Inclusivity Through Ambisonics and Gaming For People Who Are Blind

By

Jason Shegoleff

College of Media, Communication and Information

University of Colorado Boulder

Latin Honors Project

Defended on April 10th, 2024

Committee:

Faculty Advisor: Jason Sanford, Instructor, Critical Media Practices

Honors Council Representative: Roshanna Sylvester, Associate Chair, Critical Media Practices

Third Member: Dr. Lori Emerson, Associate Professor, Media Studies Department

Contents:

Abstract:

Around one-third of the world plays video games. The connections and interactions between gamers coupled with positive social teachings like teamwork and effective communication are just a few benefits of playing. However, the cues and information of these games is mostly visual, removing the ability for blind or visually impaired individuals to truly access the benefits. Visually impaired people are more susceptible to injury and mental illness and have less systems of health in place than those who can see. To truly include people who are blind within the current systems of online gaming, high quality directional audio must be implemented. This spatialized audio, called "Ambisonics" has the ability to make video games more inclusive and reduce ableist disparity within online communities. I explore directional sound and its potential impacts on the blind community to see an increase in equity within social circles and technology. The information and trends of modern society are heavily dictated through the screens of visual devices, meaning impact is often reduced without the ability to see. There is a need for the radicalization of accessibility within technology, and it may as well begin with gaming.

Keywords: Visually impaired, Ambisonics, radicalization, technology

Introduction:

Working in post-production sound studios, taking collegiate level courses and engaging with the art of sound individually has opened my eyes to the importance of the medium and its effects on larger social groups. Since early humanity, sound has been used as communication, leading to the trading of ideas, emotions and expression. These truths are still evident today, with things like phone calls, audio messages, podcasts, and playlists that we continue to share with each other so often. So much of our understanding of the human world relies on sound, and so

much of our own communities rely on the form in which abstract ideas are expressed through sound. Think of the aesthetic sound context of a large Electronic Dance Music concert. An artist on stage, publicly expressing their own perception of themes, deciphering their reality and relaying it to the crowd through sound. The crowd, for the most part without conversation, interpreting this massive message in unison, their recognition and acceptance of the performer's ideas carried out by dancing. The social and economic hierarchy of the listeners is immediately stripped for the sake of the message being interpreted correctly. This is sound in its modern context. Rich with information, mapped artistically, infused with social context and massively accessible.

The same context of sound is true for video games. The sonic-landscape and aesthetic context of online games are formatted and composed intentionally so the sounds become iconic and immediately recognizable to any user. Video game sound production allows the player to engage playfully with the in-game sound, using their controls to dictate the actions on screen, creating a conjunct relationship between sound and player. In this very same vein, the player is now the composer, or sound selector, playing the game in a way which fabricates a favorable sonic environment through a given library of sounds. My generation, Gen Z, was a main demographic for the game Minecraft. The game takes place in a seemingly earthly world, with noises of rain, sheep bleating, the chopping of wood and other natural sounds. A defining sonic feature of this game is the soundtrack by the composer C418. This soundtrack resonates with developmental memory for many. This game felt like more than just an individual experience, however. With chat boxes, interactive servers, and group play, I experienced the formation of digital and social friendships, both because of this game. One of our common understandings, the sonic landscape in which we played together.

When choosing a point of study for my thesis, I knew I was passionate about sound and I was certain I wanted to understand the stakes of the medium. The blind community is fully immersed in the reality of sound. With little to no visual cue, a person who is blind lives through a systematic means of sound. I understood it to be my duty to draw a connecting line between the Blind community and the gaming community, both with rich understandings of aural communication. This merging of identities is extremely important, the bridging of social communities can create friendships and developments of mutual concepts. Highly curated and designed game sound in combination with the highly socio-cultural use of sound in the blind community offers many lanes of exploration and advancements. To truly understand the intricacies and characteristics of both parties involves deeper research. The merging of these two distinct, sound oriented social groups can create social and cultural effects much past that of a trend or temporary interest.

Lit Review:

Online gaming communities bring people together for competitions, celebrations, game-making and entertainment. A group of people who benefit less greatly from increased social groups and advanced gaming are visually impaired or blind people. Online games market to seeing people with wildly flashy graphics and interesting console designs. These marketed games create more outwardly digi-social communities, forming groups of like-minded people and furthering human interactions online. Even with the highly reactive sound design, haptic feedback, and storytelling of modern video games, there are few of these games intended for the blind. Interactive, blind-friendly experiences like traditional board games, musical instruments, concerts and sports do not have the previously mentioned trait of social-digitality. A videogame can become a common factor combining people from different backgrounds and experiences.

Without these virtual meetups, people who are blind are more easily subjected to the reality of their true surroundings of socio-economic condition. Internet games have the power to include marginalized or inaccessible people to a realm of social richness. To truly incorporate blindness into gaming, there has to be dedicated games enabling those with disabilities to play and immerse *fully*.

How Do Blind People Play Video Games?

One of the most common techniques for blind gaming is on screen narration. This is usually an adaptation to an already-published game. The on-screen scene is verbally depicted with any significant changes or game direction that would otherwise be visual cues to a seeing player. Games that include this level of inclusivity usually incorporate additional navigation assistance tools to help users gauge distance from in-game objects or other players. This sort of verbal assistance can be well intended but unhelpful for shooter, flying, or horror games which are usually faster paced. This is because the verbal descriptions usually take more time than the game would normally allow in between actions. To insert these descriptions, there usually has to be a short pause in the game or a natural stop for the audio to play (Lloyd, 2021). These descriptions are meant to paint a picture, perhaps of what a room looks like, or how a character is moving, as well as the unspoken communication between characters or objects. Another important aspect of inclusive narrativity is the language in which the voiceover uses. An open world castle-fantasy would have different vernacular and pronunciation than that of a futuristic-cyberpunk space racer. On screen narration comes down to an incredibly detailed level. Ubisoft's "Assassin's Creed" is a popular first-person video game with over ten iterations. The 2020 release, called "Valhalla" had a slight visual difference which had to be narrated for clarity. The iconic wrist blade, usually inside the assassin's sleeve, was now moved to the outside of the

fabric. This incredibly important, yet very slight detail is apparent for seeing players, but happens to be an essential narration for blind players. From plot points, to character idiosyncrasies, all the way down to small physical details, on screen narration has an extremely important impact but a slightly outdated method. This method of on-screen narration seems to act as a sort of insufficient stand in for the experience of a larger game. Although Saylor is able to increase the size of on-screen buttons and graphics for more context about the game, Ben is playing his games with no visual cues at all. Relative experiences of blindness mean that not all accessible games are truly accessible.

There are blind focused audio-only games, but the consensus from blind individuals is that they often prefer to be part of a community. For example, Saylor, a severely impaired gamer, tends to not play audio based games made for blind people, because he prefers to “play mainstream games with or alongside his friends" (Cloutier, 2017). Or Ben Breen, a gamer born without sight, who says “I prefer stuff when it's enjoyable for more people." (Scott, 2022). Games are not played in a vacuum; they hold social and developmental importance which cannot be overstated. Seeing individuals are able to engage fully with popular games, and although people who are blind or hard of seeing have fully accessible audio only games, they often do not opt for them. Social resonance seems to play a larger role in blind-gaming than the criteria of blind-inclusive games. There is a continued relevance to gaming not just being an individual experience, but rather that of a larger, collective social interaction. These audio-only games are more primitive, lower budget, and contain a severely less expansive audience than the conventional videogame. So many common concepts in video games like inventory, traps, barriers, prompts and button selection have been developed in a system of visual game creation. Audio based games created for those who are blind cannot rely solely on in-game narration. Like

"Sonic Zoom," a more common blind-accessible game which takes place on a single track with the main character running forwards. In this game, the sound of coins and obstacles have distinct noises that increasingly gain volume as the player runs towards them. Although very one-dimensional, this is an example of an accessible game with non-narrative cues. Another example, also quite primitive, is Camel, a text game run through a computer's console in which the player must respond to text prompts to make it through a desert. This game can be made to be read aloud by a computer system, making it more accessible to those who are blind. This poses a further problem, text games require a program capable of on-screen reading, which contains its own visual elements and setup. Audio only games intended for people who are blind or hard of seeing are just that. Equally non inclusive to seeing people, these games create a void in usership. This means a blind individual's choice to play a sound-only game usually means sacrificing community and a larger cultural experience of bigger visual based video games.

What is Ambisonic Audio?

Picture yourself sitting in a chair, your eyes are closed, and you have headphones on. A sound plays through the headphones, it sounds like it came from just over your right shoulder. The sound is so spatialized that you are able to turn the chair and point your finger towards a distinct area that you believe the sound emanated from. This is an example of Ambisonics, a format of listening that feels like the listener is in a specific space. The methods of creating spatial audio for speakers and other sound-amplification devices have changed a lot over time. Originally, music was recorded on one channel, mono. Imagine an old phonograph with that trumpet-like, bronze speaker emanating like a flower from the record player. This machine would produce a singular source of audio. As time moved on, audio engineers and record companies realized that humans have two ears and began utilizing stereo mixing. Stereo mixing

included two channels for a left and right speaker. This was truly the beginning of sound *mixing* as a medium, as musicians and artists could make sound move from left to right. I'm sure many readers have tried listening to one of The Beatles early hits on headphones, only to realize that the instruments are panned entirely right or left. Today music is mostly still in stereo, but new conventions have been created so that most sound is directly "in front" of you. To make a sound appear to be "in front" of you, one would simply need to play the sound at identical volumes in both left and right channels. By increasing the sound relatively in the left channel, for example, the sound would appear to be coming from the listener's left side. The concept of stereo sound applies to headphones as well as a set of two speakers. Now, what if someone wanted to create a sound that appears to be behind the listener? That could be called spatialized audio, or Ambisonics. Generally, the same process of taking a single audio source and making it two sources could be applied to a stereo signal to make it *four sources*. By taking the right and left sources of audio and separating them into a front and a back fragment, much like the same way two mono channels create a stereo signal, an audio engineer can convincingly represent a sound coming from in front or behind a person. This four source audio track is achieved by utilizing the left and right sides of a given speaker cone of a listener's headphones, or by using a right and left speaker in front and behind a listener. Moving from stereo to four track means creating two additional dimensions of audio. This process can continue, adding additional sources of audio. To envision this, imagine being surrounded by a circle of 30 speakers. If a single speaker played a sound, the human ear would be able to generally locate the origin of that sound. This meaning, the higher number of sources or "Ambisonic order", the more realistic and detailed the sound's origin will appear. Now that you are an Ambisonic expert, I would like to add additional information and detail to the theoretical understanding: up and down. Take the previous image,

of a listener in a chair surrounded by speakers. Now picture a sphere of speakers, a dome above and below the listener. This is fully spatialized audio.

Mapping a realistic Ambisonic experience on headphones requires an additional encoding and decoding process often called Binaural listening. By using specific parts of a headphone's speaker, as well as volume and phase (the relationship between timing and location of a given waveform, as well as the given source's relationship to other identical or non-identical audio signals) headphones can produce sound that distinctly appears as if it is coming from a certain place around the listener. The idea of binaural, spatialized listening is nothing new, our ears do it naturally every day. Our brain very quickly combines information like volume and time differentiation from distinct parts of our uniquely shaped ear to accurately judge where a sound came from. All binaural listening does is imitate the way sounds travel directionally in reality.

Ambisonic listening is often used in sound design for popular online video games. Counter Strike 2 is a common first-person shooter game that utilizes Ambisonic audio in its gameplay. In order to correctly digest the audio, avid gamers wear headphones to locate the exact location of their enemies. Using headphones allows gamers to engage fully with the multi-directional aspects much more than using stereo-speakers, which can only accurately represent action happening in front of the player. The use of Ambisonics in video games becomes less effective the further the main gameplay moves from first person. For example, a game with a controllable character in birds eye view perspective will have little to no directional audio, as most of the audio will be coming from the ground, or in front of the listener. The relative significance of Ambisonic audio cues increases as the player's screen moves towards the perspective of the in-game character. The potential applications of Ambisonic audio range much further than just online video games. However, perspective plays a great role in the success of

the technology. Without specifically intended spatial concepts, Ambisonics become almost useless.

How Do Online Gaming Communication Structures Work?

Video games continue to gain social importance for good reason. Multiplayer online video games have increasingly become social arenas for people across the world. Even strictly single player games contain online communities capable of uniting gamers under a single idea. Communities found both online and in person bring people together for competitions, celebrations, game-making and entertainment. Online gamers become more outwardly social with their own groups of like-minded people, creating friendships and human interactions. With advancements in game creation and console abilities, the quality of graphics and sound have increased, creating another rise in usership. Finding a common ground through games allows otherwise antisocial people to find a place for themselves. Voice chat, Discord, and in game messaging lets people compete without pressure from an outside source or physical image. Meeting friends *because* of an event or game can create a strong bond. Video games have become a common factor in combining people from diverse backgrounds and experiences. Without these virtual meetups, gamers would be subjected to the reality of their true surroundings. For example, two people from different socio-economic backgrounds that live in the same city may never meet under the given circumstances of life. An online friendship through gaming can create avenues of further adventure with like minded people. People associate or align themselves with certain games and the people that also play those games, forging relationships and of identity empathy.

Multiplayer games create the illusion of bodily interaction and presence. Players interact through virtual avatars, capable of moving, talking and emoting in human-like ways. People

uncomfortable with their physical identity suddenly experience acceptance through virtual games. Of course, when mentioning the concepts of identity and anonymity in online gaming, it is important to acknowledge the prevalence of racism, sexism, homophobia, and other forms of discrimination.

Mental Health Risks in the Blind Community

Commonly unknown and mostly unspoken of by the seeing population, rates of poor mental health and lack of treatment are higher in the visually impaired or blind community than the seeing public. Studies from the past ten years show higher rates of depression and anxiety as well as lower rates of treatment in visually impaired people. These studies are extremely crucial in understanding the social and emotional impact of blindness. Visually impaired people were more greatly impacted by depression during the COVID-19 Pandemic than the seeing public (Tantirattanakulchai et al., 2023). Additionally, it is shown that people with low vision are more often depressed than those in the seeing public (Hussain et al., 2022). These are just a few of the large disparities. Visually impaired adults have less adequate mental health resources and care (van der Aa et al., 2015). With less accessibility to engage with medical professionals as well as the lack of a larger blind-health structure, mental health mostly goes untreated and regulated. Because of highly visual systems of inaccessible or difficult-to-navigate forms or technology, visually impaired people are susceptible to illness and injury, furthering the status of declining mental and physical health. These higher rates of illness and injury in the visually impaired community leads to higher rates of post-traumatic stress disorder (Bonsaksen et al., 2022). A systematic cycle of ignorance and inaccessibility applies social, technological and health restrictions on the non-seeing community. I would like to mention that this information is intended to be educational and is meant to open the reality of blind-related physical and mental

health to the seeing population. The reality of neglect within systems of health of visually impaired human beings often goes unspoken.

How Does Ambisonic Sound Help the Blind Community?

When interviewed about the creation of a blind-inclusive videogame in a scientific study, blind individuals requested the implementation of direct sound-to-game correlation (Chakraborty et al., 2017). Although this video game was created in a two-dimensional landscape, I would argue that a 3-D, Ambisonic environment would create a more realistic and approachable correlation between sound and game. The merging of these concepts makes the fundamental aspects of a game more inclusive and equitable. In the aforementioned game Counter Strike 2, blind individuals would be able to utilize the Ambisonic structure of sound to identify the general or exact location of enemy footsteps of gunshots. Games with Ambisonic sound advancement increase accessibility to blind players, as well as general gameplay richness. Ambisonic sound not only allows a player to hear other users, it can begin to mark the environment or obstacles that a player is in. This is achieved through wall collision noises, the echoing of sound, and the movement of other players.

Not only does Ambisonic sound aid gameplay for people who are blind, it can teach visually impaired adolescents' spatial knowledge more easily. A study done by a group of neuroscientists in Massachusetts shows that a simulation with binaural Ambisonic audio aided a group of young, blind individuals to navigate a rendering of a real-world building (Connors et al., 2014). This application of sound and game creates a positive relationship to the player, and could potentially benefit visually impaired people's spatial understanding by allowing them to engage with a space digitally. A separate study was done using an "Audio-based Environment Simulator" (Merabet et al., 2012) for blind individuals to follow a path through a building. This

study also confirmed that aural navigational skills of blind individuals increased when trained through an Ambisonic model. Not only can these scientific models inform users of paths and aid conceptual understanding of spaces, they increase risk prevention. Under a study of binaural listening and head movement, researchers in Japan were able to "enhance the localization of non-sounding obstacles" (Miura et al., 2023). A non-sounding obstacle is simply an object inside the relative path a person is walking that does not naturally emit noise. Ambisonic audio within the rendering of space, including the sound of an in-game player can greatly impact the ability for blind individuals to safely engage with a space.

Creative Project Overview:

I intend to create an audio-only multiplayer video game for mobile phones. This game will use touch control, haptic feedback, and headphones to concretely place the user in a sonic landscape and allow for interactivity. The multiplayer function will allow multiple people to interact in a single, Ambisonic environment, and perhaps communicate through voice or text-to-speech chats. The intended aspects of this video game are: teamwork, virtual movement, directional sound cues, and quick reactions.

Multiplayer lobbies will be generated by a server which hosts the game, pairing users of similar skill with one another. Once players confirm they are ready (stationary or sitting, and wearing headphones,) the game will begin. A series of levels completing audio based tasks will begin. The player who most greatly helps the team will be deemed "MVP" of the round and will obtain the luxury of choosing the gamemode of the next round. Because of this, there is a personal incentive, as well as the incentive to help one's team. The multiplayer lobby will end once a user has won three rounds. These wins will be tallied and used in matchmaking for multiplayer lobbies in the future.

The game will involve audio cues involving the movement of objects and people. Depth will be conveyed by volume, Ambisonic spread, as well as high and low frequency rolloffs. The concept of depth is extremely important, as perceived-closeness is a necessary perception of a three-dimensional game. Reverberation and echo within the space will convey the size and shape of the environment. If a level takes place outside or in a non-walled environment, boundaries will be marked by sound cues when approached.

It is important to me that the game is accessible and equitable. For this reason, I have decided to not make my game for gaming-consoles, but rather for mobile phones. Although arguably more expensive at times, phones are much more common devices with more options for cross-connectivity. For example, the “Playstation” and “Xbox” consoles often have separate servers for the same game. The portable nature of cell phones also means that my game can be played in areas outside of the home. Additionally, consoles require monitors or a TV to use a speaker system, which are visual devices that are unhelpful in this context.

This game is meant to be played with headphones. Without them, the accuracy and realistic properties of Binaural Ambisonics will be lessened or reduced to none. The use of headphones allows for the full immersion of self into virtual space. I think of this effect to be something very similar to playing a game on a virtual reality headset with your eyes closed. Perhaps in the future there will be non-visual virtual reality headsets capable of modeling the shape of the user’s ear for advanced spatialized sound.

My intention with my creative project is to make a small window into the vast benefits of realistic, directional sound in gaming. I want to allow people who are blind, as well as seeing people to experience the possibility of sound-inspired interconnectedness, and allow themselves

to reject their preconceived notion of what a video game experience should be. My video game is to be modeled after inclusivity, accessibility, and acceptance.

Reflection:

I feel a deep set intention to push this style of game into something even larger. The skillset I have acquired because of this project has enabled me to continue to work for ideas that include accessibility within the sound practice space. During my project I experienced a sense of freedom from the conventional uses of sound and video-game development in the cultural sphere of education. Because of this project, I know that I can exceed the current limitations of my art form for good.

It was important to me to increase the objective equity around the concept of gaming. Because of the nature of my game, and its general acceptance of visually impaired players, I know that a continuation of hard work would only continue to aid this community. Playing a game that is sound based is a reflection of our own reality. We are constantly barraged with sound and our brain computes directionality. This feature of my game is a continuation and replication of the real world, and a nudge to take sound more critically.

The process of creating this game was truly something I had never fully embarked on before. There were countless nights of coding and bouncing the game to my phone to check my changes. I was deeply invested in the accuracy and general difficulty of this game. I wanted this game to have an edge to it. Something that enabled a learning curve in individuals who wanted to play. Not only is there a playable learning curve to the game, there was a generally steep learning curve creating a sound-based game on a visual-based game engine.

My intention within this game was to use my own resources and education to create a working prototype of what, one day, could be a largely downloaded and highly accessible game. I am invested in the utilization of sound for the purpose of acceptance and the fusing of seeing and visually impaired communities under a singular, common concept.

Discussion:

Because of my studies at The Colorado University of Boulder I was able to initiate my work on the platform Unity quite quickly. Little to no work was needed on the visual assets in the game because of its sound based nature. I quickly realized that *testing* my game was going to be an issue because of it's multiplayer functionality, so I quickly changed the *second player* to an allotment of location based scripts and randomizations.

My game took on much of the nature of a traditional "hide and go seek" game. The hider emits occasional audio cues from its location, which allows the seeker (and player) to attempt to find based on the directional sound. In the way of the hider are obstacles. Although in Unity, these obstacles are blocks and columns, within the play of the game these obstacles emit a buzzing sound when the player becomes too close. These audio cues enable the player to traverse the area, searching for the hider, moving around dangerous objects.

Some of my biggest hurdles came with the implementation of IOS-touch controls, accurately distanced sound rolloffs, and difficulty based level creation. Some of my most rewarding moments happened during the sound design process. Every sound in this game is created by me. I wanted to make unique noises that would continue to draw the player deeper into the game. The hider needed to have a unique and human-like expression that would alert the player to their location via sound. These audio assets felt like the foundation to my game.

Creating difficulty-based levels was a challenging piece of conception. I had the job of not only introducing a select group of people to play an audio-based game for the first time, but eventually making it hard for them. This is an interesting dynamic of inclusivity that I may encounter in the future. How do we invite seeing people, who are often not aware of their critical listening skills, as well as visually impaired people who rely on critical listening skills to a hypothetical arena where *hearing* is the target sense? I am invested in the answer to this problem, and have already started my journey.

Future Plans:

Senior Capstone Event: 5/4/24

My senior capstone is a similar expansion of sound, adjacent to the priorities and beliefs implemented into my Honors Thesis. I am using a highly directional 8 speaker array to play ambisonic, interactive sound for the students, teachers, and people of Boulder. This project is in line with the accessibility and inclusivity that I so strongly promote in my Honors Thesis. The speakers for this experience were sourced entirely at the Goodwill, and the TRU Hospice Thrift. The exhibit is open to the public and encourages interaction from the viewer, making this art a shared interaction. A *light microphone* is being used instead of a conventional sound microphone, allowing the listener to be fully immersed in the signals resonating from the speakers. This event is an opportunity for me to fulfill more of my goals including accessibility and the promotion of critical listening skills bordering my current thesis topic.

Outpost Studios Presentation: June 2024

My first real entrance into the sound world was with Outpost Studios, a San Francisco company with sound work on countless large-scale projects like Commercials, Movies,

Audiobooks and more. At Outpost I had the opportunity to assist in recording assets for a Disney audiobook, a LinkedIn commercial and a Cherry Bombe Podcast. I am interested in using my connection with the studio to offer a presentation. I will present my game, thoughts and thesis, encouraging them to connect me with suitable game companies or sponsors if they find my work compelling. The presentation will highlight key themes, concepts and questions from my research on inclusivity and ambisonics. Outpost Studios will hopefully be the first of many to see my ideas. My intention with this presentation is to enable *sound only* games to be picked up by larger companies, while I continue to research inclusivity within gaming in the blind community.

Looking ahead: July 2024 and beyond

I am interested in presenting my ideas to companies outside of my range of experience. I have contacts at Riot Games, Skywalker Ranch, Pixar and Apple. These presentations would differ because of the unique nature of each company. However, the singularity between each one of these presentations would be as follows:

- Inclusivity for visually impaired people within videogames
- The impact of expanded community on mental health for those who are visually impaired
- The impacts of Ambisonics and the utilization of space spatial learning tactics
- Critical listening skills
- Further implementation of current ambisonic technology
- The push for blind-accessable games, not visual-based games with audio assistance

References:

Bonsaksen, T., Brunes, A., & Heir, T. (2022). Post-Traumatic Stress Disorder in People with Visual Impairment Compared with the General Population. *International Journal of Environmental Research and Public Health*, *19*(2), 619. https://doi.org/10.3390/ijerph19020619

Chakraborty, Joyram, Suranjan Chakraborty, Josh Dehlinger, and Joseph Hritz. "Designing Video Games for the Blind: Results of an Empirical Study." *Universal Access in the Information Society* 16, no. 3 (August 2017): 809–18. https://doi.org/10.1007/s10209-016-0510-z.

Cloutier, D. (2017, March 23). *How a blind man plays mainstream video games and the future of accessibility in games*. CBC News. https://www.cbc.ca/news/science/blind-video-gamers-1.4037944

Connors, Erin, Elizabeth Chrastil, Jaimie Sanchez, and Lotfi B. Merabet. "Action Video Game Play and Transfer of Navigation and Spatial Cognition Skills in Adolescents Who Are Blind." *Frontiers in Human Neuroscience*, March 11, 2014. https://doi.org/10.3389/fnhum.2014.00133.

Galloway, Kate. "On the Ethics of Extraction in Environmental Sound Art." *MUSICultures* 49 (2022): 111–34.

Grabski, Andreas, Toni Toni, Tom Zigrand, Rene Weller, and Gabriel Zachmann. "Kinaptic - Techniques and Insights for Creating Competitive Accessible 3D Games for Sighted and Visually Impaired Users." In *2016 IEEE Haptics Symposium (HAPTICS)*, 325–31, 2016. https://doi.org/10.1109/HAPTICS.2016.7463198.

Hussain, I., Malik, W. A., Khan, F. A., Islam, Q. ul, & Shafi, S. (2022). Comparison of Depression in Low Vision Patients and Normal Vision Patients. *Pakistan Armed Forces Medical Journal*, *72*(6), 2029.

Leo, Fabrizio, Monica Gori, and Alessandra Sciutti. "Early Blindness Modulates Haptic Object Recognition." *Frontiers in Human Neuroscience* 16 (September 8, 2022): 941593. https://doi.org/10.3389/fnhum.2022.941593.

Lloyd, R. (2021, May 13). *Developing games for low-vision players*. GamesIndustry.Biz. https://www.gamesindustry.biz/developing-games-for-low-vision-players

Macé, Marc J. -M., Florian Dramas, and Christophe Jouffrais. "Reaching to Sound Accuracy in the Peri-Personal Space of Blind and Sighted Humans." In *Computers Helping People with Special Needs*, edited by Klaus Miesenberger, Arthur Karshmer, Petr Penaz, and Wolfgang Zagler, 636–43. Lecture Notes in Computer Science. Berlin, Heidelberg: Springer, 2012. https://doi.org/10.1007/978-3-642-31534-3_93.

Mandanici, Marcella, Antonio Rodà, and Marco Ricca. "The Task of Walking Straight as an Interactive Serious Game for Blind Children." *EAI Endorsed Transactions on Serious Games* 5, no. 16 (September 2018). https://doi.org/10.4108/eai.13-7-2018.155165.

Merabet, Lotfi B., Erin C. Connors, Mark A. Halko, and Jaime Sánchez. "Teaching the Blind to Find Their Way by Playing Video Games." *PLoS One* 7, no. 9 (September 2012): e44958. https://doi.org/10.1371/journal.pone.0044958.

Messaoudi, Mohamed Dhiaeddine, Bob-Antoine J. Menelas, and Hamid Mcheick. "Review of Navigation Assistive Tools and Technologies for the Visually Impaired." *Sensors (Basel, Switzerland)* 22, no. 20 (October 17, 2022): 7888. https://doi.org/10.3390/s22207888.

Meyer-Rochow, Victor Benno, Helinä Hakko, Matti Ojamo, Hannu Uusitalo, and Markku Timonen. “Suicides in Visually Impaired Persons: A Nation-Wide Register-Linked Study from Finland Based on Thirty Years of Data.” *PLoS ONE* 10, no. 10 (October 28, 2015): e0141583. https://doi.org/10.1371/journal.pone.0141583.

Miura, Takahiro, Naoyuki Okochi, Junya Suzuki, and Tohru Ifukube. “Binaural Listening with Head Rotation Helps Persons with Blindness Perceive Narrow Obstacles.” *International Journal of Environmental Research and Public Health* 20, no. 8 (2023): 5573. https://doi.org/10.3390/ijerph20085573.

Mikulowski, Dariusz, and Marek Pilski. “Ontological Support for Teaching the Blind Students Spatial Orientation Using Virtual Sound Reality.” In *Interactive Mobile Communication Technologies and Learning*, edited by Michael E. Auer and Thrasyvoulos Tsiatsos, 309–16. Advances in Intelligent Systems and Computing. Cham: Springer International Publishing, 2018. https://doi.org/10.1007/978-3-319-75175-7_32.

Nilsson, Mats E., and Bo N. Schenkman. “Blind People Are More Sensitive than Sighted People to Binaural Sound-Location Cues, Particularly Inter-Aural Level Differences.” *Hearing Research* 332 (February 1, 2016): 223–32. https://doi.org/10.1016/j.heares.2015.09.012.

Piller, Sophia, Irene Senna, and Marc O. Ernst. “Visual Experience Shapes the Bouba-Kiki Effect and the Size-Weight Illusion upon Sight Restoration from Congenital Blindness.” *Scientific Reports (Nature Publisher Group)* 13, no. 1 (2023): 11435. https://doi.org/10.1038/s41598-023-38486-y.

Sara, Finocchietti, Esposito Davide, Monica Gori. “Monaural Auditory Spatial Abilities in Early Blind Individuals.” *I-Perception* 14, no. 1 (January 2023). https://doi.org/10.1177/20416695221149638.

Scott, K. (2022, October 12). How do visually impaired people play video games? *BBC News*. https://www.bbc.com/news/uk-scotland-tayside-central-63157128

Stadler, Viktor, and Helmut Hlavacs. “Blind Adventure - A Game Engine for Blind Game Designers.” In *Proceedings of the 2018 Annual Symposium on Computer-Human Interaction in Play*, 503–9. Melbourne VIC Australia: ACM, 2018. https://doi.org/10.1145/3242671.3242703.

Tantirattanakulchai, P., Hounnaklang, N., Pongsachareonnont, P. F., Khambhiphant, B., Hounnaklang, S., Win, N., & Tepjan, S. (2023). Impact of COVID-19 on Depressive Symptoms Among Patients with Low Vision and Blindness. *Clinical Ophthalmology*, *17*, 789–796. https://doi.org/10.2147/OPTH.S401714

van der Aa, H. P. A., Hoeben, M., Rainey, L., van Rens, G. H., M, B, Vreeken, H. L., van Nispen, R. M., & A. (2015). Why visually impaired older adults often do not receive mental health services: The patient’s perspective. *Quality of Life Research*, *24*(4), 969–978. https://doi.org/10.1007/s11136-014-0835-0

Venkatesan, Tara, and Qian Janice Wang. “Feeling Connected: The Role of Haptic Feedback in VR Concerts and the Impact of Haptic Music Players on the Music Listening Experience.” *Arts* 12, no. 4 (2023): 148. https://doi.org/10.3390/arts12040148.

Yabe, Takao, and Kimitaka Kaga. “Sound Lateralization Test in Adolescent Blind Individuals.” *NeuroReport* 16, no. 9 (June 21, 2005): 939.

Zahn, Carmen, David Leisner, Mario Niederhauser, site, Anna-Lena Roos, et al. “Effects of Game Mode in Multiplayer Video Games on Intergenerational Social Interaction: Randomized Field Study.” *JMIR Formative Research* 6, no. 2 (February 2022): e29179. https://doi.org/10.2196/29179.