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Spatial Audio

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History, Recording, Mixing, Immersion

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Surround sound is an approach to endow the fidelity and immersion of audio. The distinguishable difference between surround sound and our everyday-use stereo mixes is that surround sound adds additional audio channels behind and along each side of the listeners engulfing them in a 360º experience. The earliest forms of spatial audio were incorporated in films. This new method made the cinematic three screen method obsolete. With this new technology not only did the level of immersion increase at the movie theater, but it also gave sound engineers the freedom to be more creative and experimental on the projects. As spatial audio technology advanced and consumers began to have home theater systems, different forms of entertainment began to implement surround sound for a greater experience. Soon after music and video games began to produce works in surround sound. Today there is a plethora of spatial audio formats that range from a four speaker set-up to a twenty speaker set-up. With the amount of studios and companies creating content in surround sound it shows that the audio world is moving into a new and exciting future of spatial audio.

As spatial audio has evolved, specialized tools were created to develop surround sound mixes. An inquiry of their assets and constraints inherent with the use of this technology is necessary to comprehend the developmental change in surround sound mixing. I begin my analysis by conducting a concise historical survey of surround sound. Doing this will give the necessary information to recognize how spatial audio technology has developed over time. I will proceed by exploring popular surround sound recording and mixing techniques. Ultimately, this exploration elucidates how these mixing tools and techniques create deeper immersive listening experiences.

History of Surround Sound

Monophonic records are the earliest forms of audio playback. For this to work a record player or TV audio signal is sent to the sound system which then encodes the information and creates a single audio channel that then travels through a single speaker. In the case of having multiple speakers like in a cinema or headphones, identical audio signals are played through each of the speakers creating the image of having one audio signal. The first person to record audio in mono was Édouard-Léon Scott de Martinville of France. Marinville's goal was to create an auditory version of the photograph (Fabry 1). By 1857 Martinville's invention, the phonautograph, was capturing audio with enough precision that the academic community began to adopt his ideas. Unfortunately, Martinville never thought of a process to be able to play back any of his recordings. It wasn't until 1877 that Thomas Edison created the phonograph and the world would get the first taste at mono audio playback. Monophonic recordings were the only type of recordings available so by default they were the most popular. Everything from cassettes, vinyl, radio stations and TV stations were all outputting mono signals (Farby 1). It took almost sixty years until a new format became available.

The first introduction of stereophonic signals were produced by another Frenchmen by the name of Clément Ader in 1881. Clément essential mic'd up the stage using an array of telephone transmitters. The signal was then output in private suites in which the listeners in the room were able to distinctly hear audio signals (Scientific American 58). Stereophonic recording did not become popularized until England born Alan Blumlein patent stereophonic records films, while working as an engineer for Electric Musical Industries (EMI Group Limited). It is believed that Blemlein came up with the idea of stereo records when he and his wife visited a

movie theater, and the film lacked immersion. Sound was being played from one source and would not match up with the picture. Blumlein discussed his idea with Isaac Shoenberg and together they applied and got approved a patent for stereo sound transmission and recording on June 14th 1933 (Patent Specification 5). Some of the patents Bluemlein got approved are still being used today, like the Blumlein Pair which is a famous stereo recording technique. He also got approved for a shuffling circuit that aided in keeping a more directional recording of space. Lastly, Bluemlein was also approved for a hybrid transformer to average out the difference between the left and right signals. The first stereo discs were released in late 1933 and the first film in stereo was Walt Disney's Fantasia in 1940. Once the first new songs and films came out the consumers took the ideas and ran with it. Stereo quickly became and is still currently the standard to this day. Even though stereo is still the standard, the new developments in surround sound seem likely to take its place.

In 1997, Dolby popularized Dolby Stereo Dolby History). Dolby stereo was improved spatial audio technology by becoming the first company to incorporate the use of a center channel and rear surround channels. Dolby stereo used four separate audio channels which included left (L), center (C), right (R), and a surround channel (S). This new system made its debut in cinema for the movie 'Star Wars'. Dolby Stereo allowed the sound engineers to be more flexible and creative in placing objects in the stereo field. In the film 'Star Wars' Dolby Stereo was used to replicate the effect of having aircrafts flying overhead creating a more immersive experience. Later models of Dolby Stereo introduced a sixth audio channel known as a Low Frequency Effects (LFE) channel. This channel uses a crossover to send low-frequencies between 20Hz - 200Hz to a subwoofer. Adding a subwoofer helped films become more realistic.

."Many movie makers use the subwoofer to create a powerful rumbling in the theater, shaking the audience when there is an explosion … on-screen"(Harris 3). This enriched the movie-goers experience by giving the audience a sense of being in the location of the film. Not only did Dolby Stereo create more immersive movie experience it also incorporated a new form of condensing audio. First models of Dolby Stereo were bound to two optical tracks of space. Engineers thought back to the surround sound predecessors and came up with a 4-2-4 processing system that was inspired by quadraphonic audio (Harris 2). This led the later models of Dolby Stereo to take two channels of audio information and recreate four channels. The extra two channels allowed the engineers to place ambient audio around the listener to give them a convincing real experience.

In 1982, Dolby created Dolby Surround. This new system was created explicitly for home theater use (Dolby History 1). There were two major differences between Dolby Stereo and Surround. First Dolby Surround was now encoding audio channels as magnetic tracks on videotape instead of optical tracks (Harris 2). Secondly, early versions of Dolby Surround lacked the center channel the movie theaters had. It wasn't until 1987 that Dolby included Pro Logic. This new rendition of the home surround sound system included the center channel Dolby Surround was missing. Dolby Pro Logic found success with audio lovers that it went untouched for nine years. In 1995 Dolby introduced Dolby Digital. This new system used a different method of processing audio. Dolby Digital used an AC-3 format. This new format quickly became a global standard (Dolby Digital). Dolby Digital used a 5.1 which consisted of a left, center, right, left surround, right surround and LFE channels. Almost all movies began to release in the 5.1 format. DVDs and HD broadcasts were being released with the capability to be played

in 5.1. This new AC-3 format helped analyze the audio playing and keeping only the essential portions of audio. It would discard any wanted noise or buzz. This allowed Dolby's technology to send audio at lower data rates (Dolby Digital 5.1 1). As of year 2020 the 5.1 set-up continues to be a standard in the world of spatial audio. Many if not all movies are now being played in 5.1 Most TV broadcasts have an option to switch over to surround sound. Streaming services like Netflix and Hulu are also offering 5.1 listening experiences. As the years went by Dolby and its biggest competitors DTS have continued to grow the 5.1 set-up. Dolby and DTS began with 5.1 and moved to 7.1 adding side channels between the left and right channels and surround left and surround right. Both companies have gone as far as having 11.1 introducing two more wide surround channels. The fact that these companies continue to add speakers to their set-ups means there must be a demand for more mesmerizing audio.

With the rise of spatial audio, game developers began to take notice of this immersive sound format and began to add surround sound to video games in the early 2000s. The first attempts at this were unsuccessful as there was a delay between what was happening on screen and what was being played back through speakers that reached the player's ears (Schedeen 2). To combat this, the company Mentor created the first surround sound headphones in 2004. This became revolutionary because there was no longer a need to have a sizable listening set-up. These new headphones came in two different categories. There was "true" surround sound which means headphones come with five or seven drives replicating the five or seven speakers for 5.1 or 7.1 set-ups. "True" surround sound also included a separate low-frequency driver that acted as a subwoofer. The second option was "virtual" surround. In this option were restricted to using stereo headphones, and required an external preamp or mixamp. The way this worked was that

audio would come from the game into the pre or mix amp which would run the stereo signal through algorithms and attempt to replicate surround sound. Most companies use different algorithms so different companies' headphones would not sound the same (Scedeen 2). Having this done not only introduced millions of people into the surround sound, but also greatly improved the entire video game experience. Consumers have been excited by this new technology and they are trying to figure out how many more speakers they can add to their set-up.

Dolby Atmos was first introduced with the premiere of Disney's film Brave in June 2012. The year ended with merely twenty five theaters having access to Dolby Atmos on their property. By the end of 2013 that number jumped to three hundred (Dolby Atmos 85). By the middle of 2019 the number of locations that had Dolby Atmos installed had spiked to four thousand and four hundred. The major difference between Atmos and its predecessors was that Atoms treated every sound as an individual object instead of cramming it into a specific audio channel. This gave the opportunity to sound designers and audio engineers to pinpoint exactly where in the theater they wanted the sound to be located. Previous systems would trigger all the speakers associated with a channel. Atmos removes this by allowing the mixing engineer to precisely place the object where they want by activating only the required speaker and not the whole channel. In addition to adding individual speaker capability, more speakers were added to Atmos. Now listeners wouldn't have speakers just around them, they would also encounter speakers above their heads . This let the mixing engineer seemingly pan a helicopter fly over head. There was also a massive upgrade on the encoder used by Dolby. The new CP850 encoder allowed for 128 tracks of audio to be played at once, and was able to render up to sixty-four

speaker feeds. The new encoder was also the first to include automated calibration to continually play back audio at the highest quality possible. The CP850 also introduced a Lake EQ and 1/12th octave EQ which is used to optimize any playback for different content in different listening environments. The newest features also included individual levels and EQ for each of the speakers. Lastly, The key feature that will keep Atmos running for the foreseeable future is that Atmos has the capability to down mix. This means that if you have a 5.1 or 7.1 set-up Atmos will recognize how many speakers are connected and automatically adjust for a successful playback (Dolby Atmos Cinema Processor CP850 Line 1). In June 2014 Dolby released the home theater version of Atmos. This version of the system was identical to those used by the cinema. The home version of atmos was at a small disadvantage due to having ceiling hanging speakers. Most consumers were not pleased they had to drill a hole or hang speakers. To counteract that, speaker companies like Klipsch and Sony made speakers to distribute overhead audio. This meant there were up-firing speakers that faced the ceiling and bounced the audio from the ceiling to the listener. Now that we have a basic understanding of the evolution of surround, I will begin to explain popular surround sound recording techniques and the popular tools implemented to create a surround sound mix.

Recording Techniques

The earliest surround sound micing techniques were discovered by Roy Wallace and Arthur Haddy in the 1950s. While working for Decca Studios in England the pair of engineers tested a three mic set-up to record an orchestra. The Decca Tree technique requires two omnidirectional microphones six and a half feet apart. These two microphones will act as the left

and right of a surround sound mix. For the center microphone a cardioid or large diaphragm condenser is most optimal. This center mic is to be placed about five feet ahead of the other microphones. It is common practice that these three microphones be hanging eight to ten feet above the recording artists. The outer two microphones should be pointed down and inward toward the music, while the center microphone should be pointed down straight ahead to the artist. This was the first technique to use three recording microphones. Variations of the decca tree can determine how wide of an auditory image the listener receives. Placing the microphones closer will give a narrower sound and visa versa. In cases of recording immense groups two more omnidirectional microphones may be added on the flanks which will become the left and right surround channels (Haines 2).

Dr. Günther Theile was the engineer that discovered the Optimized Cardioid Triangle (OCT) recording technique. This recording technique uses a similar front three array as the Deca Tree but instead of omnidirectional microphones these are instead replaced by two super cardioid. The OCT technique also differs from the Deca Tree in that the side microphones are higher than then the center mic. The side microphones in OCT also face outward and the center microphone faces forward about three to five inches ahead of the side microphones. Both of the side microphones are placed about 3 feet away from each other. The Optimized Cardioid Triangle has recording angles of 90º and 160º. This ensures there is less bleed in the left, center, and right channels (Surround Sound Microphone Techniques 1).

The Hamasaki square was created by Kimio Hamasaki from Japan's NHK Laboratories. This technique was created to aid in capturing ambience in surround sound. Ambiance places a major rule in surround sound as it helps the listener connect with a sense of space. In particular

technique, four bidirectional microphones are organized in a square about six or seven feet apart. Common practices are to have the microphones face away from the recording artist. This helps in capturing the sound of the room and not the actual musician. Facing the microphones outward also aid in reducing the amount of echo that is picked up from the microphones. Normally the Hamasaki Square is placed high and further back of the space that is being recorded. The front two mics are split between the front left and right channels while the remaining microphones on the back of the square are mixed in the back surround channels.

The Hamasaki System is derived from the Hamasaki Square. This surround sound recording technique was also created by the engineers of NHK and is often referred to as the NHK surround system. In this particular set-up there are five cardioid and two omnidirectional microphones. The center microphone is plotted one to one and a half feet ahead of the rest of the microphones. The front left and right microphones are placed about a foot apart and are angled at 45º. A baffle is used to reduce the amount of bleed that is picked up from the front left and right channels. Two more cardioid microphones are used are the rear surround channels. Each of the mics are angled at 135º and located six to ten feet behind the left and right channels. There is also a distance of ten feet between the back surround channels. Lastly, the two remaining omnidirectional microphones are placed two to four feet apart from the front left and right channels. There must be about ten feet of distance between both omnidirectional microphones. Also there is a tendency when recording in this technique to enable a low pass filter at 250Hz. This helps distinguish the cardioid and omnidirectional front left and right microphones. The omnidirectional microphones allow the cardioids to pick up all of the high and mid range. The omnidirectional with the low pass filter will only pick up the frequencies at and below 250Hz.

This will become helpful in the studio so the audio engineer then is able to mix a combination of both microphones for the best blend and results.

Overtime with more experimental practices there have been engineers that have combined multiple basic surround sound recording techniques to create elaborate recordings. A prime example of this would be OCT + Hamasaki Square. In this situation the microphones that used to create the Optimized Cardioid Triangle are used to record the musicians. The remanding Hamasaki Square is used to pick up the rest of the ambiance or room tone. Techniques like this give audio engineers more freedom and creativity. With seven different microphones the engineer is no longer restricted to a 5.1 mix. The engineers are now able to create more extensive and complicated 7.1 mixes. Pairing up both recording techniques allows the engineer to have more control over the mix. For example the engineer may play around with the blend between the ambiance and the dry signal. OCT+Hamasaki brings out the best from each option and creates an embellished recording.

In these previous surround sound recording techniques each recording is collected in mono and then sent to it's appropriate output to create a surround sound mix. In the rapidly growing audio industry microphones are now being produced so an individual mic is able to record multiple channels of audio. Peter Craven and Michael Gerzon were the creators of the tetrahedral microphone. This microphone, owned by RODE, is exactly as you may imagine it. This microphone is composed of four equally spaced cardioid microphones placed in the shade of a tetrahedron. A special feature of this microphones allows it to record in mono, stereo, and surround. While recording in surround the tetrahedral microphone process audio in A-Format. The user must have access to hardware or software to convert the audio into B-Format so it is

able to be played back. The company Zylia recently released the ZM-1S spherical microphone. This signal mic consists of nineteen omnidirectional microphones in the shape of a sphere. This microphone is used primarily to record 360º. Zylia has released their own software to convert audio to B-Format and be played back through Facebook 360º or Youtube 360º (Zylia 1). Lastly, The company 3Dio has released 3D surround sound microphones. These specialized microphones are designed to replicate the human ear. These microphones consist of two microphones with ear shaped cones at the end. These ears aid in picking up audio exactly how humans listen to audio. The silicon ears are used to have the sound bounce around the ear and into the microphone to replicate an exact listening experience. With microphones being created specifically for surround sound recordings there are also specialized mixing techniques to help create a surround sound mix.

Mixing Techniques

There is a major difference between mixing sound for film and mixing music. Generally in surround sound mixing for films the audio is a reaction to what is happening on screening. The re recording mixer has effectively done their job if the audio matches the screen and doesn't cause any disruptions to the story. In film dialog is the most important sound. In a busy mix full of sound design, foley, and music the dialog must always have the priority. In most cases the most effective way to achieve this is by decreasing the amplitude of everything that is not the main dialog. In other circumstances equalization (EQ) may be applied. It is most helpful to cut around 2k Hz and 4k Hz in tracks that have a lot of midrange (DPA 1). This particular frequency range is where the human ear picks up the intelligible parts of speech. Doing this will create a

notch for the dialog to sit on top of the mix. In film most of the action will take place in the front array of the surround channels. Dialog is fixed to the center channel. Most of the sound design and foley is distributed between left right and center (Thornton 4). The surround speakers predominantly for ambience and room tone. These speakers are what make the audience feel as if they were in the same room as the actors. Early multichannel music mixes have tended to be on the safer side. The first few mixes followed similar forms of cinema audio. In today's age engineers have become more radical and experimental Because there are no set rules or standards for multi channel music mixing. the engineer has more freedom to be creative and express themselves through their mix (Ainlay 6). There is no right or wrong way to mix in surround sound. The audio industry has come to a consensus that if it sounds good it is right. Because of this we have received more decorative mixes where sounds fly across each speaker creating an immersive experience.

Imaging and panning play a massive role in any type of mix. This allows the engineer to place sound in the audio field. A popular technique is placing audio in what is known as phantom center. This is when equal amounts of the signal is being played from the left and right speaker. This creates the illusion that the source is coming from the center. Audiences quickly noticed there was an issue with this. It was found that if you move from the sweet spot the source seems to jump around due to comb filtering. With the introduction to a true center speaker in surround sound engineers no longer had to face this issue. Engineers continue to use both true and phantom center in their mixes. To achieve a phantom center without comb filtering there is a control on most DAWs called divergence. This allows the signal to be distributed to various channels. An example is having vocals panned center. With 50% divergence part of that center

channel signal is equally distributed to the left and right channels. Similar effects can be replicated along the back speakers. Engineers can also create phantom centers along the side by introducing equal amounts of signal between the left and center or center and right speakers. Phantom center between front left and surround left can be created but engineers have found they are unstable (Ainlay 34). The phantom image never seems to stay in one place and is generally not used by many engineers. The reason these phantom centers don't work is because our heads just get in our way. ‘’Math formulas called head related transfer functions predict the ability to perceive various sounds originating from different points around us”(Ainlay 55). These mathematical equations are also the reason why engineers can never properly pan from front to rear. The biggest problem facing young engineers is comb filtering. Having a force play from three or four different speakers can increase the likeliness of comb filtering. It is recommended that specific channels be turned off if the mixing engineer wanted to implement dramatic panning.

Center speakers are usually the anchor to any mix. However too much emphasis on the center may not be the best procedure to mix. The center speaker is normally the smallest speaker in a spatial audio set-up. This may cause any signals routed to the center to suffer in terms of the frequency response (Ainlay 42). Other issues that may arise is that the center channel grants the listener to hear the signal in isolation. Keeping the lead vocal solely on the center without having other instruments or effects on the channel may lead to hearing the imperfections of the vocalists performance. Having other instruments of adding divergence will help mask any of the glitches or rough patches on the vocals. A secondary benefit of placing signals in more than just the center will help emphasize that instrument and will also help with locating the sound if the

listener is to move around the room. Another interesting effect that can be done with the center speaker is creating a phantom image between the front and back speaker. This can be up to the mixing engineer if they want two front speakers and a rear or the other way around. Doing this will create a psychoacoustic effect where that signal is sitting much closer to the listener. There must be extreme caution when attempting this technique. It is quite easy to cause comb filtering from this. To prevent any comb filtering it is common practice to slightly alter EQ or pitch. Lastly, most studio engineers keep the center channel dry and have reverb along the surround channels. This may cause the center to sound out of place or "in another room" as the rest of the mix. I have found that small shorter reverbs or short delays help counter-act this and help the entire track sound as if it were coming from one place.

As stated previously the use of the rear surround channels were mostly used for ambiance. Today many engineers have become empirical. In today's age many mixing engineers have opted to use the surround speakers and create a 'in the band mix'. This is exactly as it sounds. It places the listener in the middle of the band. In this practice the rear speakers carry more transient events or sound effects. Routing sounds with a crisp attack of pop incorporate a surprise factor for the listener. Having percussive instruments being played behind you gives you a greater feeling of being in the band but may also catch you off guard which can be a refreshing change of where a wall of sound is from the front. As I hinted before, mixing engineers are able to play tricks on our brains. By pairing a center speaker with a rear speaker we can simulate a sound floating next you immersering you in sound. Lastly, rear speakers are still used just for ambience sounds. "Rear speakers serve the important function of carrying spatial positions information" (Ainlay 54). There is no importance to how the room tone was recorded placing

room tone or effects like reverb and delay can make the overall track sound bigger and wider in the sound field.

The Low Frequency Effects channel is a challenging channel to mix. The LFE as I have stated before was added to create an extra sense of immersion in films. The risk of this channel is that audio engineers may abuse it. The effects of over using the LFE will cause an overpowering amount of bass distorting any mix. The most important rule for the LFE is that “It should never be used to carry the bass content of the main speaker channels' ' (Ainlay 36). Any sound engineer must approach the LFE with care. Only small amounts of information from a kick, bass, low organ, or piano should be added to the LFE. It is common practice to have a low pass filter from 80 - 120Hz on your LFE. This will ensure only the lowest of the low gets through. When properly adjusted the use of an LFE can greatly impact the listening experience. Feeling the subwoofer hit every time there is a big bass drop or kick drum cause gives the listener a similar experience to witnessing the performance live.

Spatial Audio & Immersion

Over the last two sections I have mentioned that surround sound systems increase the levels of immersion for the listeners. In this section I will go over how this is achieved and give examples of how the audio industry is taking advantage of this situation. First off it is important to note that monophonic and stereophonic systems are dependent on the reflections that are being bounced by every object in our listening environment. This in itself immerses the listener in their own sound space. If a listening environment is properly set-up and acoustically treated levels of immersion can be increased in mono and stereo. However, these systems are unable to replicate

sounds coming from the side or behind the listener. That is the primary reason surround sound is instantly more immersive. “Our brains use level, phase, interaural time delay, and spectral characteristics to have the ability to localize sound”(Monitoring Surround-Sound Audio 33). These key factors are what allow mixing engineers to create the phantom imaging I covered in the previous section. Phantom imaging creates a sense of having a solo instrument of vocal stand next to the listener putting them in the middle of the performance.

Creating a ‘in the band mix’ is an excellent example of how surround sound can immerse the listener in music. These types of mixes can put the listener on stage with their favorite performers. The album ‘At War With The Mystics’ by the Flaming Lips is a perfect example of this. In this 5.1 mix the listener is plotted center stage with the band. We can hear the drums coming from behind us with the crashing cymbals being bounced between our left and right ears. We can hear the rhythm guitar off to the left hand side. It sounds as if the guitar player were standing two or three feet away from you. On the other side pushing a bit forward we can distinguish the lead guitar playing solo riffs. The lead and background vocals were placed in the sound field eloquently. Lead vocals sat up front and center with the background vocals also coming out of the center behind the lead, but also the background vocals were placed into the left and right channels. Keyboards were the more interesting instrument in the mix. In the first half of the album the keys sat in the back in between the two guitar plays but behind the listener. In the second half there was more experimentation. We can hear the synth clearly being panned in an “X” formation from rear-left to front-right and front-left to rear-right. What made this listening experience exceptional was that it placed the listener in the middle of a live recording session. All the instruments were placed and eragned as the band sets-up live. For the individuals that

may not have the opportunity to witness their favorite band play live a 5.1 mix can replicate the immersion of a live concert.

Surround sound systems are most commonly found in movie or home theaters, but engineers at Dolby Laboratories have begun to test spatial audio at live events. Dolby Atmos is slowly starting to be used in nightclubs. The night club Halcyon is one of three venues that utilize Dolby Atmos. Dolby Atmos is perfect for creating immersive DJ sets. With Atmos, the producers can have sound bouncing all over the room. DJ Yousef describes Atmos in a club setting as "being inside the track" (Halcyon x Dolby Atmos 1). DJ's are in favor of these technologies on dance floors. World renowned Dj, Mark Radford, explains that he enjoys the fact that he can start a sound from anywhere in the room. He states " we can now design music in a whole different way… I can bring it (sound) from behind me … above me… or underneath me" (Halcyon x Dolby Atmos 1). Having attended multiple events at Halcyon in both Atmos and mono. I can confidently say Atmos was an overall better musical experience. As the listener, I always felt in the middle of the music similar to what Yousef stated. Hearing the sound bouncing all over the club made for a more entertaining and energetic set. While listening to just a mono mix in the set always seems to fall flat. The engineers at Dolby Laboratories have done a wonderful job of making Atmos easy to use and mix in. They have made Atmos easily available on most DAWs. DJ Yousef exclaimed that using Atmos was one of the most simplistic and easy plug-ins to mix his music (Halcyon x Dolby Atmos 1). If the trend keeps following this direction Dolby Atmos will soon be at almost every concert venue or club. Atmos creates an immersive and interactive way of listening to music. Many music producers enjoy the use of Atmos and they will continue to work with it until it becomes a standard.

In the ever changing audio world spatial audio headphones have become increasingly popular in the video game community. The use of these specialized headphones allow game developers to place a sound anywhere they desire in a three dimensional space. To be clear, when humans move closer and further from a speaker playing audio, the level seems louder and softer depending on which way we move. Spatial audio headphones work the exact same way in video games. Tools like these increase the levels of immersion in video games. Players are now able to hear where rewards, enemies, or other players are located in relation to the listener's location. Doing this places the player in this virtual world. Doing this can give an advantage to the user by being able to identify players ahead, behind, above, or below them. Using these headphones can give players a higher sound quality experience as well. In instances smaller noises like hearing your weapon reload close up or hearing a monster roar from far away increases the chances the player becomes enveloped in the game. In the case of the game ' The Amazing Spider Man' spatial audio places a massive role in indicating where enzymes are located. In portions of the game the player swings through the city, and can then hear shouting and screaming coming from the back left side of them notifying the player there may be enemies behind him. Overall, spatial audio headphones are a wonderful tool to increase the feeling of being in the game.

In conclusion, the ever changing world that is the audio industry has introduced a new form of being in the center of sound. Surround sound systems have progressed immensely from quadraphonic sound to the now prevalent Dolby Atmos. There is a high importance to the recording techniques professional audio engineers use. Following these recording methods then allow the mixing engineer to follow proper surround sound mixing techniques which then lead to

improved levels of immersion in cinema, music, and video games. The audio industry has come a long way from its humble beginning but I would strongly argue that they have barely started scratching the surface of spatial audio. Spatial audio will continue to change and grow overtime and will eventually overcome stereophonic sound. We are starting to see the overthrow of stereo with spatial audio music becoming more prominent on streaming platforms. Eventually everyone is going to be listening to crisp, lifelike, immersive spatial audio.

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