], while Terraformers represents three years of design effort [16].

Some attention has been paid to the problems experienced by disabled gamers at a more general level. Guidelines have been suggested for the creation of accessible games [1][3][11], and accessible approaches to game playing and virtual environments are being developed [2][4] [5] [6] [14].

The work reported here builds on these contributions by focusing on fundamental virtual world activities that are required in non-game environments, and by exploring tools and features to support these activities for a very broad population of users.

3. POWERUP

It is not our intent to focus on the game aspects of *PowerUp*. However, in order to understand the following discussion of the accessibility features it is useful to describe the objectives of the game and the actions required to accomplish them. *PowerUp* is designed to teach middle school students (roughly ages 12 – 14) how to use science and math concepts to solve critical environmental problems. As will be clear from the *PowerUp* description, this is a complex game. Making this game accessible went far beyond testing of specific features in a laboratory setting. Rather, it was required that all aspects of the game design and implementation be addressed from the accessibility standpoint.

PowerUp is a free, online, multiplayer game in which players take on the role of Engineers, working together designing and building alternative energy solutions "to save the world." Built upon the popular Torque Game Engine [9], *PowerUp,* to date, has three separate worlds or missions which constitute the game play:

Orientation Center – meet Engineering Experts to learn about energy conservation and renewable energy sources

Wind Island – design and build a wind-turbine farm

Solar Mesa – control the operation of a concentrated solar thermal power generator

In each of these missions, the user is immersed in a three-dimensional virtual world through which they navigate, interacting with objects, artificial characters, and other human players. The player may choose a first-person view, looking at the scene from the viewpoint of their avatar (Figure 1), or a third-person view, in which the viewpoint is above and behind the avatar (Figure 2).

Along with the 3D projection of the virtual world, the user's display includes several two-dimensional overlays, called 'heads-up displays' (HUDs), each of which convey information, textual or graphical, useful in the current game situation. For example, there are HUDs indicating power levels, time remaining, compass heading, and communication either with other players or artificial characters (game-play instructions).

In order to move through the world, the player turns their avatar to face the desired direction, and then walks forwards, backwards, left, or right. Some objects in the world, such as a wind-turbine build platform, are activated using a command, "interact", while others you simply "bump into", such as a molten-salt flow-control valve.

Each of the three virtual worlds is quite large, approximately 2,000 by 2,000 "virtual meters" in size, with a varied terrain to be explored. There are buildings, including the two-story Orientation Center itself, a lighthouse, and the solar-power generator. There are hills and valleys, trees, grass, large bodies of water, and islands. In many cases, the important landmarks in the mission are not visible from the player's starting point. In the Solar Mesa mission (Figure 2), the player drives a dune buggy across the desert using a compass HUD with the bearing to the solar heliostat farm indicating in which direction the user should drive. The challenge of finding the mission objective in the world is designed to be part of the fun of the game play.

Several different models or styles of interaction are presented to the user at different times in the game. In the orientation center there are two key activities: chatting with one of the

Figure 1. Screen shot from Wind Island.

Figure 2. A screen shot from Solar Mesa.

Engineering Experts, each an artificial character with a fixed script and branching player-responses; and quiz-like dialogs about conserving electricity (e.g. "replace incandescent light bulbs with low-power fluorescent ones"). There is also a large wind turbine which the player may enter and explore.

On Wind Island (Figure 1) the player scavenges about, using the "interact" command to pick up parts from which to build a wind turbine (blades, nacelles, tower shaft sections). They then locate an empty wind turbine platform and build upon it (using a design HUD). The turbine parts are scattered among obstacles, such as cargo containers and wrecked wind turbines. Finally, during the Solar Mesa mission, the player drives a dune buggy, as mentioned, to the heliostat farm, climbs up into the operator's "chair" of each of the heliostats, and re-aligns it so the sunlight is directed to the solar collector, moves to the turbine control room, and opens the molten-salt flow-control valves to get the turbine generator moving. As a further challenge, there are "SmogGobs – dense clouds of carbon emissions that seem almost alive", moving about the landscape on Wind Island and Solar Mesa. Neutralizing these SmogGobs by aiming at them and firing what might be thought of as a "water balloon" will gain the player extra points.

4. REQUIREMENTS GATHERING

Given the long-term goal of providing technologies that could be built into virtual world engines we were motivated to find general solutions for virtual worlds, not solutions specific to the *PowerUp* game.

In addition to the work on accessible games discussed in Section 2, requirements for a 3D environment were based on our experience with Web accessibility [7]. That work illuminated issues critical to improving access for people having multiple disabilities. It informed, for example, choices for font enhancements in the game and highlighted the need for magnification of all content and controls and the need by people with visual disability and limited reading proficiency to have all text on a screen read aloud.

We also were guided in our design by methods for navigation and orientation intended for real world use by individuals with visual impairment [13][1]. Many of these are also applicable to virtual worlds, including recommendations about the kinds of information that need to be provided, and ways to present it.

Finally, in order to better understand how people with disabilities currently play or try to play virtual world games, we conducted an online, semi-structured survey of disabled game players. The survey questions asked the respondents which types of games they have tried to play and which games they play regularly, the input/output devices they prefer to use, what barriers or difficulties they have come across when playing virtual world games, and how they are able to overcome or get around those difficulties. The survey also asked what makes a game enjoyable and fun, and whether they prefer to play alone, with friends, or online.

[1] Two members of the research team met with a Lighthouse International [8] orientation and mobility instructor.

4.1 Survey results

The survey respondents were 25 adults (4 female) with a range of disabilities (6 blind, 4 low vision, 3 dexterity impairment, 10 deaf or hard of hearing, and 4 with a cognitive disability that resulted in difficulty remembering, learning, understanding, or paying attention, including ADHD). Two respondents identified as having Usher's syndrome and so classified themselves as both deaf/hard of hearing and low vision. None of the respondents in our survey reported reading difficulties of any sort.

Some of the respondents preferred games that are designed specifically for their type of disability (especially blind users). But, nearly all expressed desire to participate (or are already participating) in online virtual worlds along with the millions already doing so. Results of the survey are categorized by disability as follows:

4.1.1 Blind Players

All of our blind respondents use screen readers with stereo headphones and some use Braille output.

Problems/Preferences: Lack of textual/audio information about the surroundings was cited as the biggest deal-breaker for our blind respondents. For this reason, text-based role-playing games were very popular with this group as all information is available to them.

Strategies: Strategies used to overcome problems include exploration and trial and error, using an "axe or fist" to locate walls by sound, looking for clues online, asking friends and other players, and relying on changes in game sounds.

Design Implications: Both text and sound-based representations of in-world objects are acceptable alternatives. Audio information should include sounds that distinguish different places and changes in world state.

An additional problem is that blind users often do not have advanced graphics cards in their computers. Therefore, games that require the latest graphics technologies are either completely inaccessible or extremely slow to render. The ability to turn the graphics off is an important step to improving accessibility.

4.1.2 Players with Low Vision

Problems/Preferences: Respondents with low vision indicated that problems arise when objects in virtual worlds are very small, blend in with their background, or require visual tracking of big or sudden motion. For example, when the "wall and floor don't really contrast, [it is] difficult to see where's where [sic], such as the door."

Strategies: One respondent preferred to teleport instead of walking to avoid getting lost and to be sure of his own location. Online forums were also a popular way to get help or learn about things that could not be seen on the screen.

Design Implications: Objects in the world, especially items that are crucial for interaction and that have graphical text should have sufficient contrast and size and/or the ability to modify the contrast and size. Although none of our respondents indicated that they were color blind, common color distinctions in games (such as red / green for stop / go) should be avoided.

4.1.3 Players with Dexterity Impairments

Of the 3 respondents with dexterity impairments, one preferred a joystick or trackball and one used voice recognition software as the primary interaction with the computer.

Problems/Preferences: One respondent noted that in order to play, she “must invest time” as many tasks in games take much longer without the use of standard keyboard and mouse. “Any games that require the use of sustained keypresses to maneuver the avatar are near unworkable for me.” Similarly, another noted “anything that requires multiple keys is an issue.”

Strategies: In order to cope with these problems, our respondents use controllers to simulate extended key presses, “cheat” by skipping levels if the game allows for that, or simply give up if they cannot find a way to compete and are “easily captured.”

Design Implications: Interaction alternatives to keyboard and mouse must be available. The ability to modify the response speed required, while minimally affecting any speed objectives, may make the difference between a workable solution and a completely inaccessible game.

4.1.4 Deaf and Hard of Hearing Players

Playing with friends and other online gamers was an important aspect of game play among this group.

Problems/Preference: Games that do not provide text or visual components for audio cues and narration are the biggest barriers for deaf and hard of hearing respondents. Noises that occur in stereo are also problematic: “when you are playing first person shooters - you are supposed to hear when someone is shooting at you and even in general which direction they are shooting from.”

Strategies: Strategies included going online for hints or text versions of game narration, using brute force (try all possibilities), and avoiding games that do not have captions.

Design Implications: All sounds and in-game conversations should be augmented with either text or visual counterparts. Given that reading can be difficult for many deaf and hard of hearing players, it is recommended that text not be more difficult than 6th grade reading level.

4.1.5 Players with Cognitive Impairments

Problems/Preferences: The only problem with virtual worlds that our respondents with cognitive impairments reported was trouble remembering what to do or where to go.

Strategies: Our respondents reported going online for help and hints, consulting manuals or help guides, and playing with friends.

Design Implications: Possible designs that could help players with cognitive impairments include providing a journal or agenda of places to go next, a bread-crumb trail to help them remember where they’ve been, and providing hints that do not give away too much information (much like a co-player). In addition, although this was not an issue for our respondents, it is recommended that there be the option to have text read aloud for players who may have limited reading proficiency.

5. CORE ACCESSIBILITY FEATURES

Given the requirements above, we identified the core accessibility features for 2D and 3D elements in virtual worlds. *PowerUp* players are able to set their preferences for their accessibility options one time and have these preferences re-used when they login to the game in future sessions.

In many cases, the core features address more than one disability and can be used by a number of people. For example, text-to-speech for the text in GUIs helps not only people with vision limitations who might have difficulty seeing the text, but also helps people with dyslexia, intellectual disability, or who are not native speakers of the language.

These features were implemented by extending both the game’s script files and the capabilities of the Torque Game Engine itself. The speech was generated through calls to the built-in windows Speech API (SAPI).

5.1 Features for designing worlds

Some of the features were not enhancements to the displays and navigation, but rather were critical components of the initial game interface design. Specific examples of this were grade level of the text, in-world contrast, and the use of colors, such that no critical task information was represented by color alone.

5.2 Features for 2D Controls and Heads-Up Displays

For 2D controls and HUDs the following were considered critical. Figure 3 shows the screen that allowed users to set accessibility options in *PowerUp*.

- *Customizable fonts for all text in GUIs*. This included both changes to font size and colors, as shown in Figure 3.
- *Keyboard navigation of all GUIs and menus with speech and visual feedback*. The user can move through controls using tab and Shift+tab, using <space> or <enter> to select the current control.
- *Point-and-click-only control of GUIs*. The mouse can be used for all 2D screens and an external onscreen keyboard used for typing (in *PowerUp*, the only typing required is for password entry).
- *Self-voicing capability for HUDs*. Selecting the ‘Speech output’ option allows all text on screen to be spoken aloud. As a self-voicing technology, the speech engine is incorporated with the game software so that users do not need to have other speech software installed. Dialog boxes and HUDs can be read by pressing Alt+A and by tabbing around dialog boxes to have the name of individual controls read aloud.
- *On-screen display of sounds and captions for spoken information*.

Finally, users were able to get help with the accessibility features at any time by opening the accessibility options control panel and selecting one of the buttons (shown on the left in Figure 3) to learn tips for playing the game in different situations. Guidance on playing the game itself was provided by the engineer characters in the Orientation Center, which

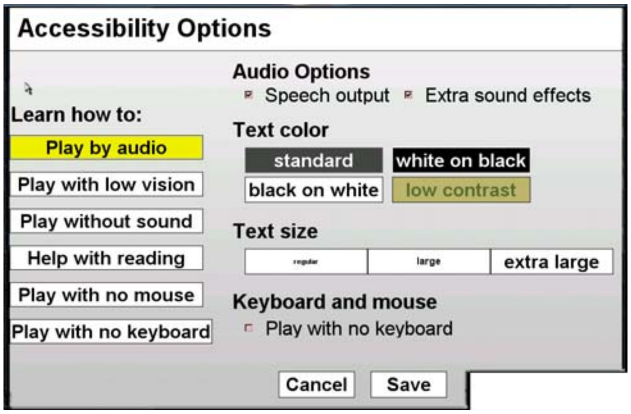

Figure 3. User-selectable accessibility options for *PowerUp*.

players could return to at any point in the game. Pressing the H key brought up online help listing keyboard commands.

5.3 Features for the 3D World

Features considered critical for a 3D world were the following:

- *Enlarging all visuals*. The user could press the Z key (for zoom in) to move from a 90° viewing angle to a 45° angle, and a 10° angle for high magnification.
- *Translating the visuals into audio*. The user can select separate sound options that turn on speech output and provide extra sound effects for the world. These sound effects include footstep sounds that change to reflect whether the player is going up or down, and different 'bump' noises for different kinds of object. Specific commands used to play via audio alone are described in Section 5.5.
- *Modes of physical access*. A number of access issues relate to moving about in the world. Some solutions are rather straightforward (such as keyboard and mouse navigation), while the ***find*** and ***controlled walk*** commands (described in Section 5.4) represent sophisticated new approaches. For *keyboard control*, the arrow keys are used to control the avatar's gaze and facing direction, while the W, S, A and D keys control movement in the world. For *mouse navigation*, a special HUD provides a set of buttons through which to control the avatar and access all the available commands. An important feature of this HUD is that it enables continuous movement without sustained mouse button presses. It can also be operated by keyboard navigation, and will form the basis of single switch access.
- *Translating the sounds into visuals*. As with 2D displays, sound events or speech in 3D environments need visual translations. These translations could be captions, animations of the sound (such as images of footsteps representing the sounds of approaching players) or other indication of unseen sounds. *PowerUp*, however, had no sounds that were not otherwise visually represented in the game, so no captioning or visual modifications were needed.

Other features, such as switch access, in-world contrast enhancement, the ability to adjust the sensitivity of the in-world movement commands, and control over other time-sensitive parameters were also considered important, but time considerations in the development cycle did not permit explorations of such features.

5.4 Navigation Tools

Many virtual environments provide a teleport function by which a user can jump their avatar to a specific location. This feature plays a vital role in accessibility. However, by itself it is not sufficient, since the location to teleport to must be known in advance. Two tools, the ***find*** and ***controlled walk*** commands, were developed to specifically support local exploration and navigation. These can be accessed using key commands, or the mouse navigation HUD.

The ***find*** command is a form of search that allows users to scan the current view for items of interest and makes it easy to accurately aim at an object, and stay locked on to it. There are two commands for this function: 'find left' and 'find right'. If the found object is moving, the avatar turns to track that object until the player indicates otherwise.

The ***controlled walk*** function, illustrated in Figure 4, is initiated when a player presses Ctrl+W. In this mode, the player's avatar is kept facing its target and walks in a straight line towards it. When the avatar reaches the target, the walk is automatically terminated without player action. If an obstacle such as another player, a cliff, or a wall is encountered on the way to the target, the walk stops but the target is remembered. The player can also terminate the walk at any time by repeating the original key press or giving another movement command. If audio is on, audio feedback is provided to indicate when and why the controlled walk has stopped. If the walk ends at an obstacle, players can side step to try to get around it, continue (e.g. walk off the edge of a cliff), or start planning an alternative route. Targets can be moving objects, such as other players. Players can follow a guide by first finding them and then starting a controlled walk towards them.

5.5 Playing by audio

Perhaps the most obvious challenge in virtual world accessibility is how to express the visual world in audio for those who cannot see the world, or for those who desire an explanation to supplement what they are seeing.

Both the ***find*** and ***controlled walk*** commands are essential for audio access. When the speech option is on, the ***find*** command provides audio feedback indicating the name and distance of the object, and relative orientation of the player. For example, finding the buggy shown in Figure 2 would give the description "electric dune buggy, 7 steps East South East". The ***controlled walk*** also provides speech feedback, telling the user the current target, and when they have reached the target or got stuck at an obstacle or cliff.

In addition, a set of ***look*** commands were developed to provide a description of a virtual world scene in words. The L key provides a detailed description of the player's current focus, while the adjacent K and ; keys provide a summary of the visible objects on the left and right of this focus point. Just as images on Web pages require a text description, objects in the 3D world must have text labels and descriptions for the ***look*** and

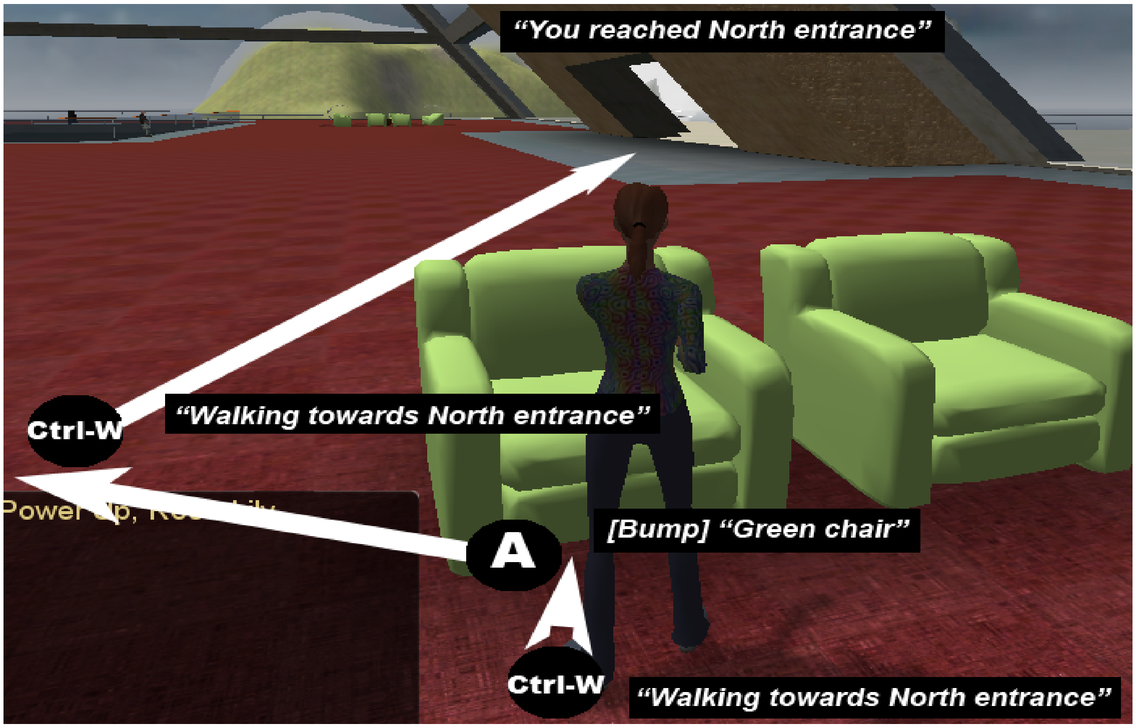

Figure 4. A controlled walk sequence from *PowerUp*.

find functions. However, the design of these labels is challenging as 3D objects may be viewed from any angle or distance, may be partially occluded by other objects, and may have status that changes dynamically (for example a light may be on or off). Researchers have begun to explore ways to select and prioritize the set of objects to be read, and generate appropriate descriptions [4][10][15].

With these tools, and the sound effects provided, there are numerous strategies players can use to get oriented and navigate in the world using audio alone. For example a player might start by using a ***look*** command to hear what is nearby, then use ***find*** to face an interesting object. The L key would provide additional information, including a list of potential obstacles between it and the player. The player can now start a ***controlled walk*** towards the target object.

Figure 4 illustrates a controlled walk sequence in which the target is the North entrance, but there is a chair blocking the path. The player presses Ctrl-W to walk towards the North entrance, and the speech feedback "Walking towards North entrance" is given. In this example, the player hears a bump sound and the words "Green chair", and the walk stops. They sidestep a little using the A key then press Ctrl-W again to continue walking towards the original object. The footstep sounds will indicate progress, until the player hears "You reached North entrance".

6. VALIDATION TO DATE

Having developed an initial set of accessibility tools and options for *PowerUp*, a group of seven legally blind teenagers were recruited to provide testing and feedback. Their input identified problems and gaps in the accessibility provision for visual impairment, and guided subsequent design iterations. Further validation with other target user groups is planned.

6.1 Participants

Seven participants (two female), aged 13-15, took part in our evaluation sessions. All are legally blind, meaning that they have visual acuity of 20/200 or less with the best correction possible. The group as a whole is representative of the legally blind population. Two are screen reader users, referred to as SR1 and SR2. Two use screen magnification software for computer access (2x and 8x levels of magnification), and will be referred to as SM1 and SM2 (screen magnification). Three do not (always) use any assistive technology for computer access, and will be referred to as NAT1-3 (no assistive technology). However, these individuals may choose to use assistive technologies for some tasks.

Unlike the survey respondents, they had never played games designed specifically for people with vision impairment, but had all played Wii sports games. Most participants also played mainstream 3D action and adventure games, in several cases for more than 10 hours per week.

6.2 Equipment and Materials

All sessions were conducted at Lighthouse International, New York [8] using four desktop machines with 19 inch monitors (2 wide screen) and two laptops with 14 inch screens. All screen resolutions were 1024 * 768 and the game occupied the whole screen. Headphones were provided. All machines connected by high bandwidth Ethernet connection to a single game server.

A background questionnaire was used to capture basic demographic information, and information about the participants' experience with virtual world games. A paper feedback questionnaire was used to record the participants' experience with specific game features, and the navigation strategies they used.

6.3 Procedure

Three 90 minute sessions were conducted over a five week period. Two researchers were present at each session. They recorded feedback as written notes. Session 1 began with oral administration of the background questionnaire, followed by a demonstration of *PowerUp*, its commands and the accessibility features. Participants then practiced moving around in the orientation center, gathering wind turbine parts, and building wind turbines. Some participants also explored the solar mission, driving the dune buggy and aligning heliostats. The researchers provided instruction on the use of the game commands, tips on game playing, and filled in missing information where gaps were apparent. When problems were observed, possible solutions were discussed with the participant. At the end of the session, participants gathered in a group and provided comments on their experiences.

In the second session, participants were asked to revisit the accessibility options and make sure they selected the options they wanted. The remainder of the session consisted of game playing practice and informal feedback to the researchers.

Based on the feedback from the first two sessions, design changes were made to many areas of the game. The spoken descriptions were expanded to indicate the direction of gaze and to group objects by distance, near to far. Non-speech audio was added on bumping into objects, and pitch of footfalls changed to indicate ascending or descending. Automatic navigation (controlled walk) was amended to stop when a sharp drop ("cliff") was reached, and the distance a ***look*** or ***find*** command would 'see' was adjusted.

The third session began with a refresher on the accessibility options and description of modifications made to the navigation commands in response to earlier feedback. Participants were then asked to perform specific tasks: customize their avatar, follow another player, teleport to the wind mission, and gather turbine parts. Again, the researchers provided assistance when requested. Finally, researchers asked the feedback questions.

6.4 Results

When selecting accessibility options, all of the participants enjoyed the sound effects. Five used the speech feedback while two (SM1, NAT1), found it intrusive. SR2 used high contrast text. Two used extra large text (SR2, NAT2), two used large text (SM1, NAT1), and three (SR1, SM2, NAT3) did not change the default text size. One participant (SR1) relied entirely on keyboard navigation.

Using their preferred settings, all participants were able to independently navigate the GUI screens in order to log on, customize their avatars, teleport to a mission, and build a wind turbine. Participants needed to be reminded how to have the whole GUI read out.

Six of the seven participants made use of the graphical display. At least one person found the standard cursor too small. All stated that the in-world contrast and lighting were sufficient in the areas they had explored.

The participants were also able to locate nearby objects and navigate to them, although they sometimes had difficulty knowing which objects were important. Three used the zoom key to get a closer look at objects. SM2 felt that an even higher zoom level would have been useful. Five found the ***find*** commands useful, though only SR1 used them extensively. The most common use was for locking on to a moving object. A long (300 step) threshold for ***find*** was preferred over a shorter one, even though this sometimes resulted in many objects being found. It may have served as a means to identify far off objects through the speech. Participants wanted to be able to find specific categories of object, such as other players.

Participants had a general preference for speech over sound effects, "because it is easier to understand". The L key was used by four participants, to hear the player's orientation and the object(s) ahead. The other look keys were forgotten by most, and only used by SR1. In general, participants felt there were too many commands to learn.

Six participants tried following another player, and five used controlled walk for this. All were successful, but one reported difficulty, especially with not knowing where the person was heading. Controlled walk was also used extensively by SR1 for getting to objects and on occasion by other players for following moving objects, or avoiding cliffs.

The greatest area of difficulty was in large scale navigation – finding specific locations, and finding team members. *PowerUp's* map feature would have addressed these issues, but was not available in time for the sessions.

All these blind and partially sighted participants were enthusiastic in their game playing and actively engaged in navigating the virtual world and accomplishing game tasks. Five participants were asked if there was anything that would prevent them from being able to play *PowerUp* independently. One participant reported several high level issues related to overall game play and large scale navigation, but all were satisfied with the accessibility of the GUIs and specific tasks tested. SR1 said "I think I could play this on my own at home".

7. DISCUSSION AND FURTHER WORK

Although usability improvements are still being made to *PowerUp*, this core set of general purpose features was effective in providing a basic level of access for people with different levels of visual impairment. Testing with individuals with motor and cognitive impairments is now required to further refine and validate the proposed set of features. There are also important features that have not yet been provided for *PowerUp*, including the use of maps, captioning, switch access, and point-to-speak capability.

After three sessions our participants were still experimenting with different strategies and learning the commands. No two participants used the same settings and tools. As users become more expert, they may develop more efficient strategies, and prefer more non-speech sound effects. Further work is required to establish what core sound effects, beyond footsteps and bumps, should be provided. It has yet to be demonstrated whether the features provided are sufficient to enable blind players to build an accurate mental model of the virtual space.

8. SUMMARY

It is clear that people with disabilities want to participate in virtual worlds, and that there are many features that can be built into such worlds to enable access.

In *PowerUp*, the level of accessibility provided has been limited more by the time and resources available than by any barriers inherent in the medium. In this work, we were fortunate to have the limited world of the *PowerUp* game as an application within which to test ideas. Again, this game was being created by an IBM development team and our task was to make it accessible. Ideally, however, the types of features described here would be built into virtual world engines. In this way, developers would not need to start from scratch in providing accessibility. Importantly, such accessibility in the engines would provide standard controls for users with disabilities in navigating virtual worlds.

As virtual worlds become more prevalent for both entertainment and community interaction, building accessibility into virtual worlds will become increasingly important. When asked 'Do you like games that let you to do things you cannot easily do in real life?' one of our survey participants summarized the situation nicely when he said, "Of course, but I think this is an issue that goes beyond disabled individuals. Most people will never have the opportunity to wage war against mystical forces in a strange, fantasy-based world. Hence, World of Warcraft is a wildly successful game. That said, as disabled individuals have a much wider pool of activities that we *can't* do, perhaps games offer us more than the average person in this respect."

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