# 1 – Introduction

In recent years, Virtual Reality (VR) and Mixed Reality (MR) has seen a growing use in the music industry typically tailored towards live events. These technologies take advantage of the immersion created by a virtual environment beyond a physical location to simulate the concert experience.

This shift towards more virtual alternatives can bypass the limitations of traditional live events, such as travel or pricing issues, allowing for a more global reach for artists and their fans. While other options have been explored, like livestreaming, has seen some success they ultimately fall short when it comes to immersion and user interaction.

In this report we will explore the role of VR and MR in live music events, providing critical analysis and high-level discussion of the design, benefits and challenges of its use.

# 2 – Literature Review

### 2.1 – Paper selection Summary

The papers analysed in this report have been chosen based on a variety of criteria such as: *Relevancy* – ensuring the paper focuses on VR/MR applications for concerts, *Recency* – ensure the research in the papers are relevant to current discussions/challenges, and *Credibility* – ensure research is coming from reputable and academic sources.

### 2.2 – Paper Analysis

**Paper 1: “Research Trends in Virtual Reality Music Concert Technology: A Systematic Literature Review” (Park, Choi, & Lee, 2024)**

* *Research Problem*: The use of VR in musical concert is in its infancy and thus is lacking in understanding of audience immersion/engagement and environment design.
* *Research Domain Challenges*: This is challenging as the solution needs to provide quality visual and audio experiences while still delivering an immersive level of interaction between audience and artist.
* *Importance*: identifying the trends that allow for audience immersion and usability/accessibility to make the experiences more engaging.
* *Proposed Solution*: There was no direct proposed solution as this paper was a literature review however there are some interesting things to consider. Virtual Reality in the context of concerts tend to have a bigger focus on the artist, more so than the social elements within real-life concerts. Additionally, there is discussion about how music can be adjusted per person, so that it could either mimic what it would feel like in that spot within the audience or to tailor to preferences of the individual.
* *Immersive Impact*: the study investigates the concept of Flow State Scale, which is when users are totally immersed in an activity. As well as diving into FSS, the paper explores many techniques, such as haptic feedback suits and real-time motion tracking to increase the immersion felt by the user.
* *Key Takeaways for Our Project*: User avatars are a great way to increase immersion as it allows users to have more expression of self within the simulation. Additionally, having multiple positions where the user can “stand” might be good to include as it may change people’s habits.

**Paper 2: “The Sentiment of a Virtual Rock Concert” (Slater, M., Cabriera, C., Senel, G. et al.**, **2023)**

* *Research Problem*: Understanding the response of participants in a virtual audience during a VR concert (more specifically a recreation of a 1983 Dire Straits concert), and how that the results and methodology could be used to improve similar scenarios, both in participant sentiments and concert reconstructions in general.
* *Research Domain Challenges*: The study found that participants experienced negative sentiments caused by the virtual audience, reporting feelings of harassment and the sensation of being stared at.
* *Importance*: This study highlights the importance of audience behaviour in the virtual experience to improve user comfort and immersion by addressing potential negative reactions.
* *Proposed Solution*: A co-design for VR scenarios, and the use of sentiment analysis in the process instead of solely relying on traditional methods such as questionnaires.
* *Immersive Impact*: Plausibility was enhanced with responsive events and spontaneous reactions when the virtual characters in the audience respond to the participant’s actions, meeting their expectations of realism. Presence was enhanced using spatial audio and realistic animations, contributing to the increased presence of the participants.
* *Key Takeaways for Our Project*: Realistic audience behaviour and sentiment analysis should be used to make the experience more user-centred for enhanced immersion.

**Paper 3: "Concert Experiences in Virtual Reality Environments" (Kelsey E. Onderdijk, Lies Bouckaert, Edith Van Dyck, Pieter‑Jan Maes, 2023)**

* *Research Problem*: The paper investigates the experiences and motivations of attendees in VR music concerts. It delves into how VR concerts compare to physical live concerts.
* *Research Domain Challenges*: Since VR concerts are considered a relatively invention, the problem lies with how VR can replicate or enhance the live concert experience in comparison to physical concerts, particularly looking at social interaction and immersion and what is done to address said problems.
* *Importance*: Insights from this research can inform platforms that develop VR concerts on how to enhance user engagement and shape the future of virtual music events.
* *Proposed Solution:* The study uses numerous methods, combining qualitative and quantitative surveys, to analyse the attendees’ motivations and experiences. The findings suggest that VR concerts are valued for their uniqueness, visual effects, and accessibility as they create an environment that is free for many and unique in customizability but falls short in comparison to physical concerts*.*
* *Immersive Impact:* MR is increasing immersion mainly through VR headsets, enhancing the sense of presence and making the attendees feel more connected to the concert environment and the artists. The study found that specifically highly immersive VR environments improve the social presence and emotional engagement of attendees by creating an experience unique to the artist whilst also maintaining the feeling of physical concert.
* *Key Takeaways for Our Problem:* The role of first-person perspectives and embodying that which makes users feel present, and a need to integrate interactive features that improve social engagement, such as real-time audience interactions or VFX design specific to the VR environment.

**Paper 4: "Enhancing Participation Experience in VR Live Concerts by Improving Motions of Virtual Audience Avatars" (Hiromu Yakura, Masataka Goto, 2023)**

* *Research Problem*: This paper covers the comparison of user participation and social engagement between real-life and virtual experiences. Where traditionally the physical crowd of a concert contributes towards the atmosphere/feel of an event, virtual experiences seem to fall short as users often watch alone or in small groups, limiting social interaction thus limiting overall immersion.
* *Research Domain Challenges*: A clear challenge is the complexity, both technically and conceptually, of achieving realistic social interactions. Additionally, network latency can disrupt synchronized movements, and simple mirroring of a user's own gestures can feel unnatural and inauthentic.
* *Importance***:** Since social interaction is such an integral part of live events, bridging that gap within a virtual experience is a challenge. Since virtual experiences rely on real-time user data to animate audience movements, a low attendance can lead to feelings of isolation for the user.
* *Proposed Solution:*Some methods explored in the paper include the mirroring of user movements onto the virtual audience, using past user data to simulate crowd movement, animating avatars in time with the beat of the song, and the use of AI or machine learning to synthesise avatar behaviour.
* *Immersive Impact:*With virtual audience members exhibiting realistic movements to the music, users will feel more immersed in the experience as part of a larger engaged social group, enhancing emotional and sensory connection to the experience.
* *Key Takeaways:*Beat-Synchronous Animation - Incorporating movements that align with musical rhythms to make the environment feel more interactive. Avoiding Self-Replication - Users found it creepy when their movements were mirrored, so designing distinct, natural crowd behaviours is key.

**Paper 5: “Bringing back the ‘live’ into the digital: Semiotics on the emergence of live VR in music concerts” (Jenske Verhamme, 2020-2021)**

* *Research Problem*: Live music events have traditionally been defined by artists and the audience sharing the space at the same time to produce a unique experience. This paper tackles the problem of reconstructing the feeling of ‘liveness’ in a virtual/digital environment.
* *Research Domain Challenges*: The main challenge brought up in the study was deriving a definitive definition for the concept of ‘liveness’ in a virtual world. Since a VR experience cannot rely on the physical aspect of an artist’s presence, the challenge is to create a convincing illusion of real-time interaction whilst still distinguishing itself from a prerecorded experience.
* *Importance*: Understanding the cultural impact of a VR concert is important as to replicate ‘liveness’, allowing these digital experiences to become a more legitimate alternative to traditional events. This will further the shift into the digital age and create more accessible experiences for a wider audience.
* *Proposed Solution:*The solutions explored in the paper are various semiotic frameworks. ‘Structural Semiotics’, this is the analysis of how the ‘signs’ within a virtual concert function and the construction of their meaning. ‘Peircean Semiotics’, this explores how the audience interpret/perceive the virtual space they are in. ‘Lotman’s Cultural Semiotics’, this examines the role of virtual concerts within the culture and evolution of live music events.
* *Immersive Impact:* Immersion within these solutions is enhanced by spatio-temporal coherence, user interactivity, and more elaborate settings that subvert the audience’s expectations and the laws of physics.
* *Key Takeaways:*Some concepts that we cantake away from this include the importance of redefining ‘liveness’ to develop a unique and immersive experience, encouraging user interaction, and blending reality with the integration of MR.

**Paper 6: “Methods and Techniques for Capturing Music Concerts for Virtual Reality Experiences” (Stephanie T. Benicek, 2018)**

* *Research Problem*: Since traditional techniques for recording concerts often fail to capture the spatial and immersive aspect of true live music events, this paper investigates how 3D audio techniques and VR-compatible recording setups can improve concert immersion.
* *Research Domain Challenges*: The broad challenge presented by this paper is optimising live performance recordings for VR experiences. The smaller, more technical aspects of this challenge consist of playback optimisation, microphone placement, audio spatialisation, and mixing techniques.
* *Importance***:** The understanding of proper sound design is important in makingperformances feel less artificial and detached. This is needed to bypass the barriers of accessibility like cost and location.
* *Proposed Solution:* The techniques of audio capture explored in this paper consist of spatial mixing, technology that make use of ambisonics like Sennheiser AMBEO microphones or an Equal Segment Microphone Array (ESMA), and user testing.
* *Immersive Impact:* Realism of the experience is enhanced by the use of 3D audio rendering, head-tracked audio, and binaural processing (essentially surround-sound audio). Combining these techniques with high-quality visual elements can help the audience’s feeling of presence in the experience.
* *Key Takeaways:* The most important concept to take away from this paper is the importance of an accurate atmosphere and ambience in a virtual environment. This is achieved through realistic sound capture, the balance of direct and indirect sound, and taking spatial awareness into account when processing the audio.

# 3 - Comparative Analysis and Critical Discussion

Over the course of the studied papers, many key themes, encompassing the various dimensions of a collaborative space in a VR concert, became most prevalent, those themes include but are not limited to Immersive techniques, Social factors, Audience behaviour, The feeling of “liveness” and finally then the more technical aspects of solutions.

When it comes to Immersive techniques the recurring ideas were ides such as haptic feedback, motion tracking and spatial audio rendering to enhance the immersion of a virtual music event. While certain methods such as spatial audio, head tracking and having users being able to interact with their environment are generally agreed to further the immersive experiences of audiences, certain put forth ideas have come under scrutiny such as the idea of mirroring the user behaviours and movements onto virtual members of the audience, as they often made users feel uncomfortable, and often described as uncanny.

Widely thought of as one of the hardest barriers to overcome in VR concert space is the lacking social engagements which are foundational to traditional concert experiences. Virtual music events tend to leave users feeling a sense of isolation furthering the sense that virtual concerts are lesser than their physical counterparts. Most research solutions mention the use of interactive avatars for users to engage amongst themselves with, coupled with interactive audience reactions. This all contributes to co-presence and the feeling of attending a concert with others as opposed to just by themselves. There should be a variety of integrated social feature that allow for users to attend concerts with friends. As it currently stands digital events still fall short in the social aspects but further additions of AI audience members who can interact in real time and improvements in user-to-user real time interactions may begin to bridge this gap between physical and virtual.

The audience is often regarded in most reports as one of the most quintessential elements of immersion and realism in the virtual music events. Most studies found that having lifeless audiences that were too rigid and obviously artificial led to dissatisfaction among users who felt it became distractingly unrealistic. Adaptive audience behaviour is essential, even with a low attendance of users the concert should still feel full and lively. One popular idea was to use previous user data to recreate their reactions to events that could be used in future concerts to make the audience feel more alive.

Some of the papers focussed on defining “liveness” in differing manners, many chose to focus on optimising real time audio processing and user interactions, but others chose to focus on semiotics and signals to measure and enhance “liveness”. Overall, it seems most sensible to combine these ideas to produce the best outcomes to produce the illusion of having a real time presence in virtual events.

Whilst mostly focussing on higher level conceptual ideas it is still important to touch on the technical challenges faced by the industry. With realism in mind specialised equipment is required to make the music sound like an authentic concert, needing the use of 3D audio processing, ambisonics and microphone arrays. But these must be placed optimally around users and function in real time which proves more than simple to resolve. Most reports agree this is the area that likely requires the most research to breach these barriers.

Another lesser discussed point, that still warrants serious consideration is the idea of user customisation, being able to personalise their avatar and be able to express themselves during a virtual event, varying from allowing them to dress up their avatar and customise their own feature to look as they desire. But it should go beyond just cosmetic personalisation’s, users should be able to adjust their position relative to the the stage, volume of the music and camera perspectives. This allows for more accessibility and inclusivity which are one of the best-selling points of virtual concerts to begin with, being able to attend a concert regardless of personal inabilities whether they be physical, financial or otherwise. As it currently stands there is a financial barrier to entry, many people do not own or have access to a VR headset which is the most used way to attend virtual events. Once this has been resolved the ability to allow those who would otherwise be unable to attend is crucial.

# 4 - Conceptual Framework for the Proposed Solution