# Creating Video Games for the Visually Impaired

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## Introduction

The video game industry has expanded rapidly in recent years, growing from a $9.5 billion industry in 2007 to a $25.1 billion industry in 2010. This growth is due to the common interest that almost all Americans now hold in games, as a seventy-two percent of all Americans play video games on a regular basis (ESA). However, because games rely heavily on impressive graphics and are primarily an immersive visual experience, very few games are made with the blind or the visually impaired in mind.

When video games first emerged in the 1970s, it was virtually impossible to create a game that did not involve some sort of visuals. This was mainly due to a lack of technology, as almost all computers, games, and electronic speakers and displays could only output crude, pixilated visuals and rough, synthesized sound. However, technology has steadily improved to the point where games that do not need visuals are a possibility.

Games for the visually impaired are an untapped industry, especially with the technology that exists today. By conducting interviews with the visually impaired we discovered what types of games the visually impaired prefer, what they would like to play, and what ideas they have for developing these games.

## The History of Video Games for the Visually Impaired

There are already a small number of game that can be played by the visually impaired. Interactive fiction and other text-based games have been popular for a long time, though to a lesser extent in recent years. Sound-based games are beginning to be explored, and may offer new genres of gaming accessible to both the sighted and the blind. Although many games have been produced that are popular within the visually impaired community, very few games are created with the visually impaired in mind.

Before video games, many board games were adapted to be played by the visually impaired. Although few games are produced with accessibility in mind, existing board games can be easily modified. Lines that need to be visible, such as the borders between spaces, can be raised with lines of dried glue to provide tactile feedback. Words or other symbols can be covered with Braille labels. Such tricks are common in the blind community (Timanus).

Interactive fiction is a genre of game in which the only exchange between the game and the player is text. The game displays text descriptions of the game world, and the player can type responses that tell the game what the player wishes to do. It is truly an interactive genre; the player has complete control of their actions in the game space provided for them.

The genre began with a computer programmer named Will Crowther in the mid-1970s. An avid caver, he decided to write a game, *Colossal Cave*, based on the Bedquilt cave section of Mammoth Cave in Kentucky. The game allowed the player to move in different directions, examine objects, and progress through the puzzles and story, all by typing commands into the terminal. These commands were simple phrases and words, such as 'GET SWORD' or 'GO LEFT.' This was the only interface with the game environment; although much later versions included pictures along with the text, the original had no accompanying visuals (Jerz).

Although *Colossal Cave* was playable as early as 1976, the game was not released to the public until 1980 on the Apple II computer. It was originally programmed in FORTRAN on a

PDP-10, a mainframe computer not accessible to casual computer users. Many subsequent versions of the game were produced, but the most popular and enduring version is the one modified and enriched by Don Woods, then a student at Stanford. He added many elements that would become staples of the genre, such as mythical creatures and other fantasy elements (Scott).

The game quickly became popular and inspired a multitude of similar games. Scott Adams created a publishing company, Adventure International, which specifically created interactive fiction games. All of the games produced by Adventure International were written specifically for home computers, bringing the genre into the public eye and increasing its popularity (Scott).

Adams' first game, *Adventureland*, was the first interactive fiction title available on home computers. Released in 1978 on the Apple II and the Commodore PET, *Adventureland* was not only the first game produced by Adventure International, but also the first text adventure available to the public. The company produced many more games until its eventual bankruptcy in 1985 (Persson).

The most famous producer of interactive fiction was the company Infocom. It was founded by members of the MIT computer science department in 1979 in order to sell a game created two years earlier, called *Zork*.

*Zork* was inspired by *Colossal Cave* and took the concept to new heights. It was capable of parsing complete sentences from the user input, and included much more material than any other game at the time. *Zork* was eventually released in 1980 by Infocom as the first installment of what would eventually become a trilogy. Although the game was originally written for the PDP-10 mainframe computer, the game was rewritten by Infocom staff for a wide variety of home computers (Barton).

http://www.youtube.com/watch?v=2mQy8hjcxYQ

Video of a playthrough of *The Hitchhiker's Guide to the Galaxy* text adventure.

The company also released one of the most famous text adventures of the 1980s. *The Hitchhiker's Guide to the Galaxy* was released in 1984. It was based on the book series of the same name by Douglas Adams, and is infamous for its tricky puzzles. One, the "Babel Fish puzzle," renders the entire game unwinnable if not performed correctly. The game's popularity secured it a spot in the history of notable video games. Editions were released as recently as 2004 ("Hitchhiker's Guide to the Galaxy Infocom Adventure").

Interactive fiction is an especially important genre of game for the visually impaired. The appeal of text adventures lies in their textual depictions of the environment and objects within the game. A visual game assumes that the player is capable of understanding information that is only visually accessible, not referenced in the sound or through any other channel of communication. With a text-based game, all information about the game is conveyed through text. Visual data must be described in words, which the visually impaired have no trouble receiving through the use of screen readers.

Because all visual information in the game is presented in a non-visual medium, nothing is left out of the text. The player can have a visual experience described to them. As one blind player of text adventures, Michael Feir, states, "If you play something like *Zork*, everything is described. And sighted people don't always do that. So, you not only get a sense of place and how places work, and how you move through them, but you also get a sense of objects. You can examine pretty much everything you can pick up in the game and it'll have a description. It's very helpful" (*Get Lamp*).

An account of the way in which visually impaired gamers play is given by Ari Damoulakis in Issue #52 of The Society for the Promotion of Adventure Games. In it, he confirms the importance of text descriptions of visual phenomena;

> “How does a blind person play interactive fiction, and what is the state of accessibility for interactive fiction? We as blind people use screen reading programs, which read the text of a computer screen back to us. Ideal for interactive fiction! As long as the interpreter is written well, there is no barrier that stops us from accessing games in the Windows environment. It is unfortunately quite disheartening, however, to see that many authors are incorporating and including graphics that are crucial to solving the plots of their games. An example of this would be the Quest game, *The Last Resort*. The description of this game seemed very delightful, coupled with the fact that there were even sounds, but unfortunately the author had incorporated graphical clues

which needed to be understood in order to solve some puzzles, which was quite a blow for me" (Damoulakis).

The founder of Adventure International, Scott Adams, purposely made his games easily accessible to screen readers and adds sections specifically to help the visually impaired play his games. He did this because he was approached by visually impaired players who asked him to add this functionality (*Get Lamp*).

Although the interactive fiction genre is a rich medium for games, they fell out of fashion in the late eighties due to the advent of graphical games. The genre now survives as a hobbyist's field, with creators distributing and developing games over the internet. Since the decline of commercial text adventures, over 2,000 new games have been produced by independent developers (*Get Lamp*).

Other video games have been popular with the visually impaired outside the genre of text adventures. In 1974, Atari released the first audio game to be mass produced. *Touch Me* was a screen-less arcade game that tested the player's eidetic memory. Four buttons on the console corresponded to four tones and colors. The colors would flash in a pattern, and the tones would play for each color. The player had to repeat the pattern presented to them without making a mistake (Grahame).

*Touch Me* was an important milestone in the history of video games for the blind. Because the colors were accompanied by an audible tone, the game was playable by the visually impaired. The game inspired Milton Bradley to come out with their memory-testing game, *Simon*, in 1977, which is still popular today.

http://www.youtube.com/watch?v=JkjjzNYDR9Q

Video of a handheld *Touch Me* in action.

Another genre of games played by the visually impaired are audio games. These games focus on conveying information to the players through sound instead of through visuals or text. As such, these games are often geared towards the visually impaired. While text adventures may offer visual descriptions of in-game objects, audio games do not even indirectly reference vision. This means that visually impaired and sighted players can play on a level playing field.

One such audio game is *Papa Sangre*, available on the iPhone. This game has no visual interface, and is played entirely through sound cues. By using headphones, the player hears sounds in the game in three dimensions, and must navigate the world using the touchscreen. This world is the world of the dead, and the player must survive and avoid danger while saving others who are trapped there. Audio cues tell the player where in space the enemies or goals are, and moves towards or away from them by controlling their footsteps with the iPhone (Webster).

http://vimeo.com/9916119

Video of the beginning of Papa Sangres in action [binaural].

This game utilizes an important tool for creating audio games for the visually impaired: Head-related Transfer Functions. These functions determine how a desired sound must be modeled in a two-channel audio stream in order for it to appear to humans to come from a particular location in space. Through appropriate utilization of this technology, an entire world can be created which is fully explorable with sound (Head-Related Transfer Functions).

One game that brings together audio games and more traditional video games is *Airik the Cleric*, created by Breakerbox Games. *Airik* is a visual game, but it has a full voice-over with non-synthetic voices. This gives fully blind players enough information to play the game, and it also gives partially-blind players the benefit of visuals (Pawloski). The game is popular in the blind community due to its accessibility (Video Gaming for the Deaf, Blind, and Otherwise Disabled Players).

Currently there are few resources available that offer information on video games for the visually impaired. There are a handful of companies that produce these games, but new titles are few and far between. All in Play is a company that creates multi-player games for both the visually impaired and the sighted, so that everyone can play on equal footing. It started in 2001, and has released five games, most of which are card games (How It Works).

Many websites offer listings of video games for the visually impaired; however, these websites only list games that are suitable after the fact. It is difficult to find games made specifically with the blind in mind, or testimonials from the visually impaired about whether or not the games are actually popular with them. This lack of information speaks volumes about the state of games for the visually impaired today.

Games for the blind are not difficult to produce, given the past success with interactive fiction and audio-based games. However, the market for games is almost entirely geared towards sighted gamers who expect the latest and most impressive graphics. With so much emphasis on the visual aspect of gaming, and the aversion towards reading in video games, the pool of blind-accessible video games is nothing compared to the ocean of highly visual titles.

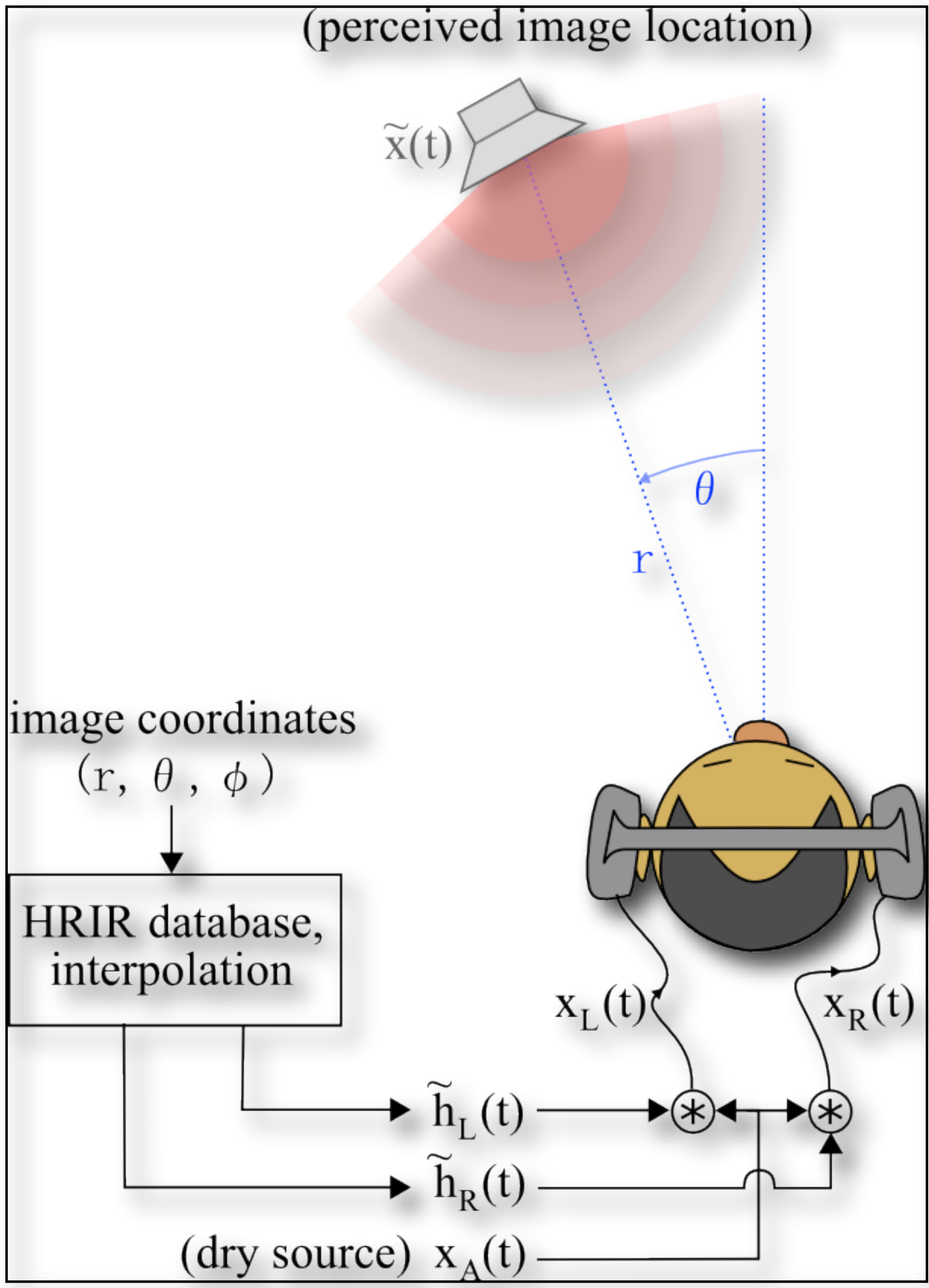
## Modern Day Technology

Although many obvious advances in technology have occurred since the 1970s, such as more hard drive space, better graphics and sound cards and the speed of processing, certain technologies and developments especially pertain to the visually impaired.

## 3D Audio and Spatialized Sound

With the recent advances in audio technology, sound is able to be presented with a 3D effect, either through special recording or post production. 3D audio effects and spatialized sound are sounds that play through a stereo output, surround sound speakers, speaker arrays, and in most cases, especially with the boom in the mobile game industry through smart phones and handheld gaming systems, headphones. This technology involves placing a sound in a virtual 3D space, such as playing a sound so it seems it is coming from above, behind, to the left, and to the right of the listener (John). Here is an example of spatialized 3D sound from the inside of a barbershop.

http://www.youtube.com/watch?v=8IXm6SuUigI




The mechanics of binaural recording.

One method for achieving this effect is through the use of binaural recording, in which microphones are attached to the left and right ears of a dummy head. This sort of recording is intended for listeners using headphones, as the recording does not translate well into stereo speakers, or any other output device, without the assistance of a third party software such as MorrowSoundTrue3D (Binaural Recording).

A more practical way to simulate 3D sound is using a game engine with the ability to take a sound and create spatial perspective by placing it in the scene of the action. This ability is common in modern engines such as Unity, ANA and the Unreal Game Development Kit. Many of these engines can be used to make titles that can be played on smartphones.

## Screen Reader

A screen reader is an assistive technology that attempts to turn what is currently being displayed on a computer monitor into a different non-standard output, such as turning it into text on a Braille output device, or, more commonly, turning text to speech. They are often combined with screen magnifiers, an application that enlarges screen content for visually impaired people. Microsoft and Windows come pre-packaged with their own stock screen readers, but much is left unaddressed in their designs. The programs most popular among the visually impaired are third-party downloads such as JAWS from Freedom Scientific, Window-Eyes from GW-Micro, and a free open-source screen reader known as NVDA  (Theofanos).

http://www.youtube.com/watch?v=IK97XMibEws

Video example of JAWS screen reader.

There are three standard types of screen readers. The first, and one of the earliest, was the CLI (command line interface) screen reader. This was used primarily in early operating systems, such as Microsoft's MS-DOS. It was designed to take input from the keyboard, which then lead to information being hooked around the system and then being read by a screen buffer. The data would then be converted to sound and, using a standard hardware output, be communicated to the user (Stoffel). This led to the first official appearance of the screen reader, developed and released by the Research Center for the Education of the Visually Handicapped (RCEVH) for the BBC Micro and the NEC Portable (Blenkhorn).

As time went on, computers advanced and developed GUI systems, so screen readers were forced to advance as well. This meant that a screen reader needed the ability to locate text at any position on the screen while also pointing out where the person using it was in context to the objects and text around it. Not only did the screen reader have to read the text back to the user, but it also had to put its position in context with the rest of the information being displayed on the screen. This led to users using the arrow keys and similar key layouts to toggle up, down, left, and right, hopping button to button around the GUI, having the name of each button read aloud or published on a refreshable Braille display output. This is one of the biggest challenges that screen readers have faced, and still continues to be one today. Developers of screen reader software find it difficult to both communicate where a person is on the screen and also what is on the screen in a reasonable amount of time (Schwerdtfeger).

Apple, Java, and Microsoft have all developed GUI screen readers that attempt to solve the problem of unknown position in users. They have run into many snags along the way, chiefly involving compatibility issues. Some screen readers do not work with some applications because of the way they were developed. For example, Microsoft Word does not work with MSAA, and very few web browsers are recognized by IAcessible2. For these applications, users must find other ways to access them, such as other screen readers or formatting the text in a way that makes in recognizable (Axistive).

Recently, almost all text-based applications, including web browsers, word processors and email programs, offer some level of support for screen reading. However, several programs, such as Flash, video games with scrolling on-screen text, and any program with text rendered in the game, have yet to be integrated into accessibility standards, leaving them unusable by most screen reader users (Apple: Voice Over).

One of the newer screen readers that has recently been developed is the web-based screen reader. Examples of this product include Spoken-Web, BrowseAloud, and ReadSpeaker. These are browser-run screen readers that turn text to speech on most web content. Although functions are limited to the browser, there are advantages to them, such as being completely free and the ability to use them on any computer without installing custom software. This is important for schools and businesses, where software installs are monitored and restricted. Apple has recently made a push to put these web readers on iPods, iPhones, and iPads, and other smartphone companies are following in their footsteps (Apple: Vision). In the following video, David

Woodbridge, a visually impaired UK citizen, reviews and explains why he likes Apple VoiceOver:

http://www.youtube.com/watch?v=QEDzitE2w_0

Users all have personal preferences on how they would like to hear their text read to them. One of the ways to change and customize a previously developed screen reader is by scripting in small tweaks, such as having punctuation read or unread, the speed at which the screen reader reads, and whether the reader should spell a word it does not know how to pronounce or do its best to pronounce it. Scripting has therefore become a important part of the screen reader experience. It can be used to customize speech verbosity, which controls the location and direction of reading. This leads the user to get a much better picture of what is displayed on the screen in their mind, for they have a consistent space in which the program starts reading and can easily refer back to it if need be. JAWS strongly supports scripting to improve their program, and developed a special scripting language for their product (Virtual Vision Technologies).

Another challenge faced by screen readers is the language barrier. Some screen readers can read multiple languages, but most struggle to pronounce non-English words in English, leading to almost incomprehensible babble. Fortunately, a few screen readers handle language change really well, such as NVDA, which goes as far as to read websites from the United Kingdom in a mock British accent (NVDA).

http://www.youtube.com/watch?v=81HbxFVrT0w

Video of a screen reader's British accent.

Touch and Haptic Feedback

Haptics, also known as haptic technology, is tactile feedback that is usually embedded in a controller of a video game. These controllers add an extra output to the game, applying forces, vibrations, and motion to the user (De-La-Torre). Below is a Logitech MOMO Racing Wheel for Xbox 360 that shows how far haptic feedback can go, imitating real wheel movement.

http://www.youtube.com/watch?v=Jy1jiygdrro

In video games, haptics are often used to enhance immersion by vibrating when collisions are detected. This could refer to being shot, shooting a gun yourself, crashing a car, getting punched, or any signal that something significant has just occurred in the game (Wolf).

Almost all cellphones have haptic feedback built-in as well, mainly to silence them during situations when it would be inappropriate for your cellphone to ring. However, on almost all phones with this haptic technology, any game played on it can also take advantage of the feedback.

## Voice Recognition Software

For sight-impaired individuals, typing on a keyboard can be quite difficult, especially when one is trying to play video games. Instead of using a keyboard for gaming and computing, voice recognition software is a new method that allows anyone, not necessarily someone who is sight-impaired, to talk to the computer and have words appear on the screen (Voice Recognition Software - An Introduction). Voice recognition works by analyzing the actual sound input and converting the data into a text string (Voice Recognition Software - An Introduction). The goal of speech recognition is to be able to listen to any person's voice and successfully recognize what that person says, regardless of dialect, language, or speech impediments. This software is extremely useful for developing games for the visually impaired because it allows the player to ignore all visual aspects and simply have a conversation with the game. Spelling is no longer a problem, because when a word is recognized by the software, the program automatically spells it correctly.

Voice recognition software requires certain calibrations in order to function properly. Every person has a distinct voice, which makes the task of voice recognition difficult. In order to tune the system for each person, speech recognition has two different phases: **enrollment** and

**verification**. During enrollment, the user is asked to repeat a short phrase or a sequence of numbers (Voice/Speech Recognition). Once enrollment is completed, verification begins. In the verification phase the data collected from enrollment is compared against a single pre-processed voiceprint to determine the difference in characteristics (Voice/Speech Recognition). This process takes a relatively short amount of time and tells the software how the user speaks. Although some newer voice recognition programs do not require this calibration, enrollment and verification are the best ways to ensure accuracy in a recognition system.

A less effective calibration technique is **identification**, which takes an input and compares the data against multiple voice patterns in order to determine the best match or matches (Voice/Speech Recognition). While a "best" match will always be found, the input data is not necessarily close to any of the choices. Therefore, the selected match may not be accurate. This glaring problem exemplifies the fact that enrollment/verification systems are more accurate than identification systems.

When speaking, people often hesitate or slur their words. In order to use voice recognition software effectively, one must learn how to talk clearly so that the program can recognize complete phrases or sentences (Voice Recognition Software - An Introduction). When users do not pronounce their words clearly, the speech recognition software has a difficult time identifying the words that the user spoke from the input data. Even with completely clear speech, occasionally the software will make a mistake and misinterpret the input data. While this error is not a common occurrence, proof-reading is still a good practice to correct any mistakes. For sight-impaired individuals, their mistakes can be found by the program reading the interpretation of the speech back to them rather than just displaying the text on the screen. An amazing feature of this software is that when a correction is made, the program will adapt and learn, so that the same mistake will not be made again (Voice Recognition Software - An Introduction). As more corrections are made, the accuracy of the system continues to improve.

Voice recognition software can have problems with speed. For the most effective use, the program should be run on a relatively new computer with a significant amount of memory. The minimum suggested requirements to run voice recognition software are a Pentium 4 or AMD Athlon 64 1 GHz of a PIII 700MHz processor with 1 GB RAM (Voice Recognition Software - An Introduction). More efficiency comes with additional memory. For example, a system with 2GB will run more smoothly. Another problem that the software can encounter is difficulty recognizing the input signal. This problem is usually more of a hardware issue. The most likely scenario is that the system is not receiving a clear signal from the microphone. The signal could be distorted due to noise or a poor connection. If background noise ends up being the main problem, higher specifications for microphone filtering become a necessity. If the hardware is not the problem, then the next likely scenario is that user is not speaking clearly, which might be an easier fix.

According to Douglas Durham, Martin Markoe, Susan Fulton and Judy Evans, seven key steps to achieving high speech accuracy exist. These seven steps expand upon the criteria that were discussed earlier.

1) A proper computer hardware system and microphone that produce clear sound input are needed (Durham). The minimum requirements described by Ability Net generally are enough to satisfy this step.

2) The microphone needs to be positioned correctly and consistently (Durham). By keeping the microphone stationary in the ideal position, noise and feedback are reduced, and the microphone receives clearer data.

3) Full enrollment must be executed (Durham). When a user performs enrollment, the software learns that person's voice patterns. Thus, the recognizable vocabulary library is expanded for the user.

4) The microphone and system must be tested to ensure accuracy (Durham). Upon completion of enrollment and verification, the user can manually check the results. Assuming no operator error exists in the system, any discrepancies with the results can be attributed to either the hardware or the software. Once the problem in the system is isolated, inadequacies can be fixed or removed.

5) The system vocabulary can be expanded to add context to the enrollment process (Durham). Certain systems are designed to learn the meanings of words in different contexts, which allows for a more accurate interpretation.

6) Users must undergo training in order to use the software effectively (Durham). By learning the proper way to communicate with a speech recognition program, users are more likely to receive the desired result from the software.

7) Users should participate in group use and observe other people operating the program (Durham). Seeing how the software responds to other users' commands gives the observer more insight into the proper use of the program.

If these seven suggestions are met, a user is likely to have an easier experience with speech recognition software.

Currently, voice recognition falls into two categories to reach this desired result. One of the groups is called a Small-Vocabulary/Many-Users system. A classic example of this system is automated telephone answering. In a Small-Vocabulary/Many-Users system, "the users can speak with a great deal of variation in accent and speech patterns, and the system will still understand them most of the time" (Grabianowski). The reason that the software has such a wide scope of recognition is because the vocabulary is limited. With a smaller vocabulary, more memory and computing power can be allocated towards interpreting the multiple ways a user can say the limited words. The extra capacity is very useful because every person speaks differently, and this system is able to overcome that obstacle. However, the best utility of this system is also the biggest hindrance; a small vocabulary only allows a limited scope of functionality. In fact, "usage is limited to a small number of predetermined commands and inputs" (Grabianowski). While a Small-Vocabulary/Many-Users system is perfect for smaller scale functionality, using this system type for larger scale projects is almost impossible.

The other voice recognition software group is referred to as a Large-Vocabulary/Limited-Users system. An example of this structure is "a business environment where a small number of users will work with the program" (Grabianowski). In this system, the majority of the focus is on flexibility of vocabulary. By using a small group of users, the system can be tuned to their voices specifically. Their pitch, tone, and dialect will be programmed into the system, so that the processor will remember a specific person's voice. With that index, the program will be able to look through word databases to convert speech to text, and this method will be extremely accurate because the system knows the tendencies and characteristics of the input voice enough to safely determine the correct output text. However, the largest discrepancy with a Large-Vocabulary/Limited-Users system is that the accuracy of the processor will automatically decrease with each additional user that is introduced. The accuracy rate will have to fall because with more variance in voices leaves less memory and processor capacity to be allocated for searching large vocabulary databases.

Obviously, both groupings have a number of positives and negatives in regards to being able to be implemented in a voice-based game. While Large-Vocabulary/Limited-Users systems would probably allow for the most creative games, they are not an ideal choice for designing fully functional video games for the sight-impaired. Designing such a system so that every person can play the game is impossible. Ideally, a Small-Vocabulary/Many-Users system would be used to design a voice recognition video game. Though the choices inside the game would be more limited than for a Large Vocabulary system, more people would be able to play and enjoy a game created this way. Because the vocabulary is limited, the game would be able to take voice inputs from every person who desired to play. Such a game might not be as strong creatively, but from a functional standpoint this game would work better.

http://www.youtube.com/watch?v=RWtmbQ0mxdU

Video example of Dragon Speaking Naturally for Windows.

Many commercial speech recognition programs are available. The most recognizable of these products is Naturally Speaking by Dragon Systems, a company founded by Dr. James Baker and Dr. Janet Baker in 1982 (History of Speech & Voice Recognition and Transcription Software). The company's goal was to create and release products that were accessible via a voice recognition prototype called DragonDictate. Only released for DOS, DragonDictate utilized statistical methods in order to recognize speech, but the hardware was not powerful enough to address word segmentation. Thus, DragonDictate was unable to recognize the boundaries of words from a continuous speech input (History of Speech & Voice Recognition and Transcription Software). In order to achieve functionality, users would have to include a long pause in between each word. Even with these long pauses, DragonDictate could not determine the beginning and ending points of individual sentences or clauses. In 1997, the prototype was converted into Naturally Speaking 1.0, which is a continuous dictation software (History of Speech & Voice Recognition and Transcription Software). Naturally Speaking was received well by the industry, and Lernout & Haupsie Corporation bought out the company in 2000 (History of Speech & Voice Recognition and Transcription Software). However, the corporation went bankrupt, and the rights to Dragon were acquired by ScanSoft. In 2005, ScanSoft rebranded as Nuance and dropped Dragon from the product name, simply referring to the software as Naturally Speaking (ScanSoft and Nuance to Merge, Creating Comprehensive

Portfolio of Enterprise Speech Solutions and Expertise). The current version of Naturally Speaking is 11.5, which was released in June 2011.

As the demand for voice recognition software increased, other corporations tried to capitalize on the market. One of the most significant is Microsoft. Originally for Windows Vista, Microsoft designed Windows Speech Recognition as a competitor in the voice recognition software industry. Using a clever marketing campaign, Microsoft claimed that the product was designed for people who want to significantly limit their use of mouse and keyboard interactions while still maintain, or in some cases increase, their overall productivity (Windows Speech Recognition). Much like other speech recognition programs, Windows Speech Recognition allows a user to dictate documents and emails, use voice commands to start and switch between applications, and control the operating system. Windows Speech Recognition has several features, with the most interesting one being the number of languages that are detectable. Currently, Windows Speech Recognition is available in English, German, French, Spanish, Japanese, and Chinese (Windows Speech Recognition). Another key feature is only available in the English version. When a user says "How do I" followed by a task that the person wants the computer to perform, the program will respond with instructions for completing the task (Windows Speech Recognition). Certain tasks are hard to figure out how to implement, and this feature saves valuable time that might otherwise be used searching the internet for a solution.

http://www.youtube.com/watch?v=Z3KU9nLEueo

Video example of Windows 7 Speech Recognition.

Recently, Microsoft decided to take its position in the voice recognition market a step further by developing a new product. In November 2010, Microsoft released Kinect for the Xbox 360 gaming console. Kinect combines motion sensing and voice recognition software in order to enhance a user's gaming experience. Initially, the Kinect only worked with games that were specifically designed for the product. Seventeen games were available for purchase when Kinect came out. The most popular titles were *Kinect Adventures, The Gunslinger*, and *Fruit Ninja* (Xbox 360 + Kinect). These games were very basic and barely touched upon the Kinect's voice recognition capabilities. In November of 2011, one year after the product's release, Microsoft made an update available for the Xbox 360 that enhanced the system's ability to utilize the Kinect's voice recognition capabilities (Lian). This new update allowed the user to navigate through the console's interface using voice commands in addition to the already easily accessible motion controls. A user simply needs to use say the word "Xbox" followed by the desired action in order to use the Kinect. This functionality is most useful for video applications, such as Netflix, Hulu Plus, and HBO Go, as the user can pause, stop, rewind, fast forward, or play a video without having to use a controller (Lian).

http://www.youtube.com/watch?v=thwfC-9oGNw

Video of *Mass Effect 3* voice command recognition via Kinect.

As game developers began to create their games with the Kinect in mind, Microsoft began releasing games with the tagline "better with Kinect." The most recent game with this feature is *Mass Effect 3*, released in March 2012 (Better with Kinect). One of the biggest problems with previous *Mass Effect* titles has been the difficulty of navigating through menus to select different powers and weapons. With the Kinect, this problem is alleviated. A gamer can simply tell the Kinect which weapon or power that is desired, and the game will recognize this choice. This feature is not limited to the player's character, as the inventory of computer controlled squad mates can also be accessed via voice control (Better with Kinect). In fact, a player can use voice control in the game for multiple interactions such as opening doors, accessing data, and conversing with other characters in the game. With this new revelation, Microsoft is slowly reaching its goal of making the Xbox 360 a completely hands-free gaming console.

Due to the success of the Kinect for the Xbox 360, Microsoft released a version Kinect for Windows. Microsoft's goal with the Kinect for Windows is to transform how people interact with computers and Windows-embedded devices in multiple industries (Kinect for Windows Features). Desktop PCs have greater processing than the Xbox 360, so the Kinect for Windows has more possible applications than the regular Kinect. The release of the Kinect for Windows included a software development kit for commercial use (Kinect for Windows Features). Users are allowed to download the commercial-ready installer for free, allowing easy installation of the runtime and driver components for end-user deployment (Kinect for Windows Features). The Kinect for Windows also has more enhanced sensor capabilities than the original Kinect. Voice recognition and motion sensors are far more sensitive, and 4 Kinect sensors can be used on the same computer (Kinect for Windows Features). These features are very important for the Kinect for Windows's functionality, but the most important difference between this product and the original predecessor is the improved software. The software development kit includes improved skeletal tracking, which allows developers to control which user is being identified by the sensor. (Kinect for Windows Features). Also, the most recent Microsoft Speech components with an improved acoustic model is included in the software. These components significantly improve the accuracy of the speech recognition software (Kinect for Windows Features). Obviously, certain hardware requirements are needed to access the software, but these requirements are easy to achieve in a computer. In order to access the software development kit the target computer must have a 32-bit or 64-bit processor, a dual-core 2.66 GHz or faster processor, a dedicated USB 2.0 bus for the peripheral, and at least 2 GB of RAM. Finally, the computer's operating system must be Windows 7 or greater (Kinect for Windows Features). By making the software development kit available to the public, Microsoft is pushing for people to develop programs that function with voice recognition software, speeding up the evolution of the technology.

http://www.youtube.com/watch?v=McNGdLGEfuw

Video of Kinect operating under Windows 7.

Another company hoping to capitalize on the rapidly increasing popularity of voice recognition software happens to be Microsoft's biggest competitor, Apple. In October 2011, Apple released the iPhone 4S. A marketing focus of the 4S was its voice recognition assistant, Siri, which allows users to send messages, schedule meetings, dial phone calls and complete other tasks by simply voicing commands (Learn More About Siri). Capable of understanding natural speech, Siri is intelligent enough to ask the user questions if the software does not understand the desired operation. Powered by the power of the dual-core A5 chip in the iPhone 4S, the software uses 3G and wireless networks to communicate with Apple's data centers, so that the program can understand what the user is requesting at a rapid speed and immediately respond (Learn More About Siri). Apple decided to make using Siri as simple as possible, so a user simply needs to hold down the home button on their phone to access the software. Once the user is finished speaking, the person can press the home button again to send the command, but the user also has the option of just waiting, as Siri can understand when a person has finished making a request. Siri then displays the message in text on the screen and provide a response. If Siri does not understand any words that were spoken, the software prompts the user to perform an internet search of the command to help with the process (Learn More About Siri). The software does not require specific speech patterns to respond. In fact, Siri's biggest selling point is that it receives commands like a conversation with a person. The user can use a natural voice and conversational tone, and the program is generally able to understand.

http://www.youtube.com/watch?v=L4D4kRbEdJw

Video of Apple Siri demonstration.

While Siri is an extremely useful voice recognition program for cellular telephones, Apple only released the product for the company's iPhone 4S. Apple does intend to make Siri available on the older iPhone 4 and iPhone 3GS (How to Install Siri on iPhone 4/3GS?). Much like the company's other products; however, Apple has no intention of making Siri accessible on any product from another company. Rival software developers understand this fact, and they hope to capitalize on Apple's position. Nuance, the company that owns the rights to Dragon NaturallySpeaking, offers a free voice recognition app called Vlingo (Yin). Vlingo was originally developed for Android phones, but the app is now available for BlackBerry, Nokia, Windows Mobile and even iPhone (Yin). Due to the popularity of Siri, more users have downloaded Vlingo. In 2011, more people downloaded Vlingo to their cellular phones than from 2005-10 (Yin). Vlingo is not necessarily the best voice recognition app, but the product is slowly becoming one of the most popular apps of the genre. Software analyst Jill Duffy conducted an experiment on all alternatives to Siri, and she determined the best alternative was Swype, another product recently acquired by Nuance. The acquisition of this product is projected to improve Nuance's position in the voice recognition software industry (Yin), which had been declining despite being one of the original pioneers.

Another company, Pioneer Corporation, released their product, Zypr, just a few weeks after Siri became available (Zypr | Voice Controlled Internet Mashups). Zypr is voice recognition software with an open API for members. Users can apply for an account and explain why they want access to the API. If the reason is deemed acceptable, the user gains access to the Zypr API (Zypr | Voice Controlled Internet Mashups). The popularity of Siri combined with Apple's strict policies of availability has caused many companies to take a stance in the voice recognition software industry. With multiple companies competing to develop the best software, the industry will evolve more rapidly, and the software will be more useful for developing games for the sight-impaired.

Braille Displays

Braille Displays are tablets which display Braille. They use movable pins that raise and lower below the surface of the tablet to create Braille letters. The tablets only offer twenty- to thirty-character displays, and sell for upwards of $2000. Due to their prohibitively high prices and lack of functionality, they are not popular with the visually impaired.

Many current technologies are replacing the need for Braille tablets. There are applications for the iPad which use its vibration to convey Braille to the user. The iPad vibrates in different patterns depending on which letter the user's finger is touching on the screen (Koh).

Another potential replacement is a film that can be placed over the screen of a tablet. iSense film responds to light by expanding and producing raised bumps. By using the film in conjunction with a Braille application that produces light dots on a dark background, the user can read Braille tactilely (Juli).

http://www.youtube.com/watch?v=XlUwj36CS7I

Video of ISense demonstration.

Perkins Interviews

In March 2012, our IQP team visited the Perkins School For The Blind in Lancaster, Massachusetts to conduct interviews with several visually impaired students about what accessibility software they used, what video games they played, and what games they would like to see made in the future. The students we interviewed all lived together in a condo, so they were very familiar with each other and from the beginning were very comfortable with group discussion, which was incredibly helpful.

We had all of the students introduce themselves by asking them their name, age, form of disability, and favorite video game. Robert, a 14 year old boy, was fully blind since birth, with only the ability to perceive light. He played the least amount of video games of the group, but when he did play, he preferred *Call of Duty: Black Ops*, playing purely through sound.

Brendan, also 14, was partially blind, being fully sighted in the left eye, although completely blind in the right. Being partially blind, he had the ability to play games with visuals, though he expressed that he preferred games like *Minecraft* because the visuals were distinguishable and clear. He also played games like *Call of Duty: Black Ops*, and thought that “a completely blind accessible first person shooter” would be awesome.

Jeremy, a 20 year old student who was also partially blind due to carconis, was also interviewed. He was not blind from birth, so he had an interesting perspective on game design and what games he enjoyed. He mentioned that he used to play PC games such as *Diablo*, but since an eye transplant went bad, he no longer has the visual capacity to view what is happening on the screen. However, with text at its largest and assistance from Siri voice recognition, he is able to use an Apple iPhone 4S.

Garret, a 17 year old who had been playing video games since he was 7, was partially blind, suffering from Septo Optic Dysplasia, which is an underdevelopment of the optic nerve. He was the student most interested in game design, with hopes of becoming a level designer in the video game industry. Like Jeremy, he also used a iPhone 4S, but relied heavily more on Siri and VoiceOver, Apple’s screen reader, than Jeremy did.

Nicholas, one of the most interesting students we interviewed, was an 18 year old who was made fully blind by a DTP vaccine. Nicholas was a huge video game fan, both of games made exclusively for the blind, and emulated ROMs of old Nintendo Entertainment System, Super Nintendo Entertainment System, Sega Genesis and Nintendo Game Boy games.

Carolin, a fully blind 15 year old girl, and Ronen, a partially-blind 15 year old boy, also joined in on the conversation late. They were both big *Super Smash Brothers* fans, playing only though sound and controller vibration.

One of the main points we took away from this discussion was that all of the students agreed that the best way they would like to experience a game is through sound. However, when asked whether they would like specialized, realistic sound, like they would experience in real life, they all argued that they would much rather receive voice cues and commands. Garret and Jeremy loved using Siri and hearing its response, and all the students were constantly arguing about who got to try it next. Jeremy pointed out that in real life they are given orders and hear voice commands almost constantly from teachers telling them where to walk and what is around them, to computers and any technology they use reading to them through screen readers.

They also made it very clear that they were sick of hearing computers and robot voices explain what was occurring to them. Nicholas and Garret were disgusted when I brought up the idea of text adventures, because both had experienced them in the past. “It’s like a robot reading me a terrible ebook,” Nicholas said, “where I have some input.” When asked whether the input was enough to make up for the synthesized voice, both Nicholas and Garret agreed that it was much too draining on the ears and boring. However, when I brought up the idea of an interactive audiobook, they were very interested. “I know Braille, but I don’t like it. Audiobooks are much easier to experience and a lot more fun”, Garret told us.

Robert even pointed out that his favorite movies were the *Die Hard* series starring Bruce Willis. This shocked us, for we assumed that sight impaired people would get virtually nothing from such a visually striking film. He corrected us, telling us that all movies in the United States, whether in theaters or on DVD, must have descriptive audio. Descriptive audio, upon further research, is an additional narration track for the blind and visually impaired which describes what happens on screen during natural pauses in the sound. Sometimes the descriptive audio plays over dialogue and important audio, when it is absolutely necessary (DCMP).

http://www.youtube.com/watch?v=dm8eNuzmeB0

Video of descriptive audio from the movie *The Green Mile.*

Garret mentioned that he thought making a competitive multiplayer game where the players' main input was spatialized sound would not even the playing field, but instead would put "too harsh a handicapped on the sighted," putting the sight impaired at an extreme advantage. When asked why, Garret responded with a scenario. "Put a sighted person in a room with a blindfold and ask them to find the door. We (the sight impaired) would find the door three hours before they would."

Brendan, however, expressed an extreme interest in the shooter genre, asking for "blind-accessible *Black-Ops*" by name. Although partially sighted, he said that he would love a first-person shooter that he could play with fellow Perkins residents and also his sighted friends. He mentioned that he played first-person shooters with his sighted friends back home all the time and that he would love to "have the advantage" and play a sound-based game with them.

Another interesting thing that we discovered during the interviews was that none of the sight impaired students likes motion control of any kind. Nicholas pointed out that it is almost impossible for a fully blind person to navigate motion controls, having no real idea where they are actually pointing. They mentioned that it may work if vibrating and sound cues were put into effect, but there has so far been no attempt to make Wii, Playstation Move or Kinect games blind accessible. “I have to sit extremely close to the television because I cannot see far,” Ronen explained, “so when I play Wii the sensor bar doesn’t pick up my movements.” Garret followed this up by mentioning that the *Metroid* series is one of his favorites, and was especially good when thrown in to the third dimension on the Nintendo Gamecube, making it a first-person shooter. However, the next two sequels to *Metroid* were on Wii with solely motion controls, making them “completely inaccessible” to him.

Nicholas made a point to say that “fighting games are the most blind accessible genre.” We asked him to clarify this, and he confirmed that he had played and beaten several of them, such as *Mortal Kombat, Street Fighter, Final Fight* and *Guilty Gear*. We asked what made them so accessible to him, and he told us that they inadvertently had all of the things he needed to enjoy a game. There are several audio cues in the fights and menus, from screaming names when selecting characters to each motion having a specific grunt or catchphrase when it is executed. Also, Nicholas said that the vibration going off in a controller when he was hit was the perfect indicator of damage taken, and gave him more than enough time to respond. However, Nicholas’ favorite part about fighting games was infinite continues and the ability to change characters upon a loss, giving players access to a new way to play if the previous character wasn’t compatible enough with their disability.

One of the last things we learned is that almost all of the students prefer NVDA as their personal screen reader. It is open source, free, and it does not require serial number or activation. An ongoing joke during the meeting was the students rattling off errors and warning messages that were read aloud when the JAWS screen reader booted up, which they all agreed was a less than satisfying piece of software. Many students also enjoyed the Apple Voice Over software on iPad, iPod, iPhone and OSX.

## Development Guidelines

By combining what we have researched about recent technology and also what we have learned by one-on-one interviews, we have formulated several guidelines and ideas on how to make fun, enjoyable, quality games for the visually impaired.

One important thing we took away from the interviews is that, as a general rule, sight-impaired players love hearing voice commands. In their regular lives, they are constantly being told where to go, when to go there, and how they should navigate themselves to get to the point they need to get to. They are extremely interested in having a game where either the artificial intelligence informed you where enemies were through voice commands (for example "enemy to your right" or "enemy at 12 o'clock"). When multiplayer was brought up, they pointed out that they would love to have social interaction with a sighted person assisting them. They were very interested in a first-person shooter where the visually impaired were the only ones with guns and the sighted were paired up with them, informing them where enemies were positioned so they could destroy them.

This opens up a whole new genre of games, being competitive video games with teams that rely on each other based on accessibility. Imagine games where the sighted can communicate things to the blind that they can not even experience, but making them a vital part of gameplay. In addition to first-person shooters, this would work really well for a competitive, less realistic racing game like *Mario Kart*. If a sight-impaired person drove the car, twisting and winding down a crazy track, a sighted person could literally become a “back-seat driver,” informing the impaired driver where and when to turn, how much to turn, and having to do it with great timing and precision. This style of play might be effectively applied to many other game genres.

The Perkins students were extremely opposed to text adventures read through JAWS or other screen readers. Most of the students considered text adventures boring, mainly because, when read with a screen reader, they are similar to everything else they hear on a daily basis, such as schoolwork, websites, and just basic navigation. To them, playing a text adventure through a software such as NVDA is just navigating through a fantasy version of their daily lives. However, they were extremely interested in audiobooks and movies with descriptive audio, so when we proposed a text adventure that was more an interactive audio book than a read-off-the-screen adventure, they got excited. They all agreed that a text adventure with spatialized sound, voice acting, sound effects and a great story would be something that they could all enjoy.

They were all huge fans of the voice commands through Siri, as well. When asked if they would like to speak their commands into a text adventure or game through a Kinect, iPhone, or other voice recognition software, they were ecstatic. Voice recognition software is at the point where controlling a text or simple adventure game completely through vocal cues is a total possibility.

If this were to all lead up to a text adventure, it would be an expansive, immersive experience. The game would be experienced most likely through headphones, mainly because that is the easiest way to present binaural sound (although it has been done through carefully placed speakers and surround sound). The game would have pre-recorded audio, so no synthesized voice or screen reader-like speech would be heard. Anything that could not be communicated through environmental noise, sound effects, and dialogue would be narrated to the player, much like how the narrator of an audiobook tells the play what is happening in the story. The player would not read what is happening on the screen, but actually experience it for themselves through sound.

For example, if two swords clashed in a fight, instead of reading on the screen "Your sword clashes with the enemies," you would hear the sound of two swords hitting, battle music, struggling grunts and fighter movement. For certain circumstances, even with precise sound effects, it may be hard to communicate what is occurring, so a narrator giving flavor text and clarification could be layered on top.

Such a game could use a speech recognition software to input commands, making it completely accessible to the blind. This also makes the game more immersive, by making the player's voice the input device, instead of using a keyboard.

Haptic feedback is something that the visually impaired rely heavily on while playing games. This was proven by their ability to enjoy *Super Smash Brothers*, a design intended for the sighted, with nothing but force feedback telling them when they have been hit, when they are hitting someone, and when the stage around them is changing. No matter what game is being made (adventure, FPS, even text adventure with booming footsteps or some other vibrations), haptic feedback should be an important aspect of the design.

Although the Perkins students thought that an all-sound game would put the visually impaired at a huge advantage over the sighted in a multiplayer game, they thought that it would work great in a single-player game. A first-person adventure game where 3D sound is used as feedback, giving in-game awareness of what's around you purely through sound cues, is something that they are really looking forward to.

Motion controls are not designed with the blind in mind, for the partially blind sit close to the television, causing skewed and non-responsive controls. The completely blind have virtually no feedback, as the only way to see where you are pointing the motion controller is to see the television.

Coincidentally, the iPhone 4S, as well as being able to do many other things, can give haptic feedback, play spatialized audio through headphones, accept and give voice commands, and create any sort of interface desirable with the touch screen, making it, in our opinion, one of the best current platforms for accessible games. Kinect and Xbox 360 are also promising, having the ability to receive and give voice commands, play spatialized sound and offer haptic-enabled control. The advantage to making games on the Xbox and Kinect is that it has an open API, whereas iOS5 has a locked API for Siri. With Apple's permission, however, there are ways to get around the locked API.

## Conclusion

While the technology exists today to make impressive games for the visually impaired, no one has taken it upon themselves to take this advanced technology and make a game. Through interviews with visually impaired students, a review of past attempts to make games for the blind, and a review of all blind-accessible technology available to make games with, it has become apparent that voice commands and voice recognition, spatialized sound, haptic feedback, and hardware such as the Kinect, Xbox 360, and iPhone 4S are the perfect tools to deliver games for the blind. Our research suggests several ideas that could be developed, including single-player first-person shooters using 3D sound as feedback, adventure audio books that accept input through voice commands, and games where the visually impaired and the sighted work as a team, with the sighted performing as spotters for blind actors. With these insights, any team with the appropriate engineering skills can make a fun, fully functioning game for the visually impaired.

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