Immersive Fan Engagement in Basketball Using Spatial Audio and 5G

Fan Engagement in Basketball
An exploratory study of the impact of audio on the fan experience in Basketball and the possibility of improving this experience using spatial audio.

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Basketball is the second most popular game in America after Football. It is viewed and followed by over 300 million people around the country. The fan experience at the stadium varies significantly as compared to watching the game at home. Most fans watch the game from the comfort of their homes rather than at the stadium due to varied reasons including but not limited to the cost of the tickets and the location of the match. Through this study, we aim to understand the different aspects of the game that affect the overall fan experience, with a deep dive on the audio component and an additional focus on making the sport inclusive to the visually impaired. We want to provide an immersive experience using technology like Spatial Audio, 5G networks and Machine Learning to promote inclusivity and better fan engagement.

Additional Keywords and phrases: Basketball, Fan engagement, Spatial Audio, Single study experiment

1. INTRODUCTION

The NBA is one of the most popular games in America. The viewership for the game has shot up by 19% for the years 2020-2022 across three broadcasting stations ESPN, ABC and TNT. The gross viewership of the game is about 5.83 Million across these channels [35]. An analysis by TopEndSports indicated that there are approximately 300 Million Basketball fans worldwide [37]. The experience at a stadium is very different from the experience at the stadiums because of the high energy in the crowds, the fan chants, and the different fan engagement strategies that have been implemented. These elements are missing when watching the match outside the stadium. However, stadium experiences are often fraught with delivering on matching expectations with cost and the promise of a high quality exciting game [38]. With the rise of communication technology and sports media broadcasting, there is now an opportunity to improve the overall fan experience and make the experience more stadium-like for those watching the game at the comfort of their homes.

Since basketball is primarily a spectator sport, the visually impaired have to be assisted by a sighted companion or rely on the commentary to be able to follow the game. However, the fan engagement aspects can be extended to them through the use of gameplay audio and tactile representations. While an audio descriptive live commentary is able to provide a more clear picture of the game than just live commentary, there is often a delay in information relaying due to the increase in the amount of information that is being relayed. This creates an off-putting experience overall because these audio descriptions are usually monotonous and robotic. The essence of gameplay sounds and experience is lost in these audio descriptions.

The delay in information relay can be avoided using 5G and the gameplay audio can be relayed as an addition to live commentary using spatial audio. The 5G network has zero latency which removes any delays or loss of information while transmitting data leading to a lossless transmission. Additionally, it has a massive advantage over existing network bandwidth in terms of network reliability, energy efficiency and overall connectivity [32]. Spatial audio provides better clarity, especially in the transmission of live audio [39]. We hypothesize that spatial audio can help provide a better experience overall in terms of the positional and directional aspects of sound as it gives the added advantage of replicating sound in the way it is heard in real life.

In this paper, we aim to understand if our hypothesis holds true by understanding the impact of audio on fan experience. We conducted interviews and a single subject experimental procedure to research the importance of audio in basketball. With the help of interviews, we aim to identify the different types of audios involved in the game that affect the experience and what factors lead to a difference in experience at the stadium vs at home. Interviews with basketball players along with fans ensure that we can propose solutions that are acceptable to both the parties involved in the game of basketball. With the help of single study research in a live environment we aim to understand if location and event mapping can be done without any visual aid and consequently to understand the importance of audio for the game of basketball.

2. RELATED WORK

2.1 Event recognition from audio signals

There have been numerous attempts in the field of audio engineering to recognize events from visual data. Audio information from a video can be used to determine important events based on pitch and sound modulation.

Various machine learning algorithms have been used to identify highlights in sports. These methods range from the use of OpenCV or Image Processing algorithms for analyzing the video and audio based identification of the events [40]. A combination of audio from the audience and commentary can be used to determine when there are advertisements or an important event occurring in the game of basketball using time series analysis [9]. Additionally, there has been research specific to recording spatial audio using sensors like Soundfield microphones that can now be used to provide a 3D sound experience [14].

New trends in audio production and broadcasting also make use of sports audio objects in Basketball for immersive sound and interactive broadcast applications [11]. Various types of audio taxonomy have been used in order to identify the exact event taking place like tagging the sounds as natural audio events, technical events, and speech to text analysis from the commentary [11]. Filippidis, Panagiotis-Marios, et al. tagged audio sounds like that of a foul, referee whistle to detect different events that occur during the game of basketball. These different possible ways of event detection form the basis for providing an immersive experience in sports.

The conversations between players and the sounds from the actual gameplay were not considered as a part of the existing research.

2.2 Audio coding for spatial audio

Audio coding is done by various broadcasting stations to compress the amount of data that is being transmitted. The main aim of audio coding is to break the signal down into its constituent parts and assemble them at the receiver end such that the audio is similar to the original.

Christof Faller in his paper recommended parametric coding of spatial audio to ensure high quality of audio at the receiver end [12]. MPEG Spatial Audio Coding Reference Model 0 architecture is another audio coding mechanism that can be used to obtain high-quality encoding [13]. Audio coding ties in with the transmission of the signals in order to provide optimal immersive experiences.

2.3 Use of 5g Technology

The invention of 5G networks has enabled a new era in the domain of broadcasting. 5G makes an enormous leap in improving the broadcasting speeds and network compatibility as compared to its predecessors [32,33]. It enables data transmission at ultra low latency and makes it possible to have instantaneous live streaming of sport events available on smart phone devices [31]. Hu Dujuan in his paper on mobile communication of sports in the 5G era speaks about how 5G leads to an increase in the range of content as well as the quality of information that can be made available to mobile users [34].

We expect that 5G would play an important role in improving the overall fan experience as it has speeds nearly ten times that of 4G networks and a latency of less than one millisecond [41]. The fans would no longer have to hear their neighbors cheer for an important event that they have not seen yet due to low transmission speeds. We hypothesize that it is yet another essential puzzle piece that could help provide a captivating experience along with the use of technologies like machine learning and spatial audio.

2.4 Accessibility

Inclusion is our top priority as designers, and a little bit of imagination always goes a long way. For a game like basketball, there were multiple questions that needed to be answered to make it accessible for the visually impaired. How would they know where the ball is on the court? How would they know that their favorite team made a basket? How could they keep track of where the players are? [36]. There are attempts at making sports inclusive for the visually impaired such as FootBraille [42], and basketball for the blind [43]. We found these attempts to make sports more inclusive as an inspiration and aim to deep dive into the fan engagement aspect for the visually impaired for Basketball as our end goal.

Visually impaired athletes and games for the differently-abled are leading avenues for technological innovations for accessibility tech. Blind athletes are better judges of spatial sound as compared to sighted non-athletes [19]. Sports within the visually impaired community are being encouraged through camps like Thunder [26] where visually impaired kids are paired with sighted peer counselors who ensure they take part in sports and have a holistic social interaction experience.

There are several attempts being made to make sports experiences more accessible and inclusive for visually impaired fans. eSight, a company that creates electronic glasses for legally blind people tested a pair of glasses with a young NBA fan with aniridia, enabling him to see his favorite game clearly for the first time [27]. Current in-stadium solutions are aimed towards wayfinding, universal design, hands-free communication, and descriptive commentary of the game [20, 23]. Newer technologies like tactile graphics, voice commands, and spatial audio are being promoted as an aid to descriptive commentary to make the experience more immersive.

Some attempts at integrating tactile graphics into solutions have involved using a camera to track player positions and depict them to the users via a refreshable tactile display [2]. However, this solution is limited by the size and cost of refreshable tactile displays. They are heavy and burdensome to carry and not everyone will be able to afford one of their own. Sports stadiums are unlikely to invest in providing their own as the investment would be larger than the payoff. Other haptic solutions, like the Fujitsu Ontenna are aimed at a more universal design for relaying information through sound modulation, lights, and vibration although it is more aimed towards hearing impaired users[23].

Audio and speech feedback has always been an essential form of information processing for the visually impaired [1]. This is especially true of certain early-blind people who use active echolocation to explore the area around them [24]. Active echolocation is carried out using tongue clicks and gauging the sound reflected to understand the presence of obstacles around provided they are big enough to bounce the sound back to the listener [22].

General accessibility tools use text-to-speech audio and voice commands to make it easier for the visually impaired to carry out daily tasks such as home assistance [4] and navigation [6]. All contemporary smartphone OS has a built-in accessibility feature that can be turned on and off as required to enable people to use their smartphones simply.

Given their high receptiveness to 2D audio, 3D audio will provide a richer auditory experience to the listeners. Spatial audio gives a clearer understanding of the environment to the visually impaired and helps them create an auditory map of their surroundings in their mind [10, 28]. Research shows that 3D audio is more effective in creating spatial awareness compared to verbal commands and communication since it is a minimal attention interface leading to lesser cognitive load on the subjects while at the same time giving more meaningful cues to the subjects [5, 30]. Spatial audio can also affect the representation of a physical space in a sighted person's mind [29].

Research shows that the visually impaired are easily able to keep up with the game when provided with descriptive commentary as well as 3D sound cues and are enthusiastic about a system that gives them the independence to enjoy their favorite game [3]. Hence in this paper, we would be focusing on understanding the audio aspects and improving the experience of a fan from an auditory point of view.

2.5 Emerging Trends in Basketball

Ever-growing technology has already led to the development of new innovations that have helped create an advanced fan experience. For a more organic spatial audio experience, mics are embedded throughout the court. [7] This not only creates a realistic fan experience, but the audio has much less profanity since it's just picking the audio in the stadium and not carrying it. Having this immersive experience helps fans dive right into the heart of the stadium because they can listen to the sound from all directions. The main drawback of this solution is that it is very expensive to embed microphone sensors throughout the stadium. It is also not easily scalable to all stadiums where basketball matches take place.

Today, advances in technology have also given room for signal processing and speaker design to make compact soundbars and even TVs have very effective and enthralling 3D experiences and soundscapes [18][16]. And this development in technology can enhance the fan experience by creating captivating audio and visual settings. Next-Generation Audio or NGA has the ability to let the user adjust the volume of the commentator to suit their preferences. They can swap introductory level commentators explaining the offside rule in football, to the team commentator giving the audience some tea from the locker room [18].

All the related work points towards the different technologies that are necessary to provide an enhanced fan experience. Using the different algorithms mentioned above for event detection, audio signals from the game that can be transmitted instantaneously with the help of 5G, and audio coding for spatial audio can not only aid in making the experience more immersive but also inclusive. With all the various technologies at play here, we do realize that there is still a need to analyze the technical feasibility of our solution. With this paper, we aim to explore and re-visit the various aspects of Basketball, keeping in mind inclusivity for the visually impaired and to ultimately try and create a fully immersive fan experience for the game.

3. RESEARCH QUESTIONS

This study sets out to understand the area of fan engagement for the game of basketball and the different factors that affect a fans experience. Audio can be used to determine different events happening from a given video [11]. Each action performed has a unique audio associated with it. We hypothesize that a fan would be able to understand the different important events occuring in the game with the help of audio and that using spatial audio can further enhance their experience.

Despite all the current advancements and ongoing research, there are a few drawbacks in the current methods used and a few gaps that are yet to be filled. Most of the existing research has been on the basis of advancements in technology and what can be achieved. In this paper, we conduct an exploratory research into understanding the different aspects of the game that elevate the experience of a fan at the courtside and how it differs from the experience of a fan streaming the game live.

Through this paper, we aim to understand the impact of audio on the overall experience of watching a basketball game. We do this through four main research questions. First, understanding the extent to which audio plays a role in improving the fan experience. Second, what aspects of the game play the fans deem important. Third, can the fans identify the gameplay through sound only without relying on visual cues. Fourth, would players be okay with their conversations being captured and would we face any ethical issues with the same.

4. METHODOLOGY

4.1 Interviews

The first step for the exploratory research was interviews. Interviews were semi-structured in nature with a certain flow being pre-decided by the research team and letting the participants guide the flow of the rest of the conversation. The interviews were thus conducted in two phases. The main objective of the interviews was to understand the motivations for an average basketball fan and identify what drives them to the game. The main themes that we wished to uncover were - i) reasons for affinity towards the game, ii) what defines the current fan experience, iii) the extent to which audio plays a part in enhancing the experience, iv) the feasibility of a spatial audio solution and whether or not fans would be inclined towards it.

Phase 1 - In the first phase, we kept the interview more informal, getting to know the background of the interviewees and how they were introduced to the game of basketball. This was followed by questions regarding their current experience with the game, the frequency at which they followed a tournament be it NBA or college basketball and their opinions on the difference between in stadium vs at home viewing for the game.

Phase 2 - Before starting the second phase of the interviews, we gave the interviewees an explanation of the research that we are conducting in order to acquaint them with the terminology of spatial audio and 360 degree audio that we would be using for the second phase of interviewing. The second phase was more structured where we asked the participants questions relating to the specific role of audio in the game of basketball, the different audios that they experienced when watching the game and how they ranked these audios in terms of priority considering what the audios were adding to the overall experience.

For the wrap up section after completing both sets of interviews, we asked participants regarding their general opinion on fan engagement for basketball and what they think could be added to our solution to make it more wholesome. The interview

sessions were recorded and transcribed with the permission of the participants. The transcriptions were used for the coding of the interviews and identifying patterns within the codes. This was done using affinity mapping where we first identified the major themes within the codes and then grouped together similar patterns within the broader themes.

Image 1. Snapshot of the affinity mapping done for the interview codes

4.2 Experimental Research

The experimental research was carried out to understand whether or not spatial audio can be used to identify/map the game by the participants if they don't have visual aids to help and consequently, understand its impact in improving the basketball fan experience. In order to measure the impact, we attempted to replicate the approximate audio experience by performing the activities in a 3D environment. It was ideally a think aloud exercise conducted out in the field where participants were asked to describe what they were thinking and hearing and attempting to map the sound to a specific action within the game.

The task was conducted with participants on an outdoor basketball court. To understand whether the users would be able to map sounds to known gameplay techniques, they were not allowed to use any visual cues. Participants were blindfolded to ensure they would not be able to use visual aids and asked to describe the sounds they were hearing in terms of the gameplay. The tests did not have any specific time limits set and participants were asked to continue the experiment till a certain number of actions had been completed within the game.

Participants were asked to stand at the half court line outside a court where a game was taking place. One of our interview participants mentioned that the middle is the best perspective to view the game which is why half court was chosen as the place to situate the experiment participants. The experiment was continued till the participants could definitively answer yes or no to the following answers being performed - i) Ball on right and left side of the court, ii) Ball near and far from the

participant position at half court, iii) Passing of the ball, iv) Basket or no basket. Answers where participants were unsure about the action being performed were not considered unless the confusion occurred two or more times in a row.

4.3 Participants

We recruited two sets of participants for the research - interviews and experiments. For the interviews, we recruited 10 participants (n=10), all male between the ages of 20-32 (Median age = 25). The participants were identified to be fans of the game of basketball who followed the game at various levels from the NBA to college basketball. Four participants (n=4) played basketball at high school and national level. They were termed as more "hardcore" fans, as self described by one of them, who were more passionate about the various fan engagement options available.The participants were from varying backgrounds, most of them were students while some were working professionals , and one was an ex-employee of the NBA. All participants were primarily based in the United States.

For the experiment, we recruited 6 participants, of which, 1 was a trial participant whose results were not considered for analysis (n=5). All participants in this experiment were students of IUPUI. There were 3 male participants and 2 female participants, between the ages of 20-28 (Median age = 24.4). There was no criteria for selecting participants for the experiment as long as they were familiar with the game of basketball regardless of whether they followed the NBA or not.

Trial Participant - The experiment was first conducted with a member of the project team. The trial experiment was carried out to understand whether such an experiment would be feasible to conduct. The initial plan for this experiment was for the participants to stand in the middle of the court while two volunteers performed a set of tasks around them. This was discarded with the help of the trial participant as we realized this would not replicate the feasibility for a real, full fledged game. Hence for the other participants we changed the protocol to observing a complete game of basketball.

5. RESULTS

The results of the interview session were coded and categorized based on certain patterns that were observed. These patterns were then used to derive conclusions regarding the research questions of this exploratory study.

Role of audio in improving fan experience

This aspect was explored during the first phase of the interview. Participants were asked the specific aspects that improved and added to their in-stadium experience of the game. Energy of stadiums and audience cheering was a pattern that appeared 8 times throughout the interview codes. One participant mentioned that the crowd reactions enhanced the enjoyment of the game in the stadium as it was easier to get swept up by the crowd cheers and chants when watching the game.

"There's a different energy about it right because you're in there you hear the stadium chanting. And whenever someone scores, for your team you hear the whole audience go off. Definitely, just like the aspect of being there and being able to cheer, there's more energy or a situation for sure."

Another participant mentioned that audience heckling was the most fun part of being in a crowd at a stadium as it would be the most nondescript people shouting out the most obscene reactions to the game.

Stadium experiences	Energy of the stadium and audience sounds	Hearing the players talk	Viewing the game up close	General sounds of the game
Responses received	8	7	4	2

Table 1. Various positive patterns of the stadium experience and the number of times that pattern appeared in the coding

Hearing the players talk appeared as a pattern 7 times. Participants mentioned that the biggest positive of going to an in-person game would be the opportunity to hear the players talk amongst themselves. One participant mentioned that they enjoyed listening to the player calls and hearing the teams trash talk each other. Another participant said that it was possible to hear what the players were saying to each other during the game which made the whole experience feel more real for him.

"Just like the actual sound of the court, sometimes like hearing the ball dribble, hearing the ball go through the net makes a really nice sound being able to hear that [would also be nice]."

General sounds of the gameplay appeared as a pattern 2 times and was considered as an attraction for participants when choosing to go in person to a game. One participant mentioned that the in-game sounds were louder and more pronounced when heard in a stadium.

Prioritization of gameplay audio

In the second phase of the interviews, participants were first explained the concept of spatial audio and how we suggest its use in improving the game watching experience. Keeping this in mind, participants were asked to describe the various audio types they could identify in basketball and how each adds to their overall experience. These responses were used to code the below table for understanding which audio types would add the most to a game watching experience.
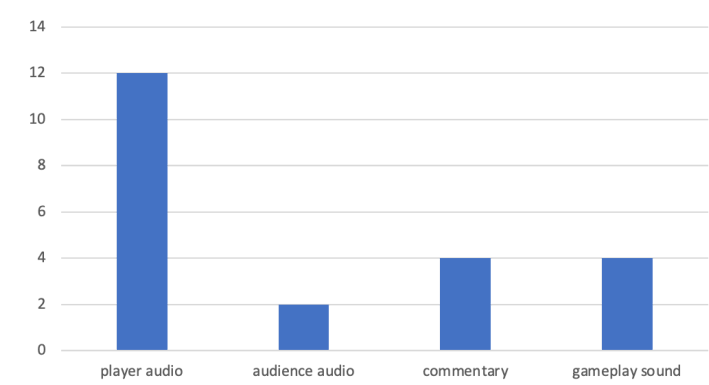

Image 2. Number of patterns observed for what audio could add the most to the game watching experience

12 patterns were observed for player audio where nearly all participants talked about player audio being a desirable aspect of a spatial audio experience for the game. Some participants merged other scenarios with this audio aspect where they expressed an interest in understanding what players and coaches talked about on the courtside as well as getting an inside look at the team huddle to see how they operate. Participants who spoke about hearing the players talk in the previous section reiterated their sentiments in this section about it adding to the experience and the potential of it providing an enhanced stadium like experience even at home. Additionally, participants who did not speak about player audio in previous sections at all also spoke about player audio in this section denoting that it is a highly desirable trait from a project like this.

Commentary and gameplay sounds were rated equally by the participants. One participant expressed satisfaction with the current experience with commentary stating that it was "already good enough" at explaining games in real time. We received two opposing views regarding the gameplay sounds where one participant felt that the dribbling and shoe squeaking sounds would be a great ambient addition to the game. On the other hand, another participant was completely against the idea as they found the shoe squeaking to be "off-putting" as they described it. Hence, this project would have to consider how opposing views like these could be balanced and what should be prioritized in providing the spatial experience to the users.

A surprising aspect was that audience audio was least mentioned when speaking about audio experience. This was a complete contrast to the previous section which mentioned the audience as the most important aspect of creating an in stadium experience. Based on the phase 1 conclusions, it was our assumption that audience audio would also be an important factor when creating the ambience for the immersive experience we are looking for. However, it seems that the fans would not be interested in the same as some deemed it to be "too distracting and loud" for a headphone experience.

Audio mapping of sounds to gameplay events

An important aspect of this study is to understand the feasibility of spatial audio and audio mapping for a fast paced game like basketball. The experimental research provided insight into this aspect. All participants were able to recognize basic actions such as the ball position on the court, right or left side of the court, and the distance of the ball from their own position. All participants except one were able to recognize that a ball was being passed between players on the court. More notably, 2 out of 5 participants were also able to recognize long vs short passes. This was defined in terms of the pass taking place from one end of the court to the other(long) vs the pass taking place on the same side of the court (short). Participant 1

defined a pass audio as the thumb or palm hitting the ball hard. All participants were also able to recognize that the ball was hitting the headboard or the rim based on the definitive "clang" sound of the ball being bounced off both those objects.

Basket being made or not being made was termed as an ambiguous event. When the ball hit the headboard especially hard, all participants were sure that the ball must have rebounded and the basket was missed. Participants 4 and 5 were able to recognize baskets when it was a smooth shot and defined it as a "swish" sound of the ball going through the net. However, when it was a less smooth shot or if the ball hit the headboard or rim softly before going through the basket, they were more reliant on other sound cues like cheering or groans to identify if the shot was being made. This was termed as unreliable audio as there could be cheers from either team side depending on whether the shot was made or not. This was the problem faced with participants 1 and 2 as they were relying on hearing cheers and claps to deduce whether a shot was made or not, and their deductions were often wrong. Participant 3 as well depended on claps to tell him whether or not a shot was made and was able to correctly recognize that a shot was made. However, it should also be noted that during his session, the players called out "good shot" when the shot was made. Hence, player and audience sounds are an important factor in recognizing the gameplay.

Finally, none of the participants were definitively able to identify that the ball had bounced out of bounds or wasn't in play. There were no specific audio markers for this action and hence would require added cues of commentary and player audio to be able to recognize. Participant 3 was the only one able to recognize a ball being out of bounds and the game restarting post a throw-in due to the relative amount of time it took for the game to restart. Other actions like the ball randomly bouncing on court while not in possession of either team also went unrecognized as the participants attributed the bouncing sound to the ball being dribbled. Periods of no play were also confusing when the game was halted for a brief break or if players were regrouping on court. However, many participants were able to track player movement across the court even when they did not have the dribbling sound to follow. Player density on the court was recognized by participant 5 based on sounds of footfalls on the court.

	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5
Ball Position on court	Yes	Yes	Yes	Yes	Yes
Ball distance from participant	Yes	Yes	Yes	Yes	Yes
Ball being passed between players	Yes	Yes	No	Yes	Yes
Basket being made/not made	No	No	Yes**	Yes	Yes
Ball hitting the rim or headboard	Yes	Yes	Yes	Yes	Yes
Ball out of bounds	Event did not occur during session	Event did not occur during session	Yes	No	No

Table 2. Audio events that were tracked during the experimental research

Another important aspect to consider here is the knowledge of the game. We noticed that participant 5 had slightly more knowledge of game rules than the other participants. Hence, when thinking aloud, they asked more specific questions. For example, when the participant heard an attempt to shoot by one of the players, the participant asked if the teams switched courts to keep a track of the scores. This confusion would have been addressed if there was access to visual cues as the color of the jersey would have provided the information needed to understand the switch. Participants comparatively less invested in the sport did not ask these questions.

Ethical Ramifications of capturing player audio

As 8 out of the 10 participants prioritized the player conversations as a form of audio that majorly impacted their experience as a fan, it raised the question of ethical ramifications of capturing the player audio. We wanted to further understand the

players perspective on how they felt about their conversations being captured and broadcasted during the live game. 58% of our participants felt that players would be open to the idea of their conversations being captured and broadcasted. 3 participants mentioned the practice of mic-ing the players during live games and felt that the spatial audio experience would not be much different from this in terms of the conversations that are captured. Another participant mentioned the player conversations are generally limited to smaller phrases like "*guard him*", "*watch that*" etc.
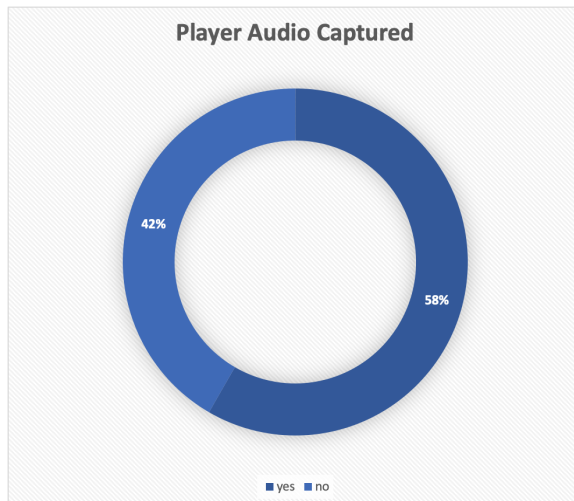

Image 3. What the participants answered to whether or not player audio should be captured

4 of our participants were also basketball players at national and high school levels. 3 of these players thought it would be okay if their audio as players was broadcasted as a part of the spatial audio. These players however mentioned that despite the opponent being able to pick on studio based strategy eventually, capturing the player sounds may make it easier for the opposing teams to analyze their codes. All the players mentioned that though they are open to the conversations being captured, they do not want that audio to be stored for future analysis.

However, one participant, an ex-employee of the NBA, shed some light on this aspect of the research. They mentioned that there could be PR-related issues with streaming player audio without any filtering. According to him, the current streaming and cable services for the game have agreements in place regarding what can and cannot be aired, and this needs to be filtered out before being provided to the consumers. This was interesting because this was the first time we understood the administrative side of things. Hence, going further in this study, along with exploring the technical feasibility, it will also be valuable to dig into administrative limitations of incorporating this idea.

6. DISCUSSION

We presented four classes of finding around the role of audio in fan experience, the users priority into the different types of audio, if the users are able to map the different sounds to identify the gameplay events in the absence of any visual aid to further understand the impact of spatial audio on fan engagement and the ethical ramifications of capturing and broadcasting player audio. We focused on improving the fan experience with the help of audio enhancement to make the sport more inclusive to the visually impaired.

Accessibility
Current solutions for inclusive fan engagement for the visually impaired fall into two main categories - (i) Audio-based engagement - where the visually impaired are provided with audio descriptive live commentary to keep up with the game [8]; and (ii) Visual based engagement - where people with higher sight deterioration are given highly magnifying glasses to be able to view the game [27]. We focused on replicating the concepts of echolocation to make the game more accessible and to reduce the dependency of the visually impaired on a human companion [24].

Importance and user preferences for audio
With the help of interviews and Single subject experimental research, we were able to identify that a fan can understand most of the gameplay based on just audio cues. The participants were able to map the position of the ball and identify the actions performed with the help of different audios in different situations. For example, the participants depended on the audio from

the audience to understand if there was a basket while the amplitude of the ball dribbling helped in identifying the location of the ball on the court. This aligned with our hypothesis that a fan would be able to understand the different important events occuring in the game with the help of audio. The main confusions faced by the participants were during situations which did not have an audio associated with the event. For example when the players swap courts post half time. In these situations commentary or an audio coded signal may be necessary to communicate the change. Hence instead of mapping the entire gameplay, it is more important to tag non-obvious actions such as taking a corner, ball not in play etc. This experiment was conducted at an outdoor court. Though we expect the results to hold true for an indoor stadium experience as well, the user testing is a part of our future work.

Broadcasting player audio

The participants during the interviews showed a strong preference towards wanting to listen to the players' conversations during the game to make the live streaming experience similar to the experience at the courtside. This raised the question on the ethical ramification of broadcasting the player conversations. On conversing with multiple players in state level and university level basketball, around 60% of the participants claimed that they would not have a problem with their conversations being broadcasted as long as it's not stored for posterity. However, further research needs to be done to understand if these findings hold true for the NBA as well.

Proposed Solution

Based on our findings, we propose a design solution where an audio sensor will be placed inside the basketball that could aid in capturing the different audios of the game. This audio will be transmitted over a 5G network, thus ensuring instantaneous relay of information. Different machine learning can be used to ensure there is little to zero disturbance (noise)and also to map the location of the ball on the court. Additionally, it can be used to map the imperceptible actions with audio cues to help users visualize the game with help of audio. This spatial audio mapping aspect would essentially help in making the game more inclusive for Basketball fans with low or no vision. In our future explorations of this study, we would like to research about the extent to which spatial audio helps in making the game inclusive.

7. CONCLUSION

We presented an exploratory study into understanding the impact of spatial audio in fan experience. We find that most of the fans mention that one of the major differences between the experience at the stadium vs watching the game live was due to their ability to hear the conversations of the players and the audience. From our research we have uncovered that different types of sounds are involved in enhancing the overall experience of a fan. Different audios like that from gameplay, commentary, audience and player conversations together enable a fan to understand the gameplay with the help of audio even without any visual cue. The fans hence wanted the option to toggle and moderate different gameplay sounds. Additionally, basketball players seemed to be okay with their audio being broadcasted if they were not stored for future analysis by the opponent teams. They mentioned that the players are occasionally mic'd up during the game currently as well. With the help of this research we were able to identify that audio does play a very important role and spatial audio would aid in enhancing the overall fan experience. For future work, we would need to look into the accessibility aspect of the solution and to what extent would it help making the sport more inclusive to the visually impared.

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