A Study on Accessibility in Games for the Visually Impaired

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ABSTRACT

Gamers with disabilities face difficulties when it comes to playing most games. This percentage of the gamers population is largely overlooked. In this paper, we will be focusing on how to achieve accessibility in games for the visually impaired. We will explore the current state of technology and design practices to provide techniques categorized in three approaches: visual, audio, and tactile. These approaches are supported with case studies as well as current research and experiments that execute such techniques for the visually impaired demographic.

CCS CONCEPTS

• **Human-centered computing** → *Accessibility design and evaluation methods.*

KEYWORDS

video games, visually impaired, accessibility, color blindness

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1 INTRODUCTION

Accessibility in games refers to the ability of playing and experiencing a game in full even when players are functioning under restricting conditions. These restricting conditions may be in result of visual, auditory, mobility, or cognitive impairments. A game that provides equal opportunity, to its players, for playing and experiencing the game completely irrelevant of the players' impairments may be called *accessible games.* An issue that the game industry has been facing is the lack of accessible games. This paper is a step towards accessible games. We will be focusing on visual impairments only. Mainstream video games are generally unplayable by people with visual impairment, mainly because the essential game content is presented with graphics. Even in the earliest days of video games, it has become the pioneer of breaking new ground in entertainment, simply through moving a flicker of light across the screen was considered incredible. The simplest game such as the arcade game **Pong** were a phenomenon, and it has easily become the earliest major success of the video game industry. For the past two decades, video games have prospered into a multi-billion-dollar industry [1]. This advancement has driven the use of modern and diverse technologies that allow gamers improved experiences. The majority of this advancements are focused around the use and development of cutting-edge graphic engines and hardware that support the enhancement of three-dimensional worlds and improving the effect of visual immersion in games. Although these technological advancements are rapidly growing, only a few developers are finding incentives to incorporate accessibility features in their games.

There are various legal, ethical, and financial incentives for making a game accessible. In the US, the 21st Century Communications and Video Accessibility Act 2010 (CVAA) requires any communications functionality and any user interface (UI) need to be accessible to people with a wide range of impairments [2]. Consider a game that is used in classroom for educational purposes, there may be legal obligation to make the game accessible.

The more important reason for making a game accessible is associated to the individual's quality of life. Allowing people with impairments especially the younger generation, to participate in activities that a person without any impairments takes for granted, could lead to a decrease of emotional pain and feeling of isolation or not belonging. In addition to entertainment, video games offer a number of benefits especially in the field of health and education [3–6]. To make these benefits available for the people with impairments, one way is to make the games accessible.

Accessibility features may increase revenue by encouraging disabled individuals to buy an accessible title. One in four New Zealanders are limited by a physical, sensory, learning, mental health or other impairemtns [7]. Hearing impairment affected 9% and vision impairment affected 4% of New Zealand population [7]. The total number of people in U.S. estimated to have their ability to play games affected by a disability is nearly 11% of its population [8]. Having accessibility features is a very positive element to be included in a game title, which could also lead to positive public relation (P.R.). from the media as well as accessibility advocacy groups provides free advertising. The future prospects for accessibility is also looking bright, as it is considered that the demand will continue to grow as the gaming population ages. As people grow older, disability and impairments may become more severe. Relatively, People are also likely to develop new disabilities and impairments as they age. Therefore, inclusion of basic accessibility features in games can help publishers and developers to continue drawing revenue from such population.

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2 WHAT IS VISUAL IMPAIRMENT

Visual impairment refers to reduced vision or vision loss that cannot be corrected or improved by glasses, medicine or surgery and makes everyday tasks difficult [9]. According to the World Health Organization (WHO), there are approximately 285 million visually impaired individuals around the world, majority of which live in developing countries. It also stated by the WHO that visual impairment is categorised in three main types; blindness, low vision and colour blindness [10]. Each of these impairments have different effect on an individual's ability to play a game.

2.1 Low Vision

Low vision is when an individual has lost certain amount of eyesight. It is often characterized by partial sight such as blurred vision, blind spots or tunnel vision, but it also includes legal blindness. However, a more functional definition is that low vision include any vision loss that negatively affects the performance of simple daily activity. In any of these circumstances, a person with low vision could still play games if there is some degree of magnification of the screen. These individuals are able to respond to visual and sound cues, but their ability to see a wide area of the game are restricted by the default magnification of the screen. The images below in Fig. 1 demonstrate the perspective of someone who has low-vision. These are examples of macular degeneration, diabetic retinopathy, retinitis pigmentosa and cataracts.

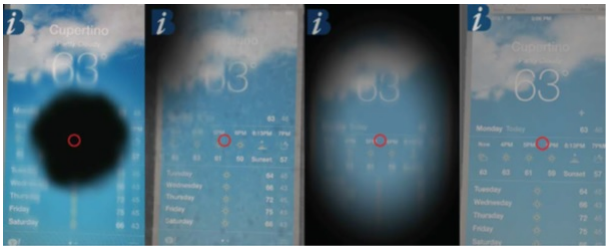

Figure 1: Examples of low vision
Source: Adapted from [11]

2.2 Colour Blindness

According to [12], colour-blindness is an inherited defect in the development of one or more of the three sets of colour sensing cones in the eye. It is estimated that 1 in 12 men (8%) and 1 in 200 women (0.5%) are affected by colour blindness. Males are more likely to be colour blind compared to females because the genes are responsible for the most common forms of colour-blindness on the X chromosome. The effects of colour blindness are more pronounced under certain game coloured schemes. The images shown in Table 1 demonstrates how the rainbow colour is perceived by each individual: Trichromacy (Normal) – a person that has no colour vision deficiencies can see all the colours in the rainbow (see row 1 of the Table 1). Tritanopia (blue-yellow blindness) – a deficient colour perception in which there is absence of blue-sensitive pigment in the retinal cones. Blue appears green and yellow appears violet or grey (see row 2 of the Table 1). Achromatopsia (Complete color-blindness) – a non-progressive and hereditary visual disorder, which is characterized by decreased vision, light sensitivity, and the absence of color vision (see row 3 of the Table 1). Protanopia (red-blindness) – such people are insensitive to red light (see row 4 of the Table 1), whereas Deuteranopia (green-blindness) is insensitive to green light (see row 5 of the Table 1).

1	Trichromacy	
2	Tritanopia	
3	Achromatopsia	
4	Protanopia	
5	Deuteranopia	

Table 1: Colour Blindness

2.3 Blindness

Blindness is usually determined as the complete loss of vision unable to be corrected by lenses. The causes of complete blindness vary depending on how the person obtained it. It could be from genetic defects, accidents or gradual visual impairment severity. It is obvious that people that are totally blind are unable to play most games because majority of the games rely on visual cues to guide the player. Blind individuals must rely on sounds or distinct hardware for them to be able to interact with the game.

3 VISUAL TECHNIQUES

There are many options and techniques to make a game accessible for the visually impaired. These techniques can vary through visual, auditory and tactile, depending on the individual's level of visual impairment. Game designers could use technologies and practices that exist today to design their game more accessible. With simple techniques such as captioning, changeable fonts, and sound could make a huge difference.

3.1 Colour-blind

3.1.1 Iconography. There are many things to consider when creating a game; elements that are analysed by different disciplines; narrative, mechanics, theory of game design and ludology and many more. Considering that entertainment is the basis of these elements, a good outset is the use of playability criteria. In [13], playability is defined as "a set of properties that describe the player's experience before a particular game system whose main objective is to provide enjoyment and entertainment...". The research also considered that playability could be analysed separately in six aspects; intrinsic, mechanics, interactive, artistic, intrapersonal and interpersonal. Among these types mentioned, interactivity seems to be the most important due to its correlations with the other aspects of playability and its broad possibilities that it depicts to facilitate accessibility for visually impaired individuals. Furthermore, playability is the

facet associated with player interaction and video game user interface development. This type of aspect of playability is strongly connected to the game interface. For example the games **Dynomite** (see Fig. 2) and **Zuma** (see Fig. 3) use colours to indicate essential game information. Such types of games are unplayable for people who have colour blind deficiencies because the game mechanic is solely reliant on matching colours. For this issue, the solution would be incorporating *iconography* as supplementary conveyance. To simplify, using text, symbols or colour-blind friendly palette to identify this kind of information. On the other hand, the games **Candy Crush** (see Fig. 4) and **Bejeweled** (see Fig. 5) are a great example for using symbols to identify information in a game.

Figure 2: Left: real Screen of Dynomite game. Right: the screen of Dynomite game if the player has deuteranopia.

Figure 3: Left: real screen of ZUMA game. Right: the screen of ZUMA if the player has Achromatopsia.

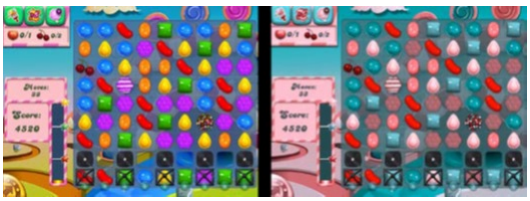

Figure 4: Left: real screen of Candy Crush game. Right: the screen of Candy Crush if the player has Tritanopia.

3.1.2 Filters. It is easier to remedy these simpler games, but when it comes to mainstream triple A titles, perhaps the most general approach of implementing colour-blind accessibility is incorporating whole-screen filters. This is meant to target the problematic colours for people who have colour-blindness. This idea of colour shifting may be the right option, but in general, other solutions should be considered first. Not all the time a colour blind filters

Figure 5: Left: real screen of Bejeweled game. Right: the screen of Bejeweled if the player has Achromatopsia.

solves the problem. Filters that modify the entire colour palette could oversaturate the aesthetic of the game, resulting into some undesirable colours. It could also introduce new clashes in some colour variations. As an example, in the game **Overwatch** (see Fig. 6), represents the vital information by colours that can be easily differentiated.

Figure 6: Normal mode of Overwatch game.

But when tritanopia mode is activated (see Fig. 7), the filter makes "friendly" and "party" colours and "enemy" and "alert" closely resembles each other. Despite the slider option of adjusting the strength, it only adjusts the differences in brightness rather than contrast.

Figure 7: Tritanopia mode of Overwatch game.

3.1.3 Colour Customization. In addition to ways to implement colour-blind accessibility in video games, the developer can approach a technique where the game provides the user customizable colour combinations or provide presets based on types of colour blindness for representing different types of vital game information. As an example, in the game **Destiny** (see Fig. 8), offers a preset of colour palettes for three types of colour blindness. The players are able to distinguish team mates and other game elements better, due to the carefully chosen colours. Another great example of a game providing customizable colour variation is the game **Auralux** (see Fig. 9). In this game, the user can freely customize the colour and look of each planet's information with many colours and different textures provided.

3.2 Low Vision

3.2.1 Customizable Fonts Style. Custom fonts are very common in game development, but the use of unconventional fonts has affected low-vision gamers negatively. Although, many game developers

Figure 8: Distinguish colour-blind friendly colour schemes accordingly depending on the mode.

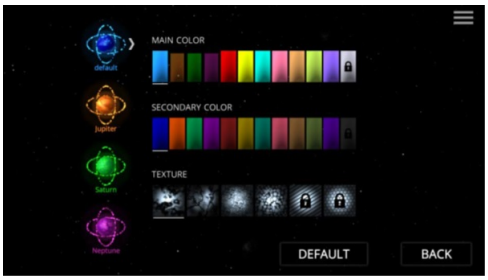

Figure 9: Auralux game: The player may change the main colour, secondary colour and the texture of each planet.

use stylized fonts to match the theme of their game, majority of these types of fonts are difficult to read by most gamers with normal vision, which automatically blocks the vision impaired gamers from reading any information. The capability to shift more complicated fonts with something more basic and simplistic fonts, will allow a low-vision gamer to make readable information on the screen easier to see. According to a study [14], font types have significant impact on the on-screen readability of an individual. The impact of specific typefaces such as; Helvetica, Courier, Arial, Verdana and Computer Modern Unicode on the on-screen readability has increased whereas italic fonts decreased someone's reading performance. Using these readable fonts improves accessibility for people not only with low vision but also people with dyslexia and hearing impaired gamers. An example of unreadable font in a game is **Fallout 3**'s Pipboy (see Fig. 10). As shown in the image, three fourth of the UI screen used for aesthetic while the remaining screen space is used for vital information in the game. The font used in this interface is nearly unreadable for gamers without visual impairment which automatically makes this vital information harder to read for people who has low-vision.

3.2.2 Customizable Fonts Size: In addition to font customization, for low-vision gamers, it is also suggested to incorporate customizable font sizes in games. Although, majority of video games do not often provide the option, if implemented, gamers with visual impairments including individuals that are considered legally or almost totally blind, are able to play most games. These sizable fonts let these visually impaired gamers read text in the subtitles,

Figure 10: Fallout3 "Pip boy" UI

UI information, directions and chats. A starting point is to have a readable standard font size for the majority of the gamers. Study [15] shows that up to a font size of 18 pt. have an effect on objective and subjective readability and comprehensibility of texts in on-screen reading. This means that the most standard readable font size is 18 pt. for normal individuals that has no visual impairments. The Fig. 10 provided above is an example of poor font size readability. Again, it is almost unreadable for normal gamers in the first glance. However, a good example of a game that has customizable font size and font type is the game **Everquest**, in which users are allowed to change not only the font size but also the typeface and the colour of the font in the chat window.

3.2.3 Customizable HUD. For those with visual impairments such as colour blindness, low vision, and people that have difficulty seeing rapid moving information, the ability to have the game's heads-up display (HUD) be customized will dramatically help their game experience. With the combination of both colour blind and font customization features applied in the HUD customization, the capability of this approach would immensely expand the accessibility of a game. This method will allow the user to separately arrange and reallocate each HUD elements according to their visual range. An example situation could be; someone that has macular degeneration (as shown in the low-vision definition) finds it difficult adjusting their sight quickly to certain points on the screen. If they are able to reallocate and reposition certain UI elements in correspondence to their visual range, their time spent and experience in the game would be less frustrating and would improve their gaming experience. These multiple alternatives can prevent the need to implement multiple accessibility further down the line in the game development process. Sensibly, this type of accessibility feature could be costly. However, some may argue that this type of customizable interface could lead to a smoother development processes and better overall design. Considering that this type of feature is expensive, there are not many games in the market that uses this technique. However, there are some mods that have been created for this purpose. Most often, games like **Skyrim** have mods that customizes the HUD.

4 AUDIO TECHNIQUES

Over the last couple of years, rapid development of technology has advanced dramatically. These technologies include 3D sound

engines and audio chips for video games. Gamers as well as game developers today value the sound content seriously than ever before. Minor sound details such as the sound of wooden floor, the noise of unoiled door opening, whistle of the wind, cricket sounds will have a direct impact on a player's experience and immersion in the game. Using sound expresses a narrative medium, similarly with graphics. 3D sound or sonic landscapes, can also be as immersive as advanced three dimensional environments. Below we detail how to get benefit of these advanced technologies to make games more accessible.

4.1 Auditory Substitution

Another usual approach to improve a game's accessibility for the visually impaired is sensory substitution. Sensory substitution could mean the elements of the visual display are replaced with auditory or haptic output. In this section, we will discuss ways on how a game developer could approach visual to auditory substitution for the visually impaired. Firstly, audio description. Audio description is a verbal commentary conveying visual elements and information. This feature lets the game to have the ability to read the text on-screen and repeat it in audio form. Many computer systems today utilise this technique for users on the web and home computers. Microsoft computers have a system called "Jaws" and the Apple Mac operating system has a build in software called "Voice Over". However, such type of feature is used mostly in fighting games. Fighting games utilises this feature when navigating through its menus, but mostly in an arcade vicinity. It also has audio responses when a player chooses a character. An example of games that have these features are **Mortal Kombat** and **Guilty Gear**. Furthermore, study [16] suggests that audio description is at its best when the users is unaware of it. It influences the various dimensions of presence in different ways. These presences include spatial presence, ecological validity, and engagement. This leads us to another approach of auditory substitution called *sound compass*, which is discussed further in the next section.

4.2 Auditory Navigation

Spatial sound allows the blind user to navigate through the game's vicinity. It also provides the blind user a rough perception of the distance to and from a game object in the direction the player is currently facing. The same study [16] conducted an experiment which suggested that feedback and area-specific sound cues in the games the participants played would have helped them encourage to participate accurately through the navigation process. There are many certain ways to approach spatial navigation; one of which is utilising *binaural hearing*.

4.3 Binaural

Binaural hearing is the integration in the central auditory pathways of bilateral (both ears) sound input. Using binaural audio in a game will enhance a user's spatial awareness. An auditory version of a famous game called **Pong** has been created for a study that embodies this technique of auditory spatial navigation [17]. The researchers implemented a system where 3D binaural sound and head tracking is used during game play. The three participants of the game found it easy to localize the paddle as it was heard only during the movement. In the end, the experiment concluded that advanced specialization techniques such as 3D binaural sounds may enhance a game experience.

4.4 Sonification

An additional approach for spatial navigation is *sonification*. Sonification is the use of non-speech audio to convey information or perceptualize data. In fact, [16] described a new approach for presenting visual information with spatial audio with the use of sonification. The results in the experiment concluded that most users can interpret the spatial representations and effectively building mental maps from acoustic signals, and associating them with spatial information. In addition, a related experiment [18] shows that the method of using binaural sounds for spatial awareness is quite effective even in physical games such as football. Specifically, in 2011, Pepsi in Sweden has arranged a soccer match between a team of visually impaired players and a team of blindfolded former professional soccer players (see Fig. 11). Each player wore a device on their head which was equipped with an application that connected the players. The device received information from the tracking system the team of researchers developed and converted it into 3D sound. The spatial sound rotated as the player moved their head. The field was rendered over the headphones allowing each player to perceive the objects around them which made them able to play soccer evenly. These research studies simply show the effectiveness of spatial navigation, so if implemented in a game, it will more likely enhance a player's game immersion and experience.

Figure 11: Pepsi "The Sound of Football"
Source: Adapted from [19]

4.5 Audio-only

With all the aid of auditory techniques and visual to auditory navigation and substitution, a game developer may approach another accessibility technique of being able to make their game turn off all graphics and only have auditory elements in their game, or having their game be able to be played even without any graphics. An excellent example of this technique is utilised by a group of students in "Audio Game Hub" [20]. This group of developers have created games that are playable by the visually impaired. They utilise the purpose of sound in their mini-game applications. Each game is designed with unique interaction patterns and gameplay mechanics. All of the games are playable for both sighted and non-sighted users. Another example of a game that is able to be played without any graphics is a Nintendo game called **1-2-switch** (see Fig.

12). In 1-2-switch, there are graphics provided but the game is not solely dependent on it. The information in the game are prompt through auditory cues as well as haptic feedback from the controller. The controller also has a build in detection camera which utilises infrared.

Figure 12: 1-2-switch game played by someone who is blind and blind folded and are still able to play the game.
Source: Adapted from [21]

5 TACTILE TECHNIQUES

One of the most common general accessibility approach for the visually impaired is through tactile (touch). Tactile output devices will allow users to perceive through touch. Although there aren't many games in the market at the moment that utilises haptic feedback, there are numerous number of research programs on the subject. The use of touch instead of vision and auditory, creates a possibility of not having any competition between our environment and the information we receive. Tactile information is received extremely discreetly and exclusive. The information a person receive through touch is strictly much more personal than other sensory substitution. Most of the time, to implement tactile system, it is required to have an output device. Generally, the most commonly used tactile devices are Braille-related products, but there are a variety of increasingly popular new area of work and experiments of advanced haptic devices that will not only allow to textual material as in the case of Braille, but also provide feedback on shapes, texture, vibrations and motion. An example of this approach is conducted from a research called **Blind Hero** [22]. The researchers of this experiment created a device that provides haptic feedback (see Fig. 13). The device is a glove with each finger containing a pager motor to deliver haptic feedback. Whenever a pager motor buzzes, the corresponding button must be pressed. In the end, the research has created a successful device that translates visual stimuli to haptic stimuli despite having to compromise some elements of the gameplay and all the participants that played **Blind Hero**, had a fun and enjoyable experience. The research also established that replacing stimuli may work to make games accessible but compromises may have to be made inevitably. It also stated that when making these compromises, one should be careful not to jeopardize gameplay. This type of sensory substitution is greatly effective due to the ability of a human brain to adapt to any situation or change. A theory in [23] called "brain plasticity", allows the human brain to adapt to changed functional demands by changing its own "structural organization and functioning", with this manner, it makes sensory substitution possible. This entails for the visually impaired individuals, makes this type of sensory substitution system especially successful. Furthermore, wearable assistive devices are increasing in popularity. However, these devices may not be affordable for many visually impaired individuals. Looking at the current state of the game industry, many of the console gaming controllers are already being used to output signal vibrations from data provided by the game. Therefore, this method may aid game accessibility to opportunities for innovation and lead in the right direction.

Figure 13: Haptic Glove
Source: Adapted from [22]

6 CONCLUSION

We provided different techniques on how game developers could enhance the experience of gamers that have visual impairments. This was achieved through various techniques that are categorized in three separate approaches; visual, audio and tactile. These approaches are supported with case studies as well as research papers of games and experiments that execute the said techniques evidently. Furthermore, the visual approach is more focused on techniques on visual correction for the graphics aspects of the game whereas the other two approaches; audio and tactile, falls under sensory substitution. However, it is understandable that not all of these techniques would completely make a game accessible to visually impaired. It is important to understand one's impairment when applying accessibility in games. It is also important to highlight that making games accessible using these various techniques, from visual manipulation to sensory substitution and any other strategies, would improve visually impaired players gaming experiences and hence would improve quality of life. Having these extensive amount of research and development may serve as inspiration for the game developers to create innovation for the upcoming years in the gaming industry.

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