Music from Anywhere & Everywhere

Exploring the Design Space of Remote Music Performances

Sophia Ppali

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To Yiayia Sophoulla and Pappous Michalakis ♡
You dedicated your lives to us, I dedicate my thesis to you.

Abstract

This thesis explores the design space of remote music performances through a Human-Computer Interaction (HCI) lens, responding to the rapid changes in the music industry which were trigged by global shifts towards digitalisation. My work aims to add to the existing body of work in remote and hybrid music performances, contributing towards bridging the gap between theoretical research and practical applications in technology design for remote music engagement. I do this by focusing on two key stakeholders: *musicians and audiences*. The research is grounded in a human-centred approach, utilising methodologies from design research to dive into the experiences, needs, and aspirations of the two stakeholder groups.

First, I examine how musicians' practices have evolved within remote and hybrid settings, identifying technological gaps in facilitating remote rehearsals in varied acoustic and visual spaces. Then, I transition to understanding remote music audiences' changing behaviours and expectations, investigating what they seek from remote music experiences now and in the future. In the latter part of the thesis I present a 'Designer's Toolkit', a compilation of design suggestions in the form of intermediate-level knowledge intended to inspire future work in remote music performances and the wider field of HCI. It bridges the findings from the initial explorations into actionable guidelines. Moreover, in this part, I also reflect on my positionality as a researcher within the research and describe how it has evolved throughout my PhD journey, with the aim to relate to other researchers working in complex and interdisciplinary domains.

Throughout my investigation, the thesis contributes to the fields of music and HCI (and beyond) by providing a fresh perspective on the current landscape of remote music performances. By doing so, my research aspires to offer inspirational starting points for future work and design initiatives that ultimately enhance the overall experience of music performed and experienced remotely for both musicians and audiences in the post-pandemic world. In addition, I advocate for human-centered approaches both towards technology design in the space, but also towards ourselves as researchers. For interaction design researchers, the work contributes methodological and conceptual tools for designing with and for complex experiential domains. For musicians and artists, it offers reflections and design directions grounded in their lived practices, supporting both creativity and adaptability in remote performance contexts. For music industry professionals and platform developers, it raises considerations around audience experience, engagement models, and the broader design of remote performance ecosystems.

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Part I

Setting the Context

Chapter 1

Introduction

In recent years, remote music performances have emerged as an exciting design space, reshaping how we create, share, and experience music. In this thesis, I explore the unique opportunities and challenges that emerge when music moves beyond physical venues and into digitally mediated spaces [97, 348, 427]. Focusing on the perspectives of two primary stakeholders, *musicians and audiences*, I build on previous research in areas such as networked music performance [287], sociology [481, 483] and musical eXtended Reality (XR) [468]. While earlier studies have tackled technical issues like latency and sound quality [87], or examined user behaviour on specific platforms like Twitch and Instagram [380, 481], my research takes a broader, human-centred lens. I engage directly with musicians and audiences using qualitative methods, including interviews, workshops, observations, and surveys. Through this process, I explore how technology can support artistic expression and immersive experience in remote settings. My work results in practical design suggestions, methodological insights, and technological prototypes that inform the development of remote music experiences that resonate with people. As remote performances become increasingly common, shaped by rapid technological development and evolving audience expectations, understanding them as a medium in their own right is both timely and necessary.

In this introductory chapter, I define remote music performances and explain the need to study them further. I share the motivations behind my work and outline the main research questions guiding the investigation. I then discuss my methodology, explaining why it is suited to the topic and how it supports exploration of the human aspects of remote music. I also reflect on my positionality and its influence on the research approach. Finally, I provide an overview of the thesis structure, giving the reader a roadmap of what to expect in the chapters ahead.

1.1 Research space and motivation

> *"Music doesn't get in. Music is already in. Music simply uncovers what is there, makes you feel emotions that you didn't necessarily know you had inside you, and runs around waking them all up. A rebirth of sorts."*
>
> – Matt Haig, How to Stop Time

Have you ever picked up an instrument and felt the world fade away while immersed in its music? Or stood among a crowd at a concert, the vibrations of the bass coursing through you, connecting you to the performer and everyone around you?

Music performance has a unique ability to immerse us completely, whether we are creating or experiencing a performance [399]. In a concert hall big or small or a rehearsal room, music fills our entire body. For both musicians and audiences alike, this experience goes beyond sound. It is an intricate blend of environment, presence, social connection and interaction that engages all five senses to generate a feeling of being entirely *in* the music and *in* the present [511]. Every time music is played, it becomes a communal event where the people (whether audience or other musicians), space, and sounds come together to form a complex, sensory experience, that is often magical [433, 511].

For musicians, creating and playing music are an irreplaceable form of expression. The synergy with fellow band members during practice, the immediate feedback from the audience in concerts, and the ambience of the venue they play in; everything contributes to a truly *immersive* experience (by immersive, I refer to a sense of being fully engaged in the moment emotionally, physically, and socially; see Section 2.1 for a detailed discussion). Every performance is a one-of-a-kind event, shaped by spontaneous interactions and the energy of the moment. Audiences, too, can experience the *immersiveness* that comes with live music. Listening to a recording on a service like Spotify might feel intimate, but hearing the same music live, surrounded by others, introduces a multisensory quality that amplifies the experience [189]. In a crowd, music becomes a source of shared emotion, turning individual reactions into collective moments; connecting people to the artist and to the music to each other. The communal atmosphere, the sound filling the room, and the understanding that this moment is unique – such elements turn live music into something difficult to replicate in other settings [167, 511].

But, in early 2020, the immersive experiences music enabled came to an abrupt halt...
When COVID-19 hit, it felt like life paused for a while, and the music with it....

The pandemic affected most aspects of our daily lives, and how music is created, shared and experienced was no exception. Rehearsal spaces closed, stages of all sizes fell silent, and the familiar rituals of live music were put on hold for a long time.

Musicians found themselves isolated; their creative practices disrupted [85]. The spontaneous interactions and creative exchanges with their fans that fuel their practice became suddenly absent. It was not just about cancelled shows and loss of income [131], it went far deeper. Practice rooms were empty; rehearsals happened in glitchy Zoom calls; the spark of existing in the same space with other musicians was also gone. Staying at home also impacted their wellbeing and, consequently, their creativity. They struggled to write music or develop ideas [85]. Audiences, too, felt the impact of the abrupt change. The communal joy of live performances was brought to a stop. The anticipation of buying tickets, the feeling of the bass pumping in their chests, and the energy of the crowd were all lost due to social distancing measures [320]. Music lovers (myself included) found themselves cut off from experiences that once brought happiness and comfort. Musicians and audiences alike had to adapt to the 'new reality' [443], where the physical and shared experience of music, an essential component of our cultural and social lives [433], was no longer possible.

In the silence, though, the connection and immersion that musicians and audience craved had not entirely disappeared. It moved online. Musicians began to embrace technology more than ever before. Even those who had never incorporated technology into their practices turned to social media and online rehearsals to keep going [414, 443]. The internet became their new concert venue, many streaming on Instagram and hosting concerts from their homes on bespoke platforms [380]. Audiences followed. Music streams became a regular occurrence, something to look forward to. Of course, digital experiences are not the same as attending in person [481] – you lose a lot through a screen – but they kept the flame alive. It was a necessary adaptation to a temporary crisis for those seeking to reconnect with the music and communities they loved. These digital performances were stopgaps, but they sparked questions that went beyond temporary crisis. *Could remote music performance become something more? Could it support creativity and connection in new ways?*

And that sparked something in me. Initially, my PhD was about using technology for emotional wellbeing, but then... well, the world changed, so my thesis changed too. As a music lover I was missing the shows. But what about the musicians? Their whole world revolved around live performances and that was now lost. That is when the focus of my thesis began to form. I started to ask myself:
Could remote music performance become immersive?
Could we design technologies that didn't just substitute what was lost; but offered something new?

During the pandemic, the importance of connection and creativity in our lives, even – or perhaps especially – when we are physically apart, was more evident than ever before. The abrupt changes it brought prompted an exploration of alternative musical expression and connection formats, fuelled by technological developments like the Internet of Things (IoT), Artificial Intelligence (AI), and the Metaverse [464, 468]. Digital platforms became lifelines, accelerating innovation and adoption in ways we had not anticipated [85, 251], leading to the rise of remote music performances. As the world slowly recovered, the shift towards digital platforms became even more prominent[1]. Therefore, starting to characterise the design space of remote music performances is more relevant than ever.

Within my work I define **remote music performances** as a wide range of musical activities where artists, audiences, or collaborators are not physically present or co-located, including digital practices that extend beyond traditional performance settings. The broad scope spans everything from live-streamed concerts [380, 481] to virtual collaborations [126] and solo performances in virtual spaces using technologies like Virtual Reality (VR) [364]. By embracing this wide-ranging definition, I acknowledge the diversity and richness of musical engagement in the digital age, emphasising the growth of remote music performances as a distinct and relatively unexplored design space that significantly diverges from traditional in-person models of music practice and performance [362].

My thesis aims to build on existing work, as well as inspire new ideas in the design space of remote music performances. I investigate how technology can be designed to enhance both musicians' artistic expression and the immersive experiences of audiences in remote settings. The pandemic was the trigger; but my thesis is not about the pandemic. Instead, it responds to a longer-term transformation in how we experience music, which has opened a distinct design space. This is not simply about translating physical experiences online. It is about exploring what remote music performances can offer on their own terms: new forms of presence, interaction, creativity, and connection that diverge from, but also complement, what happens in a venue. *What happens when a music performance goes virtual? What does that look and feel like? How can we capture the essence of immersion and connection that live music provides and translate it into the digital space?* More importantly, *how can we design technology to offer something unique instead of being a poor substitute?*

To explore these questions, I adopt a bottom-up, human-centred approach, engaging directly with musicians and audiences to understand their needs, desires, and challenges in this new landscape. Through interviews, workshops, observations, and surveys, I contribute to this emerging design space, identifying what is challenging and where we can intervene and innovate in both design and research.

[1] `https://unitedtalent.app.box.com/v/UTACOVIDConsumerStudy`

Together with both the musicians and the audiences I interacted with, we imagined how to design technology, not just for now but as we move forward. I learned a lot from these conversations, and I hope that through my thesis, other researchers and designers learn too.

My perspective might differ from others in this field: I am not a musician, computer scientist, or engineer. I seek to find that middle ground where technology becomes a tool for musical expression. Drawing on principles from HCI, music technology, and design research, I also advocate for a shift toward human-centred design when considering technology in this space, that is, creating interactive systems intricately aligned with the evolving needs of musicians and audiences. By focusing on the human aspects I wish to inform the development of technology that genuinely resonates with people.

In doing so, I hope to contribute to a future where technology does not just bridge the gap caused by physical distance but enriches our musical experiences in unprecedented ways. Whether enhancing artistic expression for musicians, creating more immersive experiences for audiences, or facilitating new forms of collaboration, the potential of remote music performances is vast and largely untapped. A remote performance should not feel like a compromise, it should be a unique experience by itself. Imagine feeling the energy of the crowd surge toward you, even from your living room, or like you are playing music in the Royal Albert Hall while at home. Regardless, the goal is not to replace live venues and their magic but to create an alternative medium that complements them. Doing so can help us support in-person performances better, ensuring they thrive alongside their digital counterparts. Through exploring this space, I want to play a part in shaping its next chapter.

This work speaks to multiple audiences. For researchers in HCI and design, it offers methodological and conceptual contributions for understanding and shaping complex design spaces. For musicians and artists, it reflects their lived experiences and presents design possibilities grounded in real needs and practices. For those working in the music industry or platform development, it raises practical and ethical questions around audience engagement, accessibility, and the future of performance infrastructure. At its core, the thesis is a call to approach technology design in this space with care and an understanding of music as more than content, as shared, situated experience.

Dear reader, as you read my thesis, I invite you to consider the incredible opportunities for creativity and connection that lie ahead in the design space of remote music performance beyond the challenges posed by the pandemic. If we focus on the human elements that make music so powerful, we can design technologies that enhance the magic of live performances, even when we are apart.

1.2 Research questions and contribution

Exploring the design space of remote music performances allows me to reimagine how musicians and audiences engage with live music in the digital age. My research seeks to re-envision musical performances in remote settings rather than adapt current practices to digital formats, using human-centred design methodologies. Moreover, working on this topic allows me to explore where I am within this space, identifying what my own voice brings to the table.

The main research questions guiding my work are:

- **RQ1:** How do musical creative practices and performances adapt to remote contexts, and what is the role of technology in facilitating this adaptation?
- **RQ2:** What are the needs and desires of musicians and audiences experiencing music performances remotely?
- **RQ3:** How do musicians and audiences perceive the opportunities and challenges of technology in remote music performances, and what implications do these perceptions when we design technology for them?
- **RQ4:** How can we use human-centred methodologies to design technology with musicians and audiences that enhance the remote music experience?

Throughout this thesis, I tackle these questions by immersing myself in the world of remote music performances (See Table 1 for details). I engage directly with musicians and audiences, attend events, facilitate workshops, and develop and refine prototypes to understand how to enhance the remote music experience from the ground up. Here are the key contributions my work makes:

Exploring the existing research landscape. Throughout my thesis, I offer an overview of existing research on remote music performances, identifying key themes, trends, and gaps in the literature. This review covers a wide range of areas, including networked music performance, the sociology of music, music in XR, and technology-mediated audience participation. This exploration directly addresses **RQ1** by providing a foundation for understanding how musical practices and performances adapt to remote settings. It also informs **RQ2** and **RQ3** by outlining the existing knowledge about musicians' and audiences' needs and perceptions regarding technology in remote music experiences.

Table 1: Mapping of research questions to chapters with brief explanations from the researcher's perspective.

Research Question (RQ)	Chapters Addressed (How I Answered the Question)
RQ1: How do musical creative practices and performances adapt to remote contexts, and what is the role of technology in facilitating this adaptation?	**Chapter 2:** I characterise the design space and survey existing technological approaches, exploring how practices adapted to remote settings. **Chapters 3 & 4:** I investigate musicians' challenges and adaptations during the pandemic, exploring the role and potential of immersive technology (VR Rehearse & Perform) in supporting their creative practices and performances. **Chapter 5:** I examine how performances are adapted across platforms through audience observations.
RQ2: What are the needs and desires of musicians and audiences experiencing music performances remotely?	**Chapters 3 & 4:** I uncover musicians' needs and desires through interviews and prototype evaluations. **Chapters 5 & 6:** I explore what audiences seek in remote performances via surveys, interviews, and a co-design workshop.
RQ3: How do musicians and audiences perceive the opportunities and challenges of technology in remote music performances, and what implications do these perceptions have when we design for them?	**Chapters 3 & 4:** I examine how musicians perceive VR's potential and limitations, informing design choices. **Chapters 5 & 6:** I investigate how audiences perceive remote technologies and identify design implications. **Chapter 7:** I synthesise these insights into a design toolkit based on their expectations, constraints, and needs.
RQ4: How can we use human-centred design methodologies to inform and co-create technology with musicians and audiences that enhance the remote music experience?	**Chapter 3:** I describe the methods used with musicians, including workshops and prototype development. **Chapters 5 & 6:** I describe multi-method audience studies and a participatory co-design workshop. **Chapter 7:** I translate human-centred findings into design dimensions and actionable guidance. **Chapter 8:** I reflect on the researcher's role and how reflexivity shaped the research process.

Understanding musicians' and audiences' experiences. I adopt a human-centred approach, using qualitative research methods to gain in-depth insights into the experiences, needs, and desires of both musicians and audiences. I employ interviews, workshops, observations, and prototype evaluations to gather plenty of data. Focusing on understanding my users, addresses **RQ2** through uncovering what musicians and audiences genuinely need and desire in remote music contexts. These insights also inform **RQ3** by revealing how individuals see the potentials and challenges of technology and lay the groundwork for **RQ4**, guiding how human-centred design can enhance artistic expression, practice, and the overall remote music experience. This contribution provides designers and technologists with a broad understanding of user experiences, emphasising the vital role of empathy in creating tools that genuinely support remote musical activities.

Speculative ideas and technological prototypes. I generate speculative design ideas that communicate insights and potential innovations within the field of remote performances. I also developed a proof-of-concept prototype demonstrating these ideas in practice, intending to help imagine and disseminate best practices. This contribution directly addresses **RQ4**, showcasing how developers can use human-centred design methodologies to create innovative technological solutions that enhance artistic expression and audience engagement. The prototype also provides valuable insights into the practical application of VR for musical practice, addressing aspects of **RQ1**.

Design insights to open up the space. Building on my findings, I offer a range of design suggestions and opportunities for developing technologies that can enhance remote music experiences. I explore different design dimensions, including sociality, embodiment, temporality, spatiality, and the senses, and present specific recommendations for how these dimensions can be considered in the design process. Additionally, I provide practical examples and guidance to assist performers, developers, and designers in incorporating emerging technologies into their performance-based practices, spanning rehearsing, performing, and music consumption. This contribution directly responds to **RQ3** and **RQ4**, bridging the gap between the identified needs and perceptions of musicians and audiences and the practical application of those insights in designing new technologies and experiences.

Methodological insights. I also contribute methodologically by demonstrating how participatory and contextually sensitive methods can be used to design for remote music performance in ways that centre the people involved. I draw on a range of approaches – from interviews and workshops to prototyping and in-the-wild observations – to engage both musicians and audiences in shaping the direction of the work. The methods I use were not applied in isolation but carefully adapted to suit each stage of the research, whether designing with musicians in early studies or observing existing practices in later phases. Across the work, reflexivity played an important role in shaping how I approached the research. Rather than adopting a neutral or detached stance, I treated my own perspective as part of the inquiry – something to be acknowledged, questioned, and adjusted. This is particularly evident in Chapter 8, where I reflect on how my background, assumptions, and emotional experiences influenced not just what I studied, but how I studied it. My reflections are not separate from the rest of the project: they shaped the questions I asked, the relationships I built, the prototypes I developed, and the way I made sense of the findings. In doing so, I extend the meaning of human-centredness in research – not only as a way of designing with and for people, but also as a way of conducting research that recognises the humanity of the researcher. My methodological contribution responds to **RQ4** by showing how careful, contextualised, situated, and reflexive design processes can support more human ways of working in HCI.

1.3 Research approach and methodology

Exploring the design space of remote music performances is inherently complex and multifaceted, intersecting various domains such as HCI, music technology, sociology, media, design research, and performance science. While my own research is primarily anchored within HCI, I acknowledge that

remote music experiences are shaped by a confluence of factors – from the technological platforms that facilitate them, to the social and cultural contexts that influence their reception. Rather than going in depth in any one of these aspects, my goal with this thesis is to take a broad perspective, looking at remote music performances from several different angles, in the hope that it will inspire new ways of thinking about them. Therefore, my approach is consciously generative, aiming to enrich the design space with new or alternative ideas and inspire future work rather than respond to a specific research gap or solving a problem [170], aligning with work by designerly HCI and beyond [179].

Acknowledging the exploratory nature of my research, I have adopted an interdisciplinary approach to my work, grounded in a constructivist research paradigm [20, 412]. Constructivism posits that knowledge is co-constructed through social interactions and shared experiences rather than being objectively discovered. Understanding is built collaboratively between the researcher and participants, acknowledging that both bring their own perspectives and experiences to the table. This perspective is particularly fitting for what I do, as I aim to understand phenomena deeply rooted in personal and collective experiences [311]. Through recognising that multiple realities exist based on individual perceptions, I explore the diverse ways musicians and audiences experience remote music performances, each shaped by their unique backgrounds and desires. Engaging with the people I design for and with, allows me to co-create knowledge that reflects their varied experiences.

Given the exploratory nature of my research, qualitative methods are the most appropriate choice, as they allow participants to express themselves freely and share their stories [20, 311], enabling me to capture the specificities of their experiences, emotions, and challenges – elements that quantitative methods might overlook. Some of the methods I employ throughout the research include:

Interviews with musicians and audiences to gather in-depth insights into their experiences. The conversational and prolonged nature of the interviews helps build rapport and encourages participants to go deeper into their thoughts and feelings.

Participatory sessions and co-design workshops to stimulate creative thinking, facilitate collaborative exploration of ideas, gather diverse perspectives and eventually generate speculative design concepts through which we can envision future scenarios and possibilities for remote music performances. Workshops also empower participants to contribute actively to the research, aligning with the constructivist emphasis on co-creating knowledge.

Observations of live-streamed music events on platforms like Twitch and VR Chat to gain context for the participants' experiences. Witnessing interactions in real-time allows for identifying patterns,

behaviours, and social dynamics that might not surface from self-reported data alone.

Prototype development, iteration and testing to translate insights and abstract ideas into practical applications. Technological prototypes enable me to bridge the gap between theory and practice, ensuring that some of the things my work proposes are grounded in the lived realities of my users.

Reflexivity and positionality to remain critically aware of how my background and assumptions shaped the research. My positionality helped build rapport with participants and interpret their perspectives, but also influenced what I paid attention to and how I framed opportunities. I regularly reflect on these dynamics and discuss interpretations with collaborators, treating my position in the research and my reflexivity as an integral part of the research process.

My methodological choices align with a broader movement in HCI and related fields towards embracing qualitative, human-centred, and participatory approaches when designing technology. Researchers are increasingly recognising that understanding complex human behaviours and experiences often requires methods that capture depth and context rather than just breadth and quantification [38, 52, 170, 171, 375]. This is particularly relevant to emergent design spaces where digital tech is not widespread yet and where, as such, foundational values are still being defined. Furthermore, adopting a constructivist, qualitative approach is consistent with practices in fields such as sociology and anthropology, where understanding social phenomena requires immersion, empathy, and reflexivity. For a detailed discussion of my methodological choices see Section 2.7.

1.4 Notes on the author's role within the research

Whenever I discuss my work, people are surprised when they find out I am not a musician myself. Fortunately, this initial surprise and their follow-up questions often lead to deeper conversations about my unique position in the research. My experiences and professional background offer a multifaceted perspective, which inevitably influences the outcomes of my work. Building on the third-wave perspective of HCI [179, 199], and in line with the constructivist approach I adopt, I embrace my own positionality and reflexivity within this thesis (rather than avoid it), acknowledging how it influences every aspect of the research process – from the questions I ask to how I interpret the data. Therefore, I made the intentional choice of writing this thesis in the first person, incorporating my own reflections where suitable [295]. Writing this way lets me be transparent about how my views and experiences shape my work while also helping me remain critically aware of potential biases,

ensuring that I continually check my assumptions against the realities presented by my participants. The qualitative methods I use further support this and enable me to build relationships, gain a look into my participants' worlds and co-construct knowledge with them. Their openness and willingness to share their experiences are invaluable, facilitated by my work's empathetic nature.

So where am I located within this research?

I am a 29-year-old white, able-bodied woman, born and raised in Cyprus within a middle-class family. Over the years, I have lived in various places, including eight years in the UK, one year in Germany, and one year in East Asia (China and Singapore). My academic journey includes a Bachelor of Arts in Digital Arts from the University of Kent, a Master of Arts in Global Innovation Design from the Royal College of Art, and a Master of Science in the same field from Imperial College London.

Although I am not a musician, my connection to the music world comes from my experiences as a digital artist and an avid concert-goer. My previous collaborations with musicians and performers on artistic projects, though outside the academic sphere, have given me an insight into their world, their passions, creative processes, and challenges. At the same time, my non-musicianship makes me an outsider, someone who is not embedded in the music scene or knows all its workings. This status contributes to a view that is less about technical musicianship and more about the experiential aspects of music performance. It enables me to approach the research with fresh eyes, offering insights that might not be apparent to those deeply ingrained within the space.

Furthermore, I consider myself a 'professional live music audience' (see in Figure 1 photos from some of the concerts I attended). Live music has always been a central part of my life. I have spent hours queueing outside stadiums to see big bands and sat in poorly lit small bars to listen to some local guys play the guitar – something I still do at least once a week. For me, live music is one of the purest forms of feeling alive. The music pumping through my chest, the fleeting moments of connection with the artist, and the collective energy of the crowd – whether that's thousands of people in a big stadium or 20 people in a bar – make every event an experience that is lived and felt. The memories I made at live music events are some of my best stories, and I am sure this is also true for many other people. So back in 2020, when the pandemic hit and live music shifted predominantly online, so did my music consumption habits. Like millions of others, I immersed myself in countless livestreams during the lockdowns, finding solace in being an audience member from my bedroom. This part of my identity allows me to empathise with the audience's perspective

Figure 1: Photos from different music events I attended during the years, from big festivals, to rock concerts, to intimate bar sessions.

and better understand what makes live music resonate with people. It also gives me first-person insights into how these experiences have transformed into the digital space. While I do not use my personal experiences as data, they serve as a foundation for relating to the participants in my research and supporting my interpretations.

Before embarking on this PhD journey, I worked as a practising designer, creating culturally sensitive interventions across diverse contexts, such as rural communities in Thailand, older adults living with dementia in Singapore, and school children in London. My experiences working in different cultural settings, coupled with my extensive travels, have made me really sensitive to the world around me, instilling in me a profound appreciation for diversity and the importance of designing culturally appropriate solutions as well as nurturing my love for human-centred (and humanity-centred) design. Working with various communities has taught me the importance of being empathetic and engaging directly with people to understand them. This, in turn, influenced my approach to working with musicians and audiences, motivating me to remain open to diverse viewpoints and to design interventions that are responsive to the participants' specific contexts.

Being situated in a School of Engineering added another dimension to my research approach. Being in an atmosphere that frequently prioritised technology over all else has given me a real grasp of the technical aspects of remote music performances. Although not an engineer or computer scien-

tist, I developed the knowledge needed to understand, discuss, and prototype technology, as well as the basic skills to function within a technocentric space. This is obvious in the earlier chapters of this thesis, where I focused on exploring how specific technologies like VR may improve remote music performances. However, as my journey evolved, my perspective began to evolve too. Seeing technology often developed without meaningful input from those it is meant to serve – like VR applications designed for wheelchair users without involving them – prompted me to question these approaches. I became aware of the limitations of technology-driven solutions prioritising novelty over meaningful impact and my values as a human-centred designer started coming into my HCI research. My critical stance grew stronger as I found my own voice as an HCI researcher – perhaps a bit too critical at times. This evolution is reflected in the later parts of the thesis, where I emphasise human experiences and the importance of designing *with* people rather than *for* them. Technology, I have come to believe, should serve as a tool to enhance human experience, not an end in itself. In Chapter 8, I unpack this transformation, amongst other things, reflecting on what I have learned as a person within the technology research world beyond the findings of the research itself. Acknowledging this personal growth is important to me, as it also highlights how my positionality continuously has influenced and has been influenced by the research process.

Overall, this thesis combines my technical understanding and human-centred perspective to bridge the gap between technology and people in the context of remote music performance. My dual focus enables me to critically evaluate the possibilities and limitations of technological interventions while advocating for solutions that improve human experiences. Recognising the value of designing with rather than for, I seek to produce collaborative, empathic work founded in the realities of those it intends to serve. Nevertheless, I also understand the constraints of my position. My experiences and viewpoints may only partially reflect the complex reality of all musicians and audience members, particularly those from backgrounds other than mine. To overcome this, I engage people from various backgrounds, carefully listen to their stories, and validate my interpretations using participant feedback and peer conversations. My reflexive approach helps ensure my work is grounded on the lived reality of those it seeks to support rather than my own assumptions.

1.5 Thesis overview

In this section, I introduce the structure of my thesis, guiding the reader through the questions and contributions that unfold across nine chapters, divided into four parts.

Part I sets the stage for my research by providing the context informing my thesis, grounding in traditional music practices and the rapid shift to digital spaces.

In *Chapter 1* (which is the current chapter), I present the purpose and scope of the thesis, explaining why it is imperative to approach the design space of remote music performances through a human-centred lens.

In *Chapter 2*, I begin to characterise the design space my work speaks to through surveying existing literature, articles, reports and performance examples. I start by defining what 'immersive' means within the context of this research, framing it not as a purely technological concept but as a multi-sensory and emotional experience that draws people in. I then explore live music as an inherently immersive medium, highlighting the conventional dynamics of musicianship and audience engagement that inform my work. I continue by examining the pandemic's impact on music performance, highlighting how digital platforms became essential yet imperfect replacements for their in-person counterparts. This shift prompts the question: *How might we translate the immersive qualities of live music into digital spaces?* Technologies like VR and AR, often labelled as 'immersive', offer possibilities. Still, as I argue in the latter part of this chapter, the real challenge is not just technical – it is about understanding and designing for immersion as an experience. Immersion stems from how people perceive, engage with, and connect to an experience – not from the tools themselves. Therefore, I propose a shift in thinking when designing for remote music performances: rather than designing for immersive technologies (or any technologies, in fact), we should focus on designing immersive experiences, letting the choice of technology, whether virtual, physical, or otherwise, serve as a facilitator. In the final section, I turn to methodologies for understanding users and designing immersive experiences. I briefly survey a range of approaches, from qualitative methods like interviews and observations to participatory techniques and speculative design, laying the groundwork for the methodological choices in later chapters.

Part II focuses on musicians, investigating how technology might support their individual creative practices when physical spaces are out of reach.

In *Chapter 3*, I start by investigating the challenges musicians face in their creative practices and how these practices were further impacted by the pandemic, particularly the challenges relating to performance spaces that fuel creative exchange and inspiration. I also explore the value immersive technologies can bring to the table, according to musicians, and how they might help combat some of these challenges. To do this, along with reviewing relevant performance literature, I conducted nine interviews with musicians and three workshop sessions run in collaboration with external researchers. The activities reveal a list of six design requirements that are important when designing immersive technology solutions for musicians. The next part of the chapter traces the development process of a musician-centric VR prototype called *VR Rehearse & Perform*, which takes shape through iterative refinement through engagement with music-makers using it. The experiences of musicians who interacted with the prototype are then presented, offering some preliminary insights into the effectiveness of VR technologies in enhancing musical rehearsal and performance practices.

In *Chapter 4*, I extend the exploration of the *VR Rehearse & Perform* prototype by presenting its final iteration and evaluating it with an additional ten musicians. The focus now includes the broader spectrum of ways VR can support musicians' creative endeavours. The results of this chapter, which are a culmination of all rounds of testing, suggest that immersive technologies hold great potential for supporting various aspects of creative musical practice, such as rehearsing, performing, and improvising. Moreover, they explain how musicians perceive such technologies and their thoughts on using them regularly in their practices. The main discussion of Chapter 4 offers insights and inspiration for designing musician-centred immersive experiences that cater to diverse musical activities and allow for new types of creative tools. The Chapter closes with a section where I step back to reflect on the design process itself. While I intended to adopt a human-centred approach – and I followed methodologies often used in HCI – I realised that my work was still shaped, to some extent, by the capabilities and constraints of the technology I chose (in this case, VR). My learnings exposed a gap between intentions and the realities of the design process, highlighting the challenges of genuinely prioritising user needs when working with emerging technologies. Consequently, in Part III, I focus on understanding audiences, what they currently do, how they engage with technology, and what matters to them in remote music experiences, This marks an evolution in my process, prioritising users' lived realities rather than treating their behaviours as data points.

Part III looks at remote audiences: their current practices, what makes their experiences meaningful, and how technology could be designed to meet their unmet desires.

In *Chapter 5*, I turn my attention to the perspectives and behaviours of remote audiences participat-

ing in music events on various platforms, such as Twitch, YouTube, and VR Chat. Utilising a qualitative multi-method approach that includes observations of existing live-streamed events, interviews with audience members, and a survey to gather insights from a broader population, I identify motivations and interaction patterns of remote music audiences. I also explore some of their challenges, including barriers to engagement and limitations in the current digital platforms. Moreover, I uncover some of the most memorable and engaging aspects of remote music events, while also examining their views on the future of remote music performances. The findings reveal audience engagement patterns in remote music events across digital platforms, uncovering how each platform's unique features and affordances shape audience interactions as well as highlighting unmet needs, desires and opportunities. The platform-specific dynamics reveal both the possibilities and limitations of current technologies for creating immersive experiences. The chapter concludes by presenting insights on challenges and opportunities for designing systems that enhance the audience experience while respecting the ways they naturally engage with these platforms.

In *Chapter 6*, I build on the findings from Chapter 5 but take a broader perspective, moving beyond platform-specific insights to explore what could make remote music experiences immersive in a more general sense, turning them from events that are lived to events that are experienced. In the first part of the Chapter 6, I synthesise the findings of the previous chapter into a list of elements that have inspirational value for designers of remote music experiences. The design elements serve as the basis for a co-design workshop with diverse stakeholders, providing a space for participants to collaboratively imagine new possibilities, focusing on the experiential qualities that make remote music engaging and memorable. The workshop resulted in four speculative design ideas, each addressing different aspects of immersion. In the chapter discussion, I present actionable design insights, focusing on the experience aspect rather than the specific technology. I conclude this chapter with a section reflecting on the methodology I followed and what others can take away from my learnings.

Part IV brings together the insights from the thesis, synthesising them into practical design guidance while reflecting on the broader implications of the work.

In *Chapter 7*, I synthesise the findings from the thesis into a practical design toolkit, offering actionable guidance for creating meaningful remote music experiences, informed by the insights gathered through working with musicians and audiences and the lessons I learned throughout the processes I followed. Here, I present design dimensions to offer ways of approaching the design of remote music performances by thinking about the experience first and allowing the technology to follow. I also present design opportunities accompanied by examples, which can serve as inspirational starting

points for new work. Lastly, I give some final reflections on designing for remote music performances.

In *Chapter 8*, I step back to reflect on the journey of my work on remote music performances and my broader experiences as an HCI researcher. I explore themes such as the "messiness" of the research and the tension between technocentric and human-centred approaches, particularly in contexts where user needs are evolving and personal. In this chapter, I also highlight the importance of alternative research outcomes – creative, non-traditional formats of disseminating academic research that may not directly align with the original goals but offer unexpected contributions nonetheless, such as art installations or exhibition booths. Beyond the design work itself, I point to the personal and emotional dimensions of conducting research. I discuss my role as a person 'in-between' disciplines, technologies, and perspectives; a position that enabled me to bridge gaps and approach problems from multiple angles. I also write about the experience of doing research while grieving, a challenge that changed my perspective on what it means to be a human-centred researcher, bringing into focus the importance of care, empathy, and connection – not only with users but also within the research community and with ourselves as researchers. I share these lessons with the hope to relate with others navigating such complex spaces and inspire them to approach their work with curiosity, openness, transparency and a willingness to embrace complexity.

In *Chapter 9*, I bring the thesis to a close, summarising the key contributions, considering the broader implications of my work and the stakeholders it speaks to. I revisit the initial research questions and summarise the essential findings and learnings. Here, I also acknowledge the thesis's limitations and outline potential future research opportunities. Overall, in this chapter, I encourage future researchers to continue expanding the boundaries of this field.

Chapter 2

Background

Remote music performances present an exciting, emerging design space shaped by rapid technological advancements and the global shifts triggered by the COVID-19 pandemic. These performances challenge the traditional ways in which we experience and create music and offer opportunities to reimagine connection, collaboration, and artistic expression in digital spaces. Nevertheless, understanding this space demands moving beyond surface-level discussions of technology and platforms. It requires a deeper exploration of the emotional, sensory, and relational qualities that make music experiences immersive, whether live or remote.

In this chapter, I present some of the existing work that sets the backdrop of my thesis, focusing on three areas: (i) the immersive qualities of live music; (ii) the pandemic's disruption of traditional practices, and (iii) the opportunities and challenges for designing meaningful remote music experiences. I frame immersion as a human experience rather than a technological feature, and I propose a shift in perspective when designing for remote music performances – one that prioritises designing for connection and engagement over just replicating live events. I also examine the current state of technology research, particularly around immersive technologies, where I draw attention to a frequent emphasis on improving or creating new technology rather than addressing the specific needs of musicians and audiences. Building on this observation, the final section of this chapter emphasises the importance of participatory and contextually sensitive approaches towards technology design, drawing on methodologies inspired by design research. Here, I lay the groundwork for my methodological approach and the human-centred perspective that drives my work. I advocate for a more inclusive and grounded way of developing technology and conducting research on remote music performances, with the goal of ensuring that the outcomes are relevant and applicable.

2.1 Defining immersion

Before diving into the context of music, it is necessary first to define what I mean by immersion and immersive experiences, as this concept underpins much of the work in this thesis. Immersion is a widely used yet ambiguous term, with its definition varying across disciplines and contexts [338]. Scholars broadly agree that it involves a sense of being or feeling surrounded by something, though its specific interpretations differ significantly depending on the field [314, 332, 388, 424, 506].

Within HCI and XR research, immersion is a term often associated with technology – think VR [424, 428, 506] or gaming [78, 231] – where it is described as the perception of being physically or emotionally present in a non-physical world. For example, Slater [424] defined immersion as a property of the system where the extent of immersion depends on how effectively the technology captures the user's senses, attention, and emotions. Similarly, Witmer and Steed [506] described immersion as a psychological state involving the sensory and perceptual engagement of the user, enabling them to feel physically or emotionally situated within a simulated environment. According to the same authors, factors that affect the level of immersion include *"isolation from the physical environment, perception of self-inclusion in the virtual environment, natural modes of interaction and control, and perception of self-movement."* While these definitions are valid, they look at immersion either as an objective characteristic of technology or a psychological state achieved through it often tied to the sophistication of a system - the more advanced the technology is, the better it will be at secluding you in a virtual environment, the higher the level of immersion would be [426].

Moving beyond technology-driven definitions, psychological immersion refers to the mental state of being deeply engaged, absorbed, or engrossed [2, 314, 338]. Along this vein, highly cited works such as Ryan [388] and Murray [332] discussed immersion as cognitive and emotional transportation, where coherence and imagination allow individuals to 'surrender' to an alternate reality, whether in literature, media, or digital environments. In their review Nilsson et al. [338], found that psychological immersion could be reached through: (i) subjective experience of being surrounded or multisensory stimulation; (ii) absorption in the narrative or the depiction of the narrative; and (iii) absorption when facing strategic or tactical challenges. In broader literature, these are often classified as different types of immersion, but all link to immersion as a mental state [2]. While these perspectives align closely with the view I take in this thesis, they often remain tied to notions of escapism - where the person being immersed loses awareness of the physical world and is entirely transported to an alternative reality, even when not explicitly tied to technology. On a different trajectory, literature

also discussed immersion as a heightened sense of presence – being intensely aware of and engaged in the here and now. This perspective is often associated with mindfulness and sensory engagement. For example, Kabat-Zinn [242] linked immersion to practices of heightened awareness, where individuals are intensely present, noticing and engaging with their surroundings. In this case, immersion focuses on connection to the immediate moment, allowing for a sense of being 'in' the world.

Within my thesis, I intentionally take an even broader view. Rather than viewing immersion as something technology enables, I see it as an experiential phenomenon that arises from the interaction between individuals, their environment, and their perceptions. It is a multisensory and emotional experience that deeply engages us in the present moment (whether in immediate or constructed environments). Being immersed is about what we feel, sense, and relate to in that moment, whether through technology, physical space, or social interaction. For me, **immersion is the state of being deeply absorbed in an experience - where attention, emotions, and senses come together to create a sense of presence and connection.** This definition, which encompasses both absorption (losing track of time and place) [376] and heightened presence (being fully aware of and engaged in the *here and now*), allows me to move beyond technological determinism or escapism, framing immersion as a multidimensional and subjective human experience which can be supported by technology but is not directly dependent on it [2]. Therefore, when talking about immersive experiences within my work, I talk about experiences that absorb and engage us in the moment regardless of the specific technology employed rather than immersive experiences as experiences enabled by technologies (i.e., XR technologies), which is the most widely used definition [92] in the field I operate.

2.2 Musicking as an immersive experience

Music is an essential aspect of our lives, intricately woven into our personal, social, and cultural fabric. It marks milestones, shapes memories, and evokes a plethora of emotions that few other stimuli can match [241]. In moments of celebration, music expresses joy and brings people together, while in times of difficulty, it offers comfort and articulates emotions that words cannot. In everyday life, music is part of our routines – from the radio playing during a morning commute to a playlist setting the mood for an evening workout. Music's ability to connect us to ourselves and others creates a sense of community and shared experience, surpassing cultural and language barriers to serve as a universal medium for expression and connection [399]. Music also reflects societal values and narratives, simultaneously acting as a mirror of culture and an agent for change [121].

Small [432]'s concept of **musicking**, introduced in the book *Musicking: The Meanings of Performing and Listening*, encapsulates the importance of music in our lives by redefining *music as a verb*, positioning it as a dynamic, active process rather than an arrangement of sound or even an art form.

> **Music** (to music)
>
> *verb*
>
> To music is to take part, in any capacity, in a musical performance, whether by performing, by listening, by rehearsing or practising, by providing material for performance (what is called composing), or by dancing [...] We might at times even extend its meaning to what the person who takes the tickets at the door is doing or the men who shift the piano and the drums. They, too, are all contributing to the nature of the event that is a musical performance.
>
> Small [432], 1998

Small [433] shifted the focus from the musical object (e.g. a composition) to the act of engaging with music, highlighting the relational and participatory nature of the experience. He argued that music's value lies not only in its auditory qualities but also in the relationships it facilitates in the place where it is happening – which are to be found *"between person and person, between individual and society, between humanity and the natural world and even perhaps the supernatural world"* [432]. Through musicking, individuals actively explore and affirm their relationships with others, their surroundings, and even their broader social or cultural contexts [433]. Small's perspectives are supported by many ethnomusicologists and performance researchers who continue to investigate and expand what it means to music [357], such as Borgo [68] who introduced the idea of transmusicking, to depict some of the characteristics of musicking in digital environments.

Building on the definition given by Small, in many ways, musicking (therefore music) could be naturally considered a form of immersive experience as it engages individuals on multiple levels, cultivating sensory, emotional and cognitive engagement [357]. The level and intensity of said immersion could vary depending on the context and the situation of the person musicking [374]. Nevertheless, whether a solitary act of listening, playing an instrument or attending a performance, participants are absorbed in a ritualised exploration of relationships - with themselves, others, the music, or the environment as Small described [433]. The ritual aspect of musicking, which draws on the language of gesture and interaction, mirrors broader societal and personal relationships, making it both an intimate and collective act according to the situation [283]. In this way, musicking can function as a lived experience of immersion, uniting sensory, emotional, and relational dimensions.

Music performance represents one of the most concrete manifestations of musicking as an immersive experience [511]. It should be noted that with the term music performance, I refer to the act of playing or presenting music in real time, encompassing a wide range of scenarios: solo or group, formal or informal, rehearsal or concert, public or private [166]. Unlike recorded or mediated music, music performance inherently brings together the physical, social, and emotional dimensions of immersion for both those who perform and those who experience it. For the performer, the act of playing music is a holistic engagement of the body, mind, and emotion - navigating the technical demands of performance with responsiveness to the immediate environment and, when present, the energy of the audience [103]. For the audience, the shared experience of being part of a crowd (large or small), tuned to the same sounds and rhythms, generates a strong sense of connection and presence [167, 498]. This is true whether the performance occurs in an intimate home setting or a grand concert hall; in both cases, music performance uniquely integrates sensory, relational, and environmental dimensions to create a deeply immersive experience – a liminal space of some sort [419, 511] where the person engaging in it loses track of time and space while simultaneously feeling fully present and anchored in the moment [235].

Although Small's writings give me an anchor through which I can describe my framing of musicking as an immersive experience, this is not a new perspective. Several other scholars have explored the immersive qualities of music performance. Studies in performance science highlight the sensory and embodied nature of live music, examining how the interaction of the performer, the audience and the environment creates a unique experiential dynamic [235]. Similarly, sociological perspectives discuss music performances' communal and ritualistic aspects of live performances, further strengthening the idea of music as a participatory and immersive act [167, 498]. Such perspectives too, frame music performance as a deeply personal act and a collective and contextual experience, setting the stage for further exploration of musicianship and audience dynamics.

2.3 Musicians and the art of creative musical practice

Musicians - which I define as individuals who improvise, compose, arrange and/or perform music - are the driving force behind the melodies that define our experiences with music [433]. Being a musician entails more than being able to play an instrument or sing a song. It involves diverse cognitive and emotional factors as outlined by Levitin [275]. Each facet is essential in musicians' ability to bring music to life, making music performance a strongly immersive experience for musicians themselves.

At its core, creative musical practice is about navigating the boundaries between structure and spontaneity [275]. **Skill development** serves as its foundation, with musicians dedicating substantial time to mastering their instruments, refining their aural and interpretive skills, and embodying their craft through repetition and deliberate practice [354]. Research consistently highlights a strong relationship between musical achievement and the amount of formal practice undertaken [431]. Repeated practice allows musicians to internalise actions, leading to 'body knowledge' or automaticity, where technical skills become second nature [240, 477, 478]. This embodied knowledge frees musicians to focus on the expressive and creative dimensions of their performance.

Skill development also serves as a foundation for **creativity**. Creativity, characterised by Webster [499] as *"the engagement of the mind in the active, structured process of thinking in sound for the purpose of producing some product that is new for the creator"*, allows musicians to experiment, take risks, and push the boundaries of their practice. Creativity in musical practice promotes critical thinking, empathy, and resilience while also enhancing coordination and spatial reasoning [477]. It also allows musicians to develop stronger bonds with their instruments, encouraging an exploratory approach [478], where they engage with them not just as tools to produce sound, but as partners in a creative journey. This relationship often leads to the discovery of new techniques, sounds, and expressions [401]. Nevertheless, Hill [205] emphasised that technical mastery alone is insufficient for musical creativity. Instead, musicians must cultivate decision-making abilities, aural sensitivity, and memory to navigate the balance between structure and spontaneity.

This balance is especially evident in **improvisation**, where musicians create music in real-time, responding intuitively to the moment [47, 477] described by Berkowitz [47] as *"spontaneous creativity within constraints"* and by Clarke [107] as *"the most conspicuous illustration of creativity in performance."* Research has shown that training in improvisation may have a 'releasing effect' on creativity, leading to greater fluency and originality in musicians [257]. It also hones cognitive flexibility and deepens the musicians' understanding of musical structure and emotional expression [401]. Composition and interpretation represent other dimensions of musical creativity. **Composition** involves the deliberate construction of new works [298], while **interpretation** focuses on shaping existing pieces in ways that reflect the musician's unique perspective [240]. Both practices demand technical precision and reflective thought, highlighting the multifaceted nature of musical creativity.

Engagement in creative musical activities has also been associated with **a state of flow** [53] - a mental state of complete immersion and focused motivation, where time seems to stand still, and the musician becomes one with the music [122], often described as being 'in the zone.' Flow states encourage

connection with the music, promoting a level of creativity and expression that is often unattainable through conscious effort alone [298]. Unlike other immersive experiences, flow involves immersion in action rather than in external stimuli. For musicians, this might occur during a particularly challenging, yet, rewarding practice session or an emotionally charged performance. However, because of its elusive nature, reaching flow is not trivial - it requires practice and preparation [513]. Indeed, an equal balance between challenge and skill is one of the requirements for reaching this mental state in [122], and studies have found that regular practice is correlated with the ability to enter a state of flow more easily [165, 304]. Flow enhances creative performance by deepening the emotional and sensory engagement of the musician, reinforcing the immersive nature of musical practice.

Live performance (which encompasses concerts, festivals, and gigs across genres), as the culmination of creative practice, offers musicians a platform to share their skills, emotions, and stories. Wood et al. [511] described musical performance as *"intimate encounters with others... about sharing an emotional experience with other people, most of whom will never see each other again."* During live music performances musicians use their interpretive choices to breathe life into music [172]. At the heart of performance is **musical expression**: a set of perceptual qualities that reflect psycho-physical relationships between 'objective' properties of the music and 'subjective' (or, rather, objective but partly person-dependent) impressions of the listener [240]. An expressive performance has the ability to evoke emotions in the audience (he or she is 'moved'), or even an aesthetic response (a more complex and profound response that involves emotional, cognitive and social factors) [96]. According to Juslin [240], musical expression is influenced by multiple factors, including the composition itself, the instrument, the performer's skill and mood, the audience's preferences, and the broader context of the performance.

Live performance also acts as a medium of connection, allowing musicians to engage with their audience through sound, gesture, and emotion [240]. As Small [433] argued, performance is a collective experience where musicians and audiences co-create meaning. Audience reactions influence the performer's delivery, creating a feedback loop that makes live music uniquely immersive. The mutual influence is particularly evident in genres that rely on improvisation or active audience participation [172]. The shared energy of live performance transforms it into a deeply relational act, where participants connect on emotional and sensory levels, collectively creating new musical experiences.

2.4 Music audiences and the 'liveness' of music events

Music audiences can be broadly described as individuals and groups who experience and interact with musical performances. While this includes a wide range of listening experiences, from solitary consumption of recorded music to participation in communal events, the focus here is specifically on *live music audiences* – encompassing of individuals who attend and engage with live music performances (from big concerts to intimate gigs). As seen in the previous section, the interaction between live music audiences and musicians is a dynamic and reciprocal process, with each shaping and enhancing the other's experience. The audience's engagement shapes the atmosphere and creates the unique character of each event. As Mulder and Hitters [328] stated, *"without people experiencing the artist's performance, the concert loses its meaning."*

Audience engagement manifests in diverse ways, influenced by the music genre, event context, and individual preferences [449]. **Physical participation** – dancing, clapping, singing, or creating mosh pits – defines much of the visible interaction in genres like rock and pop. In contrast, classical music or jazz audiences show more restrained participation, such as focused listening and controlled applauding, reflecting the contemplative nature of these settings [79]. Performers, through their style and interaction, shape these responses, guiding audience behaviour and influencing the overall energy of the event [498]. Visible acts of participation are complemented by the sensory engagement that comes from live settings. Vibrations, dynamic lighting, stage design, and the shared energy of the crowd create a multisensory environment that enhances feelings of connection and amplifies the immersive nature of live music [255].

The audience experience is further enhanced by the social dimensions of live music events [255]. Singing along to a favourite song, moving in rhythm with hundreds or thousands of others, or simply sharing emotions with fellow fans creates a shared emotional journey which generates a sense of camaraderie and deepens the connection to the event and each other [79]. A key aspect of this is the emergence of **rituals** - recurring behaviours or traditions that audiences repeat each time they attend music events [481]. These can include practices like cheering for encores, waving lights during ballads, or the synchronised chanting of lyrics. Rituals are powerful because they encapsulate shared cultural knowledge and expectations, allowing audiences to participate in a communal narrative [498], transforming each event into something both uniquely personal and collectively familiar, and contributing to a heightened sense of belonging [79]. The ritualistic nature of live music creates a sense of continuity and tradition, contributing to what sociologist Émile Durkheim termed **collective**

effervescence - a shared emotional energy and harmony that arises when groups come together for a common purpose [307, 482]. This phenomenon heightens feelings of joy and excitement and solidifies the live music experience as an emotionally charged and memorable event [267].

Another important facet of audience engagement involves **parasocial relationships** – one-sided emotional connections that audiences form with performers [449]. In music, lyrics, stage presence, and personal narratives often create a sense of intimacy, allowing audience members to feel personally connected to artists, even without direct interaction. Parasocial connections enrich the live music experience by enhancing emotional investment; for instance, a fan who feels deeply connected to an artist might experience heightened joy during a performance. The rise of social media and streaming platforms has further mediated these relationships, enabling audiences to engage with performers more intimately and perpetuating a sense of closeness [384].

The **physical space of performance** also significantly influences audience engagement [36, 263]. In smaller, more intimate settings like jazz clubs or acoustic cafes, the close proximity to the performers creates a sense of personal connection, making for an intimate experience [462, 500]. On the other hand, larger venues such as concert halls and outdoor festivals cultivate a sense of being part of a vast, unified crowd. The collective experience here is accentuated, with the audience's energy and enthusiasm feeding off each other, leading to more pronounced forms of participation, like mass singing [36]. Whether intimate or grand, the venue becomes part of the live music narrative, shaping how audiences engage with both the music and each other [500].

Moreover, we cannot discuss audience engagement in live music without discussing the concept of **liveness** - the immediacy, spontaneity, and irreplaceable nature of being physically present at a performance [17]. Liveness promotes a deep emotional and sensory connection, a singular, immersive experience where audiences become fully absorbed in the moment [255, 328]. In today's mediatised world, the concept of liveness has evolved. Live events now exist as part of an **eventsphere**, extending beyond the physical venue into the digital and social layers that surround them [264]. This shift reframes liveness from being solely about co-presence in time and space to a dynamic practice where participants actively shape their experience through media. Platforms like Instagram and Facebook facilitate a continuous interaction loop, with fans actively participating before, during, and after events - sharing updates, photos, videos, and live reactions. While social media extends the event's life and reach, it also introduces new dynamics to the live experience, with real-time sharing and global discussion becoming part of the concert's buzz [384]. Moreover, it allows attendees to document their presence and share it with others, proclaiming, "I'm here!" [97]. These practices not

only extend the event's reach but also enable participants to contribute to a broader discourse , which Hammelburg [191] describes as *ambassadorship*: attendees use media to express personal experiences while simultaneously promoting the event within their networks.

In her work, Hammelburg [190], rather than viewing liveness as inherent to the medium or event, argued that it emerges through the alignment of physical and mediated environments to create shared moments of **'being now here together'** . This perspective emphasises the active role of participants in shaping their experience of liveness and highlights how digital interactions enrich the immersive qualities of live events by layering physical presence with social and emotional dimensions [394]. Hammelburg [190] further reconceptualised of liveness through the idea of *kairos* (the opportune moment) to highlight its relational and situated nature. Rather than being a fixed 'now,' liveness is a constructed 'nowness' shaped by the interplay of past, present, and future, moving beyond immediacy and simultaneity to consider how spatiality and sociality contribute to the live experience. For instance, event participants use media not only to navigate proximity and distance but also to construct a sense of place and perform their social identities, all of which enrich their perception of being there. Importantly, this perspective challenges the assumption that physical presence at an event is inherently more authentic than mediated participation. Being there live is a performative practice enacted through various media strategies, whether one is physically present or experiencing the event from a distance. The unpredictability of live performances (spontaneous interactions, improvisations, or audience reactions) heightens the immersion for both physically and digitally present participants, reinforcing the unique and memorable character of each event. Media practices, rather than merely mediating a pre-existing reality, actively construct the live experience, pinpointing to the agency of event-goers in crafting meaningful instances of liveness.

2.5 Music in times of crisis

The immersive qualities of live music and the intricate dynamics between musicians and audiences were abruptly challenged when the COVID-19 pandemic upended traditional practices. On 11th of March 2020, the World Health Organisation declared COVID-19 a pandemic, prompting global lockdowns and social distancing measures aimed at restricting human interaction as a way to 'flatten the curve' of infections. The world and its priorities changed overnight. As expected, these lockdowns severely impacted all social and economic areas [108], including the music scene, which faced an abrupt and fundamental transformation [413, 414, 443]. Concerts, festivals and tours of all shapes

and sizes - like all other social gatherings - were cancelled or postponed for the foreseeable future. The absence of live events had a negative impact on every person associated with the music industry. Artists, many of whom rely on live performances as their primary source of income [473], found themselves without a platform to showcase their craft [414]. Audiences were forced to trade concert venues for computer screens [380]. This had a ripple effect on event organisers, venue staff, technical crews, and other industries that rely on performances for their livelihoods, leading to a broader conversation about the vulnerability of the music industry in the face of global crises [320].

Physical co-presence, one of the essential elements of music performance's immersive nature, was replaced by an urgent need to reimagine connection in a socially distanced world [454]. This disruption catalysed rapid technological innovation and adaptation [345] as musicians and audiences sought ways to sustain the depth of engagement and community that music so powerfully provides. In this section, I explore how these shifts transformed the landscape of music performance, revealing both the challenges and opportunities for immersion in a new digital era.

2.5.1 Music, online

Amid the social and economic disruption caused by COVID-19, one feature of the social landscape stood out. Unlike previous pandemics, this time, the world was interconnected through digital technologies, which were widely used not only to convey information (and disinformation) and to keep businesses and families in touch but also to provide diversion, solace and inspiration to everyone confined in their homes as part of national pandemic control measures [229]. From the early days of the pandemic, music became a beacon of hope, fulfilling emotional, social, and personal needs during a time of uncertainty and isolation [396]. As the pandemic persisted, the music scene swiftly adapted to the new reality and musicians and listeners turned to the digital world. New patterns of music consumption spread with the speed of the virus itself, offering a unique form of solace and connection [158]. While live-streamed music performances and online collaborations were not novel concepts, the pandemic brought unprecedented reliance on digital platforms, reshaping how music was shared, experienced, and consumed. This shift introduced both opportunities and challenges.

The rise of virtual concerts – i.e., performances streamed live or on-demand via the internet and other forms of interacting with music online – became a hallmark of the pandemic era. Artists quickly transitioned from physical stages to digital platforms such as Instagram, YouTube, and Twitch. Such platforms gained momentum and became stages for performances, providing artists a fresh

avenue to connect with audiences [151, 251, 380], and demonstrating that even in the darkest times, music can bring light and comfort [85, 320]. Renowned musicians like John Legend took to these platforms, performing for fans directly from their homes, turning living spaces into cosy concert venues[2]. Global initiatives such as "One World: Together at Home" and "One Love Asia Concert", also saw artists inviting fans into their private homes. They were performing in casual attire for televised virtual charity events to raise funds for front-line workers and those affected by COVID-19 [312], further contributing to the feeling of unity and support that live music online encouraged. At the same time, symphony orchestras, opera houses, and concert venues embraced digital formats, sharing recordings and live streams to maintain public engagement and rejuvenate their presence [46, 276, 450]. These efforts demonstrated music's ability to overcome physical boundaries, fostering collective resilience and highlighting its cultural significance even during a global crisis.

Alongside the rise of alternative stages for music performance, new trends in music creation also appeared in the form of reworkings of existing music or new compositions on the theme of COVID-19 and/or the lockdown itself. This work often included fun and thought-provoking videos that proliferated on social media platforms like YouTube and TikTok under hashtags such as #coronasongs, #quarantunes, and #songsofcomfort [236]. Such songs and performances addressing the pandemic's impact resonated deeply and reflected shared feelings of uncertainty, hope, and the human spirit's endurance, highlighting the power of music to uplift spirits, provide comfort, and bring people together, even when physically apart [193]. The pandemic also accelerated innovation in virtual concert experiences. Artists like Travis Scott, Ariana Grande, BTS or Lil Nas X collaborated with platforms like Fortnite, Minecraft or Roblox to deliver virtual concerts, drawing millions of viewers and showcasing the innovative potential of combining music with digital gaming landscapes[3]. These events demonstrated the potential for digital spaces to deliver large-scale, interactive music experiences. By combining music with gaming environments, these performances further showcased the creative possibilities of emerging technologies while broadening access to live events [46].

Through these adaptations, the music industry demonstrated remarkable resilience and creativity, finding ways to innovate and connect despite unprecedented challenges. The pandemic brought out the enduring importance of music together with transformative potential of technology in reimagining how it is experienced and shared.

[2] https://www.globalcitizen.org/en/content/john-legend-together-at-home-against-coronavirus/
[3] https://www.mirrorworld.media/lil-nas-x-to-travis-scott-the-biggest-metaverse-concerts/

2.5.2 Musician's life circumstances and the transformation of musical practice

While the digital shift opened new avenues for music consumption and new performance formats, it also imposed profound changes on the lives and practices of musicians. Beyond the technological adaptations and creative opportunities, musicians faced significant challenges in navigating this new landscape [85, 414]. The absence of physical co-presence disrupted established ways of collaborating, performing, and connecting with audiences, while the reliance on digital platforms introduced new technical and creative limitations [454]. These shifts forced musicians to reevaluate not only their professional identities but also the very nature of their craft.

The pandemic's most immediate impact was **economic**. The abrupt halt of live events eliminated a primary source of income for many musicians, particularly freelancers and those in the early stages of their careers [443, 456, 528]. This financial strain was exacerbated by the unpredictability of lockdowns and the lack of alternative income streams [110]. Along these lines, studies found that musicians' perception of job insecurity also increased, with many feeling uncertain about future employment opportunities [3, 111]. This insecurity was exacerbated by the lack of effective short-term income support and the limited success of pivoting to online media strategies [3].

Beyond the financial toll, the pandemic had a significant impact on musicians' **mental health**. Studies from the UK [443] and the US [495, 528] revealed that reduced income, isolation, and job insecurity were strongly associated with increased depression, loneliness, and reduced overall wellbeing. These issues were more common among women, non-binary individuals, older adults, and people with disabilities [501]. Moreover, the pandemic led to the loss of community and social support networks, which are crucial for musicians' wellbeing [528]. Musicians reported feelings of grief, loss, and disconnection from their creative communities, highlighting the emotional toll of a world in which physical co-presence – so central to musical practice – was no longer possible [501]. Many musicians also struggled with their professional identities, expressing anxiety and uncertainty about their future in the industry [75, 111]. Pandemic-related stress, coupled with financial instability, further diminished motivation and creative energy, making it difficult for musicians to engage in their art even though they knew that it might help [85].

The COVID-19 pandemic also significantly impacted the practices of musicians, affecting their routines and the spaces they worked in. The changes to musicians' daily schedules impacted their ability to maintain a **regular music practice.** Many musicians experienced a reduction or fluctuation in their practice time during the pandemic due to the lack of professional commitments and the overall un-

certainty [149, 152]. For example, Cai et al. [85] found that the free time due to cancelled gigs and tours had negative consequences, with musicians reporting an amorphous, unstructured schedule that led to procrastination and a loss of creative purpose. The spaces musicians work in were also impacted, what Taylor et al. [454] referred to as a 'crisis of spatial materiality'. Traditional **rehearsal spaces and studios** became inaccessible due to health restrictions, pushing musicians to transform living rooms, bedrooms, and other unconventional settings into makeshift rehearsal spaces [85, 454]. These environments were acoustically limited, felt uninspiring and reinforced feelings of isolation. Nonetheless, some musicians responded to these conditions by focusing on individual skill development and new creative approaches [85, 149]. They drew inspiration from familiar surroundings, such as natural outdoor sounds or domestic noise [85]. Some used their free time to refine their technique, set personal goals, participate in virtual ensembles, or initiate new projects [85, 149, 529]. Others reassessed the gig-driven nature of their careers as [85] found. They considered ways to achieve greater control over their creative work in the future.

To sustain their work, during these times, musicians also started to **embrace more technology**. Online tools became essential for composition, rehearsal, and recording, enabling musicians to maintain creative output despite physical distancing [75, 149]. For example, a study by Onderdijk et al. [346] reported a 79% decrease in live public performances during lockdowns but a 264% increase in online music-making. Musicians turned to social media platforms like YouTube, Facebook, Twitter, and TikTok to perform live-streamed concerts and share recorded videos from their homes, creating the 'coronamusic' phenomenon [193, 380, 396]. Moreover, the pandemic necessitated new forms of remote collaboration with musicians experimenting with different technological infrastructures and tools [156]. Real-time rehearsals using video conferencing tools like Zoom became common [126, 323]. In addition, musicians formed large-scale virtual orchestras and choirs, participated in global online forums, and started collaborative projects [40]. For example a study by Benford et al. [40], looked at two traditional folk clubs, with no previous interest to engage with technology, transitioned to the online space during COVID-19, finding new ways to appropriate technology to support their needs. Such activities helped maintain a sense of community and belonging even when musicians could not physically be together [158]. In addition, asynchronous methods of collaboration became popular – such as musicians sending each other recordings [346]. Onderdijk et al. [346] found that in many cases musicians preferred such methods, rather than turn to unfamiliar frameworks enabling network-based musical collaboration. Beyond enabling collaboration, these methods became a way to compensate for the lack of psychological safety experienced in remote collaborations as they allowed musicians to experiment freely and edit their contributions without the pressure of

immediate judgment [85]. The adaptations embraced by musicians also highlighted the limitations of existing technologies for live musical interaction, such as latency issues [40, 346]. Nevertheless, even the challenges musicians faced further demonstrated their resilience and adaptability, as they prompted them to become more creative [85, 110, 443]. For example, the constraints of remote collaboration prompted some musicians to experiment with **new musical styles**, such as incorporating silence as a creative element and adjusting their rhythms to accommodate latency [85]. This creativity demonstrated how limitations can sometimes lead to unexpected artistic innovations [110, 111].

2.5.3 Moving forward

Overall, the pandemic accelerated the music industry's adoption of digital platforms, revealing their potential to complement traditional live performances[4]. Live streaming offered artists unprecedented global reach, connecting them with audiences in regions previously untouched by tours [181]. While concerns about cannibalising in-person ticket sales persist, live streaming is increasingly seen as complementary, fulfilling distinct audience needs [131, 345]. The period of transformation brought to surface music's adaptability and the value of remote formats. These lessons continue to shape the relationship between music and technology, ensuring its relevance in a rapidly changing world.

2.6 Technology for remote music performances

Technology has always been deeply intertwined with music, from the development of instruments to recording and broadcasting innovations that expanded how music is created, shared, and experienced [191, 326, 478]. In the context of remote music performances, it takes on an even more significant role, bridging distances while reshaping ideas of liveness, collaboration, and engagement. In this section I look at how technologies have supported and redefined remote music practices.

2.6.1 Music in HCI

Within the HCI research space, music has become a dynamic area of study, focusing on how technology influences and reshapes musical creation, performance, and audience experience. This space brings together researchers, designers, musicians, and technologists to explore how computational

[4] `https://unitedtalent.app.box.com/v/UTACOVIDConsumerStudy`

systems transform music-making, performance, and audience engagement. Communities such as CHIME (Computer-Human Interaction and Music Network)[5] and NIME (New Interfaces for Musical Expression)[6] highlight advances in musical interfaces and embodied interaction [216], while initiatives like the Internet of Sounds network[7] and journals such as the Journal of New Music Research[8] extend this dialogue, examining the evolving relationships between music and technology.

HCI music research spans digital and virtual instrument design [409], audience interaction [112], and novel interfaces that push boundaries of creativity and connection. Gesture-based controllers, adaptive systems, and multisensory performances illustrate how technology can expand artistic possibilities [315, 453]. Emerging tools like AR, VR, and IoT allow users to compose and perform in immersive, three-dimensional environments, breaking traditional constraints [186]. The proposed subfield of Music-Human-Computer Interaction goes deeper into how music interfaces shape creativity and experience [213]. Holland et al. [216] traced this research trajectory, covering topics such as embodied interaction, VR, gaming, and dance [215]. These efforts align with third-wave HCI trends, emphasising cultural context, embodiment, and emotional resonance [186, 214].

The scope of music-related work in HCI is vast. In the following sections I will focus on work relevant to remote music performances, specifically looking at musicians and audiences. The narrower lens allows for a more detailed discussion of how musicians and audiences experience, interact with, and adapt to remote and technologically mediated music practices. I would like to note here that much of the research I discuss involves immersive technologies because of the significant role they play in enabling remote music experiences. Although I proposed a shift in framing 'immersive' as an experiential quality rather than a purely technological feature, it is important to acknowledge that many advancements in the remote music space are inherently tied to these technologies.

2.6.2 Technology for creative musical practice

The creative process of making music has long been shaped by advancements in technology. In the context of remote musical practice, emerging technologies such as XR and and networked systems have begun to redefine how musicians engage with their craft [411]. Here, I explore how these technologies enable new forms of creativity, focusing on their role in supporting musicians working across physical and virtual spaces.

[5] https://www.chime.ac.uk
[6] https://www.nime.org
[7] https://internetofsounds.net/
[8] https://www.tandfonline.com/journals/nnmr20

Technology for creative mindset

The relationship between musicians, their tools, and the environment is central to the creative process. Emerging technologies have explored methods for rethinking this relationship, often placing emphasis on flexible, personalised virtual settings that enable new forms of composition and performance. Customisable virtual environments, for example, have shown potential in improving creative flow. Schlagowski et al. [403] developed a VR application for composing percussive beats, demonstrating that tailored environments significantly enhance creative flow. Personalisation improved user experience and addressed specific creative needs, fostering innovation. However, experienced musicians found these tools less expressive than traditional methods, indicating the need to integrate familiar instruments and workflows to bridge this gap.

Research has also targeted broader creative tasks like composition and sound design. Soundfield [175] presented a way to manipulate spatial sound as a compositional element, moving beyond static music-making towards more immersive, multi-layered configurations. VR Open Scores [306] took this a step further, embedding aleatoric musical scores into virtual spaces to encourage exploratory rather than strictly linear compositional approaches. Such efforts have grown more accessible through platforms leveraging WebXR and Web Audio APIs [86], which offer immersive creative tools directly in web browsers, widening participation and inclusivity. These developments can also support remote performance contexts, as seen in Coretet [185], where pre-composed scores appear as virtual markers on instruments, integrating composition and performance into a unified practice.

Physical and virtual interfaces remain important factors in ensuring these tools are practical. Piivert [49], with its six degrees-of-freedom tracking and pressure sensitivity, exemplifies how well-designed input devices can enhance musicians' control over complex environments. Yet musicians often prefer physical controllers for their tactile precision and reliability, as noted by Bennington et al. [43]. These findings point to a key balance that must be struck. Technological solutions should support new creative paradigms while respecting established practices, ensuring that remote music-making becomes more expressive and accessible without sacrificing the control that musicians value.

Virtual Reality Musical Instruments (VRMIs)

Virtual Reality Musical Instruments (VRMIs) are digital instruments designed to be played in virtual spaces, often accessed through Head Mounted Displays (HMDs) or immersive systems like caves

[409][9]. They combine sound and visuals, allowing musicians to interact with their instruments in new ways. Some research explores how to recreate traditional instruments, such as drums [182, 301, 502], while other projects introduce entirely new virtual instruments. Concordia [435], for example, uses planetary movements to inspire exploratory, sonified compositions. VRMIs are not limited to performance. They have supported new forms of music composition through collaborative sequencers [318], VR-based digital audio workstation interfaces [12], and looping systems [48, 50]. Some designs rely on unusual note arrangements, such as wedge-shaped note layouts [322], or imaginative virtual worlds like those filled with planets and satellites [114]. This versatility aligns with related concepts like smart instruments, which use sensors, connectivity, and embedded intelligence to create new musical experiences [465]. However, VRMIs come with several challenges. They lack an established tradition and repertoire, which makes it difficult for them to become mainstream. Designing these instruments demands expertise across music, technology, and spatial design. For example, Berthaut [51] stressed the importance of integrating VRMIs into well-planned artistic and spatial contexts. Although they show promise, VRMIs remain a niche innovation that requires further refinement and integration before gaining wider acceptance.

Technology for remote collaboration

Technologies supporting remote music performance have expanded opportunities for real-time collaboration among musicians, regardless of their physical location. Along this line, Networked Music Performance (NMP) is a field dedicated to supporting synchronous musical interaction over computer networks, with the goal of reproducing the immediacy and responsiveness found in co-located sessions [91, 225, 387]. Some systems aim to enhance local interactions, such as the VR step sequencer LeMo [319], Carillon's shared virtual instrument [187], and Coretet's ensemble environment [185]. Others focus on geographically dispersed groups, as seen in ARLooper, which employs augmented reality to synchronise recording, playback, and sound manipulation across different locations [353]. NMP platforms address issues like latency and connectivity to approximate the timing and expressiveness of face-to-face performances. However, many solutions concentrate on the performers' experience while leaving audiences as passive observers. Events often rely on one-way live-streaming with limited opportunities for viewers to engage [398, 480]. The Internet of Musical Things (IoMusT) framework envisions a more connected and participatory future. It aims to establish low-latency, multi-directional communication channels, allowing audiences to actively contribute to the perfor-

[9] Caves are immersive VR environments where projectors are directed to between three and six of the walls of a room-sized cube

mance [209, 467, 516]. Realising this vision remains challenging. Barriers such as ensuring reliable connectivity, addressing hardware constraints, and implementing cohesive design approaches that integrate both remote performers and audiences must still be overcome.

Immersive technologies for rehearsing and skill development

Research has also investigated how immersive environments can support remote music rehearsal and skill development, with studies tackling issues such as performance anxiety, and the need to accommodate musicians with varying levels of expertise. For instance, VR exposure training has proven effective in helping musicians manage stage fright. Bissonnette et al. [56] demonstrated how VR systems can simulate concert-like environments, offering a practical alternative to physical stage presence. Similarly, the Royal College of Music's Performance Simulator [15, 16] immerses students in realistic recital conditions, complete with video-projected audiences, stage lighting, and auditory cues like applause and coughing. Nevertheless, while these systems have shown success in reducing anxiety and improving performance readiness, they face limitations such as lack of portability and an inability to replicate complex acoustics, pointing towards the need for more adaptable and acoustically sophisticated solutions.

Further research has focused on improving the quality of immersive auditory feedback. Sophisticated 3D audio rendering has enabled musicians to experience a range of virtual acoustical settings, from large concert halls to smaller, historically significant venues [243, 253]. Such environments help learners understand spatial acoustics and encourage experimentation in composition and improvisation [127, 355]. Other studies have integrated AR technologies to provide real-time visual feedback to musicians. Early tools, such as the guitar training system developed by Motokawa and Saito [324], overlay chord names onto a live camera feed of the player's fingers. Similar systems have been developed for piano [55, 517] and drums [521], delivering intuitive feedback that makes practice sessions engaging and effective. HMDs have since combined physical instruments with virtual overlays, as in the HoloKeys piano system [180], which preserves familiar ergonomics while introducing digital guidance. Similar work was conducted by Fanger et al. [150] who proposed the design of an XR Piano training system. While such work has shown promise, most of the systems lack the precision and expressiveness needed for higher-level training [410], and many still focus on beginners rather than professional musicians. Moreover, they require complicated setups making them impractical for use outside of laboratory settings.

2.6.3 Technology and the transformation of music audiences

The digital transformation of music events has led audience experiences into a new era, shifting audiences from passive observers to active participants [92, 97]. The evolving dynamic, where music experiences transform and audiences become part of both their creation and their reception – as an active participant, player, performer, conductor, creator and controller of content [95] – demands new approaches to support audience engagement across these roles, as shown by emerging technologies and research examples [92]. The shift toward participatory experiences happens in two primary spaces: the in-person audience, where technology enhances co-located experiences, and the remote audience, where digital platforms enable participation from afar. Additionally, at the intersection of these two modes, hybrid experiences engage simultaneously in-person and online audiences, creating interconnected layers of participation. Beyond these physical formats, engagement has also a time-based dimension – both during and after the experience – and multiple modes of interaction, forming a multidimensional framework for audience involvement [191].

Audience engagement in music performances has long focused on enhancing live, in-person experiences through new methods and technologies, particularly within the domain of electronic music. For example, Correia et al. [113] addressed the common challenge of audience disconnect caused by the lack of visible feedback in laptop-based or sensor-driven music. The authors argued that live visuals can support audience understanding by making the performer's interactions with the system more transparent and interpretable. Through techniques such as mapped audiovisual correspondences and dynamic visual cues, their work demonstrated visuals are important in clarifying the relationship between input (performer actions) and output (audiovisual results), enhancing the audience's cognitive engagement, and their emotional and sensory connection to the performance. Extending these ideas, other examples explored how technologies such as haptics, mobile phones, and interactive tools can enrich in-person experiences across various contexts [208, 239, 248, 270, 469, 514].

Building on this foundation, Bauer and Bouchara [34] expanded the scope of audience engagement by exploring the potential of AR for remote and individualised music experiences. Their work shifts attention from the concert stage to the private sphere, transforming solitary listening into an interactive event. Climb! [39], by contrast, employed a more intricate approach, integrating in-person performances with digital tools such as projected visuals, a mobile app, and an online archive. The layered design engaged both live audiences and those revisiting the performance through digital platforms, offering opportunities for learning and reinterpretation thereby extending engagement

beyond the live event. These advancements were further complemented by research into multisensory technologies and VR applications. For example, haptic rendering pipelines, such as those proposed by Jung et al. [238], Jung and Clester [239], have been designed to translate performers' motions into tactile feedback, enriching sensory connections and creating a shared language of physical feedback, addressing the limitations of earlier systems, which relied on discrete haptic stimuli disconnected from the performance context. Similarly, VR has shown potential in making music experiences accessible to blind and low-vision audiences, enabling these individuals to actively participate in immersive musical performances, overcoming traditional barriers to inclusion. Beyond accessibility, VR technologies have introduced new possibilities for real-time composition and historical reinterpretation. Tools like SpectraScore [89] allowed audiences and performers to co-create music in virtual environments, translating audio signals into visual objects. Similarly, projects like the VR opera set in Gobeklitepe [90] combine astronomical data and spectralist techniques to create ritualistic soundscapes, offering audiences an opportunity to explore historically inspired environments. Many studies in these domains reported benefits such as improved transparency of performer actions, heightened sensory and emotional connections, and creative opportunities for audience involvement. However, most studies prioritised technical stability, paying less attention to how such technologies could integrate with remote or hybrid contexts. Broader questions about how these systems might fit into wider socio-technical environments remain largely unanswered.

2.7 Towards designing human-centred remote music experiences

While there is a growing body of HCI and design research focused on remote and technologically mediated music experiences, particularly within areas such as XR, sonic interaction design, and the Internet of Sounds [464, 468], much of this work tends to emphasise the *what* of technology: the systems developed, their technical capabilities, or the specific use cases they address. These contributions are important, especially since target specific use cases and offer situated insights that are meaningful in their own right. However, what is often less visible is the *why and how* behind the work: the design reasoning, the constraints navigated, or the broader questions the work raises about human experience. Articulating these aspects can offer significant learning, not only for adapting or critiquing existing approaches but also for shaping future ones.

This is where a human-centred design approach becomes particularly relevant [445]. Rather than prioritising the capabilities of a technology, a human-centred perspective focuses on the experiences,

needs, and values of those engaging with it. It makes room for the complexity of people's practices, contexts, environments, and aspirations, and encourages reflection not only on what is built, but on how it is used and why it matters. In this thesis, I adopt this orientation to explore remote music performance from the ground up, centering musicians and audiences as co-creators of meaning, and paying attention to the messy, iterative, and reflective aspects of the design process. This approach supports a shift away from technology-led development, and towards designing experiences that resonate with people in their own terms.

Human-centred design emphasises designing not only for usability or functionality but also for the relationships, social contexts, and cultural values that shape how products or technologies are experienced [174]. This can help ensure that the things we design (whether technologies, products, artefacts, systems) facilitate human connection by matching *"the needs and capabilities of the people for whom they are intended"* [339, 395]. Adopting human-centred design can expand the space for innovation, inviting new researchers and practitioners to contribute to the field to propose adaptable frameworks, tools, and practices that can serve as entry points for interdisciplinary exploration. Unlike user-centred design [339], which often frames users as passive recipients of technology – it looks at people's roles as users; human-centred design adopts a wider perspective – it looks at them as people/humans [445, 460]. Human-centred design emphasises designing for the relationships and ecosystems surrounding individuals [174, 445]. For example, in remote music performances, the experience of a solo musician, an ensemble, or an audience member is not isolated; it is co-constructed within the performance context, shaped by their interactions within the broader performance environment. By accounting for these dynamics, human-centred design approaches can enable the creation of technologies sensitive to the varied ways people engage with music.

2.7.1 Human-centred methodologies in HCI

HCI has evolved from focusing on usability – making systems easier to use – to understanding users' needs before designing solutions [24, 116]. This shift aligns with the three waves of HCI [62] where the third wave recognises how technology is embedded in all aspects of life, blending work and home contexts, and emphasising constructs like experience, emotion, and meaning [63]. The third wave laid the groundwork for the broader adoption of human-centred design within HCI, emphasising the need to align technological innovation with the behaviours, needs, and contexts of its users [445]. At its core, human-centred design involves iterative processes that engage users throughout the design lifecycle, from ideation to evaluation, positioning technology as a facilitator rather than

just a functional tool [339]. This makes it particularly suitable for addressing some of the complex, open-ended challenges HCI tackles.

Human-centred design has been applied across diverse topics in HCI, reflecting its adaptability and relevance. In accessibility, it has led to technologies empowering users with disabilities through participatory design and iterative testing [356, 524]. In healthcare, it has informed the development of patient-centred systems, including those tailored for low-resource settings [212]. In music, it has involved musicians and audiences in designing interactive systems for technology-mediated participation [207]. These are only very few examples that showcase human-centred design's strength in addressing context-dependent areas, but they also highlight its variability and ability to apply to basically any type of topic with varying levels of depth and fidelity. Some projects embrace its methods holistically, engaging users as active collaborators throughout the process, while others limit user involvement to late-stage validation or usability testing [445]. This diversity, while a strength, can lead to inconsistencies in how human-centred design is understood and applied, raising questions about its authenticity in different contexts. It is important to note here, that since interpretations and understanding of human-centred design can vary widely, what I describe here may not resonate with some but could fully encapsulate the understanding others have of it. My own understanding continues to evolve as I go deeper into research and engage with different perspectives.

Publication venues like CHI conference on Human Factors in Computing Systems[10], Design Interactive Systems (DIS)[11], and Participatory Design Conference (PDC)[12] have championed human-centred design by encouraging creative and context-sensitive approaches to technology design. Researchers from design backgrounds often adopt human-centred design holistically throughout their work [7, 9]. Conversely, work from technical disciplines may use human-centred design more superficially [72], treating it as a validation step or a buzzword[13] rather than a guiding philosophy [451, 519]. While both approaches have merit, narrowly framed applications risk oversimplifying the principles of human-centred design overlooking the broader cultural and social ecosystems that they are uniquely equipped to address [445]).

Despite these challenges, human-centred design remains essential for projects that intersect human values and technology. Its exploratory nature makes it especially suitable for interdisciplinary fields like remote music performance, where it helps navigate complex ecosystems involving performers,

[10] `https://chi2025.acm.org`
[11] `https://dis.acm.org/`
[12] `https://dl.acm.org/conference/pdc`
[13] I often find that this happens a lot with the terms co-design and participatory design within HCI.

audiences, and technologies. Here, human-centred design approaches offer me a way to explore and expand the design space through the eyes of its people.

2.7.2 Approaches to human-centred design

Human-centred design uses techniques that prioritise communication, empathy, and understanding between designers and the people a design is intended for [445]. Unlike traditional design, which often centres on the designer's vision or the technological substrate, the emphasis is shifted to the needs, desires, and experiences of users – sometimes uncovering insights users themselves had not consciously recognised. In the section that follows, I explore some of the approaches, methodologies, tools and bodies of work that have informed my own research, highlight their relevance while also identifying gaps or tensions that emerge in their application. Some of these approaches align more closely with human-centred design principles, while others may not strictly fall under the human-centred design umbrella but still offer ways for understanding and addressing human-centred challenges. Moreover, I want to note the text that follows is not exhaustive and does not aim to provide rigid definitions or analysis; the goal is to offer an overview of key topics and their intersections while recognising the overlaps and fluidity between them.

Participatory design and co-design

Participatory design and co-design are key methodologies within human-centred design, emphasising collaboration with stakeholders as 'creative partners' [184]. Both approaches aim to ensure inclusivity and that design outcomes reflect users' needs, values, and experiences [491]. While often used interchangeably in HCI, they differ in focus. Participatory design has roots in Scandinavian traditions of the 1970s [143] and centres on political and ethical commitments to empowerment [65, 330], seeking to involve users as partners, leveraging their domain expertise to shape systems and tools that address their real-world contexts. Co-design, on the other hand, prioritises the collaborative process of ideation and creation, often integrating broader groups – including non-users such as stakeholders or policymakers – and blending participatory principles with design thinking frameworks [395]. This distinction is significant in HCI, where especially co-design is sometimes misapplied, with projects claiming to be co-designed but limiting user involvement to feedback or validation rather than genuine collaboration and partnership [28].

Workshops are a core practice in both participatory design and co-design, offering structured spaces for collaboration and creativity [118, 183, 224]. Other techniques, such as design games, mock-ups, and storyboarding, encourage participation and mutual understanding [183, 210]. Tools like design card decks provide prompts for creative discussions, while probes such as diaries or self-documentation kits enable participants to share insights from their everyday lives, enriching the design process with contextual understanding [6]. Role-playing and enactments surface tacit knowledge and emotions, facilitating co-creation and shared ownership of outcomes [395, 510]. Such methods help overcome power imbalances by giving participants the tools to articulate their perspectives.

These methods are not without challenges. Poor facilitation can result in superficial involvement or tokenism, undermining the democratic ethos of these approaches [159]. Power imbalances can favour designers' voices over participants' [145], while diverse stakeholders may have conflicting priorities, requiring careful mediation [18]. Additionally, the focus of participatory design has narrowed to usability and satisfaction, moving away from its origins in broader social and political change [25, 57, 64]. To address this, within the community there has been calls for expanding the scope of participatory design practices through integrating new methods, tools and theories, such as learning from disciplines like sociology and anthopology and embracing approaches like research through design [170], constructive design [260], and speculative design [142]. Such methods could broaden participatory design's scope, allowing it to tackle pressing global issues like climate change or public sector challenges while also critically engaging with technology design to explore alternatives that prioritise user benefit and open-source principles.

In my work on remote music performances, participatory design and co-design are essential for engaging musicians and audiences as collaborators in shaping technologies that align with their creative practices. I adopt a perspective that blends these methodologies, acknowledging their distinctions while adapting them to the unique challenges of my research context.

Understanding users and their contexts

Contextual engagement methods capture the complexity of users' lives, practices, relationships, and environments, recognising how social, cultural, and physical contexts shape their behaviour and needs [460]. In-depth interviews are central to this approach. They provide the time and space to build trust, uncover tacit knowledge, and explore personal narratives and cultural details essential for designing technologies that align with users' real experiences [1, 60]. Semi-structured interviews,

often used alongside contextual methods, offer flexibility to gain insights into behaviours and needs.

Beyond interviews, contextual and situated approaches focus on studying users within the specific environments where they operate [237, 385], recognising that technologies are shaped by – and shape – the social, cultural, and physical contexts around them [385]. Techniques such as ethnography and contextual inquiry prioritise engagement with users in their environments, allowing for capturing context-specific insights often overlooked in controlled settings. Ethnography uses long-term observation to uncover patterns and values [237], while contextual inquiries focus on workflows and decision-making by observing users in situ [218]. Along these lines, Vera and Simon [486], who proposed the situated action approach, argued that human behaviour is not fully predictable but emerges dynamically in response to the specific context. This aligns with the view of Mackrill [300] who explained that situated methods *"emphasise the situating contexts … with the complex relation between the context and design situation. Such methods involve different actors and stakeholders, as well as societal structures given by institutions, regulations, market mechanisms, and so forth."*

While these methods provide deep insights, they present challenges. They are time-intensive and require navigating ethical complexities, such as informed consent, power dynamics, and participant privacy, particularly in vulnerable communities [325]. Findings from specific contexts can risk overgeneralisation, particularly in interdisciplinary fields like HCI, where cultural and technical differences influence applicability [195]. Navigating situated approaches in online environments presents additional complexities, requiring adapting methods to fit digital realities. Digital ethnography or 'netnography' provide tools to study online interactions [333] but raise ethical concerns around consent, privacy, and blurred personal-public boundaries [11]. Researchers must also account for unique digital affordances, such as asynchronous communication and virtual anonymity [206].

In my research, these methods have been essential for understanding how remote music technologies fit into musicians' and audiences' lives. In-depth interviews uncovered creative practices and aspirations, while contextual and situated methods, such as event observations, revealed the dynamic interactions between people, digital spaces, and tools. To complement these methods I also used qualitative surveys, particularly in the audience-focused phase of the study, to gather broader perspectives and open-ended reflections on remote music experiences. The surveys complemented the interviews and observations by capturing personal attitudes and behaviours in participants' own words, and helped inform the focus of follow-up qualitative work. Together, these approaches grounded my designs in users' realities and opened opportunities for innovation.

Prototyping

Prototyping is a core element of HCI and human-centred design, enabling designers to externalise ideas, test assumptions, critique, and refine solutions through iterative processes [279, 310, 341]. Prototypes can range from low-fidelity, such as sketches and wireframes, for quick exploration to high-fidelity ones, simulating real-world interactions for detailed user testing. Mixed-fidelity prototypes combine both, focusing resources on critical areas while maintaining flexibility in others [279, 310]. Prototypes can take many forms, such as physical artefacts or digital ones [173]. The flexibility enabled by their form and fidelity makes prototyping invaluable for iterative design, where constant testing and refinement can inform decisions and enhance outcomes [173, 340].

Prototyping methods have expanded further with immersive and embodied methods. Embodied prototyping techniques (e.g., Wizard-of-Oz prototypes, speculative enactments, magic machines) involve physically enacting or simulating interactions - with users 'acting out' potential designs, emphasising the tactile, emotional, and social dimensions of design [9, 52, 140, 146, 420]. Immersive prototypes, using technologies like VR and AR, enable stakeholders to experience designs in realistic or future-oriented scenarios, bridging the physical and digital [119, 250, 315]. Such prototypes exist on a spectrum, ranging from AR, where virtual elements are added to physical models, to augmented virtuality, where physical elements are added to virtual models [119]. These methods are particularly effective for evaluating complex or speculative designs, as well as prototyping experiences [81] rather than artefacts because they allow users to visualise and interact with a design in its its intended environment [250]. However, the challenges of high cost, technical complexity, and fidelity calibration must be managed to ensure accessibility and effectiveness [119, 250].

Prototyping, while a great tool also introduces several tensions that require careful navigation, including balancing fidelity to avoid oversimplification or premature narrowing of the design space [310]. Prototypes are also inherently subjective, and their interpretation can vary across stakeholders, risking miscommunication or misalignment of design intent [279, 341]. Additionally, while prototypes exist in the present, they often aim to evaluate future scenarios, creating uncertainty about their long-term relevance [393]. These challenges highlight the importance of iterative refinement and careful alignment with design goals. Within my own work, I used prototypes to explore user interactions, refining designs to support creative practices, and addressing the domain's complexities.

Speculative design, design fiction and other ways for imagining the future

Speculative design uses design to explore future possibilities [142]. It has become a recognised approach in HCI, offering tools to critique and imagine potential futures through narratives, artefacts, scenarios, and interventions [510], by shifting attention to societal, cultural, and ethical questions. By engaging with 'what if' scenarios, speculative design is used to challenge assumptions, provoke discussion, and expand the boundaries of design possibilities [142]. This also allows designers to envision design spaces unconstrained by the practical realities driving many real-world design projects and to critically reflect on the limits of current approaches while suggesting alternatives.

A strength of speculative design lies in its ability to help stakeholders envision alternative futures and question technology's role in society [142]. Methods such as critical design artefacts [493], catalogues of ideas [7, 118], 'magic machines' [9], and speculative enactments (immersive [420] or not [146]) create thought-provoking representations of potential worlds. These approaches are particularly useful for addressing 'wicked problems' like sustainability, AI ethics, and social justice, where future directions are uncertain [438]. However, speculative design can face challenges, such as ambiguous intent, which requires clear communication to ensure its provocations are meaningful [510]. Additionally, Thibault [457]'s critique of 'design kitsch' highlights the risks of superficial projects that mimic speculative methods without engaging with critical societal issues.

Speculative design broadens imagination, challenges assumptions about what is possible, and opens new avenues for designing technologies [61]. It educates stakeholders on emerging possibilities and highlights opportunities for future innovation [137]. In my research on remote music performance, speculative design helped imagine technological futures unconstrained by existing limitations, uncovering hidden assumptions and inspiring new approaches to designing for connection and creativity. Most importantly, it encouraged conversations, offering insights that challenge norms and expand the boundaries of what is possible and desirable in this space.

Embracing reflexivity

Reflexivity – the practice of critically examining one's role, assumptions, and influence within a research or design project – is very important in human-centred design. In HCI, reflexivity prompts researchers to question how their positionality, decisions, and values shape both the design process and its outcomes [262, 445]. Rooted in feminist and participatory traditions, reflexivity moves beyond

'objectivity' by recognising the researcher's subjectivity as integral to the work [29]. Self-awareness ensures research is ethically grounded and attuned to the cultural, social, and political contexts of technology use. It also highlights power dynamics in research, urging designers to consider whose perspectives are prioritised during decision-making [138].

In human-centred design, reflexivity extends to the researcher's own practices. Early critiques of ethnography warned against essentialising cultures or reinforcing imbalances through the 'god voice' of supposedly objective accounts [194]. Reflexive methodologies address this by acknowledging the researcher's influence on knowledge production, integrating their perspectives into the work [169]. This approach has gained traction in HCI, where ethnographic research often includes the researcher's emotional labour, subjective experiences, and ethical dilemmas [23, 133]. Such practices empower researchers to explore the interplay between their identities, the research context, and the outcomes they produce, leading to more honest insights [222].

In my research on remote music performances, being reflexive allows me to examine my assumptions, methods, and evolving understanding. It allows me to adapt, remain transparent, and ensure ethical soundness. Reflecting on my dual role as researcher and participant in this thesis, I navigate tensions and opportunities that arise during the design process, grounding my insights in an awareness of my influence. Inspired by Doucet's concept of "gossamer walls" [138], I aim for clarity and accountability in interpreting and sharing my findings.

2.8 Bringing it all together

In this chapter, I brought together perspectives from musicology, HCI, XR, and performance studies to explore what makes music immersive and meaningful, and how these qualities are transformed in remote contexts. I examined immersion not as a fixed attribute of technology but as a lived and multifaceted experience shaped by attention, emotion, space, and social presence. I also considered how musicians and audiences adapted their practices in response to the pandemic, and how technologies both supported and constrained new forms of musical expression. Below, I give a summary of recurring themes and tensions that guided the decisions I made in the rest of the thesis:

Immersion is not only about escapism or high-fidelity simulation. Rather than framing immersion as the result of isolating technologies or sensory substitution, I emphasised immersion as a dynamic, situated state that can involve being absorbed in activity, attuned to the present moment,

or participating in social and ritual interaction [338, 432]. This framing widens the possibilities for designing remote music experiences that are engaging and meaningful without necessarily relying on fully immersive technologies.

Music is a social, relational, and participatory act. I drew on Small's concept of musicking to foreground the interactive and contextual nature of music performance [433]. Whether in-person or remote, music unfolds through the relationships between performers, audiences, and their environments. Understanding these dynamics is key to making sense of how meaning is created and shared in remote performances.

Creative practice involves both structure and improvisation. Musicians move between formal routines and open-ended exploration. Practices such as rehearsing, composing, and improvising require tools that support control and precision while also leaving space for spontaneity and emergence [47, 401]. The impact of the pandemic made this balancing act more visible, as many musicians had to renegotiate their workflows and spaces.

Audiences contribute to liveness and meaning. The presence and participation of audiences, through physical reactions, rituals, and even parasocial connections, shape the emotional and immersive qualities of live music [481, 498]. In remote contexts, these contributions become more complex, involving new layers of mediated interaction, which are not always supported by existing platforms.

Technological solutions are often mismatched with everyday practices. While there is no shortage of technical innovation, especially in XR and networked music performance, many systems are designed around ideal use cases that overlook the lived realities of musicians and audiences [85, 346]. These include constraints around space, time, access, and mental wellbeing, all of which shape how people can meaningfully engage with remote music experiences.

Human-centred and participatory approaches offer a way forward. I made a case for situating design in lived experience, paying attention to context, values, and the messy, affective dimensions of practice [174, 445]. Participatory methods are not only useful for generating ideas, but for developing designs that align with how people actually make, experience, and share music.

These ideas provide me with a foundation for the methodological and empirical work that follows. They informed how I approached the study of remote music performances, how technologies are critiqued, and how I explored new possibilities; not by chasing technological novelty, but by centring the people and practices that give music its meaning.

Part II

Musicians

Musicians continuously react and adapt to the environments they play in. The acoustic and visual feedback they receive from the space impacts their performance [471], and provides musicians with different forums to exercise creativity that pertain to both i) the expressive playing of a predetermined piece of music and ii) improvisation (i.e., the playing of music pieces not specified in advance) [129]. While the room itself shapes and changes the music being played, musicians rarely have the ability to rehearse in the spaces in which they ultimately perform. Access to performing venues for rehearsing purposes is limited in time and often comes with a prohibitive financial cost. Therefore, musicians have to settle for rehearsal rooms with varying qualities, where the acoustic parameters are frequently not ideally designed [352]. The COVID-19 pandemic exacerbated these challenges and brought additional ones (e.g., in terms of access to physical spaces, time management, and entering proper mindsets) [442] that further affected and transformed the creative practices of musicians as pointed out by [85] in their insightful analysis.

Given these constraints, it becomes vital to re-evaluate traditional practices and investigate the design of solutions to support musicians' creative processes and to provide them with alternative spaces where they can continue their creative pursuits [85]. In this context, immersive technologies, such as VR, provide a compelling tool for investigating these possibilities. With its capacity to simulate diverse environments, real or imagined [427], VR presents an opportunity to examine how technology can create immersive experiences that address the physical and logistical barriers musicians face. I ask: *How might we leverage VR's ability to transport users to myriads of worlds, real or unreal [427], to design solutions to some of the physical and logistical barriers musicians face?*

Figure 2: What if VR, with its ability to transport users to myriads of worlds, real or unreal, could be used to address some of the barriers musicians encounter?

While VR is not new to the performing arts space, its potential to support the creative practices of performers demands further investigation. Previous research has looked into VR as a medium to study audiences attending performances [97, 280, 288] or as a tool for delivering new types of musical instruments [410]. However, the potential of VR to serve performers as a creativity support tool, especially those facing the challenges mentioned above, has yet to be fully explored. By leveraging

VR, we can study how immersive, customisable environments might enable musicians to engage with their craft in ways not possible within conventional physical spaces. These environments could offer new forms of acoustic and visual stimulation, supporting creative exploration while accommodating the diverse needs of musicians [34, 403].

The subsequent chapters. detail my use of VR as an investigative tool to better understand and design immersive experiences for musicians. Central to this work is the development of *VR Rehearse & Perform*, a VR prototype designed to facilitate personal music practice within virtual environments [266, 364]. *VR Rehearse & Perform* emerged through an iterative design process and serves as a means to explore how VR might enrich musicians' creative processes. Rather than presenting VR as a definitive solution, my goal is to utilise it as a medium to examine how musicians interact with immersive settings and uncover insights into their potential benefits and limitations. It is worth noting that the work presented in the subsequent chapters focuses on personal creative musical practice. The motivation for this is that musicians' solitary work is as crucial as their social practices but is often overlooked in technology design compared to collaborative and live performance-focused technologies. Personal practice is where skills are honed, creativity is nurtured, and a deep, introspective connection with music is developed [203].

Importantly, this research also contributes to broader discussions about designing technologies for musicians. I see VR as a lens through which to engage with the design challenges and opportunities in this space, not as a one-size-fits-all answer. I employ it to examine and initiate dialogue on enhancing musicians' creative processes. VR's immersive and interactive nature makes it a tangible tool to explore how technology may help musicians overcome the limits of conventional performance spaces and the shifting dynamics of their practice environments.

The following research questions guided the work:

- **RQII-1:** What are the key challenges and opportunities musicians face in creating immersive and engaging personal practice experiences at home? How might we design technology be designed to address these needs?
- **RQII-2:** What qualities of immersive environments best support musicians' creative practices, and how might we design these environments to enhance their experience?
- **RQII-3:** How do musicians perceive the role of immersive technologies in shaping their creative practice, and what insights can we gain from this?

To address the aforementioned research questions, in the following chapters, I first identify a set of design requirements ((DR) for musician-centred VR experiences, informed by insights from 11 musicians and 15 performance scientists representing a broad range of musical expertise. Secondly, I develop and introduce a novel VR system prototype *VR Rehearse & Perform*, evaluated through its application in creative music practice with a diverse group of 19 musicians (see Figure 3). Thirdly, I discuss the implications of my findings and provide insights for developing immersive experiences tailored explicitly to some of the unique demands of musicians. The discussion is informed by the qualitative analysis of the feedback collected while evaluating *VR Rehearse & Perform*. Lastly, I go beyond the immediate research findings and reflect on what I have learned as a researcher within the project, discussing my approach and contemplating on the human-centred aspects of my work.

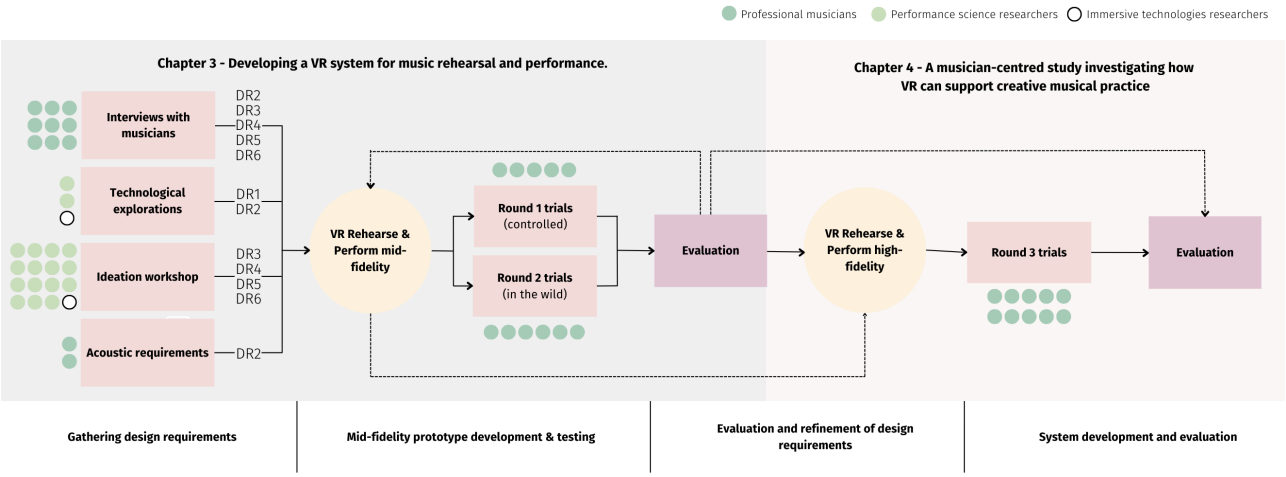


Figure 3: Overview of the methodology followed in Chapter 3 and Chapter 4

I led the project and its resulting publications, but my colleagues' contributions were invaluable. With the support of my advisor, Alexandra Covaci, and others, the project achieved significant milestones. Innovate UK funded the first version of the software presented in Chapter 3 through the Innovation Consultancy, led by Dr Vali Lalioti, who conceptualised the idea and led three of the activities: technological experimentations, an ideation workshop, and gathering acoustic insights. The work secured further funding from the UK's Arts and Humanities Research Council through the HEartS Pro grant, which explored the pandemic's impact on arts professionals and the design of supportive technologies. Under this grant, I worked on and presented the resulting VRST and CHI papers. Ragnar Hrafnkelsson, the developer of the 3DTi audio spatialisation plug-in, created its Unity version and supported its integration into *VR Rehearse & Perform*. Dr Bea Wohl contributed from the start, providing ideas and assisting in disseminating outcomes. Andrew Thomas managed data collection for the in-the-wild evaluation. Boyd Branch helped analyse the *Facilitating the creative practice* theme.

Chapter 3

From Practice Room to Virtual Stage. Developing a Virtual Reality system for music rehearsal and performance.

In this chapter, I explore how immersive technologies can support musicians by presenting *VR Rehearse & Perform*, a prototype designed to enhance creative musical practice. Here, *VR Rehearse & Perform* emerges as a case study that exemplifies how digital tools can be used as a medium for supporting musicians' creative needs related to space. In the sections that follow, I outline the iterative design, development, and initial evaluation of *VR Rehearse & Perform*, illustrating the prototype's evolution to meet the specific needs of individual musicians. These needs were identified from a thorough review of the existing literature and further refined through targeted activities with musicians and performance-science researchers at every step, embodying a musician-centred design philosophy. The collaboration took the form of in-depth interviews, hands-on technological explorations, interactive workshops, and an acoustic session, all of which contributed to shaping the design and functionality of the VR system. I then detail the development phase and present two phases of preliminary evaluation. The initial evaluations were important for beginning to understand the value of immersive technologies in creative practice, and identifying areas for improvement. Feedback from these evaluations informed the final prototype version, which is further explored in the subsequent chapter. Lastly, I outline some initial design insights gathered during the entire process with the hope of inspiring other designers to venture into similar work.

3.1 Background

3.1.1 Musical space as an instrument

Rehearsal and performance venues set the tone for music-makers and performers. The acoustic and visual experiences of musicians in the spaces they perform in are complex and organic in nature, entailing a continuous interaction with the environment [258]. Schärer Kalkandjiev and Weinzierl [400] described how, for music makers, the environment is an instrument in itself. Furthermore, as shown by Ueno et al. [472], objective differences identified in the tempo and extent of vibrato employed by musicians demonstrate their tendency to relate to the physical characteristics of concert halls and subconsciously adjust their playing technique. Ueno and Tachibana [470] proposed a cognitive model of musicians' performing action and showed that, during a performance, to generate the desired musical image, music-makers extend their physical sensations into the sound field of the concert hall to sense all its characteristics.

The complex, subjective experience musicians have with the stage acoustics enables them to form a musical representation through insight (i.e., an "aha!" moment or a string of insightful realisations), implicit learning [127] (i.e., the acquisition of knowledge about a complex stimulus domain in an incidental manner) and deliberate practice [148]. These cause a sense of intuition, spontaneity, and skill acquisition based on procedural learning and, therefore, are closely tied to musical practice components, including intuitive creativity, composition, expressive playing of music, and improvisation [127]. The dynamic coupling between the sonic world and the individual action of music-makers is further necessary for flow [488] – the mental state of complete absorption in activities or performances [123] that allows artists to tap into an abundant stream of inspiration. These processes show that the importance of continuously reacting and adapting to diverse sonic worlds cannot be overstated in the context of musicians' creative practice.

Despite this, the differences in character between a typical practice or composition venue and the performance space are often stark. Music-makers have to settle for rehearsal rooms with varying qualities, often poor, where the acoustic parameters are not ideally designed [352]. Therefore, they cannot account for the complexity of the perceptual effects involved in the musical practice. Furthermore, rehearsal spaces are not representative of the large, high-pressure environments in which musicians aspire to perform. This situation was further exacerbated by the COVID-19 pandemic, which imposed severe restrictions on the use of physical spaces [85, 442].

3.1.2 Musical space as a creative medium

The experience musicians have with the space can be examined *"both at the level of the reception and performance of music and at the level of internal processing"* [129]. Musicians do not simply play an instrument; they play a 'room' [259], and the 'room' they play is both a physical space and a mental model of the sonic world they form in their imagination. The 'room' in this context is not simply the sonic and visual environment but includes the cognitive processes being stimulated in relation to making the music. The perception of space relies on complex sensory information provided by all perceptual systems: visual, auditory, haptic, and olfactory-gustatory. Sound is only one component, as each place has its acoustics and arouses specific expectations associated with it - for instance, we expect to hear the sound of birds in a forest [299]. The visual dimension of spaces is always carefully considered in purpose-built halls, where significant attention is given not only to the acoustic design but also to the visual impression [352]. This is in agreement with Bargum et al. [30], who stressed the importance of visuals for musicians perceiving and recognising sounds in simulated concert halls.

In a recent study observing music-makers' responses to the COVID-19 pandemic, participants identified three key ways creativity was affected by the physical location of performance ;*"as a creative trigger to encourage one to start making music; as a creative input and creative prompt; as a means to create psychologically safe spaces to support creative risk taking"* [85]. For example, the authors showed that interstitial spaces (e.g., elevators) could be perceived as a trigger for creative experimentation, while being outside provides inspiration, connecting musicians to new ideas. This demonstrates how visual and acoustic spaces can be used as complex tools for injecting variety during music-making, fostering new waves of creativity. This recursive play between perceiving the external environment and musical imagination reflects how musicologist Mark M. Reybrouck described musical creativity; as a *"process of sensory–motor integration, with a gradual shift from presentational immediacy to symbolic representation"* [381]. 'Presentational immediacy' here refers to the immediate physical (acoustic and visual) environment being played in, and 'symbolic representation' refers to the mental or psychic formulations the musician is experiencing (which are independent of the sensory data being processed). Reybrouck described these simultaneously active, creative processes holistically as *"coping with the sonic world"*, which is always both part of the physical environment and part of the imagination [381]. Whether looking at the creative products or the creative experience, musicians are continuously reacting and adapting to these sonic worlds, which impacts their performance [471].

3.1.3 VR for creative musical practice

VR can break down the walls of our daily living spaces and transport us to simulated or novel virtualenvironments [427]. It does so by replacing physical senses with computer-generated ones, which can feel just as real. When the substitution is effective, the brain appears to infer its perceptual model from the virtual world, corresponding to the actual sensory data stream. However, effective substitution is an ideal and depends on the sensory systems being included. My survey of VR music applications indicated that work has most often centred around vision, while the rendering of realistic sound effects appears to be an often overlooked component. Although modelling realistic sound propagation in VR is possible through the spatialisation of the Room Impulse Response (RIR), the room's transfer function between the sound source and microphone, this involves a large computational overhead [402], making it challenging to achieve in real-time.

Nevertheless, recent technological developments enabled the emergence of immersive sound- rendering experiences, which can represent a new tool for music-makers by offering ways of creating and experiencing [411]. Research has shown the potential of the auralisation of immersive environments including: the development of computational acoustic models for the reproduction of the acoustics of historical sites such as the Théâtre de l'Athénée [243] or Notre-Dame Cathedral [247]; the evaluation of audiences' experience [417]; providing solutions for music performance anxiety [56]; and developing virtual musical instruments [410]. Surprisingly, however, the complex facets of creative musical practice in immersive spaces have not been thoroughly examined. To the best of my knowledge, one of the only attempts to address this gap was made by Aufegger et al. [16], who proposed a performance simulator[14] where musicians can be repeatedly exposed to realistic performance situations through a process of sequential simulation. This simulator consists of a physical rehearsal room where key features of the recital ritual and its environment are manipulated (for details see 3.3.2). Evaluation results from music students showed that this performance space can benefit musicians' performance and reduce their anxiety [15, 16]. It is important to note here some of the significant limitations of this technology: i) the lack of portability; ii) the limited overall acoustic impression of musicians, as the sound does not simulate that of a concert hall; iii) the absence of user tracking, preventing natural sensorimotor contingencies from being experienced [427], and negatively impacting on musicians' sense of 'being there'. Although music makers saw the potential for such simulators to help them overcome challenges impacting their performance quality, how virtual visual and sonic worlds can be used to support their practice is still uncharted territory.

[14] `https://www.rcm.ac.uk/research/projects/performancesimulator/`

3.2 Methodology overview

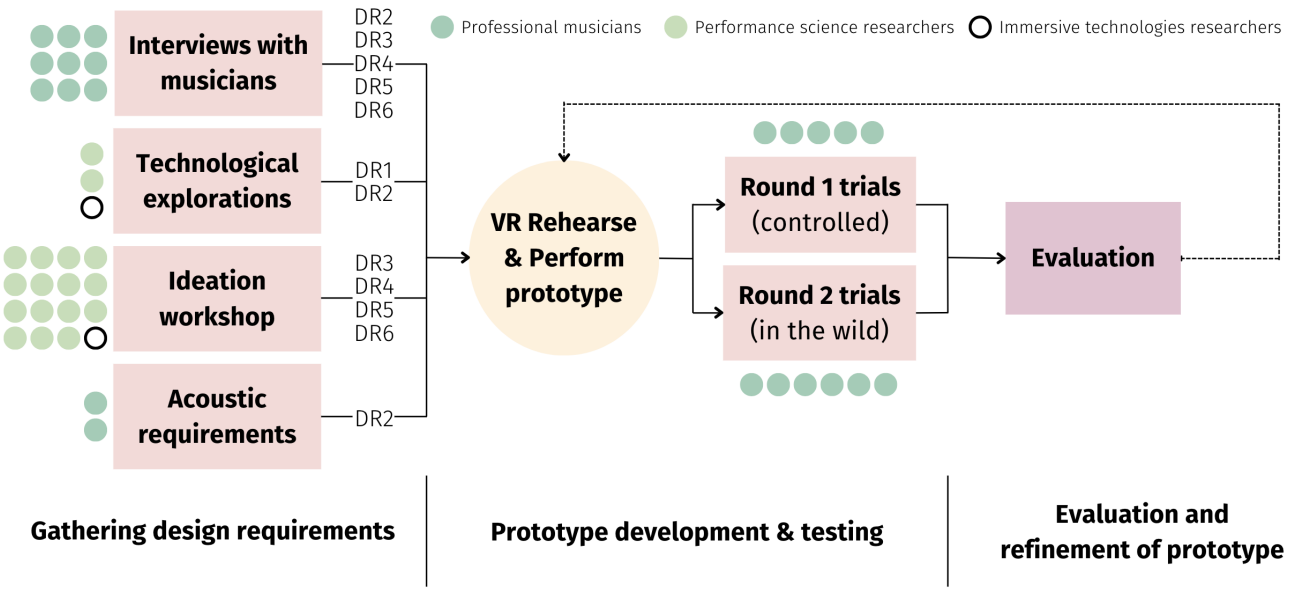


Figure 4: The process of defining the design requirements and developing *VR Rehearse & Perform* based on user insights and rounds of iteration.

The main goal of the first part of the study was to discover insights about musicians' practice routines and experiences that could inspire innovative ways to design technologies for supporting them (Figure 4 gives an overview of the process I followed). Using a musician-centred approach, the first step was to engage with professional musicians and performance science researchers to capture a broad range of experiences about how immersive environments could support different facets of their work. This was done through a series of targeted activities, run with my collaborators, aimed at ii) understanding their specific needs and preferences and ii) exploring together how immersive technologies could be integrated into their workflows to support their practice. Activities included:

- *Interviews* providing insights into the array of strategies musicians employ during their practice and opening discussions on potential designs of technology to aid their routines.
- *Technological explorations* offering perspectives from performance science experts on the capabilities and limitations of existing tools, in supporting musical development.
- *An ideation workshop*, proposing ideas for developing immersive technologies to enhance music practice sessions.
- *A session to gather acoustic requirements* exposing musicians to audio spatialisation solutions to understand the necessity for realistic audio spatialisation and reverberation in creating immersive auditory environments.

In these activities, I involved 11 musicians, 15 performance science researchers, and two experts in immersive technology. The data from the interviews and the notes from the other three sessions were synthesised into a list of six design requirements that guided the design of the *VR Rehearse & Perform* system. The requirements were derived to ensure the VR platform would cater to some of the diverse needs of musicians and showcase its potential for enhancing their practice by providing immersive, customisable environments conducive to creative exploration and technical refinement.

With the requirements as a blueprint, I started developing *VR Rehearse & Perform*, a prototype aimed to simulate performance spaces, offering adjustable acoustic properties and providing environments that could inspire creative musical practice. This phase was characterised by an iterative design process, where the initial prototype was continuously refined based on feedback and the evolving understanding of musicians' needs. The first prototype was evaluated in a lab setting and in the wild, involving 11 musicians. To gather feedback and inform further iterations of the prototype, I interviewed the participants. I conducted a preliminary analysis of their answers to ensure that each version of *VR Rehearse & Perform* is more closely aligned with the practical realities and aspirations of the potential users of such technologies.

3.3 Gathering user insights

In the sections below, I present in detail the activities we conducted to learn about musicians' practices, needs and attitudes towards technology, as well as the insights gained from each activity. It is worth noting here that this part of the work was exploratory in nature, aiming to surface initial design opportunities rather than test generalisable hypotheses. As such, participant demographic data (e.g., age, gender, musical genre) were not systematically collected at the time. This decision partly stemmed from my inexperience as a researcher, but also reflected the study's goals – the focus was on uncovering relevant experiences, perspectives, and design opportunities. Participants in all activities were selected for their expertise and engagement with performance and technology depending of the goal of each of the sessions.

3.3.1 Interviews with musicians

The initial phase of the research involved in-depth interviews with nine professional musicians (i.e., individuals who earn a living through their musical performances, either individually or with a group of other musicians) of different backgrounds (M1-M9). During the interviews I asked questions about their professional experiences, daily practices, and the unique challenges they encounter, particularly related to the spaces they rehearse and perform in. Additionally, I investigated the impact of COVID-19 pandemic on their professional lives, highlighting the unique challenges it introduced in their day-to-day musical endeavours. Our discussions also explored musicians' receptiveness to adopting technologies such as VR. All interviews were conducted online and followed a semi-structured interview protocol, lasting between 20-40 minutes. Interviews were audio-recorded, transcribed and analysed using a combination of inductive and deductive thematic analysis [73]. Initial codes were assigned based on the overarching topics of interest such as 'acoustic properties', 'space', 'impact of COVID-19 on wellbeing', and 'potential of VR'. Subsequent codes were added as I shifted through the data such as 'lighting', 'creative mindset'. In the sections below, I briefly present the main themes that emerged as salient for the broadest range of participants, framed around the insights that informed the subsequent development of the VR prototype.

It is worth noting here that these interviews were done in the first year of the pandemic, when little to no research was done on the impact of COVID-19 on professional musicians. Later, academic research was published [85, 443], which points to some of the things we found through the interviews, and I use this to resonate with and strengthen the work in other parts of this chapter.

The importance of acoustics and visuals in musicians' performance preparation.

The unanimous agreement among musicians on the significance of the acoustic properties of performance spaces, demonstrates a desire for environments that can adapt to the distinct requirements of different musical genres and styles. Musicians such as M1 and M7 expressed a need for spaces that allow for soundproofing and adjustable acoustic properties to eliminate sound reflections and cater to specific sound quality needs: *"I think the biggest thing is having a room that we can go all out, where we are not restricted by any sound barriers. I would love to have a room where it is no sound through, good acoustics, sound panels, where there is no reflection of sound (M1)"*; *"It always helps me, as a percussionist, to have really dry acoustics. [...] It has to be some kind of fabric to have*

a nice sound (M7)." Furthermore, the need for flexible acoustic setups that can be tailored to accommodate various instruments was expressed by M4: *"if you can change the acoustic characteristics of the room, that would be very useful (M4).*"

Moreover, musicians emphasised the importance of pre-performance access to the venues where they ultimately play music to fine-tune acoustics and visuals for achieving optimal performance conditions. M4 explained *"Practices within the venue is good. So we check the visuals to see how things look, get the lighting set up. We need to know which drums to sit where, to see how the acoustics suit (M4).*" M8 further elaborated *"the thing that I look for in a venue is where the sweet spot is in the sound of the room in which we're playing. [...] in order to be able to do that comfortably, I have to find the sweet spot in the room itself (M8).*" M9 goes on to clarify that access to a space prior to the performance also allows for checking the lights, a key part of getting into a performance mindset: *"it would be helpful, to have the lights set as they would be in the concert. I would suggest: don't underestimate the importance of lighting. This is something I did underestimate earlier on. Lighting is so important not just to musicians, but to how you present a performance and how you feel when you are performing (M9).*" Such quotes reveal a need for performance venues to provide musicians with sufficient time and flexibility to adjust lighting, visuals and sound to their preferences.

Yet, access to performance spaces right before the performance is often limited, forcing musicians to set up their instruments and soundcheck in a short time-frame. *"We only get about 15 minutes to about half an hour usually before the show actually starts. [...] and sometimes you don't get soundcheck at all. So you just literally set your instruments up and you plug in, you do a quick mumble on the bass or the guitar, and that's it (M5)*". To overcome this challenge, musicians often emulate the performance setup during their rehearsals, striving to recreate the conditions they will encounter on stage. However, this practice is also not always feasible due to the constraints of rehearsal spaces. *"We don't necessarily rehearse in the places that we use. But it helps, sometimes to face in the direction that the stage would be, when we practice. So you're kind of rehearsing as the actual performance itself. But we can't necessarily do that always in the studios that we book (M6)*". This limitation highlights a gap in pre-performance arrangements. It suggests a need for better access and preparation opportunities in performance venues, as early access is necessary for technical preparations and for ensuring that performers can create the right atmosphere for their show, significantly impacting the overall quality of the performance and the audience's experience.

These findings align with and extend the existing literature I present in Section 3.1.1, which underlined the importance of the acoustic features of the space in enabling musicians to train, perform and

adjust their playing techniques [400, 472]. Although research in this area has focused on the acoustic properties of the space, the data indicates that the visual dimension is also important in musicians' practice, as it enables them to prepare for performances more effectively. The interplay between acoustics and visuals influences the musicians' ability to rehearse in a manner that mimics the live performance environment and impacts their emotional and psychological readiness.

Musicians need spaces for enhanced creativity and expression.

Access to a variety of locations was perceived as important for creative musical practice, emphasising the intricate relationship between physical surroundings and musical expression. M9, for instance, emphasised how the music genre musicians work with directly correlates with and influences their spatial needs: *"I think having space to rehearse is important. Depending on the sort of music you're producing, if you're doing intimate folk music, a small space is useful. If you're doing bigger sounding pop or rock, you want more space for a louder sound (M9)."* In addition, the interviews revealed that both visual and acoustic stimuli within the music practice space play an important role in inspiring musicians. M9 expressed a desire for creatively inspiring surroundings, stating: *"I suppose I want the surroundings to be creatively inspiring in some way; they don't need to be massively interesting, but you don't want to be surrounded by laundry drying or a washing machine. Because those kind of things don't make me feel creative. You want to step out of the humdrum of existence[...] if you're rehearsing amongst things, which take you off away from the creative sphere, which is why I like rehearsing in my shed, because I'm surrounded by things and pictures or pieces of music that will remind me of my musical world instead of my real world (M9)"*. Some other participants, like M8, prioritised minimalist and bare practice rooms, explaining *"I like practice rooms to be absolutely minimal and totally bare. Because when I'm rehearsing and when I'm working with spontaneous music, the visuals are inside me. Not external, they're internal. [...] If I'm in a forest, I'm listening to the trees more. I'm listening to the location and the sound that's coming back at me. Or I did a series of pieces in an old fort and the sound of what I was listening to was the sound in the walls and responding to the memory that people have placed there previously (M8)"*. The contrast between external and internal stimuli illustrates the diverse ways in which musicians draw their inspiration, demonstrating the role of environmental factors in shaping the creative process, whether by providing a visually stimulating backdrop or by allowing musicians to explore the auditory landscape of their surroundings. Insights from our interviews strengthen findings in [403] and [85], which showed that musicians mentally associate certain spaces with creativity, enabling these spaces to serve as

creative triggers.

Performing is a therapeutic necessity for musicians.

The challenges presented by the COVID-19 pandemic have stressed the role of performance as a therapeutic outlet for musicians, pointing towards the broader topic of mental health and creativity within the music community [136]. As live events stopped, this deprived musicians of their primary means of expression and, at the same time, amplified feelings of isolation and mental strain. Testimonies from individuals like M1 point to performance's therapeutic value, offering solace and a sense of release from personal struggles: *"And with mental health, when I perform, I usually say it is therapy, because any issues we have when we perform, [...] they don't exist anymore, because you feel relaxed. This is very therapeutical [...] And I miss that, and it has affected me a lot personally (M1)"*. Concurrently, M2 and M6's experiences with increased isolation and diminishing motivation reflect the profound emotional toll that such disruptions can exact on creative individuals: *"it is very tough for me to practice and I feel more isolated because of it (M2)"*; *"it's hard to stay motivated when you can't see the light at the end of the tunnel [...] I personally feel that I have to be in a happier place to be able to produce or play music (M6)."* This highlights the necessity for alternative avenues that support musicians' mental wellbeing and creative expression, extending beyond the immediate crisis induced by the pandemic. Musgrave [334] observed a tension between music as a free tool – to express, to play, to create – which has many positive wellbeing benefits and music as employment and a form of performance perfectionism and optimisation, which, for some, can have negative wellbeing ramifications. This duality was also addressed by Gross and Musgrave [178], who mentioned *"making music is therapeutic, making a career from music can be traumatic"*. It seems that a way to address this paradox is for musicians to centralise the joy of music-making and focus less on the career element of their musical work, as proposed by Bonde et al. [67].

Musicians' shift to technology.

Musicians' experiences during the pandemic led to the urgency of integrating technology into their creative and performance practices. As mentioned by M9, the shift to a digital mode of operation was not a choice but a necessity, compelling musicians to develop digital skills for teaching, rehearsing, performing, and collaborating online: *"I've had to work a lot more digitally. [...] All moved online, of course, I had to learn to edit video for my students and for other musicians. I put on a lockdown*

concert in March as well. So actually, I've had to develop my skills (M9)". The transition to the digital space, while showcasing musicians' resilience and adaptability, also uncovered significant challenges. Musicians like M5 expressed concerns over the overwhelming abundance of platforms and the difficulties in standing out and monetising their work in a saturated online environment: *"I mean, we have the choice, [...] but there's so many platforms out there that it becomes a little bit overwhelming, it really needs to be something special. And it's a hard thing to do, [...] some musicians are better at it than others. So, I guess they could probably survive in these times by using new technology (M5)."* M1 further critiqued the current digital infrastructure's inability to support the nuances of live performances, indicating a gap between existing technologies and the specific needs of musicians: *"See, the online performance platforms are good, but then they were never updated properly. It was like nobody ever thought that we might need technology like that. So, the technology we have right now is not good enough to support major performances. So I would say, technology advancement would have helped people perform now (M1)".* My findings further strengthen insights from the existing literature [85, 404, 490], demonstrating that the pandemic has triggered a change within the music industry, which pushed artists to navigate the intricacies of digital spaces more than ever before. This narrative also builds upon and expands the literature on digital transformation, suggesting that the challenges and opportunities presented by the pandemic could serve as a catalyst for reimagining the role of technology in creative industries [251].

Musicians are interested in VR for enhanced creative expression.

When asked about the possibility of using tools such as VR to support their creative practices, musicians expressed optimism about VR's potential to simulate physical presence within a performance or rehearsal space, with one noting the distinct advantage of VR in making one feel as if *"you're actually sitting there, in the comfort of your home (M1)"*, thus marking a substantial benefit over traditional online platforms. VR was not only seen for its potential to eliminating travel and venue costs but also opening up opportunities to rehearse and perform in virtually any space they can imagine, from intimate settings to grand concert halls: *"For example, I'm playing the instrument, and I feel that I am in a big hall, it'd be very nice (M3)."*

Moreover, data from interviews also pointed to VR's capability for inspiring improvisation and spontaneous composition, suggesting that immersive experiences could lead musicians to engage with their instruments and environments in more creative ways, free from the constraints of sheet music: *"When you have a headset on, it will preclude the idea of reading music. That's where you've probably*

seen, you've either got to memorise something and then repeat it, or you can do what I do, which is this kind of spontaneous interaction with the environment (M8)". Musicians also anticipated that VR could offer new types of creative expression, allowing them to interact with the visual stimulus and explore musical ideas in dynamic, visually inspiring settings: *"I would be playing them to the visual stimulus, rather than regurgitating and remembering something. And then it's another aspect of playing [...] it would be another experience, another aspect to what I do. I don't think it would be an alternative, it would be another aspect to facilitate the creative spark in order to be able to get to an audience, and I think it's something that definitely is worth exploring (M8)"*.

Nevertheless, despite the potential of tools like VR, musicians identified some concerns that need to be addressed to realise its benefits fully. Sound quality was considered paramount, as a realistic and immersive soundscape is essential for providing musicians with the proper feedback and environment for practising and performing: *"to have the sound, you have to be able to create the sound, the actual natural reverberating or the natural resonance of the sound in the hole that you're going to be playing in. Because then you play to that sound. And it changes, well, from my point of view, it changes the aspect of what I'm going to do (M8)"*. Additionally, latency, or the delay between an action and its perceived response, was highlighted as a major consideration, as it could disrupt the performance flow and create frustration for musicians. *"I think the only thing that would make me not try any new technology if there will be any delay. So if I'm talking to you, and it takes some time for you to get that, I think that would create a lot of miscommunication with music and it will be very frustrating (M1)"*. Existing research has already shown that immersive technologies have provided new possibilities for the exploration of musical interaction with the development of virtual reality musical instruments [409, 410]. However, as shown in Section 3.1.3, for musicians, there is still significant unexplored potential in this area.

3.3.2 Technological explorations

The goal of technological explorations was to gather insights into the features and limitations of current solutions for developing performance skills and to understand how the features of existing technologies could be utilised for designing new systems. We conducted two one-hour-sessions with the experts who led the initiative for the performance simulator in the Royal College of Music [106, 503] – one of the only immersive solutions at the time targeted towards improving music performance as noted in Section 3.1.3 – and an immersive technology researcher.

In the first session, we experienced the performance simulator and held a discussion about the benefits and limitations of the current system, as well as directions for future improvement (see Figure 5). The simulator creates the atmosphere and sounds of a live concert via a large screen in the middle of a music room (similar to earlier VR CAVE systems). It operates in two modes (i) concert featuring a virtual audience who applaud, cough, fidget, talk and even boo, and (ii) audition simulation featuring an audition panel of three stern-looking judges, who may smile, fold their arms or talk to one another. The 'personality' of both the audience and judging panel can be pre-set to friendly, indifferent or hostile. An AV recording system further allows musicians to watch, evaluate and share their performances in the simulator immediately afterwards on any web-enabled device. Although this system showed a positive impact on students' anxiety management [16], the performance experts re-iterated a number of limitations extending from what has already been reported in existing studies. Firstly, the simulator is confined to the school premises and occupies a significant amount of space. Moreover, it does not allow for the manipulation of the acoustic parameters - while rehearsing, musicians are limited to the acoustic impression of that room, without the possibility of experiencing the sound of appropriate concert halls or performance venues. Additionally, the visual cues are projected on the room's walls, and the front projection restricts the musician's movements (i.e., crossing close to the audience will cast shadows on the projected wall). As highlighted towards the end of the discussion, these drawbacks and the access limitations resulting from the pandemic hint towards an opportunity for portable immersive experiences that can expose musicians to different environments while allowing them to experiment in their musical practice.

Figure 5: Photographs of the performance simulator at the Royal College of Music. Musicians can play their instrument to a projected audience.

In the second session, in order to understand how different portable immersive technologies would fit with the unique aspects of music performance, we exposed the performance experts to commercially available VR and AR HMDs, including the HoloLens, HTC Vive and Oculus. This triggered a discussion related to the different user experiences in head-mounted vs projection-based systems and the opportunities and challenges that come with these types of systems. During this session, the

two performance science experts who trialled the HMDs, commented on the portable nature of such systems and the opportunities that come with spatial audio. Referring specifically to the VR HMDs, they appreciated the increased level of immersion they provide and their ability to teleport the user fully to new environments but raised concerns regarding the need for using controllers as a mode of interaction. They pointed out that relying on controllers for interaction could hinder musicians' ability to play and engage with their instruments in a natural and intuitive manner. Conversely, when discussing AR HMDs, like the HoloLens, which employ hand-tracking technology, the experts noted that these devices have the potential to facilitate more seamless interaction with musical instruments. However, they also acknowledged that AR HMDs might not offer the same level of immersion as VR HMDs, hence do not provide the same opportunities, making it essential to strike a balance between natural interactions and immersion to effectively support creative musical practice.

3.3.3 Ideation workshop

During the ideation workshop, we engaged with 15 performance science researchers (all practising musicians) and an immersive technologies expert, in a session aimed at gathering ideas for prototyping an immersive system for performance preparation. The input we gave for the workshop consisted of a 30-minute presentation on some of the problems musicians face related to space, insights from the technological explorations activity, as well as showcasing relevant past work. We then posed the question: *"How might immersive technologies be designed to support performance preparation?"* and had a one-hour ideation session in groups of three to identify areas where musicians themselves would use VR technologies in their own practice and potential designs and features for musician-centred immersive applications.

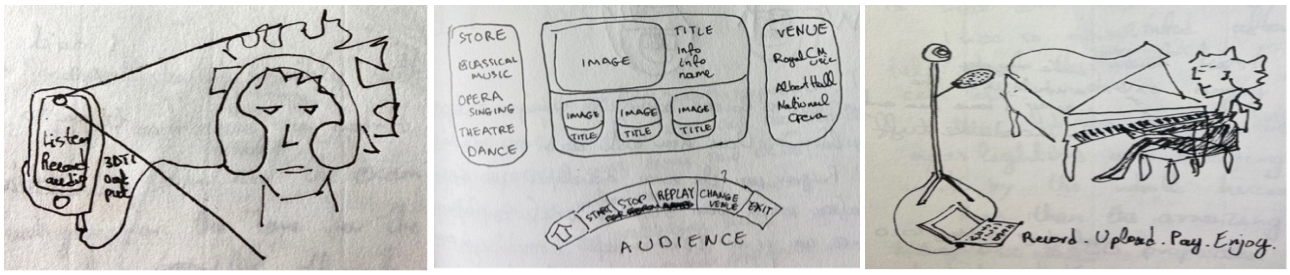


Figure 6: Sketches of some of the ideas that inspired VR Rehearse & Perform (from left to right): singing and hearing their performance with the reverberation of the venue in real-time, audience menu for choosing and playing performances in VR and recording pianist with live mic and rendering in VR with acoustics of real venue

Workshop participants, supported by the researcher facilitators, identified a set opportunities in designing immersive experiences for musicians (see Figure 6 for some of the sketches produced in the workshop). Their ideas pointed towards VR's potential for:

- Practising in diverse virtual spaces and experimenting with diverse acoustic settings
- Simulating performances in iconic, life-goal venues to fulfil aspirations
- Viewing one's own performance from audience's perspective to gain new insights
- Reliving successful past performances for motivation and learning
- Accessing a digital library of concert halls for varied rehearsal experiences
- Adjusting lighting within the virtual environment to aid performance mindset
- Utilising immersive spaces for emotional regulation, especially to manage performance anxiety

Besides the potential uses of tools like VR for musical practice, the discussions during the workshop also uncovered broader themes. For example, musicians spoke about how important concert venues are for them; even though VR could teleport them to any imaginable environment, they mostly wanted to visit existing – iconic or familiar – performance venues. This reveals the inspiration musicians draw from such spaces and their intrinsic value, pointing towards their cultural significance and suggesting that this is something that tools like VR could be used for. Additionally, the focus on customisable acoustic and visual settings, along with tools for emotional regulation, pointed towards the multifaceted nature of performance preparation. This process involves psychological and emotional preparation, areas where VR offers unique support.

During the closing discussion, participants acknowledged that while practising using today's HMDs might not be a feasible option for musicians due to their bulkiness and potential discomfort, there is a growing potential for their use as technology continues to advance. Their interest suggested an openness for integrating immersive tools into their creative processes to enhance their practice and performance experiences.

3.3.4 Gathering acoustic requirements

During the interviews and workshop, the importance of acoustic quality was reinforced by the musicians and performance scientists. Therefore, to further investigate what should be considered when designing acoustics for immersive systems dedicated to musicians, we ran a short session with two musicians where they trialled the 3DTi Toolkit - an open-source system for designing and rendering realistic audio spatialisation and reverberation models, developed as part of the EU-funded project

3D Tune-In (3DTi) [124]. The 3DTi toolkit enabled us to have musicians play their instrument and listen to emulated acoustics of different spaces. The two musicians downloaded the 3DTi Toolkit and explored its use by playing their musical instruments and listening back to the real-time sound the system produced when emulating the acoustics of small, medium, and large performance rooms. The discussion that followed the testing confirmed that each performance space has its own unique acoustic characteristics that are important to maintain even in a virtual setting. Mismatched acoustics – where the audio does not accurately represent the spatial or reverberant qualities of the intended environment – disrupted their immersion and performance quality. However, musicians also emphasised the importance of having high-quality acoustics during performance preparation over visual stimuli.

3.4 From user insights to design requirements

Overall, insights from the activities we conducted show that musicians use the space acoustics and visuals in complex ways, contributing to their skill development, creativity, and wellbeing. Music-makers we engaged with emphasised the need for spaces that answer the acoustic requirements of different music genres and instruments, which could be addressed by creating systems offering adjustable acoustics to replicate everything from intimate, dry acoustics to expansive, reverberant concert halls. Visual customisation was also deemed vital for its role in creating the ambience of various performance settings. During the interviews, participants shared their experiences with recent technology adoptions and indicated a desire for new solutions that could support their practice. They also expressed an interest in exploring immersive technologies and talked about opportunities that these could bring. In this context, VR shows potential in enabling musicians to overcome some of their traditional spatial and acoustic constraints by offering them the possibility to make and practise music in any imagined space with tailored acoustic properties and visual settings, thereby opening up new horizons for artistic expression.

To explore the aforementioned potentials, I built on the insights gained and identified six essential design requirements for immersive musical practice, through iterative discussions with all collaborators involved in the project. I present them below and illustrate how we derived them from the different activities (see Figure 4). The storyboard in Figure 7 presents an experience design emerging from these design requirements.

Figure 7: *VR Rehearse & Perform*, a storyboard of the musician's experience: musician at home, wearing their headset, selecting the type of music they want to play and a location they want to visit like nature or a performance hall and then they are able to play music, being immersed in that environment

While experimenting with various headsets in activities presented in Section 3.3.3, performance science researchers observed that using hand controllers to operate the user interface could affect musicians' engagement with their instruments. Their feedback highlighted the importance of natural interactions and freedom of movement while performing, which was translated into the formulation of DR1.

- **DR1:** *Natural user interactions* that enable musicians to switch between playing their instruments and interacting with the user interface.

Experimenting with the accurate acoustics of a space is one of the strongest themes that arose from our activities. During the interviews, participants talked about how this could help them practice for performances as it will allow them to mirror some of the conditions they would face in a live venue, and train their skills by adjusting their techniques to different acoustic settings (Section 3.3.1). The need for accurate acoustics was further strengthened by musicians involved in gathering acoustic requirements in Section 3.3.4. Despite the importance of acoustics, the fact that existent simulators

do not enable musicians to experiment with the real, accurate acoustics of spaces they ultimately perform in, was indicated as an important limitation during the technological exploration session presented in Section 3.3.2. To understand how realistic acoustic simulation could enhance musicians' practice, we formulated DR2.

- **DR2:** *Accurate acoustics* of the environments the musicians are in.

Throughout the interviews, musicians also pointed out how visual elements, such as lighting or the aesthetics of a space, significantly impact their ability to get into the right mindset for rehearsing, performing or creating music. In the workshop, participants expanded on this with ideas about using immersive technologies to transform any space into an inspiring, real or imaginary, performance venue. Therefore, in order to enable musicians to create their desired ambience and simulate various performance settings, we derived DR3.

- **DR3:** *Customisation of the visual features* of the environment (e.g., lights) that can be used to set up the atmosphere for different types of performances.

Musicians emphasised that musical practice has various nuances – from performing to composing and improvising – that require producing different mindsets through various creative triggers. Insights from our data, supported by research [85, 403], showcase that musicians often associate specific spaces with creativity. Moreover, to initiate and maintain their creative pursuits, musicians mentioned the need for various elements as sources for inspiration. These elements (i.e., acoustic and spatial variety) are the building blocks of DR4 and DR5. By enabling the creation of virtual environments that act as inspirational spaces, VR systems can support musicians in finding their creative flow, offering a diverse range of settings designed to stimulate and enhance their musical creativity and practice.

- **DR4:** *Customisation of the acoustic features of the environment* (e.g., reverberation levels), which would enable musicians to change the acoustic parameters depending on their instruments and the type of music they want to play.
- **DR5:** *Spaces that can be used as creative triggers.* This requirement is also supported by findings reported in [85] stating that music-makers mentally associate certain physical spaces with creativity.

Considering the emotional challenges associated with music playing, including performance anxiety and the impact of COVID-19 on their wellbeing, musicians expressed a need for environments that could help manage their emotions, for example, stimulating the feelings associated with music performance. Insights presented in Section 3.3.1 and enforced during activities presented in Section 3.3.3 showed VR systems could be a promising solution, offering virtual spaces that evoke feelings of performing like excitement, anxiety, or the exhilaration of being in front of an audience. Such spaces could help prepare musicians not just technically but also emotionally for performance, as well as evoke different emotions that can contribute to creativity and inspiration. They can allow musicians to navigate the emotional ups and downs of music performance in controlled and supportive visual settings. This context informed the formulation of DR6.

- **DR6:** *Immersive spaces that regulate emotions.* For example spaces that prompt emotions similar to those of a performance.

3.5 VR Rehearse & Perform prototype design

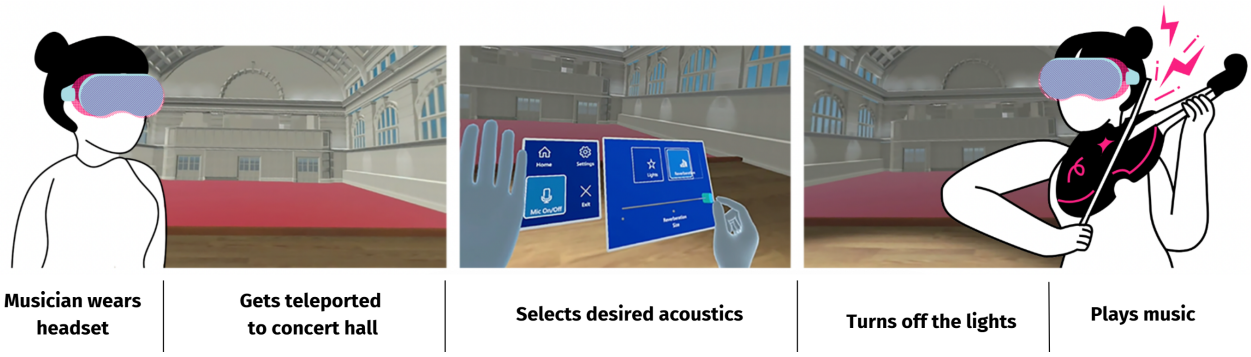


Figure 8: *VR Rehearse & Perform* - a Virtual Reality system to support musicians' practice.

Following the design requirements we formulated from the activities with the music-makers, a mixed fidelity prototype [310] called *VR Rehearse & Perform* was developed (see Figure 8). I describe the prototype as mixed fidelity, following the five dimensions given by McCurdy et al. [310]: it is high fidelity in two of the dimensions – depth of functionality, richness of interactivity – and mid to low fidelity in the other three – level of visual refinement, breadth of functionality and richness of data model.

The prototype was used to refine our understanding of musicians' needs and how immersive technologies could play a role in their creative musical practice, through a tangible experience. *VR Rehearse & Perform* served as a tool for eliciting more informed dialogue and authentic feedback from

musicians. It allowed musicians to have a hands-on, practical experience with a VR application tailored to some of their specific needs, offering valuable insights into how such tools might be adopted and embraced by the music community. In the section below, I describe the technical implementation of the prototype as well as relevant design choices I made based on the findings of the earlier explorations.

Functionality. When the application starts, musicians are positioned in the middle of a concert hall's stage. A real-time microphone input feature of *VR Rehearse & Perform* enables the performer to speak, sing or play an instrument and listen to real-time audio feedback from the virtual environment. At this stage, because of the national lockdown imposed by the pandemic, we did not have access to capture the acoustics of the performance hall we modelled. Therefore, for this version of the software, we offered musicians the possibility to choose between *approximate* acoustics emulating a small (shorter decay), medium and big auditorium (longer decay) (I note here that because of this, **DR2** was not fully met in this version of the prototype, but later on with the refined prototype in Section 4.1). Given the need for customisation expressed through **DR3** and **DR4**, users are able to interact with the lights of the auditorium – adjusting their intensity – and to choose between the three types of acoustics available for this version. Users also have the option to turn off the acoustic feedback and listen to the natural sound of their instrument in the physical room they are in.

Game engine and VR platform. *VR Rehearse & Perform* was developed using Unity 3D game engine[15], combined with the Oculus Integration Package SDK, and was deployed on the Oculus Quest 1. The Quest was chosen because of its ease of use, portability and low cost, all indicating the potential for a more inclusive technology, accessible to many musicians [135]. Furthermore, Oculus Quest has hand-tracking capabilities and allows for external headphone input for controlled sound quality.

Sound. According to [196], acoustics are influenced by the "*musical spatiality relating to the acoustic conditions of performance (types of enclosures, outdoor environments)*" and by the location of musicians and sound sources within the performance space. Therefore, to be able to meet **DR2** and ensure accurate and high-quality spatialisation and reverberation of the sound, we adapted the 3DTi toolkit [124] into a plug-in for Unity. We chose to use 3DTi because of its accuracy in simulating human hearing. While other similar tools exist (for example Resonance audio[16]), they usually focus

[15] `https://unity.com`
[16] `https://resonance-audio.github.io/resonance-audio/`

on efficiency and performance rather than accuracy. To the best of our knowledge, other existing tools do not allow for the creation of authentic acoustic reproductions, limiting users to the customisation of a set of specific parameters. 3DTi allows the input of the exact acoustics of a space. The spatialisation and 3D reverberation features of the toolkit mean that the audio output is directly correlated to the user's head position and direction in the space. This feature has the potential to support immersion and improve users' experience [76], and can also be used as a musical tool [168].

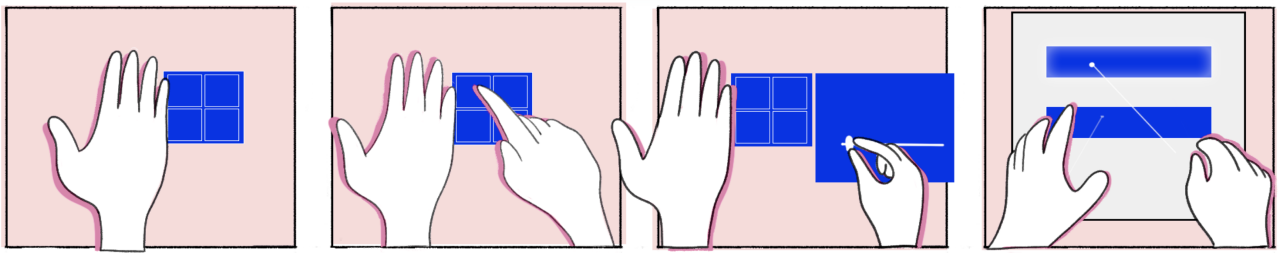
Existing Unity libraries struggle with real-time audio processing[17], leading to noticeable latency. While latency is inherent to Digital Signal Processing (DSP), efforts have been made to minimise it, especially in applications like networked music-making [468]. Participants in our study highlighted latency as a major concern for remote music performances. Typically, DSP latency ranges from 10–20 ms, but higher values can create unnatural delays detectable by the human ears [84]. This issue is worsened on the Oculus Quest's Android-based operating system and the headset's limited processing power. Initially, using Unity's microphone input alongside the 3DTi plugin to simulate room acoustics resulted in over 400 ms of latency. To address this, we developed a native audio plug-in for Unity using the Juce platform. Unlike Unity's default audio loop, this plug-in created a separate audio loop, reducing latency to 20–35 ms.

Figure 9: The Amaryllis Fleming Concert Hall and the 3D model we created based on it

Performing space. The virtual environment we chose for this version of the prototype was a 3D representation of the *the Royal College of Music's Amaryllis Fleming Concert Hall*[18] (Figure 15, first image). A low-polygon 3D model was developed using Maya 2020, based on a high quality point cloud of the venue, captured with a Leica BLK360 LiDAR camera, that included texture information (Figure 9, second image). The choice of the Royal College of Music's Amaryllis Fleming Concert Hall as the virtual environment served **DR5** by offering a space associated with high levels of creativity and **DR6**

[17] https://gametorrahod.com/android-native-audio-primer-for-unity-developers/
[18] https://www.rcm.ac.uk/hire/hirethercmforanevent/amaryllisflemingconcerthall/

by replicating a venue that can evoke the emotional intensity of live performances. Using a famous concert venue as the first performing space was mostly inspired by the workshop discussions about musicians' dreams of performing in renowned venues and the role of such experiences in combating performance anxiety. Moreover, we went for a minimalistic approach to the 3D development of the space for three reasons: i) musicians expressing the need for non-cluttered spaces when performing during the interviews ii) so that visual feedback does not overpower a user from focusing on the oral feedback [403] and iii) to optimise performance.



Palm facing inwards | **Pressing a button using the index finger** | **Pinch and drag** | **Palm facing outwards and pinching**

Figure 10: The gestures used in *VR Rehearse and Perform*

User interaction. Our experiential explorations with musicians and performance researchers indicated the importance of having a controller-free interaction with *VR Rehearse & Perform*. This is necessary because musical artists need to play their instruments without any constraints and have limited non-essential interaction during practice [233]. Motivated by this and to address **DR1**, I used Mixed Reality Toolkit (MRTK) – an open-source, cross-platform development kit for mixed reality applications[19] – to enable hand-tracking as the main form of user interaction in the prototype. By doing so, we enabled musicians to interact naturally with *VR Rehearse & Perform*, as they do not need to constantly switch between VR controllers and their musical instruments. The MRTK was chosen, as it comes with a set of pre-defined gestures that enable to user to interact with the interface, as well as with a set of pre-made user interface components that can be easily customised (see Figures 10).

3.6 Musicians dive into VR

User experience pilots. The prototype was refined before extensive participant evaluations through conducting three pilot sessions with three guitarists (see Figure 3.6). None of them had prior experience with the software. Two of the musicians had used VR before, but not hand-tracking technology,

[19] `https://docs.microsoft.com/en-us/windows/mixed-reality/mrtk-unity/`

Figure 11: Musicians giving feedback on the first version of *VR Rehearse & Perform*.

while the third musician had no prior VR experience. The pilot aimed to ensure that the system functioned as expected and that user interactions were intuitive. During these initial tests, users provided feedback on improving the prototype, which had previously only been used by researchers familiar with VR and the software. Participants found that the menus used for controlling the experience were too small and challenging for inexperienced hand-tracking users. To address this, menus were scaled up to enhance accessibility, and buttons replaced sliders and drop-downs whenever possible. The reverb selection remained a slider but was significantly increased in size for easier use. Furthermore, audio feedback was added when an interaction takes place, e.g a button is pressed.

3.6.1 Testing protocol

To assess the implementation of the design requirements gathered in the first phase and to evaluate the functionality of *VR Rehearse & Perform*, two rounds of tests were carried (controlled and in-the-wild) with 11 professional musicians (i.e., their main source of income comes from music), taking advantage of their domain-specific experience. The goal was to explore the impact of our design choices and identify infeasible and missing functions or interactions [487].

Figure 12: Using hand gestures (the user turns their left palm inwards) a menu appears.

Round 1 - Controlled. In *Round 1*, five musicians (P1-P5; 4 males and 1 female; aged 40-69 – see Table 3) experimented with playing different musical compositions while immersed in our software. These experiments took place in person, in one of our research labs, and lasted between 1 and 2 hours. They were followed by semi-structured interviews that were audio recorded.

Round 2 - In the wild. *Round 2*, involved six vocalists from different musical backgrounds (P6-P11; 2 males and 4 females; aged 20-40 – see Table 3), and was designed as an in-the-wild experiment. Given that it took place under a period of full national lockdown, the in-person contact between researchers and participants was minimal (i.e., the researcher was not present when the musicians used the software). We worked with vocalists as it required the least amount of set-up on the musicians' side to use without guidance. Participants were given an Oculus Quest 2[20] with a standalone version of *VR Rehearse & Perform* installed for several days, and were instructed to use it for their musical practice at home or at a location of their convenience. This was followed by an online questionnaire covering the topics of comfort, ease of use and operation, and the impact of the quality of visuals and audio on singing. A semi-structured online interview lasting 25-30 minutes was conducted post-experience to give participants an opportunity to expand on their responses.

3.6.2 Participants, data and analysis

Participants were recruited through social media as well as our personal and professional networks. Prior to their participation in our study, all participants were given a participant information sheet and signed consent and photography/video release forms, approved by the Ethics Committee at the Royal College of Music. These gave permission for the interviews to be audio recorded and the software tests to be photographed, screen-captured and video recorded[21].

The audio recordings of the interviews in *Round 1 and Round 2* were transcribed. The transcripts were coded and labelled using deductive thematic analysis for this initial round, which was focused on understanding how participants used *VR Rehearse & Perform*. The interviews conducted in these two rounds informed the design of the final iteration of the prototype. They were further analysed as part of the overall result themes that are presented in Chapter 4.

[20] As Oculus Quest 2 became available on the market, we decided to port our prototype to this headset. This came with significant improvements to visual and audio performance, due to its much faster processor, better display, and more RAM.

[21] This was not done for the *Round* in-the-wild evaluations

Table 2: Participants details for Round 1 and Round 2: ID, occupation, instrument played while in *VR Rehearse & Perform*, type of music performed, evaluation round they participated in.

PID	Occupation	Instrument	Type of music	Eval. round
P1	Professional flute player and music teacher	Base flute	Improvisation	1 + 3
P2	Multi-instrumentalist musician and music teacher	Yukalele and singing	Own music + Improvisation	1 + 3
P3	Professional Japanese drum player	Japanese drums	Improvisation	1
P4	Professional guitarist and vocalist(band member)	Singing	Improvisation	1
P5	Professional keyboard player (band member)	Keyboard	Random Notes	1
P6	Postgraduate and professional opera singer	Singing	Known musical piece	2
P7	Postgraduate musician	Singing	Known musical piece	2
P8	Postgraduate and professional opera singer	Singing	Known musical piece	2
P9	Postgraduate and professional opera singer	Singing	Known musical piece	2
P10	Undergraduate musician, vocal principal study	Singing	Known musical piece	2
P11	Former professional jazz singer	Singing	Known musical piece	2

3.6.3 Preliminary findings

In general, musicians in *Round 1* and *Round 2* were positive about the potential of VR to support their practice, connecting the immersive space with an enhanced ability to perform *"I think it might make a big difference, especially for singers. It's always difficult to find a good room to rehearse (P8)"*; *" I love the chance to sing and experiment with new sounds and new ideas in a space I was. I was convinced I was there. I found it very moving to be in the space. And it did feel empowering (P2)."*

Figure 13: Participants using *VR Rehearse & Perform*.

Sound. The three reverberation options provided were perceived as being very similar to an emptier and fuller (with audience) auditorium, and musicians played around with them, with no specific option being preferred *"I enjoyed the fact that you could change the reverberation change the sound of the venue (P3)"*, *I think it's a really good one because you want to play around with it. [...] so being able to do that it's really useful (P5)"*. For some musicians the sound quality was found satisfactory

with the quality of the 3D reverberation being positively evaluated. For more experienced musicians like P1, the sound quality was not to the standard it needed to be which interfered with their flow *"that [the sound quality] was interfering with the performance. So there was no flow. And it needed it, that the audio side of it needs to be much more balanced and brought up to a technically much higher specification (P1)"*. Furthermore, for P2 the biggest reverberation option was not enough and they suggested providing options for even bigger sound in order for musicians to fully be immersed in the experience *"When you can hear reverb in your performance, it makes you feel more immersed in the sound you're producing, it makes you feel less exposed. There's a danger in a large concert hall like that, that you do feel exposed, that you feel that you're a small voice in a large space. Whereas, if you add reverb to it, you feel like you're part of the space. More immersed in it (P2)."*

Participants who had performed previously in the real Amaryllis Fleming concert hall provided mixed feedback – two tried to select the setting that was more similar to the original sound of the room *"I know that room as well. So I performed in there, and I know it's not the lightest acoustic [...] I know that it's going to be a bigger room so I adjusted it (P5)"*, while another participant found that the fact that the acoustics is different is problematic and interfered with their feelings of immersion *"That's the most important thing is that I was aware that it was a constructed reality, rather than another, real reality. [...] The fact that I know the hall that we're in, the audio side of it was somewhat lacking in terms of what I am used to (P1)."* This showcases that the acoustic expectations of musicians might vary depending on various factors, such as their experience of playing in similar spaces.

User interface and interaction. In terms of the user interface, hand-tracking was considered an acceptable interaction method when it came to using VR as a rehearsing tool because it enabled musicians to keep their hands free to play their instruments *"if you're playing an instrument in there, of course in your hands you can stop for a second, lift up the hands, do stuff and then kind of go back to playing again (P6) ."* It also allowed them to switch easily between playing their instrument and interacting with the virtual environment. The VR prototype would have had very limited use if it was only usable with physical controllers.

Visuals. Although in this round of evaluations, most feedback focused on the sound, the visual cues provided by the virtual environment were also considered important. For P2 the lighting was an important aspect of the experience, and the lights-off version was not satisfactory enough to get them in the correct mindset: *" One thing that's worth thinking about is dark, light and dark.*

Whenever I record a song, and I know a lot of singers are the same, you want it to be often pitch black. [...] all I'm suggesting there is you might give environments which are darker rather than so lit. That might bring more out in the performers in a way you might not expect. Not necessarily black because it'll be pointless, but like to have a sense of dimmer lighting could be productive (P2)." Moreover, musicians commented on the level of realism, asking for more life-like environments *"I mean I liked it, and we talked about neuro-linguistic programming, where you envisage the space you're in. That's just that's what this is doing. And this is just taking it to another level, and I think it is a technique that a lot of singers use envisaging, and so it's helping with that. But if you can make it more realistic, it would be even better (P6)."*

Additionally, music-makers who were familiar with the space identified some inaccuracies when comparing the virtual environment and the physical hall (e.g., comments were made about the lighting, the absence of chairs and of the piano from the stage): *"I'm not sure about the spotlights or whatever you call them but some stage lighting like that might probably help with the immersion (P8)."* P8 further elaborated that the more lifelike the venue is, the more immersed they would feel which can lead to easier getting into a performance mindset *"more lifelike I would have wanted, with details like the piano and stuff like that make a big difference. Just tricking yourself that you are in a performance space usually makes you sing better because your subconscious says, "oh now it's for real". It's not just any regular practise. I like that because then you [take] the performance opportunity more. So I think being as detailed as accurate as possible might help with that as well to keep up the illusion - or whatever you want to call it (P8)."*

VR for creative musical practice. All music-makers reported enthusiasm about having the possibility to perform in spaces that recreate, both visually and acoustically, famous venues. *"I could never play in, say the Royal Albert Hall. So it'd be great to play in the Royal Albert and see how it is (P3)."*, *"You could probably go for venues such as the Albert Hall, Red Rocks in America, the Hollywood bow, you know, those kind of places like Carnegie Hall in New York. So the kind of the venues that are well known for having good ambience, or good sound (P5)."* Additionally, musicians reinforced their interest in being transported to other realities where they could interact with other types of sonic worlds (e.g., forest, cave) and improvise with environmental sounds: *"So background audio tracks to suggest that space. So you might want to write a song, that's inspired by a beautiful pool within a forest. And so as you're seeing and writing that song, you might hear the rush of water or the falling water, or the noise of the forest, etc, just simply to inspire you to write that song. Or rehearse*

that song. That'd be quite interesting (P2)." At the same time, they emphasised that making music is often a collaborative process; therefore, having the possibility to play with others in these immersive worlds would have a significant impact on their practice.

3.7 Closing thoughts

In this chapter, I have outlined the design, implementation, and initial evaluation of *VR Rehearse & Perform*, using VR as a tool to study the design of immersive environments for musicians' creative practices. This part of my work provided a valuable opportunity to explore how digital tools might address challenges faced by musicians, such as limited access to suitable rehearsal spaces and the need for environments that inspire creativity and emotional regulation. Crucially, this work offered insights into the potential of immersive settings, not just as technological innovations but as meaningful spaces that support users' creative processes.

Focusing on VR from the outset allowed for an in-depth exploration of its unique affordances, including spatial audio and customisable environments, and how these might respond to musicians' needs. However, this decision also introduced constraints. Framing the project around VR's capabilities shaped the work according to the technology's limitations, including hardware requirements and challenges in maintaining intuitive interactions. While this focus yielded valuable insights, it also highlighted gaps, prompting reflection on how well the technology aligns with the varied workflows of musicians. Looking back, I also realise that my understanding of human-centred design within the context of HCI was still developing at the time. While the iterative process and user engagement in shaping the prototype were important, if I were to redo it, I would probably have done things differently. For example, I would have included one (or many) additional middle steps between identifying design requirements and building the prototype. These step could have involved further exploratory methods, such as co-design activities, to ensure that the musicians' needs were not subtly shaped or constrained by the capabilities of VR itself and to allow for a bigger diversity of ideas to emerge.

However, I also recognise the value of creating and presenting a prototype like *VR Rehearse & Perform* to the musicians. During the interviews, when I asked about VR's potential, responses often reflected participants' perceptions of the technology rather than the possibilities it might offer. Without a tangible prototype, it would have been challenging for musicians to imagine how immersive experiences could be designed for their practices. Even those who had used VR before could not easily imagine

how it would help them because they were so constraint on what it can not do – e.g., they would not be able to see their instrument. Having a working system allowed them to engage directly with the concept and provide feedback grounded in interaction rather than speculation, offering richer insights into what worked, what did not, and why. Therefore, an important insight from this work is the importance of balancing exploratory and practical approaches when designing immersive environments. While the prototype subtly influenced the trajectory of the project, narrowing the scope in ways that might have overlooked broader possibilities, putting it into musicians' hands was invaluable. It demonstrated how tangible tools can spark dialogue and generate insights, even within the confines of specific technological frameworks.

Moreover, throughout the process of iteration and refinement, the dynamic nature of interpreting and implementing design requirements became increasingly evident. As the project evolved, so too did my understanding of these requirements, shaped significantly by how musicians interacted with the system. Reflecting on this, the importance of adopting an adaptable approach to development becomes apparent, one that accommodates the shifting landscapes of technology and musician needs. As I move into the next chapter, I build on the initial findings, refining the prototype based on the feedback gathered and exploring how these refinements influence musicians' experiences. The system's preliminary evaluation has laid a foundation for future development, pointing to areas where further refinement and research are needed. I also shift my approach from evaluating the final prototype to asking the musicians for the potential of technologies similar to the prototype to support them, using it as some sort of 'immersive provotype' [66]. The aim is to deepen my understanding of how immersive environments, facilitated through tools like VR, can support creative musical practices while reflecting on how this process can inform the design of future systems.

Chapter 4

Keep the VRhythm going. A musician-centred study investigating how Virtual Reality can support creative musical practice

In this chapter, I present the evolution of the *VR Rehearse & Perform* prototype, exploring how it grew and adapted in response to the preliminary evaluation carried out in Section 3.6. Following the iterative refinement of the system, incorporating feedback from its initial testing phase, I refined the prototype to better probe VR's capabilities and implications for musicians. Here, the updated version of the system was tested with a group of ten musicians, selected to provide a wide range of perspectives. Through a combination of hands-on testing sessions and in-depth interviews, I gathered valuable insights into VR's role in shaping musical practice, creativity and performance preparation. Analysing the feedback and experiences shared by the participating musicians, provided me with a clearer picture of the potential benefits and existing limitations of using VR in music practice. In this chapter I present these findings, discussing how VR could support musical creativity and performance preparation as well as what these insights could reveal about designing immersive experiences for creative musical practice. The platform itself is a medium through which I hope to inspire new ways of thinking about technology design in the field of remote music performances.

4.1 Re-thinking the implementation of the design requirements for musician-centred VR

The insights gathered from the preliminary evaluation presented in the previous chapter allowed me to revisit and refine different design features of the prototype to best meet the needs of music-makers. Based on this, *VR Rehearse & Perform* was enhanced by the addition of several new features (see Figure 14 for all the included features).

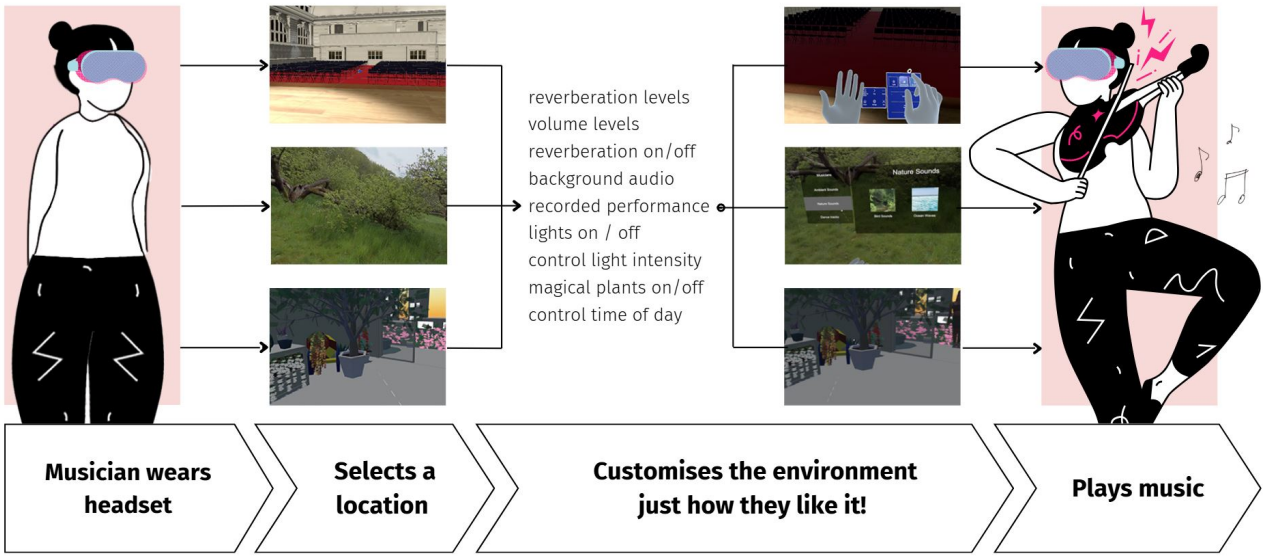


Figure 14: Features of *VR Rehearse & Perform*

For example, based on participants' feedback, I increased the **visual realism of the concert hall** by improving the lights setup and the design of the space (see Figure 15 for the evolution of the room design). This was achieved by adding chairs in the amphitheater and a piano on the stage and improving the modelling of the space. In addition, the option for darker lighting with spotlights became available.

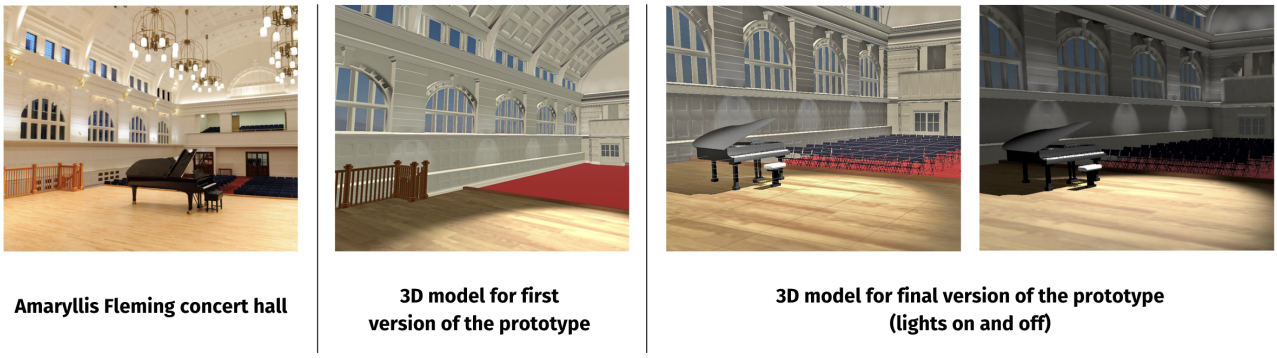


Figure 15: The progression of the 3D model of the concert hall

Additionally, to fully fulfil **DR2** and meet musicians' requests for accurate acoustics as well as fuller reverb, I added the **RIR of the Amaryllis Fleming Hall** as one of the reverberation options musicians can choose from. Impulse responses from various locations in the auditorium were captured using an ambisonic microphone (See Figure 16). For the prototype I used the RIR captured from the front of the stage, the same location the performer is located when in the virtual environment. The addition of the RIR of the concert hall as a reverberation option increased the latency of the audio. Therefore, for the subsequent evaluations, the headset was used tethered to a laptop to minimise the latency.

Figure 16: Scanning of the Amaryllis Fleming Hall with an ambisonic microphone

Furthermore, given the interest expressed in the evaluation rounds to experiment and improvise with different environmental audio cues, I expanded **DR4**, allowing users to customise not only the reverberation of the virtual environments but also the **addition of various audio triggers**. Informed by musical practice, as a result of the interviews we carried out in the previous stage, we added a library of background audio (e.g., crowd noises, nature sounds, orchard sounds, ambient music) that could be enabled in any of the performance spaces. I chose to have a common library of audio effects for all the environments to observe whether musicians tend to experiment with sounds that are not necessarily semantically congruent with the visual information they are presented within the chosen setting. This approach was inspired by [125], who highlighted that one of the measures of creativity is a certain flexibility to inconsistency, contradiction, and paradox. Therefore, I aimed to understand musicians' choice of sounds, their flexibility for experimentation and how this might influence their musical practice by inducing desired emotional and behavioural effects [405].

To allow musicians access to spaces that could support different dimensions of their practice (**DR5** and **DR6**), I added **two more environments** depicting a natural setting (a 360-degree video of an orchard) and a magical flat (where musicians can change the time of the day and make imaginary plants appear). The choice of environments was motivated by the insights from the interviews with musicians expressing interest in natural environments and extraordinary spaces (See Figure 17).

Figure 17: Three spaces for different mindsets: A magical flat, an orchard, and a concert hall

To enable musicians to improvise with other artistic acts, I added a **library of performances** pre-recorded in front of a green screen (e.g., musical and dance performances) – see Figure 18 for musicians being recorded and Figure 19 for how I went from the green screen recording to the performances in the software. We added this option to respond to the calls for collaborative features within the prototype. I understand that pre-recorded performances do not equal real-time collaboration, but since we were investigating the potential of VR in this space, I felt that this addition would communicate the idea.

Figure 18: Performers being captured in front of a green screen

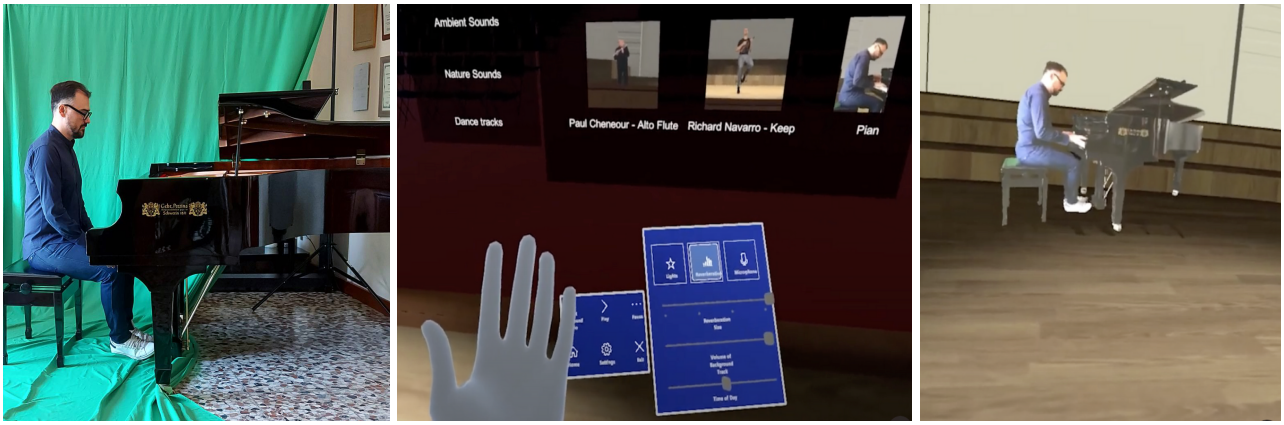


Figure 19: From the green screen to *VR Rehearse & Perform*

4.2 Musicians dive into VR (again!)

Testing protocol: Round 3. After the iterations in the software, we ran a new round of in-depth evaluation. The sessions took place in person, in a research lab, and lasted around two hours. They consisted of the following phases: a) a brief introduction about the project followed by musicians signing consent forms; b) 5-10 minutes of semi-structured interviews on the musicians' backgrounds and their experience with technology and VR; c) engagement in musical practice without VR; d) a brief introduction of the system and its functionalities, followed by experimentation and engagement in musical practice with their chosen features (e.g., environments, environmental sounds, reverberation levels, etc.) of *VR Rehearse & Perform*; e) semi-structured interviews on their experience and the potential of using VR for their musical practice, carried out at the end of their experimentation (see protocol in Appendix 2).

Participants. Ten musicians of various backgrounds (P1, P2, P12-P19; 8 males, 2 females; aged 21-69 – Table 3) took part in the *Round 3* evaluations. Musicians were recruited through our personal and professional networks as well as through our collaboration with the RCM. All participants had previous experience with VR which helped avoid the novelty effect that comes when using a headset the first time, therefore helping us gather more in-depth insights about perceptions.

Table 3: Participant details for Round 3. ID, occupation, instrument played while in VR Rehearse & Perform, type of music performed, evaluation round they participated in.

PID	Occupation	Instrument	Type of music	Eval. round
P1	Professional flute player and music teacher	Base flute	Improvisation based on the environment	1 + 3
P2	Multi-instrumentalist musician and music teacher	Yukalele and singing	Improvisation based on the environment	1 + 3
P12	Professional classical pianist	Piano	Random notes	3
P13	Formerly professional bass player, classically trained on piano. Postgraduate performance science student	Piano	Known musical piece	3
P14	Multi-instrumentalist musician and music teacher	Keyboard and singing	Own music	3
P15	Multi-instrumentalist professional musician and music teacher	Resonator guitar + singing	Improvised	3
P16	Hobbyist, student musician	Electric guitar	Known musical piece	3
P17	Professional vocalist and postgraduate performance science student	Singing	Improvisation based on the environment	3
P18	Multi-instrumentalist musician and music teacher	Acoustic guitar	Known piece	3
P19	Professional composer, improviser and music lecturer	Vibraphone	Improvisation based on the environment	3

Hardware. I used the Oculus Quest 2 headset for this round of evaluations. To reduce the latency introduced by the RIR of the hall (average 250 ms), I tethered the headset to a laptop and the instruments to an external audio interface connected to the laptop. These measures minimised the latency induced by the authentic acoustics of the hall to an average of 40 ms. As audio renderers, musicians were able to choose between using: i) the built-in speakers of the headset – these provide good quality spatial audio, while allowing users to listen to the sound of their surroundings at the same time, and ii) noise cancelling headphones, which provide better audio quality, louder, more targeted sound and complete isolation from the surroundings.

Data and analysis. Prior to their participation in our study, all participants were given a participant information sheet and signed consent and photography/video release forms, approved by the Ethics committee at the University of Arts London, Creative Computing Institute, as well as the Ethics Board at the Royal College of Music. These gave permission for the interviews to be audio recorded and the software tests to be photographed, screen-captured, and video recorded. The audio recordings of the interviews in *Round 3* were transcribed. Transcripts from all rounds of evaluation were coded and labelled, using a combination of deductive and inductive analysis [80, 458]. Initial codes were assigned based on our guiding research questions regarding 'presence', 'creativity', 'space', 'relationship with the instrument', and 'performance mindset'. Subsequent codes were added based on the frequency of sentiments shared by multiple participants. The observational data from the video recordings complemented the interview data during the analysis. The following themes emerged as salient for the broadest range of participants: *Presence as an antecedent of flow*, *The sound of being "here and there"*, *Relationship with the instrument*, *Facilitating creative musical practice*.

4.3 Evaluating VR's role in supporting creative musical practice

"I wasn't sure if I was inspired or intimidated, which was really cool. Because that could be a feeling that a performer could tap into to further their practice or their creativity and come up with new material (P17)."

4.3.1 Presence as an antecedent of flow

Presence and mes-mersion

We observed throughout our study that, when interacting with *VR Rehearse & Perform*, participants were ready to suspend disbelief and perform: *"I didn't actually think I was in an orchard. If I was actually in an orchard, the sky is grey, I'd be thinking, I hope it doesn't rain. And that didn't even occur to me. [...] It's like you kind of suspend your disbelief [...] and play along with the environment (P19)."* The **sense of 'being there'** – in the virtual environment – and the emotions associated with it were amplified in settings associated with traditional spaces that musicians play in. For example, the concert hall environment, while being a traditional performance venue, also inspired some of the strongest emotional reactions, with participants experiencing a sense of awe and reverence, *"when I first got into it, and it was this big hall, it kind of made me feel better than I was (P16)."* Another participant commented *"I would have happily hammered away the piano for hours, because it's quite a nice way to play in that concert hall (P13)."* Participants paid particular attention to how they sounded in the hall, *"I was more immersed in hearing the acoustic in that space (P16)"*, and some participants also commented on their openness to being influenced by the realism of the virtual environment: *"Just tricking yourself that you are in a performance space usually makes you sing better because then your subconscious, or your body says, 'oh now it's for real' (P9)."* The **visual and acoustic accuracy of the hall** in particular appears to have had a transformational effect on the way musicians perceived themselves, one participant describing *"I felt like more of a musician, because I was in the place, you know, with the instruments and all of that in that grand concert hall (P16)."*

The transformational, almost magical power of the space was experienced by another participant who referred to the concert hall as *"sacred (P19)"*, showing the intense meaning attributed to this space. This relates to the concept of a *sacred sphere*, or special place where the significance and meaning of certain social actions become amplified. According to [444], the function of a sacred

sphere (related in its most obvious materialisation to spaces and location) is to connect the factual world with an *otherworld* that can "take on multiple nonreligious qualities, which may play out in all kinds of artistic narratives, film, music, literature, sculpture and so on." Although fully independent of the religious world, **sacred artistic spaces** (e.g., iconic buildings with outstanding visuals and acoustics) might feel similar to religion itself, unleashing feelings difficult to articulate. We use *mesmersion* to describe the feelings of magnetic pull a musician experiences when making music in accurate simulations of such "sacred" spaces. This suggests the power virtual iconic venues might have not only on inducing the right creative mindset – cited as one of more important factors in musical practice [85] – but also on unleashing musical performances that go beyond the everyday.

The orchard environment, for example, was perceived as less immersive than the concert hall (endowed with 'sacred' significance) by most musicians: *"The concert hall was much more immersive. In the outdoors one, at first, before I started playing, I felt like I was outdoors. As soon as I started playing, it took it away. Because I was, I think my brain had sort of figured out « oh okay this is just a photo» (P14)"*; *"I felt more immersed in the virtual flat than I did in the orchard. I can't explain why that is. Maybe because in the orchard, there's so many more other sensory experiences like heat and breeze and the sound of the birds, whereas in a flat you're used to not having all the other senses (P2)."* One explanation for this could be that the sense of presence is enhanced in more immersive, computer generated settings that are: i) surrounding – the sensory signals (i.e., sound) approached participants from any virtual direction; ii) matching – the participants' proprioceptive feedback about body movements matched the information rendered on the display [428]. This confirms and extends recent findings reported by [523], who showed that computer-generated virtual content (i.e, nature) performs better than 360-degree videos when it comes to the experienced feelings of presence. In pursuit of presence, improved sensory realism and quality might exert a powerful effect, but it is unclear how this ever-increasing fidelity might benefit musicians' practice.

In the flow - Tapping into an abundant stream of inspirations

Musicians not only reported feeling being 'there', but **this 'there' remained interesting** through the contribution of sound and the variety of virtual environments provided. Participants connected the immersive spaces they were exposed to with an enhanced ability to improvise and perform: *"I'm aware that the environment that has been created within VR is an illusion. But it's a very helpful illusion. [...] I'm responding to the background stimulus of what it's asking me to do. In other words, there are tone centres, which give me guidance from where I can then move away from or back*

Figure 20: Musicians playing their instruments in *VR Rehearse & Perform*

to (P1)." Another participant commented on how much it supported visualisation techniques often used by musicians to place themselves in a performance frame of mind: *"you [have to] envisage the space you're in. That's [...] what this is doing but this is just taking it to another level (P8)."* The connection between feeling 'there' and the fact that this 'there' specifically facilitates the act of performing and improvisation correlates with several dimensions of flow described by [122] such as: merging of 'action-awareness' or being fully absorbed in the moment; direct and immediate feedback meaningful to the task; the ability to concentrate on the task; being an autotelic activity. Some participants made observations concerning warping or losing sense of time and space: *"I would say even then I felt slightly more focused when I was in the VR, because obviously, it kind of, you put on the headphones and kind of isolates the white noise, and you're just there and you just hear the instrument. And I felt like time definitely went more slowly (P16)"*; *"It just felt like I was in a different time dimension inside the VR (P17)."* Remarks pointing to the positive emotions emerging from the evaluation sessions speak to the autotelic experience musicians felt while performing and improvising as well as the merging of action-awareness.

Although most participants reported a strong sense of presence that inspired them to be more experimental while in *VR Rehearse & Perform*, they also mentioned **moments of distraction** *"And I was distracted by the wow factor, that's for sure. But that would go obviously after you use it a bit. (P19)."*

However, we observed that the distractions described by participants did not seem to interrupt flow, but rather seemed to redirect it. P19 continues: *"But I was kind of... I was really trying to play and hear how the software... you know, how the software responded within the spaces. So it was partly about playing, it wasn't exactly about me playing, you know, it's like, how is it within this space? So I don't know if that's being distracted or not, or just having your focus in a slightly different space (P19)."* 'Having your focus in a slightly different place' might also act as a brain boost, training important aspects of musicians' practice: *"I tried so many different things. Nature landscape distracted at first, very focused, after I started singing. Hall, again, distracted at first focused at points and then distracted at other points, because I wanted to look around, which is actually what would happen in a real performance, where there would be people in the seats and maybe somebody up in the balcony, and there would be musicians on the stage. So it's actually a really good exercise in a building focus and maintaining like integrity of your focus (P17)."* However, we note that for this sensation of *constructive distraction* to work for musicians, the challenge and the skill level need to be balanced (one of the key dimensions of flow). If this condition is not met (i.e, for pianists who could not play without seeing the instrument), the distraction will result in frustration: *"The trickiest thing is not being able to see the keyboard. I don't play frequently on the piano and also, I don't read music, I tend to look at the keyboard all the time. So for me, I think particularly that was difficult (P13)."* Whenever participants overcame this, they became fully self absorbed in the moment *"But after a little while, I think the reality of not seeing the guitar kind of set in, and then something clicked and I was just more on autopilot, and I was just able to hit the notes a little bit better (P16)."*

4.3.2 The sound of being "here and there"

In general, participants perceived the acoustic experience as being realistic *"You play, you're in the room, you can hear the effect of the acoustics, which is mild, but it's noticeable (P13)."* Moreover, P13, who was familiar with the Amaryllis Fleming Concert Hall, mentioned *"I think the quality of the reverb was high and it worked well. It was less artificial sounding, more natural sounding (P13)."* The latency resulting from the real-time microphone input, impacted the experience of musicians in different ways. For example, P11 turned off the simulated sound *"I did not like hearing myself with a delay (P11)"*, while P17 and P2 removed their headphones and listened to the audio coming from the headset's speakers *"There was definitely a very noticeable latency when I had the headphones on [...]. But once the headphones were off, it was completely fine. I think if there was latency it was very minimal, to the point where I could just work with it. I could hear the reverb, which was really*

awesome (P17)." P9 noted that although they noticed some latency, it was something that they could get used to "*until I found the right balance of the feedback it was, it required a bit of playing around and getting used to, but then once I found it, it was quite impressive actually (P9).*" P16 and P19 mentioned they did not experience any latency while playing. Overall, we observed that some of the participants utilised **specific types of coping mechanisms to compensate for the audio perception of latency** such as changing focus, tempo or dynamic, or shifting their gestures and strike ahead of the beat to align the delayed sound, which were observed also in a non-VR context by [176].

Interestingly, using the Quest's native audio system created a unique sonic world, where the sound of the physical space musicians were located in, blended with the sound of the virtual space they were experiencing. P17 continued by explaining how they found value in this for their music-making "*The sound quality was pretty cool [...] I preferred not having the headphones because I could actually hear my own voice as well, whilst hearing audio from the headset output. And I think it helps to train, it adds an element of naturalness to it (P17).*" In general, participants expressed different views about the optimal sound output device for their VR music jam and there was no general consensus if headphones or the Quest Audio system was better in terms of quality and experience. P8 commented that they preferred the Quest's audio system as "*... they just felt a bit more natural than the headphones. I mean, especially for an opera singer. I just feel that you know, having earphones really like is really [too much there] and it's... you know, it shuts down everything. I just feel more comfortable with the built-in speakers (P8).*" On the contrary, P19 saw benefits in using the headphones because they "*[...] cut that out (i.e., the sound of the physical room), it did make a big difference, actually. So I could really hear the room (i.e., the virtual space). And I found that when I moved my head, I was hearing it sort of slightly differently in the room as well (P19).*" For P2, removing the headphones had an impact on their immersion in spaces where the blended sonic world did not match their acoustic expectations of the space "*I felt more immersed in the flat, when it was a more closed acoustic, similar to the one in this room we are in. Whereas the hall didn't really do that for me. Maybe because it wasn't quite loud enough (P2).*"

4.3.3 Relationship with the instrument

While wearing the headset, participants could see their hands but were unable to see their instruments (i.e., the instrument was not tracked and visible in VR - Figure 20). Accordingly, **they relied on auditory and haptic cues to play music**. Musicians often have strong bonds with their instruments and as [421] showed, feeling united with their instrument can lead to improved mental well-being,

higher levels of confidence and reduced performance anxiety. It was hence important to explore how the inability to see instruments in VR affected the musician-instrument relationship, how it influenced the perception of embodiment in VR and, consequently how it affected musicians' performance.

Music-playing is a multisensory experience involving perceptual, cognitive and motor components. One of the most prevalent forms of sensory information that accompanies audition when playing music is touch [509]. For musicians whose regular playing relies more on auditory and haptic feedback, not seeing their instrument had no impact on how they felt towards it. For example, P1 noted that once they found the flute's mouthpiece, everything was fine *"the VR didn't affect the level of what I do. It didn't detract from the quality and the style and the delivery...."* Musicians who played string instruments took more time to adjust to not being able to see them *"... playing in VR, it was confusing at first, it took a little while for my brain to adjust to the situation (P16)."* Nevertheless, after getting accustomed to the lack of visual feedback from the instrument, they perceived this as a positive aspect of VR, which enabled them to train new sensory skills and enhanced their connection to their instrument *"[I felt] probably more connected to it [the instrument] because I couldn't see it. And because it becomes a touch and feel and sound thing. I think it's preferable. Actually having the opportunity to almost play blindfolded is quite nice (P15)."* Both P15 and P18 saw great potential in this aspect of *VR Rehearse & Perform* in terms of improving their practice *"I think I like not being able to see [the instrument], relying completely on muscle memory is definitely something that I should practice. [...] I feel [...] not being able to see the instrument is actually quite positive (P18)."*

Even-though auditory feedback is crucial for all musicians, in the case of pianists, Banton [26] found that when deprived of visual feedback (i.e., not seeing the piano) they tend to make more mistakes than when deprived of auditory feedback (i.e., not hearing the piano). This was also evident in our study, as musicians who play key-based instruments were the group that struggled the most to play music and felt most disconnected from their instrument. P5, P12, P13 stated that they could not play continuously at all. P12 commented on his experience *"I didn't know which keys to press to really get out what I want [...] but I felt very limited to how freely I can move around the keyboard (P12)."* Surprisingly though, after getting used to not seeing their hands, P14 was able to perform an entire song in VR. They attributed this to having a 'perfect pitch' (i.e., absolute pitch [21]): *"I have what's called perfect pitch. So the reason I could play things a little bit easier because when you play a note, I can hear the note. [...] I definitely was relying on that quite a lot when I couldn't see the keys (P14)."*

Percussion instruments are another type of instrument that one would expect visual feedback is important when played. Before their session, P3 raised a concern about the fact that they would be unable to see their drum *"I think it's good to see the drums. [...] Because we do play the sides, the edge of the the actual drum skin right into the centre, it makes completely different sounds (P3)."* However, they changed their mind after using *VR Rehearse & Perform* and identified a technique to overcome this. They found that if they touch the periphery of their drum when in VR, they could adjust well to not being able to see the instrument *"it wasn't a problem once I got used to the idea that I couldn't see out of my peripheral vision (P3)."* P19 embraced the idea as they already had experience with playing in a blindfolded band. Due to the pandemic they had not performed blindfolded for about a year *"I kind of lost where the instrument was, and where the notes were [...] If I was going to use this [VR] seriously, I put more time into re-learning my tactile relationship with my instrument (P19)"* . Nevertheless, when asked about their relationship with the instrument while in VR they described it as *"definitely experimental, it felt really playful. [...] I felt really connected because it's like, I know this instrument, and I know this thing so well. But spatially, I was having problems (P19)."* They suggested that a simple solution for this would be *"a point of reference for where the vibraphone is, actually that's all it needs. It doesn't need to be a visual vibraphone it could just be where the edges are, or something like that. That would just make a massive difference."*

Several participants sang in VR - some in combination with their other instruments. P17, one of the singers in our study, described their body as their instrument and explained how the strong feelings of immersion they experienced affected their relationship with it. *"I was so immersed in what my eyes were seeing that, I as a trained vocalist, forgot about my body and every now and then I remembered: wait no I have to like control my core to like, play my instrument."* This suggests that although their feeling of being present in the environment (often referred to as Place Illusion [425]) was high, their feelings of body-ownership were reduced; hence they momentarily lost agency of the rest of their body. For vocalists, being aware of their body and breathing patterns is crucial not only in terms of the singing output, but also in terms of protecting their voice [296]. This lack of embodiment in the virtual environment " *[...] could contribute to bad habits about not being aware of your core support, and your feet (P17)."* The same participant also commented that this aspect *"could be improved with familiarity so that you don't lose yourself completely."* or by *"having [...] a visual cue that says, hey, you have a body [...] you've got an entire, instrument below your neck that you need to be aware of. So even if it's like an avatar in a mirror [...] that could be very beneficial."* Additionally, the headset presented another barrier to singing in some cases, due to its position on the face, which prevented the expression of some specific notes. P17 elaborated on this *"if you do something brighter, or*

clankier or something that requires your mouth to be like a bit wider [...] that would be hard because the headset rests right on top of here. I noticed that as long as you're taking the jargon away, as long as you're doing, like rounded, warm sounds, it's completely fine." In addition, P6, P8, and P9 who are opera singers, all commented on the weight of the headset and how it affected their singing *"the weight of the headset pulls down on the neck. And you really notice that as a singer because alignment is very important to get right. You find yourself constantly having to [move] against it (P6)."* The weight and fit of the headset were a problem only for participants who sing.

4.3.4 Facilitating creative musical practice

Access to restricted spaces

The immersive visual environments as well as the dynamic acoustical properties of each corresponding space were frequently associated with an enhanced ability to prepare material for public performance. Participants described how *VR Rehearse & Perform* provided a meaningful **sense of access to otherwise restricted performance venues**, allowing musicians a novel sense of freedom to sonically explore a venue before performance, and contributed to an easing of anxiety associated with anticipation of performing in those spaces. As one participant described, *"preparing for a concert, one of the things you have to deal with is, is the psychology of performing"* elaborating that concert halls can be overwhelming but to prepare, *"practising as much as you can in the space is what you need to do (P19)"* . Musicians, however, rarely get many opportunities to rehearse in the spaces they are expected to perform in, and subsequently can struggle to feel adequately prepared for a performance. Four participants described how the quality of the visual environments was enough with *VR Rehearse & Perform* to evoke a feeling of really rehearsing in a concert hall, *"It feels like what it used to be, you know, a year and a half ago [before the national lockdown] (P15)."* Another similarly described how *"the concert hall environment was stimulating a similar feeling to... performing in public (P1)."* These feelings were in turn associated with an enhanced ability to be creative in venues that otherwise could feel intimidating and instead *"use it like a playground (P17)."* P13 described how the VR rehearsal experience was superior to playing in dedicated rehearsal spaces that *"are tiny, they're padded, they are acoustically dead (P13)."* In addition to evoking qualities of a familiar performance venue or experience through VR, participants described how *VR Rehearse & Perform* could allow access to *"sacred spaces within the world of music"* that are *"very hard to get access to (P19)."* This idea was validated by another participant who remarked after their experience that it was *"probably the*

only way for me to play in that concert hall (P13)." Such *sacred* or rather iconic venues are not simply remarkable for their social or cultural prestige, but often have been uniquely designed to resonate in a particularly unique and pleasing way. Participants observed that the particular acoustics of each virtual environment as well as the ability to manipulate the level of reverberation and addition of ambient sound enhanced their experience.

Playing the room

The dynamic range of acoustic experience afforded by *VR Rehearse & Perform* was a frequently cited positive characteristic of the experience, as one participant explained: *"from a practising point of view, it has massive benefits, because you are interacting even more with your ears than you are by actually just looking at where the things are (P15).*" The sound produced by a musician's instrument is a product not only of the particular resonating qualities of the instrument, but also of those sounds mixing with the environment. Accordingly, **the acoustic properties of a given space become a literal extension of the instrument** that the musician must take into account. As one of the vocalists in our study explained,"*the acoustics of the room can really change… how you project, how you shape your vowels, how you phrase, what colour you use for your tone, and texture (P17).*" Participants responded differently to the various options for shaping the acoustics of the room and the ability to add and remove additional sounds. For one vocalist, *"I could hear the reverb, which was really awesome. I could play around with it and go to like the max setting (P17)*", while the vocalist playing with a ukulele preferred and *"felt more immersed in the flat (P2).*" Some enjoyed *"… that you can have an audience and turn them on or off (P14)*", while another felt *"I don't actually care about the people that are in the audience (P15).*" Not all of the participants explored the full range of additional sound options, but one that did expressed *"I really liked the kind of variety in the accompaniment I could have. There was like the nature sounds, and there was the musicians that I improvised over the guitarist, and then I improvised over a person dancing (P17).*" The visual environment played a role in particular for improvising musicians who described that the presence of virtual environments directly affected what they paid attention to, *"When I was playing on my own, I was responding to the the sound in the room. When I'm playing with the background, I'm responding to the background stimulus of what it's asking you to do (P1).*" Such observations support the potential of VR to not only address challenges musicians experience when travel is restricted, but to enhance traditional training and introduce new techniques for training the mind of the performer. In particular, our results indicate that the majority of participants experienced a direct impact from the VR world on not only what they played,

but how they played, and how it felt to play. Overall, while participants varied in opinion on which particular room acoustics they preferred and how useful a given accompaniment might be, there was general agreement that *"if you're going to perform … and then you have this like a week before or two weeks before, I think it could be quite useful, because then you already have an inkling of what like(sic) sound carries (P17)."* In addition to helping performers shape their sounds for performance in a particular venue or setting some participants pointed out that *VR Rehearse & Perform* would be a useful tool for overcoming some of the psychological challenges related to performance.

Mindset for performance

Besides the challenge of adapting to the acoustics of a given venue in a relatively short period of time, we learned that even being in a music hall virtually can induce anxiety for many. Performance venues can be intimidating to musicians for a variety of reasons. Strikingly, in our study we found participants describing that in the concert hall, *"I really felt a bit more kind of inhibited (P2)"*, *"It was weird there… I think because I'm slightly apprehensive about going back to a big theatre (P19)."* Another described how unlike the other VR locations, in the hall they felt, *"in the back of my head is, (sic) is pulling it, you know, like you would be if you're on stage (P16)."* Similarly, the fourth participant described, *"When you're playing in the [virtual] flat, it could be compared to, similarly to, practising at home – in the hall, I'm focusing on an exterior and playing as though I'm playing to an audience (P1)."* These feelings were noteworthy in how they affected performance: *"in the [hall], some of my bugbears with classical music started to come into play… should I really be playing like free improvisation?… I can't do wacky crazy stuff (P19)."* Feeling 'weird' and 'inhibited' in the hall, rather than being perceived as an obstacle to rehearsing in VR, was described as a potential source of empowerment. *"So this is great, I can be here trying this out and (sic) getting confident again within a bigger space (P2)."* P17 described, *"as a performer I struggle with opening my eyes and looking at the people in front of me, but I could do that in VR."* They explained further *"in terms of training, spontaneity, and nervousness and kind of shyness, to an extent, I preferred being in VR, because it just proved to me that technically, I'm competent, it's just interpersonally, I'm a little nervous or a little shy (P17)."* P16 and P1 both described how in a performance anxiety context, VR *"could be a really useful experience, you know, in school (P16)"* or *"great aid for musicians, even actors, dancers, and anybody that's doing a mic, stand-up comedians, or even politicians or people having to deliver conferences or speeches (P1)."*

Stimulating creativity

A key motivation for our study was to see how VR might address some of the challenges musicians reported during periods of social isolation [85]. The need for this was reinforced by such observations from our own participants describing how they *"do lose inspiration just being in the same environment over and over and...you start to feel very sluggish (P17)."* Therefore, we set out to investigate to what extent **virtual worlds could inspire more enjoyment**, and function as a 'trigger' to be creative, as a direct 'input and creative prompt', and as a way to stimulate a 'psychological safe space'. Overall, musicians enjoyed the environmental variety provided, with one participant describing *"the variety between the landscapes was so striking, I really enjoyed just being able to travel from this grassy natural world, into a constructed Hall into a little flat (P17)."* The ability to feel present in the environments was reported to have a direct effect on feelings of creativity: *"Aesthetically, it puts me in a more creative space (P19)."* In general, participants shared similar observations that, *"in terms of how it makes you feel, it certainly puts you in the right kind of frame of mind (P13)."*

Notably, participants had a wide range of **different interpretations of how the different VR environments stimulated them creatively**: *"you'd find yourself playing different in different situations (P15)"* and they expressed desire to explore how different environments can inspire different types of music playing *"what would interest me in the different environments is that it could push you creatively, you know put me in an Astrobot world, I'm going to play something different than what I would in an auditorium, or what I would in a little sort of smoky bar setting. And it's got loads of great potential for experimentation (P15)."* For others, the ability of VR to isolate the user from the outside world and completely immerse them in new environments provided a safe space for experimentation *"there was like a minute where I was like I cycled through a bunch of different styles where I went from like Eastern style singing into like scalped jazz, singing and then read mixing and then I just cycled through a bunch of styles and that is something normally I would do inside my own bedroom or like in the bathroom or a very isolated [space] (P17)."*

Moreover, for P18, being in the virtual orchard inspired feeling linked to the music they were playing, describing how they felt *"enlightened... because it kind of goes into the piece of music(P18)"*, reflecting a sense of cohesion between the musician's internalised 'sonic world' and the external one. Similar feelings were observed from P19 while playing music in the flat *"I was trying some other things out with my voice so there was something that was happening that made me more creative. It made me want to create more with the song because I was in a place where which I felt was imaginatively and*

creatively in line with the song itself (P2)." This connection between the music as a kind of existing sonic world that became 'enlightened' by the orchard environment or 'creatively in line' with the flat, supports Reybrouck's explanation that creativity in the musician manifests as a *"continuous interaction with their environment in an attempt to keep any disturbances within critical limits.*" Traditionally, the environment of rehearsal rarely matches the internalised sonic world of the piece, suggesting there is a cognitive load for the musician to ignore the 'tiny, padded, acoustically dead' practice environment they usually find themselves in: *"we usually stay away from the practice booths cause it's so difficult to know what you're doing when when it's so completely dense, and you get nothing back (P9).*" Our results suggest that VR technologies have the potential to expose musicians to environments that match the emotions their music induces, providing a meaningful way to reduce the cognitive load, and in turn allow for more creative attention to be placed on musical expression itself, therefore inspiring different kinds of creative practices.

4.4 Designing musician-centred VR experiences

The applications of VR are extensive and range across numerous domains of knowledge; however, research has not looked until now at how VR might benefit music-makers and their creative practice. Specifically, while some research efforts have focused on VR musical instruments for extending musical experiences (see [409] for a survey on this), the complex relationship musicians have with rehearsal and performance spaces has been neglected. Music-makers are always playing a duet with the space. Authentic sound reconstructions in VR could thus open up the possibility for musicians to incorporate, in their creative practice, a variety of virtual rehearsal and concert spaces to enhance their practice. To enable this and to find meaningful ways to support musicians, I took an iterative approach, where we involved music-makers in the process of formulating a set of design requirements for immersive experiences dedicated to musical practice. Based on these requirements, I built *VR Rehearse & Perform*, a system that allows music-makers to engage in their musical practice in three customisable – both visually and acoustically – environments.

The visuals and the dynamic range of the acoustic experiences afforded by the system had a direct impact not only on what musicians played, but also on how they played and how it felt to play (see Table 6 for a summary of our findings). Many participants appreciated that the environmental variety functioned as an inspiring creative prompt that triggered a creative mindset and contributed to an easing of anxiety associated with the anticipation of performing in those spaces. From my partici-

pants' observations, it appears that tools like VR have the potential to become a solution to some of the challenges they face beyond the pandemic. They described that *VR Rehearse & Perform* allowed them to place their creative attention on musical expression itself, supporting existing and inspiring new forms of music-making. Most musicians observed the potential for more effective training from home or from spaces that do not meet their acoustic needs. Inspired by their experience with *VR Rehearse & Perform*, two participants have since bought a VR headset and integrated it in their musical practice. In the following sections, I discuss some insights we gathered from our observations, which can inspire future research and design of musician-centred VR experiences.

4.4.1 Creative distractions

The variety of virtual environments and the contribution of sound allowed our participants not only to feel 'there', but also to transform this 'there' into something interesting, which enhanced their musical practice. Most of our participants' behaviour and observations suggest that they achieved a state of flow while performing in *VR Rehearse & Perform*. Some reported experiencing distractions during the interaction with the system, but these distractions seemed to have fuelled their subsequent experimentation. It is important to emphasise here that distractions should not necessarily be seen as a barrier to facilitating flow, as long as they open up a new creative output rather than halting performance. "Having your focus in a slightly different space" may stimulate broader associative thinking and creativity in music as shown in research on the benefits of multitasking. This suggests that focused attention may in fact be detrimental for a creative performance and phenomena that involve concurrent thoughts or emotions, such as mind wandering and interruptions, might improve the performance on creative tasks [245, 246, 284]. Dreyfus and Dreyfus [141] actually emphasised the role that intuition plays in facilitating skilled performance. However, one must also keep in mind that mindless inattention to detail can suppress full control – one of the core characteristics of flow.

It is also important to note here that despite the clear rationale for assuming a clear correlation between flow and performance, results yielded by empirical research defy easy interpretation [351]. While a number of studies have found a positive relationship [98, 448] in the context of games, academic performance, or sports, others suggested that the relationship between performance and flow is weak or even non-existent [130, 147]. Notably, Harris et al. [197] found in their systematic review that "current evidence is unable to determine the exact nature of the flow-performance relationship" despite identifying a "consistent medium-sized relationship between flow experience and task performance" across 22 studies. These variations in results might be supported by the work of van der

Linden et al. [476], who showed that different types of tasks can elicit different types of flow. Further investigation is necessary to explore how flow relates to performance in musical practice. Our observations present an opportunity for further study into how to engineer creative distractions in the context of audio-first immersive experiences, so that the resulting energy and increased cognitive flexibility spill over into musical practice.

Table 4: Summary of findings from exposing musicians to VR Rehearse & Perform

Main theme	**Sub-theme**	**Key findings**
Presence as an antecedent of flow	Presence and mesmersion	Virtual iconic venues enabled musicians to experience stronger feelings of magnetic pull than casual settings (i.e., the orchard, the flat). This induced the right creative mindset and unleashed performances that go beyond the everyday.
	In the flow	The connection between feeling 'there' and the fact that this 'there' specifically facilitated the act of performing and improvisation correlates with several dimensions of flow [122].
The sound of being "here and there"	n.a.	Music-makers found the acoustic experience realistic. The latency impacted the experience of musicians in different ways and some participants utilised various coping mechanisms to adjust to it. The unique sonic world created by Quest's native audio system was perceived valuable by some of the musicians, while others preferred the more targeted sound the headphones provided.
Relationship with the instrument	n.a.	The absence of instruments from the VR simulation impacted musicians differently depending on the instrument they were playing: 1) key-based instruments: significant challenges; 2) string instruments: more time needed to adjust, but once this is achieved, the practice is seen beneficial; 3) percussion instruments: experimental relationship; 4) singers: lack of body awareness and problems with the fit of the headset.
Facilitating creative musical practice	Access to restricted spaces	*VR Rehearse & Perform* provided a meaningful sense of access to otherwise restricted performance venues, allowing musicians a novel sense of freedom to sonically explore a venue before performance.
	Playing the Room	Exposure to a variety of sonic worlds in VR helps performers shape their sounds for performance in a particular venue or setting.
	Mindset for performance	*VR Rehearse & Perform* enabled musicians to enter the mindset for performance and this was perceived as a potential source of empowerment.
	Stimulating creativity	The environmental variety was positively associated by musicians with feelings of creativity. VR provided a meaningful way to reduce the cognitive load, and in turn allow for more creative attention to be placed on musical expression itself.

4.4.2 Music anywhere and everywhere

Musicians rarely get opportunities to rehearse in the spaces they later perform in and subsequently frequently struggle to feel adequately prepared for a performance. Additionally, every style and type of music often evolves in a particular acoustic ambience; therefore, each composition sounds best in the space with its intended acoustics [45]. With VR, any room can serve all the purposes and become a space that not only triggers a creative mindset but enriches the musical practice in ways that until now have not been possible.

Virtual and acoustic reconstructions of historical venues [243, 247] have been done in the past, but not in the context of musical practice. The results of our study indicate that such reconstructions could

be utilised for designing musician-centred VR experiences aimed at supporting musical training and rehearsal. By providing access (both visually and acoustically) to simulated performing venues, VR opens up the possibility for musicians to incorporate performance halls' acoustics into their regular practice. Theoretically, this has always been possible by travelling to venues and playing music in spaces with different acoustic characteristics. Practically, however, this is impossible as performance venues are often inaccessible. Moreover, these spaces can be recreations of "sacred" venues, enabling musicians to experiment with the "finest halls in existence" [45]. During our study, we observed that the immersive concert hall environment – perceived as one of the "sacred" places to perform in – had a magical, transformational power on musicians, *mes-mersed them* and empowered them to explore new ideas.

Musician-centred VR experiences have the potential to benefit those who want to play in a virtual venue before taking the stage for the first time; those who want to know how their voices would sound in a particular space; and those who wish a virtual space to sing in or be inspired by. Furthermore, VR has the potential to benefit new musicians who are unfamiliar with stage dynamics or those unable to obtain enough practice time in a certain space. By having access to virtual replicas of locations, musicians could rehearse there and get a sense of the room's acoustics without being physically present. This can impact their familiarity with the venues by providing them with a psychologically safe space to practice in, which could help lessen emotions of musical performance anxiety when on stage. The VR environment can therefore assist by preparing the musicians for the stage, with the visual familiarity and sense of space imparted by the spatial audio reducing the sensations of strangeness, trepidation, or unfamiliarity associated with walking out onto a new stage for the first time, or after a long break (for example, due to the impact of COVID-19 on access to indoor spaces).

4.4.3 The quest for balancing accurate acoustics and lower latency

The average audio latency of *VR Rehearse & Perform* differed depending on the acoustic setting: i) 20 ms for the the approximate, plausible acoustics emulating the sound of auditoriums of different sizes; ii) 40 ms for the accurate acoustics based on the RIR of the Amaryllis Fleming Concert Hall. This audio delay is similar to the early reflections [461] that can be experienced by musicians in large acoustic spaces such as churches, with the added long reverberation times [32]. Participants in our study found the latency of the plausible acoustics mostly unnoticeable and manageable. Opinions varied when it came to the perceived latency of the accurate acoustics settings: key-based instruments players were most affected by it, experiencing significant challenges while performing

due to the tactile feedback their instrument require; string, percussion and voice instruments music-makers noticed the latency and used various coping mechanisms to deal with it – for example they: i) took off the noise-cancelling headphones and listened to the blended acoustics of the physical and virtual world which provided an illusion of reduced latency; ii) decreased the tempo of their performance; iii) started to sing louder to drown out the delayed sound. We note that the audio delay was unnoticeable for two participants who are used to playing music on online platforms and the afferent latency of this. These mixed perceptions are in line with findings reported in [27, 176, 463], where the amount of tolerable latency was shown to vary significantly for musicians.. The results of Greeff [176] indicate that the capacity to tolerate performance hindrances such as unwanted amounts of latency is not influenced by the formal training, but by the previous studio experience, the approach to performance, and the ability to put emotion into the musical act.

There are various possible solutions to address these variations in the perceived latency threshold for an optimal performance. One could consider replacing the accurate sound reproduction with its plausible version for example using the method suggested in [422]. This alternative is supported by VR studies that analysed the effect of visual cues on the plausibility of audio rendering and showed a dominance of vision over acoustic cues [22]. However, Remaggi et al. [378] signal a gap in the literature related to the thresholds for the evaluation of acoustics' plausibility in VR reproductions. It is therefore not clear how different sound reproductions are perceived in a multimodal medium like VR where the presence of visual stimuli might mask the perceptual differences between real and synthetic acoustic environments. Given the limitations introduced by the audio latency, it would be important to explore how musicians perceive this latency under sound reproductions of different levels of accuracy and the impact of each sound reproduction on their experience in VR. Another possibility is to allow musicians to spend more time in *VR Rehearse & Perform*, therefore enabling them to adjust to its latency. Detaching the aural part from Unity and implementing it in more advanced audio programming environments (e.g., PD/Max/MSP, etc), can also reduce the latency problem but in the same time, affect the portability of the solution. Finally, as technology continues to advance, and more powerful processors are introduced in standalone headsets, the real-time processing of *authentic* audio will come with less and less latency.

4.4.4 Virtual environments as creative triggers

VR can not only teleport users to familiar spaces but also to inaccessible physical spaces, as well as new "magical" visual and sonic environments [427]. In our study I observed that the three dif-

ferent spaces musicians were able to teleport in, induced different types of emotional responses. In the concert hall participants reported feelings similar to those they have when performing. In the orchard, participants felt 'enlightened and relaxed'. In the flat, they felt more at home, more comfortable therefore more experimental. These feelings influenced the types of music they chose to play, or the way they performed. This unique aspect afforded by VR enabled music-makers to access a variety of creative triggers, which enhanced their ability to infuse various emotions in their performance, to compose and improvise.

Each of these spaces became a different instrument musicians enthusiastically started to experiment with. Whether for performing known pieces or for prototyping new music inspired by the sounds of the places they were immersed in, all musicians appreciated positively the immediate access to the various sonic virtual worlds. Although, audio was initially deemed as more important than the visuals, once musicians started experimenting with the virtual environments in *VR Rehearse & Perform*, they remarked that the visual cues allowed them to experience and enter different mindsets. Music is multisensorial, therefore being 'there' had a significant appeal for music-makers because it stimulated various sensory areas. In choosing the audio elements to accompany the various environments, we observed that our participants chose congruent effects, that semantically matched the settings (i.e., the sound of the birds in the orchard; the noise of the crowd in the venue). An interesting direction for future research would be to explore if there are occasions where a break in semantically matching sounds and environments (for instance by providing visuals that adapt to sound based on crossmodal correspondences [441]) can provide new types of creative pathways.

4.4.5 Designing with the instrument in mind

Existing studies in musical VR experiences are mostly focused on the interactions which take place within the virtual world [14, 409], or passive experiences where the user sits backs and listens [416]. However, when designing VR for musicians, there is a need to consider how they interact both with the physical space their body is in and the virtual space their 'mind' is in. Th3 interaction is evident in their relationship with the instrument, which is located in the physical space while they are in the virtual environment.

For musicians, their instrument is often an extension of their creativity, and feeling connected to it might directly promote enjoyment, engagement, and motivation when playing [421]. While conducting our study, we anticipated that one of the barriers musicians would face is the inability to see their

instruments in VR. This was indeed the case for key-based musicians who were able to see their hands but not their instruments' keys, as well as some of the singers who felt a disconnection with the rest of their body and consequently a lack of embodiment within VR.

Surprisingly, for string-based and percussion musicians, although frustrating at first, this lack of visual cues appeared to also open up new ways of bonding with their instruments. However, the role visualisations play in relation to professional musicians remains unclear. Participants in our study reported that not seeing their instrument enabled them to explore using other senses, such as touch or hearing, enhancing their connection and instrument awareness – after all, it is well known that professional musicians often do not look at their instrument while playing [10]. One could argue that this could also be achieved by playing blindfolded or by having the lights off. However, VR provides the unique possibility of still engaging with the visual senses, enabling the musician to focus more on the environment and the sound they are producing rather than the accuracy of their hand placement.

Nevertheless, when designing musician-centred VR applications, developers should consider ways of including musicians' instruments as part of the experience. This would make such technologies accessible to a broader range of musicians. Various methods could be used to achieve the incorporation of the instrument. For singers, visual access to a mirror or virtual avatar could reinforce body ownership and presence, which has been shown to support embodiment in therapeutic settings [429]. When it comes to incorporating physical instruments, one increasingly viable option is the use of MR headsets (or MR functionalities on existing VR headsets), which allow users to see and interact with their physical environment while immersed in digital content. Devices such as the Meta Quest and Apple Vision Pro offer different approaches to this[22]. For instance, the Meta Quest's Passthrough API[23] enables a video feed of the user's surroundings to be layered with virtual elements. This allows musicians to see their real instruments while still engaging with a virtual stage or visualisation, making it easier to retain physical awareness and embodiment. Similarly, Apple's Vision Pro[24] is designed from the ground up for spatial computing, offering high-resolution passthrough and the ability to anchor digital content within the user's real environment, which could support more seamless interactions between physical instruments and virtual effects or settings. Incorporating MR in this way would allow musicians to benefit from the atmospheric and sensory richness of VR without compromising their ability to play. For example, a keyboardist could see both their hands and the keys while surrounded by immersive visuals, or a drummer could maintain spatial awareness of their kit while

[22] At the time of running the study such functionalities were not available.
[23] `https://developers.meta.com/horizon/documentation/unity/unity-passthrough/`
[24] `https://www.apple.com/apple-vision-pro/`

engaging with reactive, music-driven environments. As MR technology becomes accessible, future musician-centred applications could leverage these affordances to bridge the gap between physical and virtual performance spaces, enabling more intuitive and inclusive experiences.

4.5 Learnings and implications for design

Looking back on the entire process encompassing the activities for gathering user insights, the design requirements, the development of the *VR Rehearse & Perform* prototype and its evaluation, here I briefly present several design implications which arose from what I learned, laid out to provide actionable guidance for similar future design endeavours.

To design systems that cater to user needs, designers could:

Facilitate tangible experiences early. The immersive prototype served as an effective tool for engaging musicians in meaningful discussions about VR's possibilities in their practice. This emphasises the importance of providing users with tangible experiences of new technologies early on in the design process. Such experiences allow users to articulate more detailed feedback and envision practical applications [221], ultimately enriching the design process with their perspectives.

Iterate designs informed by diverse testing environments. The project's methodology, which combined a controlled lab setting with in-the-wild testing (although introduced due to COVID-19), emphasised the value of iterative design informed by feedback from diverse testing environments. I encourage designers to employ a mix of testing scenarios to gather different types of insights, accounting for the variability in user contexts and environmental factors.

Cater for a spectrum of experiences. Users bring diverse skills and backgrounds, as seen in musicians with varying expertise and instruments. Flexible design is crucial – offering customisable features like adjustable acoustics and lighting enables systems to accommodate a wide range of needs and skill levels. However, it is important to note that musicians often thrive on complexity; the challenge of mastering an instrument or tool is part of the creative process [217]. Simplified interfaces can support beginners, but designers should also embrace complexity, where it inspires creativity and innovation. Striking this balance can lead to systems that empower both exploration and mastery, promoting deeper engagement and technology adoption.

Balance immersion with realism. The mixed feedback I received regarding the realism of the virtual

environments signals a fine line between meeting users' expectations for realism and going into 'uncanny valley' territory [350]. Designers should aim to achieve a harmonious balance, capitalising on the immersive potential of technologies like VR while ensuring that the virtual representations are sufficiently realistic (or believable) to lead to stronger feelings of immersion and presence.

Encourage collaborative and creative exploration. The interest expressed by musicians in using VR for collaborative practices and exploring new sonic worlds suggests the potential of immersive experiences to support collaborative creativity. Designers could explore features that enable shared experiences, collaboration, and creative exploration beyond traditional boundaries, tapping into the collective imagination of musicians.

Encourage serendipitous discoveries. The exploration of new sonic worlds and the desire for environments that inspire creativity highlight the value of designing for serendipitous discoveries. By incorporating elements that encourage users to experiment and explore — such as hidden features, randomised acoustic effects, or visually dynamic environments — designers could stimulate curiosity and cultivate an environment ripe that could encourage creative breakthroughs.

Facilitate reflective practice. The use of VR environments for rehearsal and performance preparation suggests the opportunity to facilitate reflective practice. Designers could integrate features that allow users to record, review, and reflect on their performances within the virtual space, providing tools for self-assessment, feedback, and growth. This could extend to incorporating AI-driven analytics or feedback mechanisms that offer constructive insights into the user's practice sessions.

4.6 Reflections on designing VR for creative musical practice

When I first set out to explore immersive musical experiences, my goal was to ensure that the concept of immersion was not dictated by technology. To me, immersion was always about human experience: the feeling of being fully absorbed in an activity, the way a moment can pull you in completely, and how environments, whether physical or virtual, can shape creative possibilities. Yet, despite this intention, I found myself deep in the specifics of a particular technology; VR headsets, virtual halls, and programmed environments. Instead of stepping back to think more broadly about the human elements, much of my focus became tied to designing and fine-tuning a system.

Looking back, I see how this tension shaped the process. My original aim was to focus on the emo-

tional, personal dimensions of immersion, but the work of building VR Rehearse & Perform drew me into the technical details: refining acoustics, addressing latency, and polishing interactions. It became easy to lose sight of the fact that immersion isn't about the technology itself. It is about how people inhabit and interact with these spaces, bringing their own histories, cultures, and creativity into the mix. Much like interpreting a musical score, musicians brought their unique sensibilities to the virtual environments. Designing for immersion should have been less about achieving technical perfection and more about creating a dialogue between the space and the performer.

What stood out to me was how the differences between virtual and conventional rehearsal spaces could spark new insights. A virtual 'sacred' hall might amplify a performer's sense of purpose, while an unexpected acoustic mismatch could encourage experimentation. These moments did not depend on flawless technology. They came from the way the environments interrupted routine habits and inspired curiosity. This experience reshaped my understanding of what it means to design immersive spaces. It is not just about solving technical challenges but about anticipating and interpreting what musicians might need to experiment, grow, or feel inspired. The technology became a prompt, not a prescription. The real success of an 'immersive' tool is not in its technical sophistication – it is in its We do know this, but sometimes, as designers, we forget it.

The process also showed me how difficult it can be to maintain a human-centred focus when working with complex technologies. Although I set out to prioritise musicians' needs, my early decision to frame the project around VR subtly shaped the outcomes. Musicians engaged with a system already limited by VR's constraints, which affected their ability to imagine ideal immersive experiences outside of those boundaries. Their feedback often centred on the system's existing features rather than their broader creative needs. In hindsight, I see how speculative design or co-creation workshops earlier in the process could have allowed for a more open exploration. These methods might have given musicians space to imagine beyond the prototype, resulting in insights that were not tied to what VR could or could not do. Instead, the early introduction of a prototype meant much of the process felt reactive, asking musicians to respond to something already defined rather than helping shape the framework from the start. Another tension came in focusing primarily on individual musicians. While solo practice was central to the system's design, participants often talked about the importance of collaboration and community in their creative processes. This was not a focus of the system, partly because of practical constraints, but it reflects how design decisions can simplify complex realities. A more human-centred approach might have engaged directly with these social dynamics, even if it introduced additional challenges.

I now see human-centred design as a process of continual adjustment, shaped by the realities of the people involved. It is also about recognising how my own decisions as a designer influence the possibilities. Immersion is not a fixed quality of a system; it's created through the interactions and interpretations of the people using it. Recognising this shifts the emphasis from trying to control every aspect of the design to enabling conditions where meaningful engagements can happen. I hope that others designing in this space also start considering not just what the environment does (and how we make that environment or technology or whatever we are making), but how it encourages musicians to take risks, find confidence, and discover new expressive paths in an ever-evolving digital world. Moving forward, I have come to see immersive environments as evolving prompts rather than fixed solutions, challenging routines and encourage creativity, but the process of designing them is not about offering definitive answers. It is about creating opportunities for experimentation and growth, and that requires an ongoing commitment to listening, reflecting, and adapting.

4.7 Limitations

According to the findings of this work, musician-centred immersive experiences are a promising medium for supporting music-makers' practice, complementing traditional techniques. Yet, I also encountered seemingly-inevitable challenges.

Focus on VR as a medium. My work centres on the affordances and constraints of VR as a tool for creating immersive environments. While this provided valuable insights, it also limited exploration of other potentially complementary or alternative technologies. A broader investigation into different modalities or hybrid approaches could have uncovered additional pathways for supporting musicians' creative practices.

Limited range of participants. While the participants came from diverse musical backgrounds, the sample size was relatively small and skewed toward professional and experienced musicians, based in the Kent Area of UK or from London. This focus might overlook the needs and perspectives of less experienced musicians or those from different cultural or creative contexts, who may have differing relationships with technology and musical practice. A larger sample would have enabled a more robust evaluation of the software using standardised instruments such as the Flow State Scale or the Presence questionnaire. I initially aimed for this, but early trials showed that standardised questionnaires offered limited insight into the situated, affective aspects I was exploring. Since the aim was

to inspire design rather than evaluate the software itself, a smaller, exploratory approach was more appropriate; a strategy consistent with other research in design-led HCI. Future work could broaden the participant base and combine qualitative and quantitative methods to better understand how diverse users experience remote music-making and how design strategies might need to vary.

Technological constraints. The prototype relied heavily on the capabilities and limitations of VR, such as the latency introduced by real-time audio processing and the inability to fully integrate physical instruments into the virtual environment. While these constraints were acknowledged and partially addressed (e.g., by tethering the headset or offering alternative audio setups), they inevitably shaped the user experience and may have impacted the insights gathered during evaluations.

Focus on individual practice. The design and evaluation of the prototype centred predominantly on solo musical practice. While this focus aligned with the project's aims, it overlooked opportunities to explore collaborative or ensemble-based practices, which are also central to many musicians' creative workflows. Expanding the scope to include social and collaborative features could provide richer insights into the broader potential of immersive technologies.

Pandemic context. The evaluations were conducted under national lockdown conditions, which introduced variables that may affect the generalisability of the findings. The unique circumstances of the pandemic may have influenced participants' experiences with the system, including their receptivity to virtual rehearsal spaces and their interaction with the technology.

4.8 Conclusion

The past two chapters have explored how VR can support musicians in their creative musical practices by focusing on the design, development, and iterative evaluation of *VR Rehearse & Perform*. Guided by insights from musicians and performance experts, this work highlights both the potential and the limitations of VR as a tool for rehearsing, performance preparation, improvisation, and composition. The findings suggest that VR can also indirectly aid in managing performance anxiety, offering musicians immersive spaces that inspire creativity and experimentation. While these outcomes are promising, the chapter has also been an opportunity for reflection on the human-centred-ness of my approach. The work in these chapters contributes to broader discussions on designing for creative fields like the performing arts and theatrical experiences, offering insights into the complexities and nuances of balancing human needs with technological possibilities.

Part III

Audiences

The changes COVID-19 brought impacted not only musicians, but also audiences, who turned more than ever to digital platforms, making virtual concerts and live streams a central part of their music experiences. Remote music events – spanning livestreams, interactive sessions, and VR concerts – surfaced as vital lifelines during this period [450], initially adopted out of necessity rather than a planned move directed from the music industry. These events offered a way for fans to connect with their favourite musicians during isolation, showcasing the music community's resilience and creativity [85, 450]. Today, remote music performances break geographical barriers, enabling diverse global audiences to experience music together in new, often unexpected ways. They have also reshaped performer-audience dynamics, promoting a sense of community and shared experience [156, 347, 443] while hinting at a more sustainable model for music events [83].

With digital platforms now an established and popular avenue for reaching remote audiences, it is important to recognise that the landscape of remote music performances is incredibly diverse and different platforms come with different benefits and drawbacks. For instance, Twitch facilitates interactive, monetisable experiences, with music content growing by 359% during the first year of the pandemic [232, 481], while Instagram Live offers intimate, versatile streaming. VR-based platforms like VRChat immerse users in 3D environments, enabling social interaction and dance-like participation [348, 430]. Concurrently, new platforms (e.g., Veeps[25], StageIt[26]) also appeared in this space. However, post-pandemic, some platforms have already disappeared, while others struggle to attract a significant audience. These challenges could be attributed to a lack of understanding of the unique preferences and needs of remote concertgoers, which complicates the creation of a satisfying experience. As such, the continued success of both established and emerging platforms depends on a deeper understanding of user demands across the online space. This knowledge will be key to ensuring that remote performance solutions evolve beyond short-lived trends, establishing a foundation for effectively meeting the needs of those who experience them.

Existing research in the space, while valuable, is limited. Traditional concert experiences have been studied from diverse perspectives, with the HCI community focusing on topics such as in-person technology-mediated audience participation [209, 516]. In contrast, the domain of remote music events for audiences is still largely unexplored, with few studies looking at identifying and characterising design challenges within this space. While recent scholarly efforts have begun to address this gap, their scope has generally been narrow. Whether exploring audience interactions on specific platforms such as Twitch [232, 481] and Facebook [483], studying individual events [177, 380], or eval-

[25] https://veeps.com
[26] https://www.stageit.com

uating particular technological systems [520], existing research tends to be somehow fragmented. It often overlooks the complex interplay between platforms, cross-platform trends, and evolving user behaviours that define the broader ecosystem of remote music performances. Moreover, current studies fail to recognise the unique affordances of the digital space as a medium for experiencing live music, treating it more as a digital extension of in-person events rather than exploring its potential as a distinct form of musical experience.

The work I present in the following two chapters represents a step towards bridging these gaps by: (i) exploring and analysing audiences' needs, behaviour, and expectations via surveys, interviews, observations, and a design workshop, and (ii) providing design recommendations based on these insights. With this, my goal is to enrich existing research by exploring the diverse landscape of remote music performances from the perspective of audiences across various platforms.

The following research questions guide my work:

- **RQ-III-1**: How do audiences experience and make meaning of remote music performances across different platforms, and what personal, social, and emotional needs drive their engagement?
- **RQIII-2**: How does technology influence the audience experience in remote music performances?
- **RQIII-3**: What challenges and opportunities do audiences encounter when participating in remote music performances, and how we use these to inform the design of more enriching experiences?
- **RQIII-4**: How might we design immersive music experiences to encourage emotional connection, creativity, and a sense of presence for audiences and performers?

To answer these research questions, I structured my work into two phases: Phase 1 presented in Chapter 5 and Phase 2 presented in Chapter 6. **Phase 1** is focused on answering **RQIII-1** and **RQIII-2** by collecting and analysing qualitative data from 92 remote music attendees and observing 11 remote concerts. This phase aims to uncover how audiences engage with remote music performances, identify their unmet needs, and examine the role technology plays in shaping their experiences. **Phase 2** builds on the findings of Phase 1 to answer **RQ-III-3** and **RQIII-4**. Here, I synthesise the result themes from Chapter 5 into dimensions important to audiences attending remote music events, further categorised into 17 recurrent design elements, each providing inspirational value for designing

remote music experiences (**RQIII-3**), going beyond improving existing platforms. I then expand on this through the results of an in-person participatory workshop with diverse stakeholders. The goal of the workshop phase was to explore how diverse stakeholders use the identified dimensions and elements to generate speculative design solutions for online music performances. After the ideation process, I carefully reviewed these solutions to assess their alignment with the identified elements and their potential benefits and challenges. The evaluation helped me identify any perspectives the initial analysis may have overlooked and allowed me to formulate key design insights that can guide future development and refinement of online music performance technologies – see Figure 21 for a detailed breakdown of these phases. Through this exploration, my work aims to serve both as a source of inspiration and a practical guide for designers and researchers in this space by assisting them in making informed decisions about content creation, platform selection, and design of engaging remote music experiences that resonate with the needs and aspirations of audiences.

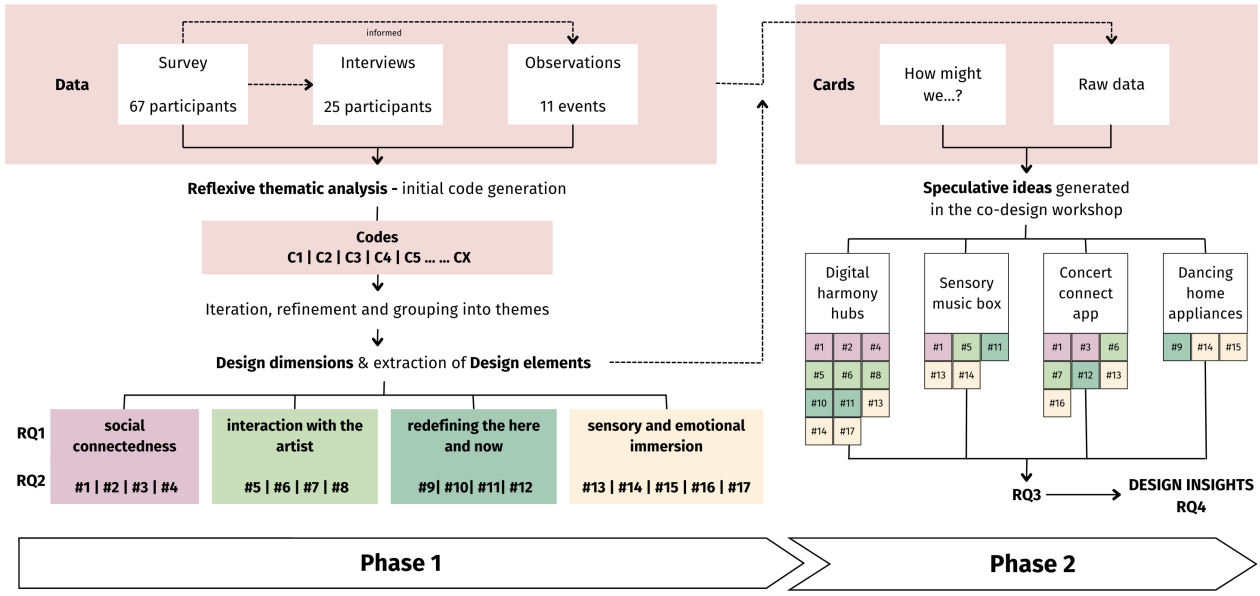


Figure 21: A detailed break down of our project phases, data analysis, and interdependencies between steps

I led the work presented in these chapters, but its synthesis would not have been possible without the support of many great people. First, my advisor, Alexandra Covaci, provided feedback and guidance throughout. Max Scorer helped me clean the interview transcripts, code the data, and brainstorm with me to develop the result themes. My sister, Elena Ppali, helped me edit this work for conference publications. Luca Turchet and Alberto Boem, supported me in the first part of the study, introducing me to the field of Networked Music Performances and invited me to the Internet of Sound conference. The people from VOLTA XR gave me a first insight into the Twitch space, and let me be in their meetings to learn more about it. Lastly, Eva Forest, Maria Llop, Mayank Loonker, Ethan Cheung supported the event observations.

Chapter 5

The virtual concert goer. Audience perspectives on remote music performances

In this chapter, I dive into understanding the audiences who use various digital platforms for accessing live music remotely. In doing so, I complement and enrich prior research in this area, which is often focused on specific platforms or events, risking to overlook the broader needs and experiences of users. Thus, my approach is panoramic, recognising that each platform has its unique characteristics and technological affordances, which together shape the overall user experience of remote audiences. To achieve this, I adopt a qualitative multi-method research approach, which includes: (i) a detailed survey to capture a broad range of audience perspectives; (ii) in-depth interviews that provide insights into individual experiences and motivations; and (iii) observations of remote music events, allowing me to examine real-time engagement and behaviours in the context of live, virtual performances. This combination of methods enabled me to deepen my understanding of how audiences interact with and perceive remote music events across different platforms.

5.1 Background

5.1.1 Audiences in the digital age

Traditionally, audiences have been understood as consumers of content across various forms of media, including music, theatre, cinema, and games. However, digital technologies have significantly reshaped this role, shifting audiences from passive spectators to active participants [230]. Schrøder [406] defined audiences in the digital age as *"The people who, in their capacity of social actors, are attending to, negotiating the meaning of, and sometimes participate in the multimodal processes initiated or carried out by institutional media."* As this definition highlights, in a digital landscape marked by interactivity and multimedia, the role of audiences has shifted from passive spectators to active participants [230]. People are no longer only consuming content but are also shaping its meaning and reach through real-time interaction, commentary, and sharing [92].

Live-streaming platforms like Twitch and YouTube have facilitated this transition by integrating chat and content creation tools, allowing audiences to directly engage with creators and influence their experience in ways that feel personal and communal [188, 234, 508]. By supporting both synchronous and asynchronous engagement, these platforms remove geographic barriers and create a participatory culture where creator - audience relationships moves from "one-to-many" communication to "many-to-many" communication within the online space [82, 446].

The nature of this engagement varies across different content genres [507]. For example, on gaming streams, commentary and shoutouts are often used to strengthen community [249, 515], as well as options for collaborative gaming between streamers and viewers [446, 497], blurring the lines between player and spectator[408]. Meditation live streams, by contrast, focus on fostering consistency and community among practitioners, despite the weaker sense of social presence compared to in-person sessions [277]. Similarly, study-with-me and ambient streams offer a steady, reassuring background environment, where engagement is less about direct interaction and more about co-presence and motivation [271]. Meanwhile, cultural and knowledge learning streams provide a platform for experts, such as practitioners of intangible cultural heritage [289, 291] to engage with a large audience in real-time, facilitating interactive learning and cultural preservation, which can be further enhanced through collaborative archival documentation of the content [290]. Moreover, in some cases, creators extend audience interaction through digital personas. For instance, VTubing, where streamers use animated avatars to represent themselves, allows for an alternative form of presence [294] that

maintains anonymity while allowing flexibility in how the streamers present themselves and perform during the streams [494]. This format used mostly in gaming and entertainment streams, is attracting a growing viewership in East Asia, opening up new opportunities for creative expression in the digital space [269, 494].

One major outcome of such interactions is the intensification of parasocial relationships — one-sided emotional bonds audiences form with creators [220]. While traditional media mainly facilitated unidirectional relationships, digital platforms enable a more mutual connection, where brief live engagements nurture what Baym [35] called connected fans. Interactions through live chat, acknowledgments, or personalised responses, create a sense of familiarity and connection that further bridges the gap between creators and audiences. Studies show these bonds deepen engagement and loyalty, amplifying the immediacy and intimacy of the streaming experience [33, 160, 261].

5.1.2 Music audiences 2.0 and 3.0

The rise of livestreaming platforms and the digitalisation of music consumption has significantly reshaped live music experiences. Historically, digital platforms served as supplements to in-person music events, but the COVID-19 pandemic transformed them into primary venues for artist-audience interaction [413, 414, 443]. Platforms like YouTube, Instagram, and Twitch allowed artists such as John Legend to connect with remote audiences from their homes, providing intimacy and access in ways previously unimagined [251, 361]. Meanwhile, large-scale virtual concerts by artists like Travis Scott on gaming platforms like Fortnite and Roblox drew millions of viewers, marking a new era for live, virtual events [200]. Independent musicians also leveraged these platforms to host live, interactive performances, cultivating close-knit community experiences [181]. The rapid adoption of livestreaming suggests lasting shifts in artist-audience dynamics, emphasising the need for ongoing research to understand the economic, social, and creative impacts of digital platforms for live music, on the music industry.

Current studies in the area of remote participation in music concerts from the audience's perspective looked into isolated platforms or analysed specific events with a focus on distinct dimensions of the audience experience, such as solidarity and connectivity among the audience, the dynamics of artist-audience interaction, or the phenomena of platform appropriation. For example, Vandenberg et al. [483] explored how livestreamed concerts on Facebook Live foster collective solidarity, while Rendell [380] analysed "portal shows" through three case studies (online events on Instagram,

Twitch, and StageIt), and argued that such shows can offer nuanced ways for artist-audience interactions through spatial convergence afforded by video streaming and digital interfaces. Other scholars offered an ethnographic perspective on a jazz concert held during the pandemic, emphasising the spontaneity of the event and the unpredictable interactions between musicians and their real-time audience [134]. A study by Benford et al. [40] presents an ethnographic account of how two traditional folk clubs transitioned to online experiences using platforms like Zoom and Facebook. Based on their observations, the authors suggest that there is potential value in expanding the ways audiences can participate in online performances, and encourage a more varied and interactive approach. This viewpoint is further reinforced by Vandenberg [481], who investigated music consumption on Twitch and emphasised that digital platforms are best suited for enabling smaller-scale interactions. However, these studies largely lack a holistic, panoramic perspective that would allow us to understand broader engagement dynamics across multiple types of digital spaces and music genres. As a result, there is limited insight into how different platform affordances and audience expectations converge to shape a cohesive remote music experience.

5.2 Capturing remote music audiences experiences

Building on the insights and the limitations of previous research, the central objective of this study was to probe into existing audience experiences during participation in remote music events across diverse digital platforms to discover opportunities for understanding audiences' behaviour and enhancing their engagement, enjoyment, and interaction in remote music settings. I adopted a trifold data collection approach to ensure a holistic view of the audience experience through:

1. **a 26-question online survey** to gather insights into audience demographics, preferences, and attitudes toward remote music events;
2. **semi-structured interviews** to go deeper into the complexities of audience engagement through personal narratives, which could not be fully explored through surveys alone;
3. **observations of 11 remote music events**, totalling approximately 18 hours, across various platforms including *Twitch*, *YouTube*, *Instagram*, *Social VR*, and *Video On Demand (VoD)* to directly witness audience behaviours and interactions in real-time.

The sequence of the data collection allowed me to refine my understanding of the audience experience progressively. Starting with a broad foundation via the survey, I captured general audience demographics and preferences, then the interviews added depth and detail, and the observations provided real-world context and validation. I used the survey results to inform the structure and focus of the semi-structured interviews, ensuring that the deeper explorations were grounded in the preliminary data trends. Subsequently, insights from both the surveys and interviews guided the observational study, allowing me to target specific behaviours and interaction patterns across platforms. The findings were then integrated to begin mapping out a clearer picture of how audiences currently engage with remote music performances (**RQ-III-1**) and the role of technology in shaping these experiences (**RQ-III-2**). The qualitative multi-method approach validated the findings through multiple lenses and enriched the understanding of explicit audience interactions and feedback. The study was approved by the Central Research Ethics Advisory Group at the University of Kent. Below, I detail the methods associated with each data source.

5.2.1 Data collection

Qualitative survey. I started my research with a survey to gain an overview of remote audiences' general attitudes, preferences, and demographics[27]. The survey was created using Microsoft Forms and consisted of 28 questions (structured and unstructured) that addressed a variety of aspects, including platform usage, attendance frequency, viewing habits, overall experiences, preferences, challenges, and a comparison with in-person concerts. Example questions included:
"How often do you attend music events from home / remotely?";
"What type of remote/virtual/hybrid events do you attend?"; "What platforms do you use ?";
"Please describe your most memorable (positive or not) at-home music performance experience. What made it stand out?";
"What aspects do you enjoy the least? For instance, what challenges, frustrations or limitations have you encountered when attending music events from home / remotely?"
The survey was the initial step in my methodological progression, employed to establish a macro-level understanding of audience characteristics and general trends across a range of platforms, allowing me to capture a broad spectrum of perspectives, including those less active or visible during music events. Through identifying key areas of interest from the responses, I was able to tailor the focus of the interviews and subsequent observations.

[27] `https://forms.office.com/e/fQKDkx5v5g`

Semi-structured interviews. Building upon the insights gained from the survey, I conducted interviews with 25 remote concert attendees, allowing me to go deeper into the individual experiences and perceptions of remote music audiences, to clarify ambiguities, and to understand the audience's journey better (see protocol in Appendix 3). The data from the survey guided the selection of interview participants and helped me identify key platforms and modes of interaction to explore in more depth, such as the role of interactive features in enhancing audience engagement and the impact of platform choice on the overall experience. It is worth pointing out that for the interviews, I did not specifically focus on the most popular platforms, but on the types of platforms I thought were more interesting to understand. For example, five of the interviews were with Social VR users because that was a space I was interested in getting a clearer image of, since those who engage in such events did so on a regular basis.

Interviews were conducted in person and online, depending on participant availability, and lasted between one and two hours. They followed a semi-structured format that ensured consistency while allowing participants to share unique insights. Participants were compensated with a £20 Amazon Voucher for their time. All interviews were audio-recorded and transcribed using an online automated transcription tool. Subsequently, two student researchers cleaned the transcripts to ensure accuracy. The data gathered from the interviews provided depth to my understanding of the audience's emotional and behavioural responses during remote music events and added layers of meaning to the initial survey findings. Furthermore, they guided the focus of the observations, highlighting specific aspects of audience engagement to look out for.

Remote music performance observations The observations of remote music performances complemented the findings from the survey and interviews. Through them, I was able to gain first-hand experience and capture real-time audience behaviours in the natural setting of the remote music performances. In addition, they provided me with contextual insights of how audiences experienced and interacted within this setup. Observational data was particularly valuable in verifying self-reported information from earlier phases and in uncovering behavioural patterns that may not have been articulated by participants. I conducted the observations last to validate and complement the data from surveys and interviews, while also identifying behaviours participants may not have mentioned.

I observed a selection of 11 live online music events hosted on platforms like Twitch, YouTube, Instagram, Meta Horizon Worlds, and VoD (see Table 5). The events and platforms were selected to rep-

Table 5: Summary of remote music events observed

ID	Event	Platform	Music Genre	Viewers	Length (mins)	Description
O1	J.Balvin Futurum	Meta horizon worlds	Rap / Pop	<20	40	A 180-degree concert of a selection of the artist's best hits. The platform allowed audiences to view the concert in VR, use interactive drum kits and fashion props.
O2	Hybrid Drum N Bass set	YouTube using Volta	Drum N Bass	<100	90	Hybrid event where remote audience influenced the background visuals by inputting keywords into the chat. The streamed content was simultaneously displayed behind the artist at the in-person event. Remote viewers were able to see the physical venue and the in-person audience. No interaction between the artist and the remote audience (see Figure 26b).
O3	Electronic music competition	Twitch using extensions	Electronic Dance Music (EDM)	<100	180	The event was hybrid with in-person audience in the same physical location as the presenters. Musicians were streaming and performing live music from their respective countries. The broadcast incorporated interactive visuals and allowed for audience voting (see Figure 26a).
O4	Drum N Bass DJ set	Twitch and VRChat	Drum N Bass	<200	60	A DJ set simultaneously streamed on Twitch and VRChat. The audience dancing in VRChat was visible as the background of the Twitch Stream, behind the DJ. Shout-outs to new and returning viewers, stream chat and donations were all visible in the event screen (see Figure 25b).
O5	Hybrid DJ set	Twitch using Volta	EDM	<400	120	Hybrid outdoor event allowing remote audience to influence the background visuals by inputting keywords into the chat. The content streamed on Twitch was simultaneously projected on the buildings behind the artist. Remote viewers were able to see the physical space and the in-person audience (see Figure 25a).
O6	Piano set	Twitch	Classical / covers	<1000	120	Artist playing piano from their bedroom, taking in song requests from the audience, Mostly for game or movie soundtracks. The artist looks at chat between songs and interacts with the audience verbally.
O7	Aerosmith	Youtube	Classic Rock	<1000	60	Aerosmith Rockisums Maximus Tour old concert was streamed for the first time, as an "one off" event. No possibility to re-watch after event finished.
O8	Foo Fighters	Veeps	Alternative Rock	n.a.	90	The band's pre-recorded performance was broadcast online and remained accessible for 72 hours. It included behind-the-scenes clips and conversations among band between tracks. A live chat feature allowed viewers to comment in real-time (see Figure 27a).
O9	BTS "Proof"	Youtube	Pop	aprox 1mil	30	Album release event during which the band performed songs from the album in an outdoor setting. Between songs, artists would talk between them and discuss the stories of the music. The event is still available online to re-watch with the chat replay available too. (see Figure 27b)
O10	Eurovision 2023	VoD (BBC iPlayer)	Pop	162mil	240	An international broadcast of the European music competition incorporated audience voting through an app. Online viewers actively engaged with the event, using Eurovision-specific hashtags on platforms such as X to share opinions and memes and follow the competition in real-time.
O11	Live at Home	Instagram Live	Acoustic	>300K	60	Weekly sessions during which the artist would sing the ten most popular songs chosen by the audience that week. A live-chat allowed in-real time commenting and the artist read and replied to comments in between songs.

resent a diverse range of formats, audience sizes, technological interfaces, and interaction styles[28]. I primarily focused on observing remote music performances on platforms mentioned by the participants, ensuring that our observations were directly relevant to the experiences and preferences expressed (i.e., YouTube, Instagram, Twitch, VoD)[29]. To broaden my understanding, I also included two events on platforms that were not explicitly mentioned by participants (Meta horizon worlds and Veeps). The observations were both passive (to understand the natural flow of events) and ac-

[28]Although four events electronic music events, each had a different type of configuration and interaction.

[29]Video conferencing platforms were frequently mentioned by our participants. Nevertheless, the event observations happened after COVID-19, hence such platforms were no longer used for concerts, therefore we did not observe them.

tive (to interact with the interface and other users to empathise with them). All events were observed by myself, with one of the event being observed by three other researchers and three of the events being observed by two other researchers.

Observation data was captured real-time, using post-its and screenshots on a collaborative Miro board[30] (see Figure 22), focusing on elements such as audience participation, technological affordances, and the dynamics between performers and viewers. The integration of observational findings with the insights from the survey and interviews, allowed me to construct a multidimensional understanding of the remote music performance audience experience, ensuring that the conclusions were grounded in a blend of reported experiences and observable behaviours.

Figure 22: Example of how observations were captured on Miro

5.2.2 Participants

Survey participants and interview participants were two distinct groups, with no overlaps between groups. To recruit participants who attend remote music events we shared links to a sign-up form – where potential participants would indicate if they were interested in an interview or fill in a survey – with our personal and professional networks via personal correspondence, emails, social media, distributed 40 postcards to students in an international university and reached out to relevant groups who could help us spread the word on their social media pages. All participants were informed of the study's purpose and provided informed consent.

[30] `https://miro.com/`

Survey participants 67 participants were recruited, from 16 nationalities (including Europe, North America and East Asia) and ages ranging from 18 to over 55 (27%: 18-24, 40%: 25-34, 12%: 35-44, 9%: 45-54, and 12%: over 55). Participants identified as 33 women, 32 men, 1 non-binary and 1 individual who preferred not to disclose their gender. Remote event attendance included 14% weekly, 5% monthly, 15% seasonal, 15% yearly, and 51% rarely (attended few such events). Participants used a variety of platforms to engage with remote music events with the most commonly used being YouTube (59%), VoD (53%), Instagram / Tik Tok / Facebook (24%), Facebook (28%), teleconferencing platforms such as Zoom (20%), Twitch (19%), social VR tools (10%) and Others (e.g., Veeps, Discord) (15%).

Interview participants I conducted semi-structured interviews with 25 participants. Participants identified as 10 women, 14 men, and 1 individual who preferred not to disclose their gender. Their ages spanned several brackets: 28%: 18-24, 52%: 25-34, 10%: 35-44, 6%: 45-54, and 4%: over 55. Their nationalities included Britain, Spain, Italy, Taiwan, Turkey, Greece, Cyprus, Romania, Liechtenstein, Germany, and the USA. Every participant had attended at least a few remote music events. Their attendance frequency varied: 24% attended events occasionally (a few events here and there), 20% at least once a year, 28% attended three or more events annually, 12% monthly, and 16% weekly. The platforms they used included VoD (24%), YouTube (48%), Instagram / Tik Tok / Facebook (28%), Twitch (28%) specialised streaming platforms (28%), social VR tools (20%) and other platforms such as Zoom (8%), with all participants having used multiple platforms.

5.2.3 Data analysis

The data collected from the questionnaire, interviews, and observations were analysed using a reflexive thematic analysis (RTA) [73, 74]. As researchers, we actively engaged in creating and refining the analysis, thus embodying the role of co-creators in the interpretative process. Moreover, in line with the principles of RTA [73] I purposefully did not pursue inter-coder reliability and embraced my own perspectives and those of the researchers I worked with [73].

I employed an iterative open-ended coding process, identifying data patterns related to desires, opportunities and challenges. I started by analysing the survey data. First, I familiarised myself with the data by reading the entire dataset. At this point, I documented my thoughts and took preliminary notes such as *Participants want to keep the performer in the spotlight, without overshadowing them with technology*; *It appears there is a general consensus that current engagement strategies are*

insufficiently interactive or engaging; *The concept of "live" appears fluid among participants within this digital environment, as discussions about live and recorded content often overlap*; etc. Some of the notes informed the interview questions and the finalised thematic analysis. This was followed by a preliminary coding[31] of the open-ended questions. After processing similarly the remaining data (such as interviews and observations), I refined the coding.

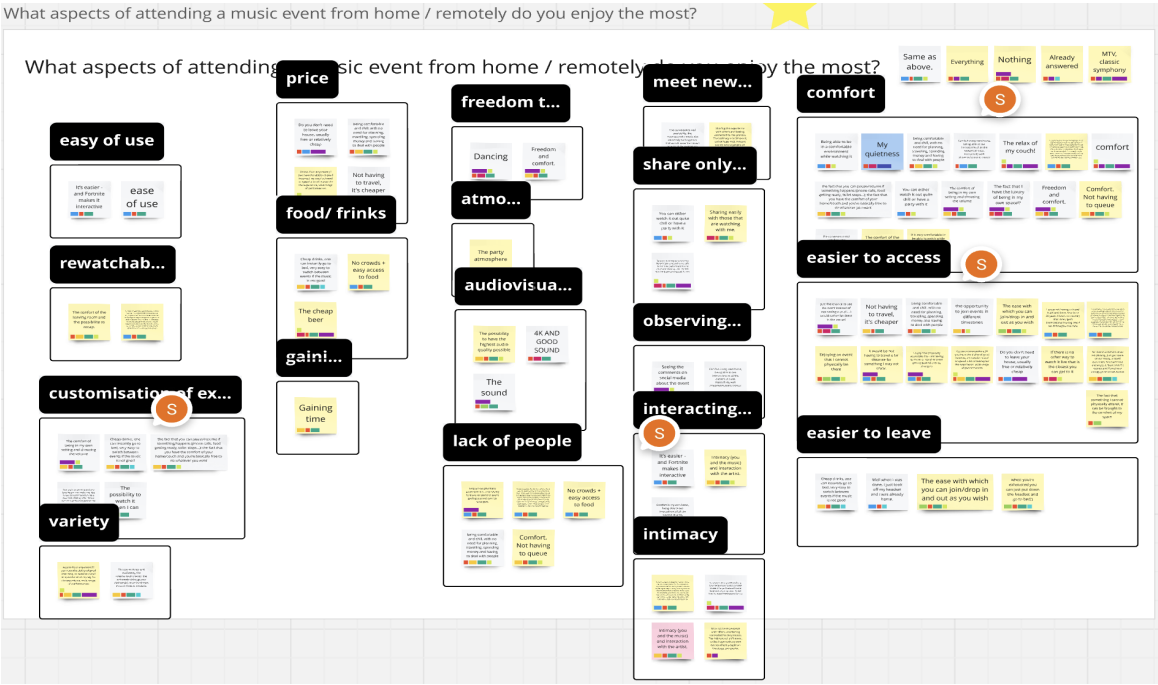


Figure 23: Example of how the preliminary round of coding for the survey was conducted on Miro

Subsequently, one of the two student researchers who helped clean the transcripts – therefore, was familiar with the data – collaborated with me to review and further interpret the coded data. We had regular meetings to reflect on our findings, discuss the codes, and start identifying patterns of data that we believed could be further developed into themes. To triangulate our findings, we compared data and codes from the three sources, looking for convergences and divergences. This involved creating data clusters comprising data from all data sources through aligning observational notes with self-reported experiences from the survey and detailed narratives from interviews. Where discrepancies arose, we discussed and reflected on them further to understand the underlying reasons. In addition, throughout this process, we identified user journeys and engagement characteristics specific to the main platforms our participants used, enabling us to map out distinct interaction patterns and preferences inherent to each platform. The insights gained from this analysis were pivotal in shaping our understanding of platform-specific dynamics.

To support this step of the analysis, a shared Miro board was used, where detailed documentation

[31] examples: [C1] Emotional disconnection occurs in remote viewing; [C2] Remote events offer limited sensory experience; [C3] Audio and visual elements are not completely immersive; etc.

of the process was brought together with interesting parts of the code and observational data (see Figure 23). The Miro board was used to visually organise and cluster codes into categories, themes, and sub-themes. The board also served as a collaborative tool, enabling the members of the wider research team to familiarise themselves with parts of the data without having to go through the huge amounts of information collected. Moreover, it helped us collectively review, adjust, and refine coding categories, allowing for iterative feedback and discussions.

Over the course of the analysis stage, regular meetings took place where the rest of the researchers had the opportunity to enrich the analysis with their different perspectives and experiences. During the meetings, the findings were discussed and further iterated by gradually determining which codes were most useful for interpreting relevant themes, how they may be combined according to shared meanings, and which could be discarded. Furthermore, I also shared my personal reflections, helping the research team better understand the context of the data groupings. The team discussions helped us resolve discrepancies, refine definitions, and ensure the final themes accurately captured the participants' experiences. The generated topics were finally grouped in four higher-level themes encapsulating key insights drawn from the triangulated data sources.

5.2.4 Researcher perspectives and positionality

It is important to recognise that researchers' backgrounds and perspectives inherently shape the analytical lens applied in qualitative work. As the main researcher in this study (for a full statement of positionality, see Chapter 1), I immersed myself in some of the communities and events that form the basis of this work, driven both by personal interest and also to ensure academic rigour. Firstly, as an avid concertgoer who also actively engages with remote music events, my interest naturally extended into my research. This helped me establish connections with the people I engaged with, facilitating a level of rapport and understanding that enriched the data collection process.

Moreover, recognising the importance of first-hand experience, I made an effort to directly engage and become familiar with the two big platforms with which I previously had no lived experiences. This was done to gain insider knowledge, as I felt it was quite important for me to be able to stand by what my results were saying. After seeing VRChat was one of the main platforms where survey participants attend remote music performances on a regular basis, I actively interacted with the tightly-knit community there to learn more about how events and interactions take place in that context. Gaining access to some of the private Discord servers, which serve as hubs for gaining access

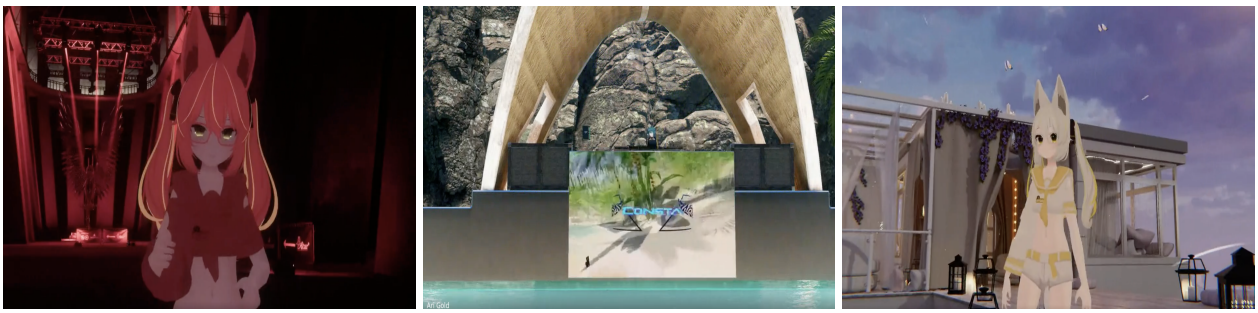


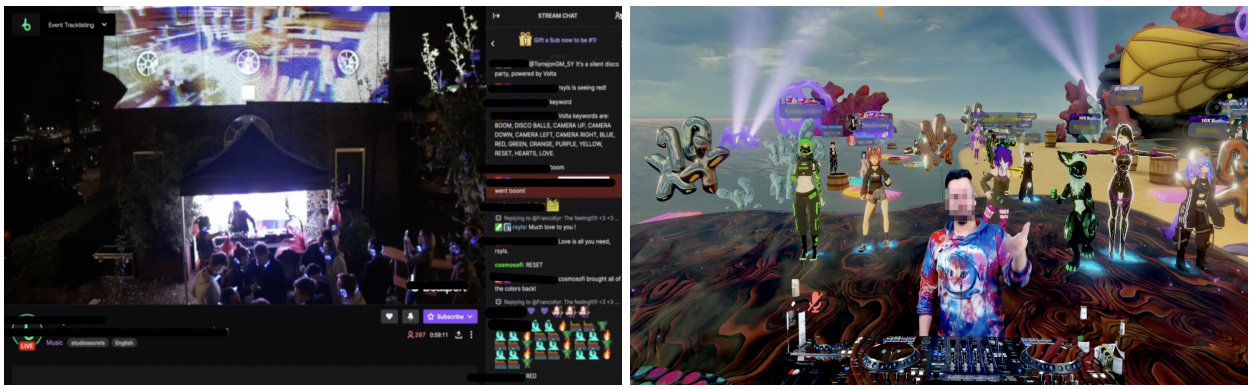
Figure 24: Tour of the VRChat Rave scene by one of the participants

to VRChat music events, required earning the trust of the community members by being transparent about my intentions and curiosity. This helped me build rapport with the people I interviewed, three of whom did the interviews through VRChat so that they could show me around the spaces they attend remote events in, their avatar skins and so on (see Figure 24). My engagement with the VRChat music scene gave me invaluable insights into the community's dynamics, leaving me with a deeper understanding of the cultural and social intricacies that define the space I would not have had if I had not actively engaged with it. Moreover, the interaction with the VRChat community during this study (although brief) inspired me to keep working in the space and better understand its (often misunderstood) people. Since then, I have conducted further research to understand the lived experiences of people who spend extensive amounts of hours in Social VR platforms.

My investigation of Twitch's music scene involved a significant amount of time browsing through the Music Channels[32], as well as direct engagement with industry insiders, including several interactions with the team of VOLTA XR[33] – a company that provides an extension for Twitch which allows audiences to influence the visuals of a performance. I participated in many of their events (three of which are an official part of my documentation), and attended five debriefing sessions with VOLTA's UX designers and developers. During the meetings, we discussed each event to identify: (i) what went well; (ii) areas of improvement, and (iii) potential enhancements to their tools. The iterative process of evaluation and discussion enabled me to exchange ideas in a collaborative environment and helped me go deeper into the details of interactivity in Twitch.

Further, the wider team I collaborated with for this research comprised experts from design, performance, XR, and music technology. While their diverse backgrounds enriched our analysis, they also introduced specific subjectivities. I acknowledge that our unique positions influenced various facets of this research, including the selection of events observed and the interpretation of the results.

[32] `https://www.twitch.tv/directory/category/music`
[33] `https://www.volta-xr.com`



(a) O5 - AI-enhanced chat using a chatbot to address latency, enabling real-time keyword-triggered customisation

(b) O4 - Twitch and VRChat stream showcasing a DJ set with virtual participants dancing in the live background

Figure 25: Selected screenshots from observed events during the study.

5.3 Platforms for remote music performances

In exploring remote music experiences, I identified several ways in which audiences engage with music events online. At the heart of these experiences is technology, which acts as a bridge, connecting audiences with artists, the music, and each other. Technological mediation impacts the remote music experience, from the choice of platform to the quality of the stream and the range of interactive features available. In essence, technology becomes both a mediator and an enabler, influencing how audiences interact with and perceive the events and providing new possibilities of engagement. Participants in our study frequently highlighted the array of platforms available for attending remote music experiences, ranging from mainstream streaming services to immersive VR platforms. Each of these platforms offers a unique set of features, interface designs, and interaction possibilities, influencing the audiences engagement level and overall event experience, as well as their evolving needs and desires. This range indicates that the future of digital music experiences is not one-size-fits-all but rather a spectrum of tailored options to meet the needs and preferences of audiences. Before I present the main themes developed from the data analysis, in this section we provide a summary of the platforms our participants used, some of their reported affordances and limitations, and the audiences' interactions with them. It is important to clarify that these insights are based on our participants' experiences and thus represent common, but not exhaustive use cases[34].

Twitch[35] is a livestreaming platform initially known for gaming [455] but increasingly popular for live music performances, especially among indie and experimental artists. It enables real-time direct interaction between artists and audiences through chat, emotes, and interactive extensions,

[34]Video-streaming platforms like Zoom were omitted due to the lack of events post-pandemic.
[35]`https://www.twitch.tv/`

allowing for personal and unscripted engagement. Engagement ranges from casual conversation to responding to music requests, creating a highly interactive and personalised music experience. All our interview participants who used Twitch for music were also avid gamers. This likely explains their familiarity with Twitch's digital norms and interactive culture, as well as their frequent use of the platform for music. Participants often reported using Twitch passively, streaming music in the background while multitasking. One noted, *"Whenever I listen to music on Twitch, it's not an experience that captures my entire attention [...] I always have it open on the second monitor or in the background (PI10)."* This behaviour reflects a broader trend of multitasking in digital media consumption [227]. Despite passive use, moments of active participation are common. Users join the chat to engage in digital rituals that create a shared experience. As one participant said, *"The chat is a huge part of the experience. Something bad happens, everyone spams an emote [...] Something good happens, they hype the thing up (PI2)."* Moreover, interactive extensions on Twitch, such as voting polls and Volta XR, further enhance the experience by allowing audiences to influence the performance, thus adding an element of experimentation and personalisation. However, we observed during certain events (like O3 and O5) that these features sometimes constrained dialogue among viewers (see Figure 26a). Users became more engrossed in the features, which limited audience-to-audience and audience-to-artist interaction, suggesting that while interactive extensions offer novel ways to experience music, they may create a trade-off between personal engagement and communal interaction.

YouTube[36], is a global video-sharing platform that allows users to upload, view, and share videos across a vast array of content categories. Its widespread accessibility, high-quality video streaming features, and massive user base make it a primary destination for streaming music performances. Youtube was the most popular platform amongst our participants, as it caters to a diverse audience demographic from casual listeners to dedicated fans of specific artists or genres, with usage patterns varying significantly. Our participants reported using YouTube primarily to access mainstream music performances and big-name artists' concerts (either livestreamed or pre-recorded but played one off such as O7). Unlike Twitch, engagement on YouTube often appeared as more sporadic and one-off, particularly for live music events. Our study observed that direct interaction with artists or other audiences on YouTube is less frequent (or non existent). One of the reasons for this is the larger scale of events and audiences, which often makes personal interaction challenging and less likely. PI7 noted *"On YouTube, there are tons of messages happening, so it's quite difficult to even interact (PI7)."* Another issue highlighted by our study participants is the sometimes overwhelming nature of

[36] `https://www.youtube.com/`

YouTube's algorithm-driven content suggestions. While this feature can aid in discovering music, it can also lead users away from their intent, contributing to a less focused music experience.

Social VR platforms, such as VRChat[37], Engage VR[38] and Meta Horizon Worlds[39], enable users to interact in immersive, three-dimensional virtual spaces avatars through VR headsets [316, 317]. In recent years, they have emerged as spaces where users go to experience live music [303]. Amongst our participants, VRChat stands out as a popular choice, with regular users engaging with it on a daily or weekly basis. One participant shared: *"Basically, I attend more or less every drum piece event, and because VRChat is worldwide, you can go wherever you want. Later I will go to a dancing world to dance for one or two hours and after that I will go to a Rave (PI7)."* In VRChat, small to medium electronic artists often perform in magical spaces, creating an intimate, community-centric atmosphere. Users engage primarily through VR headsets and motion trackers, with some enhancing their experience using haptic vests for tactile feedback. Despite the computational demands, this immersive setup contributes to a concert experience that many participants described as closely mirroring the feelings of live, in-person performances. Notably, VRChat performances are often simultaneously streamed on Twitch (O4), allowing non-VR users to engage as well. As one participant explained *"A lot of VR events have a video player in the world, and you just show a Twitch stream... It's pretty much that you have the same music, and you listen to the same video feed, just in very different contexts (PI10)."* Social interaction is a significant aspect of these platforms; attendees go to dance [360], meet friends, or even perform as part of the show, enriching their virtual experience. The ability to customise avatars allows users to express their individuality [161] and enhances the sense of presence during virtual concerts. However, the capacity limitations of social VR present a challenge. For instance, VRChat allows only 80 people per instance of a world, meaning larger audiences must be spread across multiple, unconnected instances, and typically only the first instance features the live artist. This segmentation can make it difficult to create a unified concert experience, yet it allows for more intimate and varied interactions within smaller groups.

Bespoke platforms like Veeps[40] and StageIt[41] are specialised online services hosting remote music performances that often require ticket purchases. They gained popularity during the COVID-19 pandemic, catering to audiences who value exclusivity and superior production quality. They offer exclusive, high-quality musical experiences not typically available on mainstream platforms. The

[37] `https://hello.vrchat.com/`
[38] `https://engagevr.io/`
[39] `https://horizon.meta.com/`
[40] `https://veeps.com`
[41] `https://www.stageit.com/`

type of audience that gravitates towards these platforms typically includes avid music fans who are willing to pay for the added value that these platforms provide, often seen in the form of high audio quality, meticulously curated line-ups, and unique interactive features such as Q&As. Participants appreciated that these platforms closely mimic attending high-end concerts or festivals, offering the convenience of remote access and the opportunity to support their favourite artists directly. However, despite their premium offerings, participants noted that bespoke platforms sometimes lack the wide-ranging community feel of more accessible platforms like YouTube or Twitch, leading to a more isolated viewing experience with limited interaction among music enthusiasts. Additionally, discoverability is a significant challenge. Without large user bases or sophisticated recommendation algorithms, these platforms rely on targeted marketing and word-of-mouth, making it harder for users to find new and interesting events. Some participants even had difficulty recalling the names of these platforms, indicating issues with brand recognition in a crowded digital space. While they offer valuable experiences, bespoke platforms may need to improve their visibility and community features to fully enhance user engagement.

Video on Demand (VoD) services provide high-quality, structured access to pre-recorded or live-streamed content, offering the flexibility to watch major events on demand, much like traditional television. Participants frequently mentioned VoD platforms such as BBC iPlayer[42] as their preferred choice for watching live from home large-scale physical music events. The performances streamed by VoD platforms were valued for their high production quality, with participants appreciating features like behind-the-scenes footage and expert commentary, which contribute to a polished viewing experience. Moreover, VoD platforms deliver widely broadcast content that appeals across age groups, thus are ideal for events that bring together diverse audiences – from younger viewers to older generations accustomed to TV broadcasts. Unlike interactive streaming platforms, VoD services lack real-time engagement features, but this was not seen as a limitation. On the contrary, participants noted that they use VoD services to watch live music performances with others, in the same physical space. For events like Glastonbury or Eurovision, participants valued the shared experience of watching with family or friends, often transforming their living spaces into festival sites.

Social media platforms like Instagram Live[43] provide artists with accessible ways to perform music and engage directly with fans in real time. Through livestreaming features, artists can host impromptu sessions, planned performances, or interactive Q&A events. Participants in our study valued the informal and personal connections these platforms encourage. The ease of discovering and ac-

[42] https://www.bbc.co.uk/iplayer
[43] https://www.instagram.com/

cessing music content on social media was a significant draw, appealing to both casual listeners and dedicated fans. Direct interaction through comments and reactions enhanced the sense of community, allowing fans to engage with artists in real time. This cultivated a sense of intimacy not typically found on platforms like YouTube or Twitch, where larger audiences and more structured interfaces can dilute personal engagement. However, participants also noted limitations. The transient nature of content meant live events could be easily missed, and the ephemeral experience contrasted with platforms where content remains accessible indefinitely. While this fleeting nature heightened the exclusivity of live events, it posed challenges for lasting engagement. Additionally, some observed that audio and video quality on social media platforms could be lower compared to dedicated music services. Content discoverability was another issue; algorithm-driven feeds impacted the consistency of finding and engaging with live music events.

5.4 Audience perspectives on remote music performances

"I think we will definitely see more hybrid events in the future. I think a lot more events will start to be ones where you'd be able to consume a lot more of them online as they're happening.[...] So it's very important in which direction it goes. Do you use the technology to enhance the show being put on by the artist? Or, do you use the technology to try and grab more people in to come and watch the show (PI2)"?

In the following sections, I unpack the specific facets of the audience experience, capturing both the joys and the gaps encountered. I report on the overarching themes I developed through the analysis which look into (i) social connectedness, (ii) interaction with the artist, (iii) redefining the here and now and (iv) sensory and emotional immersion. The themes point towards opportunities and challenges in the space and for further design and research. Interview participants are named as **PI1-25**, survey participants are named as **PS1-67** and event observations are named as **O1-O11**.

5.4.1 Social connectedness

Community building

The emergence of new **communities centred on attending music events** remotely is a significant aspect of the modern digital landscape. PI10's experience exemplifies this phenomenon, how virtual interactions are breaking through digital confines and cultivating novel connections: *"I've made so many friends (online) that I just want to hang out with [...] exactly the same reason why I would go out with friends in real life (PI10)."* Integral to this community building is the role of chat and other interactive features, which facilitate a deeper level of engagement among remote music audiences: *"Having some level of interaction for the audience, I think is also really important. And, I think that's what sort of holds people's attention (PI15)."* This active participation creates a sense of belonging and identity among members, extending beyond their usual social circles to include diverse viewpoints, as described by PI11: it is *"nice because it creates some sort of debate, some friendly fights about who we didn't like (PI11)".* As communities form up around various platforms, the special features of those platforms become more than tools of communication, they become active agents of cultural identification. For example, PI4 described during one performance on a custom concert platform, users typed almost in unison *"the cow emoji and a bell (P104)"* whenever they were hearing the sound of a 'cowbell' spamming the chat. until the lead singer noticed and interrupted the performance to ask, *"Cowbell? Why is everyone saying cowbell?"* Such experiences resonate far beyond the performance and emerge as cultural artefacts and signifiers of membership to an exclusive kind of fandom,*"watching it together [...] I felt like I was part of the group, in it, in the tribe (PI4)."* The tribes and groups forming around the experience of remote live music, like any other community, appear to develop around the **emergence of shared idioms, rituals, and collective memory** of the remote performance. As communities around remote music events solidify on various digital platforms, the distinctive features of each platform become integral to the cultural identity of these groups.

On YouTube, communities are often bound through its algorithm, with interactions focusing more on engagement through the chat. For example, in the O9 event, fans used purple emojis to signify their love for BTS performing, revealing the establishment of a communal language and identity and creating a sense of belonging and solidarity among the fans. On Twitch, the community dynamics are further shaped by the platform's interactive features. As PI10 notes, the use of *"a bunch of blinking emoji (PI10)",* during streams is a common practice to *"hype up the mood,"* demonstrating how digital expressions can enhance the collective experience. Additionally, PI3's observation about using spe-

cific catchphrases related to past events highlights a deeper level of community engagement: *"if you use one of the catchphrases about something happened three years ago at this sort of event, they will know what you mean (PI3)."* These phrases act as 'callbacks' to shared experiences, fostering a sense of collective memory and belonging among long-time members. Such practices, including 'emote spamming' and the use of unique catchphrases, have evolved into ways for community members to signal their 'in' status within the group. This behaviour exemplifies developing a shared language and cultural norms unique to the Twitch community.

(a) O3 - International DJs perform in a livestreamed event blending in-person and online audiences via Twitch extensions

(b) O2 - Interactive keywords drive performance customisation, taking over the chat and shifting focus from general conversation to visual engagement

Figure 26: Screenshots from observed events during study.

In social VR communities, unique expressions of appreciation, such as *"throwing a snowflake emoji"*, at the DJ to signify approval while eschewing more common symbols like hearts (as mentioned by PI5), illustrate the development of specific **embodied communal rituals and symbols**. These practices are not retained in VR but are adapted to align with its immersive environment, showcasing the community's shared interests and the development of a unique cultural identity within the VR space. Unlike the more public and observable interactions on platforms like Twitch, VR communities tend to form in intimate, semi-private spaces. These communities are built on personal interactions and word-of-mouth, as highlighted by PI1's description of a public VR world that serves as a gateway for newcomers to navigate the VR community *"There's one world, Club Orion, that's public, there's like almost always someone inside... maybe you befriend them... and then you kind of start to learn where to go (PI1)."* Members also collaboratively shape their environment, illustrating the community's adaptability, inclusivity, and strong emotional ties. As PI6 notes, *"remote live performance in VR is authentic, part of a folk culture (PI6)"*, that one must be actively involved in to fully appreciate.

Remote music concerts as third spaces

Digital platforms overcome the confines of physical venues, allowing attendees to access them with no limits and to authentically express themselves. As noted by PI19: *"It is really good that we do have those technology options available to make it more accessible for people. People that would be really anxious to go in person for whatever reason, not a pandemic situation just in general, or if there was a disability that prohibited them going (PI19)."* Notably, these digital concerts directly address the concerns voiced by 35 survey participants who expressed frustration with the crowds and disruptive behaviour at traditional events. Digital concerts become more than just an alternative mode of participation; they function as **digital 'third spaces'** [344], where people come together for communal experiences, providing a transformative arena for self-discovery, identity exploration, and meaningful connections. Within these spaces, attendees *"can just be like in a safe space basically (PI10)"*, free from the challenges often associated with conventional in-person music events.

Remote concerts offer a refuge for individuals grappling with social anxiety and inhibitions that can be exacerbated in the midst of large, crowded gatherings. For them, digital events provide an environment where they can **engage with live music on their own terms**, free from stimuli that might trigger their anxieties. Take the example of PI1, who finds solace in the 80-person limitation of VRChat events: *"I'm not a person who can stay with huge groups of people [...] that's what I really like about chat the VR rave scene. There's also limit of 80 people. [...] It's like in this world only 80 people could join (PI1)."* Furthermore, the slight anonymising effect of the digital spaces acts as social lubricant, as explained by PI6: *"Certainly people with social anxiety do report they are a lot more comfortable operating in a virtual environment. I suppose some of the social cue stuff around facial or physical communication sort of flattens the complexity of the social experience (PI6)."*

In contrast to traditional in-person concerts where self-expression might be limited to clothing or merchandise, remote music events enable a new type of freedom. Attendees have a multitude of creative tools at their disposal, including avatars and pseudonyms, that allow them to **explore and express facets of their personalities**. As noted by PI10 when talking about VRChat *"People can definitely express themselves more. [...] some people who because of different reasons, don't want to go out in real life [...] can just be in VRChat, be like in a safe space basically (PI10)."* Moreover, PI1 emphasised how avatars create a protective shield, enabling attendees to present themselves genuinely and safely: *"I feel like I can be more myself here. Cause when [...] I want to meet someone at the club, I feel awkward. [...] I feel it's easier because you're in a safe space. I have my avatar, they have their*

avatar, they can be a woman, they can be a man, they can be whatever [...] it doesn't really matter (PI1)." The ability to experiment with diverse identities without self-consciousness further broadens the scope for self-expression. Moreover, dancing and freely expressing oneself at home, as described by PI20, PI18, and PI14, becomes a liberating experience, free from the inhibitions of crowded public settings. " *we're here with other people, you're doing silly stuff, you're dancing, singing all together, and you kind of don't care what's going on because you're in your house, so you're free (PI14).*"

In addition, attendees in digital spaces have the autonomy to **curate their level of participation**. Whether they prefer active engagement by interacting with others, or a more passive role by simply immersing themselves in the music from the comfort of their homes, the choice is theirs. The ability to stay anonymous further amplifies this flexibility. Attendees can selectively reveal aspects of themselves, navigating the concert experience with a level of privacy and freedom that traditional in-person events cannot offer. This distinction became evident during event observations, where real-time interactions unfolded between participants. Yet, the context of these exchanges remained shrouded in mystery due to our limited knowledge about the individuals behind the screens. Additionally, individuals such as PI21, PI2, PI3, and PI4 described themselves as 'lurkers' on Twitch (i.e attend events but do not post) [297], further showcasing the plethora of engagement options.

However, the newfound freedom of expression also presents unique challenges. The adaptability of identities and the relative lack of moderation, while encouraging diverse interactions, can sometimes result in **disruptive behaviour**, such as a lack of social etiquette and increased harassment. PI4 attributed it to the fact that *"social contracts are completely nonexistent (PI4).*" The same participant explained that this might be due to the fact that some of these spaces such as Twitch and VRChat have originated in gaming, which has a reputation for attracting users that showcase toxic behaviours. Because of anonymity, people in virtual spaces feel emboldened to say and do things that they would not in a physical space *"you might get banned, but who cares (PI2)?.*" During our event observations, particularly in cases like events O7 and O9, which took place on platforms like YouTube with substantial audiences, there were frequent instances of inappropriate comments from users. Fortunately, due to the fleeting nature of chat, these comments were often swiftly replaced with emojis and other responses within seconds. Nevertheless, their occurrence serves as a reminder of the difficulties in moderating expansive digital spaces, such as those hosting music events.

This challenge becomes more pronounced in immersive platforms like VRChat, where the digital experience closely resembles the physical one [162]. In these environments, issues akin to those encountered in real-world events arise but are exacerbated by the **absence of traditional moderation**

mechanisms. As PI1 highlighted, problems like harassment, unruly behaviour, and the presence of intoxicated individuals or minors also exist in VR environments and become even more pronounced in the rave scene: *"When you have your headset on, it doesn't feel like you're drunk (PI1)."* This can lead to people acting out in ways they would not if they were sober, for example, by being disruptive or even engaging in sexual acts in the middle of the music event. The lack of 'security' makes events even more challenging to manage and even if there is security, anonymity can make it difficult to police misconduct. For example, while many VRChat music venues have hosts who attempt to maintain order, people who get kicked out for inappropriate behaviour can easily return with a new account. This makes it much harder to hold people accountable for their actions than it would be in a physical space. Furthermore, these digital communities **often adhere to unwritten rules and norms** that not everyone may be aware of, as exemplified by PI10's statement: *"if you go to an event, you do not drop a portal to another world. Obviously you can't that in real life there's no equivalent to that. You don't do that. And that's why it's also common etiquette too in VRChat (PI10)."* This highlights the need for the establishment of new norms and etiquette tailored to these virtual communities that strike a balance between the freedom of expression and the necessity of maintaining respect for shared spaces, ensuring a harmonious and enjoyable experience for all participants.

5.4.2 Interaction with the artist

Artist-audience interactions as community building blocks

In our study, participants frequently emphasised the importance of creating a sense of **closeness with the artist**, a dynamic they viewed as distinct from in-person events. *"I think the strength of remote technology for music events is exactly the creation of that feeling of a one-to-one connection with the artist and that intimacy that comes with it (PS42)."* Unlike traditional live events where the scale and setting might limit personal interaction, remote events can create an environment where fans feel a **personal connection with the artist**: *"Remote events offer more opportunities for intimate feelings with the artist. It's just you and them in some occasions, you see them up close and personal even if you are miles away. [...] It's really nice to just sit there and have your own emotional moment with the artist. I mean, you can do that in live experiences but it's slightly embarrassing."*; *"So it actually felt really indulgent because you just had that person in your living room. It felt like a personal concert and there was no one else watering that down (PI12)."* This **sense of intimacy** is heightened by the digital platforms' ability to facilitate points of view that might not be

possible in a physical venue " *to see the performers from a clear and close up side makes it feel like they are performing just for me (PS7)",* or by the increased exposure fans gain to the entire music making experience *"I feel [...] a more personal relationship with [artists] when you get a sense of what happens behind the scenes (PI2)."* Moreover, in Social VR, the sense of intimacy is even more amplified with the artist's presence in the virtual space, with many users trying to be as close to the artist performing as possible. Our participants explained that in events where the 80 person limit is reached and instances of the same event are created, they prefer to be in the instance where the artist is, even taking up roles such as go-go dancers [360] to achieve that.

Another aspect that stood out for audience members was receiving **recognition from the performer**, such as a "shout out", as mentioned by PS12, *"I think that the artist responding to the fans is important (PS12)."* This element of personalised, direct interaction was often highlighted in our survey and interviews as one of the important aspects of remote music performances. Our own observations in various remote music events corroborated this sentiment, reinforcing the importance of this personal engagement. This could be attributed to the audience's wish to feel a closer connection to the performer. Furthermore, describing their experience PI15 described *"So, the fact I could just tap on my phone and send the artist I'm watching a message, and I know it's going to pop up in front of his face at some point. Knowing that you are almost like apprehensive about touching your phone in the wrong way, in case you accidentally send the wrong emoji or whatever. And I think that was quite exciting (PI15)"* Such direct exchanges with the artists enabled by digital platforms also appeared to be some of the most memorable aspects of remote music performances for some participants like PI11 *"a musician on Instagram playing the piano [...] he read my account name out and played a song I requested"* Shout outs took different shapes during our observations. For example, in the event O4, usernames appeared prominently on the screen during the Twitch stream, giving each fan a visible moment of recognition. In event O6, the artist personally acknowledged specific fans by name and played their song requests. Fans responded with emojis and enthusiastic comments, reinforcing a sense of connection and excitement that made the interaction feel meaningful and direct. Moreover, due to such interactions the phenomenon of ***parasocial relationships***, *"where fans feel they know artists intimately due to their music or online presence, even if they have never actually interacted (PI2)"*, is becoming more emphasised when interaction moves online.

However, it is important to note that while digital intimacy in remote music performances can sometimes be authentic, it can also create an **illusion of connection**. This concern was articulated by some of our interviewees, such as PI8, who observed, *"it can give a false sense of belonging and friendship*

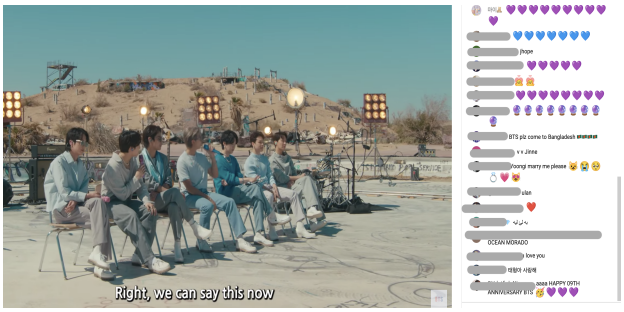
and connection because technically, even if I'm watching someone live, I'm not actually connecting with them. To them, I'm literally just a username, if they see that (PI8)." The immediacy of digital interactions can sometimes lead to a skewed perception of connection, where fans feel a deep bond with the artist, even if it is one-sided. The same participant elaborated *"Even when there's some artists that go live and you comment and they read it out or they'll reply to you, it genuinely feels like a sense of "They know me," they don't know you, you're one of a million whom they've replied to this month. Especially for people that are vulnerable, I think it gives us a false sense of what a real connection is like and that can really skew people's perceptions to a point that can be quite dangerous or it can lead to loneliness, it can lead to all sorts of things (PI8)."* This points to the potential for a discrepancy between the perceived intimacy and the actual level of connection, emphasising the need for a balanced understanding of the nature of remote engagements.

Collaborative artistry, co-creation and playful interaction

Online space blur the boundaries between artists and their audiences, leading to opportunities of **co-creation and collaborative artistry**. PI9 gave an example of this shift: *"Snow Patrol had Saturday Sessions where he would interact with the audience on Instagram live. He would ask the audience for lyrics, and a song emerged from that, crafted from the lyrics provided by their fans (PI9)."* This was also evident in our event observations, where we saw a desire from remote audiences to engage more profoundly and collaboratively, yearning for a role in the co-creation process. We observed a surge in message participation when platforms used extensions such as VOLTA XR (O2, O5), which facilitates audience involvement in shaping the concert visuals through text commands. Moreover, interaction further intensified when the effects were overlaying the artist, signifying a desire to connect with them beyond just having an impact on the performance. Furthermore, in O6 and O11, audiences engaged a lot more actively in the sections where the artists asked for their contributions or thoughts as to what to play next, voicing their thoughts and eagerly trying to engage in the music-making process. Overall, our data indicates the audience's interest in experimenting with tools that allow them to actively shape the events they are attending virtually. This type of active audience participation was further echoed when PI9 noted the value of artists directly interacting with fans on livestreams, saying, *"you could see the artist replying to the comments, which was fun to watch (PI9)."* The emphasis on collaboration extends beyond traditional music creation. As PI2 pointed out, *"for remote experiences, the interaction with the artist should be a given... it's more about community engagement and how the artists and the chat interact with each other (PI20)."*

Additionally, the inclination towards playful engagement during remote music events is a key aspect of co-creation between artists and audiences. Our events observations revealed a desire to engage in playful activities while attending remote music events. We saw that participants often appropriated features of existing digital platforms for playful interactions, engaging in impromptu activities both among themselves and with the performers. This kind of emergent play manifested in various forms, from smaller types of spontaneous interactions such as play with words during chat conversations (O2 – Table 5), emoji patterns and chants (O7, O9 – Table 5, Figure 3) to more structured forms of play leaning towards gamification such as fans and artists creating their own games and challenges during the performance (O6, O3 – Table 5). Moreover, during the interviews and questionnaires, when participants talked about the aspects of remote events they most enjoy, they often gave examples of interactions that went beyond back and forth with the performer and included mini 'games' that determined the music being played *"There's also a YouTuber [...] who asks audiences to give him three to five words and raps using those three to five words (PI2)."* Such instances could be considered as *play potentials* - i.e., existing manifestations of playful engagement that emerge naturally in ordinary scenarios and that seem to be contextually meaningful and socio-emotionally productive [6]. They reveal a natural inclination for audiences and artists to seek and create their own entertaining experiences during remote music events.

(a) O8 - A one-off, pre-recorded Foo Fighters concert, showing the singer's intimate style. Fans engage real-time with emojis



(b) O9 - Purple hearts light up the chat as fans show their devotion to BTS, adding a touch of virtual togetherness to the online concert

Figure 27: Screenshots from observed events during the study.

5.4.3 Redefining here and now through remote music

Temporal fluidity

Traditional live music performances are inherently ephemeral, unfolding uniquely in the present moment in a certain location and creating a sense of shared experience and immediacy. This liveness is a defining characteristic of in-person events, captivating audiences with its raw energy and

unpredictable twists *"seeing your favourite band and listening to their music and that ephemeral nature of that. So, even though they play a set list, no two sets are going to be the same because of the environments and the music and it feels authentic in that way (PI7)."* Digital platforms such as Twitch, Instagram Live, and VRChat have redefined our **understanding of 'live'**, as they offer dynamic, flexible ways for audiences to engage with events. From real-time interaction to asynchronous engagement, they create a new kind of liveness, one that is not strictly tied to the moment but defined by the depth and quality of participation. Drawing from [479], where liveness is viewed as a multi-faceted constellation, I explore the essence of 'live' in remote music performances by considering the rhetoric around a platform, its technological features, and the users' lived experiences.

Audiences online engage with content in surprisingly diverse ways. Some remain synchronised with real-time broadcasts, while others leverage the digital medium's flexibility to pause, rewind, or explore the historical content and chat archives. PI8 noted, *"So in real life, no matter how you're feeling, if you are hungry or wherever happens, it's happening. Whereas online, I can [...] I can pause it, and actually, obviously, there's a convenience that comes with that (PI8)."* This flexibility reshapes what 'live' means, allowing to pause a livestream and dissect, discuss, and deeply engage with specific moments as they unfold. This is in contrast to in-person events, where discussions are often postponed until the end, relying on *collective memory*. One participant noted, *"You can control what's happening, [...] you can rewind [...] sometimes I'll spot things, I'll press pause and have a running commentary alongside what I am actually seeing (PI12)."*

Moreover, it appears that even pre-recorded music performances can evoke a strong sense of **liveness** among viewers. Even though events O1, O7 and O8 (see Figure 27a) were pre-recorded performances, because they were streamed during a certain moment in time, audiences interacted between them as if they were attending a live event. During event O1, attendees danced and cheered while the concert was being broadcast and during events O7 and O8, audiences used the chat the same way they did in live-streamed events, commenting at certain moments, cheering the artist, and interacting with the performance as it was unfolding. The perception of *liveness* is therefore a combination of the viewer's belief, which is anchored by specific markers and cues within the content, and their active interactions with both the performance and other audience members.

However, these perceptions are not always consistent. A live performance can feel less engaging if the artist fails to respond to audience input, while pre-recorded events with active audience participation can feel alive and dynamic. PI6 reflected on this **layering of time and experience**: *"Once you start immersing yourself in the possibility space of these live performances, it could be interesting to*

start sort of layering levels of reality on top of each other, like this sort of layering of temporally things that happened in the past happening alongside what you're experiencing right now and sort of layering on previous audiences onto the experience (PI6)." The dynamic interaction with time unlocks novel creative avenues for performers and creators, in helping them craft experiences that truly resonate with the audience's evolving definition of *live*. PI6 exemplifies: *"But that in itself is kind of an interesting wrinkle on the sort of recorded experience performed as a live concert as you get some oddities like that (PI6)"* – i.e., the artist (Fatboy Slim) is in the audience of his show.

The perception of liveness is also influenced by the **immediacy of interactions**. Delays, even minor ones, can disrupt the audience's sense of being part of a live event. This was evident in O2 and O5 (see Section 5), where users anticipated real-time responses to commands like *boom*, *spin*, and *light*. However, in O2 latency in visualising these commands disrupted the audience's sense of 'liveness' (see Figure 26b), highlighting the delicate balance between platform capabilities and user expectations. In O5 this was mitigated by introducing a chatbot that would write back the comment and the name of the user who said it a few seconds later to imitate immediacy (see Figure 25a).

Intriguingly, the findings also suggest that when the remote experience offers distinct advantages, participants were inclined to seek inventive solutions to navigate and mitigate latency-related challenges. PI5, who regularly engages in dancing during VRChat music events [360] remarked: *"And the problem is everybody lives in a different part of the world and there's a lag between the time you see the image and hear it [...] It's not synchronised dancing at all, which is another reason when I'm dancing in VRChat at a rave, I don't dance with other people because we're always slightly offbeat and it's very irritating. So I just solo dance (PI5)."* The participant went on to explain how they adjust their dancing to work well with the latency: *"because it's only sampling at a certain rate before it sends the movement information over the internet to the main servers. And so I tend to try to make sure my movements are not very fast. I'll try to use smoother, slower motions. And the same thing with the leg movements. I don't do any super fast fancy footwork because it will look bad."*

Such observations reveal a broader transformation in how live music experiences are defined in digital spaces. Traditional boundaries between live, replayed, and asynchronous events dissolve, enabling audiences to engage across time. Fans are no longer limited to experiencing a moment in real time. They can revisit past performances, interact with other viewers asynchronously, and contribute to a continuum of shared experiences.

Impossible music experiences

Our participants expressed that for them, remote music events are distinct opportunities for novel engagement – with the other audiences, the artist and the performance itself. As PI2 puts it: *"Why should you try to emulate something when using technology, you can make a unique and different experience that can be just as enjoyable (PI102)"?* Feedback indicates that technology is not just an enabler, but rather a driving force for otherwise **impossible experiences** [484]. One participant described *"The most recent unforgettable experience in VR was the Fat Boy Slim virtual performance in ENGAGE XR. It was unforgettable for being amazing and ground-breaking, and unforgettable for being overwhelming and over-stimulating [...] Still, it was amazing as it showed the possible, even how VR can do the impossible (PI16)."* As PI16 further noted *"I think [...] virtual events are going to be more technological and more conceptual and they don't have to deal with the practical issues of crowd control or rain (PI16)."*

Moreover, for artists themselves, technology presents a remarkable opportunity to overcome the constraints of the physical environments (e.g., venue size, logistical challenges, or budget constraints). This transformation is particularly valuable for smaller artists or those performing from home, who may have previously been restricted in their ability to deliver visually captivating performances. Our observation of the electronic music competition (O3) (see Table 5) exemplified the potential with musicians effortlessly mixed their music from their individual locations to a venue hosting an in-person audience. The performance was further enriched by the inclusion of interactive visuals (see Figure 26a), creating a multisensory experience that captivated the audience, who also voted for the competition's winner.

In addition, the space of remote concerts also allows users to **actively shape their virtual encounters**, choosing their own 'impossible' elements: *"A lot of times I'm wearing different avatars [...] I like dancing with avatars that actually have an extra pair of limbs because it's usually synchronised with my dominant arm, and so you can come up with some interesting moves with your arms. And I don't care how I look because that's not how I look in real life. This is my virtual self (PI5)."* This was also evident during O4 where not only the event was in a magical location, but also those attending in VRChat took impossible forms (see Figure 25b). Such possibilities for impossible experiences were used by our participants to also envision what they would want to see in the future: *"My most memorable online one was in the Natural History Museum... but could you use VR to stimulate like a place so the artists wouldn't have to pay for the licence to be there? The person could decide which*

place they want to see, which suits the type of the concert better. Can you also use VR to stimulate standing at the front of a stage or with the artists backstage? (PI9)"

Accessing the inaccessible

Traditional in-person events often demand significant commitments, including travel expenses and high ticket prices, rendering some events a luxury that many cannot afford. This frustration with the financial burden associated with in-person events was articulated by 14 questionnaire participants and further elaborated upon by interviewees. For instance, PI13, discussing Glastonbury, a renowned music festival in the UK, highlighted how the event has evolved beyond its original concept as an affordable music holiday for working-class people: *"I think originally the idea was it was a holiday that working-class people who wanted to listen to music could afford to go on, and that's really not what it is anymore. It's beyond quite a lot of people's financial budgets... I always watch Glastonbury because I definitely can't afford to go there anymore because the tickets are really expensive. I kind of think it's almost better at home (PI13)."* Digital platforms have made this easier by offering **free or affordable streaming options**, democratising access. PI9 highlighted: *"It might actually be better at home, especially with big artists. For example, with Niall Horan, if I had went to a live event, unless I wanted to pay a kidney, I would not have been at the front to actually see his face while singing while at home you could see the emotion on his face (PI9)."* This newfound accessibility has also addressed the perennial problem of sold-out events, where highly sought-after tickets vanish within minutes[44].

Furthermore, remote music events have obliterated **geographical barriers**, providing opportunities for individuals who cannot attend in person due to location. The ease of access was cited by 15 questionnaire participants as a primary benefit and motivation for participating in remote music events. PI1 shared their experience, emphasising the importance of accessibility in their decision to join the VRChat Drum N Bass community: *"Where I live, there's nothing really going on... So when I somehow discovered that there's a VR community, I was like, 'Hey, that's kind of cool (PI1)."* Additionally, dedicated fans of music genres such as Kpop, like PI14 and PI7, have found remote music events to be their primary means of engaging with their favourite artists due to the geographical challenges involved: *"These live events are often held in locations that can be challenging to access, especially for the K-pop side, which is mostly based in Asia. So it's a lot difficult to get there... So you can see it whenever you are, you just need a screen, a passcode, and a Wi-Fi connection (PI14)."* In addition, for participants like PI16, the shift to digital platforms also aligns with a more **sustainable future**

[44] `https://help.ticketmaster.co.uk/hc/en-us/articles/360018800214-Why-do-tickets-sell-out-quickly-`

"conversations about sustainability are going to become way more prevalent [...] So, I think using technology that's more sustainably powered, but also that allows people to attend events in ways that are more sustainable, if that's minimising travel to and from events for example (PI16)."

In addition, several participants pointed out that online music events can offer greater **accessibility for people with disabilities**, because they eliminate the need to physically navigate potentially inaccessible spaces and allow individuals to engage from the comfort of their homes. PI16 who has fibromyalgia explained the difficulty of attending in-person events due to their chronic pain and inability to stand for long periods: *"me being in a standing crowd is a real problem and as much as a venue can be like, "Oh we'll put a chair in the corner for you", that then just feels uncomfortable and isolating, and so that's something that I think is beneficial in terms of a virtual event (PI16)."* PI5 further highlighted how online music events can be more accessible for those with hearing impairments: *"if deaf people, or people who are hard of hearing, go to a concert with just one person there, they're not actually going to be able to hear the lyrics (PI5)."* The same participant gave as an example Rhianna's performance at the Super Bowl *"One example that comes to mind is Rihanna's performance at the Super Bowl. [...] When they televised it, they had Justina Miles, as an American sign language interpreter who is an amazing, amazing performer, so she was dancing as she was signing, and it was a brilliant performance on her part, alongside Rihanna, that made deaf people and hard of hearing people able to engage with the event in a way that, normally, they wouldn't be able to (PI5)."* Online platforms can offer features like closed captions and adjustable volume control, which can be crucial for people with hearing loss to fully experience the music. This contrasts with in-person events, where these features are often unavailable, putting individuals with hearing impairments at a disadvantage.

In addition, a few participants talked about the difficulties that **large crowds and intense sensory stimulation** at in-person events can pose for individuals with certain disabilities or to those with safety concerns. PI12 mentioned that online events are preferable for those who are sensitive to noise and crowds. They explained that online events can provide a more controlled and comfortable sensory experience, allowing individuals to adjust the volume, lighting, and other elements to suit their needs. PI16 also explained:*"If you are someone who is concerned about safety in public spaces, I think that's a very real fear to have. Especially, you see like Travis Scott, was it Astro World? That huge crush of people and people died in a crowd at a concert. Or the Ariana Grande concert. If you are concerned about that, you're not going to get crushed in your house. So that's a real benefit, I think, if security and personal safety is a worry for you, then I think that's a major benefit to having*

online events. And, if things in the US keep going the way that they're going with shootings, then I think that might become a lot more popular there (PI16)."

However, remote music events are not without challenges. Some individuals, like PI8, express **feelings of missing out** when attending events remotely: *"you just feel like you're missing out."* For example, PI2 described how a concert during the pandemic exacerbated their sense of disconnection: *"because it was mid-Covid and I was already feeling pretty terrible about everything going on, seeing that made me feel weirder, you realise what you're missing out on and what could be happening. So I was like: Okay, this is too much for me right now. This is making me upset rather than actually helping."* 11 survey participants mentioned **technical issues like internet connectivity** and lagging as major frustrations. PS62 observed: *"Lagging streams seems to be the biggest problem as so many people are watching (PS62)."* This is especially problematic during large events where infrastructure can not support the audience size. PS42 explained: *"Connection issues can make you feel less a part (disconnected) from the experience (PS42)."* Five participants reported that poor sound and video quality further contribute to disconnection, with some stating they are unwilling to invest in better audio systems just for music. Additionally, others noted that having to pay to interact or be seen impacts perceived accessibility: *"Possibly if [there is] aspects of voting and having to pay, I'm aware some funds need to go towards it but it cuts off how accessible the event is (PS55)."*

5.4.4 Sensory and emotional Immersion

Physical space transcendence

In-person music events are often celebrated for their ability to create liminal spaces –thresholds where attendees step out of their everyday lives and into an extraordinary experience [419]. As PI16 articulated, *"When you go to a music event [...] it feels very much like a liminal space. I like that it doesn't feel like part of the real world [...] and then you leave and then the world is normal again (PI16)."* These events allow audiences to fully immerse themselves in a setting governed by its own rhythms and dynamics, enabling a heightened focus and connection to the music.

In contrast, remote music experiences, such as virtual concerts or livestreams, often struggle to recreate this clear **separation between the ordinary and the extraordinary**. At home, the boundaries between the immersive qualities of a music event and the **distractions and interruptions** of daily life are blurred. PI15 highlights this tension: *"It's very easy to get up mid-song and go make a cup of tea if*

you want to, whereas you would never do that in a live performance (PI15)." The same participant went on to explain that they often watch live events on VoD platforms while simultaneously doing other things like sewing, knitting or cooking. Moreover, **the ease of multitasking** at home is amplified by the constant availability of other media. PI16 explained that they might simultaneously watch a concert and engage with social media or even work on their laptops. Such disruptions, noted by nearly all interview participants and 6 survey respondents, can detract from the immersive potential of remote events. The **lack of social pressure and accountability** that comes with attending a performance with others in – person, further exacerbates distraction and disengagement during at-home attendance. PI4 explained: *"You're with other fans, you feel you're part of a collective, [...] A digital experience, it's a bit more passive [...] It feels a lot more easy to become disconnected, because the environment doesn't lend itself. When I'm watching live music, I'm in that moment with others. So, it's really hard to be like, "Oh what's on my phone?" But, when you're in your bedroom, even if it's my favourite band, I might walk off to the toilet or to get a drink, and it's much easier to switch off and not pay attention because I am on my own. You lose that feeling that something – I don't know if it's a benefit, but you definitely lose substance from being with others (PI4).*"

Despite these challenges, remote music experiences offer distinct advantages, particularly in the comfort and personalisation they afford [54] as mentioned by 16 participants in our survey. As PI9 observes, *"It's two different experiences: the ones at home, I watch them on the TV with the lights off and warm clothes on my couch with my blanket, which was very comfortable. While at the venue, it's a different experience. It depends on what mood you are in, sometimes I would prefer the ones at home, but sometimes I would prefer to be at the venue (PI9).*" This flexibility allows individuals to **tailor the experience** to their preferences and emotional state, which can enhance the sense of enjoyment and intimacy. Participants also described efforts to bridge the gap between live and remote experiences by transforming their homes into immersive environments. PI14 recounts, *"I connected the speakers I have here, so we are watching the screen and [...] you can start to feel that vibe with the music pumping in your chest, but then again, you're in your house, you can get comfortable and do whatever you like and you enjoy with others (PI14).*"

This phenomenon extends beyond sonic enhancements. During preparations for major events like Eurovision and Glastonbury, audiences exhibit a remarkable commitment to **physically transforming their living environments**. For instance, both PI12 and PI13 shared their experiences of turning their homes into mini Glastonbury festivals: *"Actually we've had our own Glastonbury quite a few times. We've got our attic so it's really dark. We've got a big cinema screen so we can create our own festival*

up there (PI13)." PI12 described how their partner decorated their entire garden and house to resemble Glastonbury, using decorations, trinkets, and even grass-themed place-mats to create a holistic festival environment. During the observation of Eurovision (O10) and the fan conversations on X, numerous fans shared images of their homes and outfits, showcasing their efforts to harmonise their personal spaces with the event's ambiance, similar to experiences of watching Eurovision described by PI14 and PI11. In such examples the event itself sometimes become secondary to the social interaction happening in the physical space, while at other points it becomes their focal point [415]. In these ways, individuals actively strive to transpose the essence of live events into their own homes, enhancing their immersive and social experiences while cocooning. While remote music events cannot entirely replicate the liminal qualities of live concerts, our findings showcase how audiences creatively adapt their home surroundings to match the immersive energy of live music.

Being 'in' the music

Live music at its core is a multisensory experience, immersing attendees in vivid sights, sounds, temperatures and even smells. The *scent* of a venue, *"the kick of the drums in your chest and the bass and the flow of the people (PI2)",* – all these elements converge to create lasting memories. However, the digital reality of remote music events often grapples with what can be termed as 'sensory paucity' – the diminished sensory richness in digital environments compared to real-world experiences.

Despite their high-quality visuals and audio, platforms like TV, Twitch, YouTube and Instagram Live **cannot replicate the immersion** of in-person music events. This can lead to: *"feeling disconnected from the experience (PS10)",* and *"like you are watching the event out of your window (PS2)."* 13 participants identified this as a key limitation. PI18 emphasised, *"In person music is more of a sensory experience, whereas online it's mainly seeing and hearing (PI18)."* Discussing in-person events, our participants vividly recounted their experiences, providing intricate descriptions of everything from the scents in the air to the concert venue's specific details. They recalled meeting people, and even recollected details like the weather and the time of day. However, when reflecting on remote events, participants had difficulty. Some expressed limited memories, with one participant stating, *"I don't really remember much (PI3)."* In contrast to the detailed recollections of in-person events, memories of remote events tended to be more general, often centred on the music itself or the event as a whole rather than specific moments. This was also evident in the survey, where all the responses on memorable in-person music events were significantly longer and more detailed than the responses about **memorable remote music events**. PI19 explained, *"there's just something about being in an*

audience with loads of other people [...] it feels more of an event, more of a memory (PI19)."

Moreover, in-person events inherently demand a level of commitment and effort, encompassing elements like travelling to the venue, structuring one's day around the event, and investing in tickets. This investment, both emotionally and physically, magnifies the event's significance in our participants' recollections. This contrasts starkly with remote events, where these facets of commitment, physical presence, and multisensoriality are often absent, leading to a different kind of memory and overall experience, "*I think there's a lot more memories associated with [in person] music for me [...] memories from when you get the ticket, up until the day before, or the day of, and then seeing it (PI18).*" This discrepancy in the depth of engagement between online and in-person viewing extends to the perceived value and memorability of remote events. As PI6 points out, "*People [online] may RSVP, right? They may say that they're going to go and then they forget about it [...] in a way that you simply wouldn't do if you had bought tickets to a real life thing. [...] You plan your whole day around that (PI6).*" Furthermore, these quotes subtly touch upon the paradox of choice. In the digital space, the sheer volume of available content can be overwhelming. When everything is readily accessible, the value of individual experiences can diminish. It is the classic quality versus quantity debate. While we can watch countless events from home, the sheer volume makes it challenging to assign distinct value to each, leading to a blur in memory.

Unlike screen performances, in VR environments, the experience is inherently more immersive, **amplifying the sense of presence** in the event. For participants like PI17, PI5, PI1 and PI10 who use full body tracking, a ritual of preparation is required, contributing to feeling a deeper connection to the event. PI17 explains, "*When I actually put on the stuff [VR equipment] and kind of go in, VR actually has that spatial aspect [...] and you kind of feel that you connect with the people a lot more (PI17).*" Participants described their VR experiences as vividly (or even more so) as the in-person ones. PI1 explained "*people who don't have VR, have no idea what we're talking about [...] it's so immersive to be there. It really is another kind of reality, it's not virtual anymore, it's a reality (PI1).*" This supports findings by Onderdijk et al. [347], showing that attending a concert in VR leads to greater feelings of physical presence than viewing a normal YouTube livestream. To increase their presence further, two of the VR participants in our study mentioned using haptic vests, which convert musical beats into vibrations, mimicking the tangible, visceral experience of music. However, despite VR's capacity for heightened immersion, it continues to face challenges in fully recreating the multisensory richness found in in-person events. Participants reported that "*the physicality of music, most of all is different. Not specifically the feeling of bodies around you, but the actual pumping of the base that*

is different (PI17)." The same participant goes on to explain that "*I would say that the music feels better in real life [...], but the actual music is probably better when I go to VR events.*"

Overall, even though technology has its limitations in replicating the multisensory richness and commitment associated with traditional in-person concerts, People continually seek authentic and memorable experiences which might not depend solely on technology but on how these experiences resonate with them on an emotional and personal level.

5.5 Discussion

Research on technology for remote music events has predominantly focused on performers [387], or on audiences of specific events and platforms through a sociological lens [380, 481]. My study aimed to bridge this gap, offering insights into how remote music audiences engage with, interact in, and perceive these events, considering their unique preferences and challenges. By examining the multifaceted practices and experiences of remote music audiences, my work informs the development of more inclusive and engaging remote music experiences, enhancing both performer-audience interaction and overall participation. In the sections below, I build on some of the findings (see Table 6 for a summary of results) and extend them through a generative perspective by reflecting on potential lessons our data offers. Based on this, I outline some insights and considerations for designing remote music experiences. While the insights presented here are substantial, they are not all-encompassing. Instead, they serve as a starting point, carving out a design space that future HCI research can go into, aiming to refine and elevate the experiences of remote music audiences.

5.5.1 So how does one choose a platform?

The relationship between digital platforms and the types of remote music events they support emerges from a dynamic interplay of factors, including music genre, performance style, platform affordances, and audience expectations. Reviewers of this work in the past encouraged a specific focus on genre, which indeed shapes audience engagement in both physical and virtual contexts [132, 163]. Although music listening has become more solitary through services like Spotify [204], live performance, now often mediated by technology, retains its social essence, with genres influencing how people gather and interact, [42, 193, 254]. Nevertheless, the findings indicate that while genre plays a key role in guiding initial platform choices, no single factor acts in isolation. Instead, the final

Table 6: Summary of findings from audience perspectives on remote music performances

Main theme	Sub-theme	Key findings
Social connectedness	Community building	Audiences form remote music communities with shared rituals, emojis, and platform-specific expressions—signalling group identity and belonging.
	Remote music concerts as third spaces	Remote concerts offer accessible, safe spaces where people express themselves through avatars, choose how they participate, and escape social anxiety. Anonymity enables self-expression but can result in harassment and rule-breaking. VR spaces lack effective moderation or shared norms.
Interaction with the artist	Artist-audience interactions as community building blocks	Audiences seek closeness and recognition—shout-outs and intimate formats increase perceived connection, though risks of parasocial illusions remain.
	Collaborative artistry, co-creation and playful interaction	Audiences co-create through requests, commands, and games. Playful exchanges enhance engagement and blur artist-audience boundaries.
Redefining here and now through remote music	Temporal fluidity	Audiences pause, rewind, or time-shift events. Liveness becomes layered—shaped more by shared chat and interaction than by real-time presence.
	Impossible music experiences	Technology enables surreal, location-less performances and expressive avatars. Fans embrace experiences that go beyond real-world limits.
	Accessing the inaccessible	Remote events reduce financial, geographic, and physical barriers—expanding access, especially for disabled or anxious attendees.
Sensory and emotional immersion	Physical space transcendence	Remote events lack the liminality of live gigs, but fans recreate immersion by transforming home spaces and tailoring sensory input.
	Being 'in' the music	Remote events offer fewer sensory cues and memories. VR enhances presence and emotion but can't fully match physical co-presence.

decision is shaped by a combination of motives, both artistic and practical. The performance's goals and scale, the audience's technological comfort, and the artist's available resources and creative vision all interact. Thus, there is no universal 'best' platform. Instead, for those working in the space it is important to weigh what they hope to achieve against what their audiences expect, then select platforms whose technical capabilities and cultural norms best match these objectives.

Some platforms, such as VRChat and Twitch, naturally favour **experimental performances** common in electronic genres like Drum N Bass or EDM. In these types of performances, the artist's instrument is not always visible, making immersive visuals essential [113]. These platforms enable rich sensory experiences through interactive features such as real-time chat, emotes, custom overlays, and shared 3D environments where avatars move to the music). The focus becomes less about the artist close-ups and more on creating a shared, synchronous experience, aligning with the music's emphasis on atmosphere, rhythm, and communal participation [452]. This encourages social bonding through synchrony in music, interaction, play and dance [268, 321]. Moreover, in these types of performances the goal of the artist themselves in not so much to attract a big audience but more about attracting a dedicated audience that interacts and plays with them throughout.

In contrast, platforms like YouTube, StageIt, and Veeps support **artist-centric, visually rich performances** appealing to fans of rock, pop, or other genres that emphasise an artist's physicality, personality, and emotional expression. In these types of performances, our results indicate that fans are often drawn more to the artists themselves than to the overall experience of the music stream, making artist visibility paramount. The affordances of these platforms, including high-quality video and audio, as well as the more curated content they provide, enable this. The emphasis on artist-focused visuals aligns with the importance of performer presence in rock and pop music, where charisma and stage persona play significant roles. Our participants highlighted that being able to see the artist up close enhances their emotional connection and engagement with the performance. Social aspects and emotional proximity are further enhanced through interactive features like real-time comments and live chats. These tools facilitate direct interaction between artists and fans, fostering a sense of intimacy and community. This suggests that tailored interactive tools can (to some extend) effectively recreate the communal feel of live gatherings [44], especially in genres where fans value close emotional proximity to performers Følstad et al. [154]. Monetisation opportunities also play a significant role in platform choice for these genres with fans often willing to purchase tickets to support their favourite artists and gain access to exclusive content. This willingness to pay reflects a commitment similar to attending physical concerts.

Performance style and **event scale** further shapes platform suitability. For example, acoustic sessions from home thrive on platforms like Instagram Live where the casual nature of the interface encourages spontaneous and intimate interactions. Both emerging and established artists of any music genre use these platforms to deliver informal, personal concerts – often just the artist and their guitar – that offer a close sense of intimacy. The casual settings and direct interaction features enable artists to connect with fans on a personal level, replicating the feel of small venue gigs or acoustic sessions [154]. Our participants valued this direct engagement, appreciating the authenticity and immediacy of these performances. Artists often respond to comments in real time, enhancing the sense of closeness and fostering a strong sense of community. Larger-scale hybrid events with substantial budgets, such as Eurovision, and formal concerts, by contrast, are better suited to platforms like YouTube, VoD or bespoke systems designed for high-production and value performances. These platforms provide polished, high-quality recordings, catering to audiences who value fidelity and formality. In these contexts, spontaneity is less expected; instead, the emphasis is on delivering seamless, uninterrupted experiences. VoD platforms offer features like multiple camera angles, high-definition video, and superior sound quality. Interactive features are minimal, aligning with traditional concert etiquette where the audience's role is to observe and reflect rather than interact.

This setup mirrors the contemplative nature of classical music appreciation, allowing audiences to immerse themselves in the performance without distractions.

Audience expectations and **technological literacy** also shape the final platform choice. VRChat attracts a tech-savvy and community-oriented audience accustomed to the platform's social dynamics and eager for immersive experiences. Twitch caters to viewers familiar with its real-time chat and participatory culture, often drawing from the gaming and streaming communities who value immediate feedback and a sense of shared experience. Conversely, audiences engaging with VoD platforms like BBC iPlayer may prioritise polished, passive viewing experiences, as these platforms cater to contemplative engagement with minimal interactivity. The artists' goals and resources are also important here. Independent artists lacking major production budgets may prefer Instagram Live for its simplicity and direct artist-fan dialogue. More established acts, able to afford staff, equipment, and dedicated streaming engineers, can explore platforms with advanced customisation, ensuring they deliver experiences worthy of their brand identity. Artists who like to experiment with technology and like to try new things can explore platforms that allow them to 'edit' their performance, either through introducing custom plugi-ns, creating new types of sounds or letting them co-create with their audiences.

Overall, my findings suggest that while genre provides an entry point for understanding platform alignment, it is the interplay of multiple factors — performance style, platform features, audience needs, and technological literacy — that ultimately determines the suitability of a platform for a given performance. No single platform can effectively accommodate all types of remote music performances. What works for an immersive electronic music event may not suit a formal classical concert or an intimate acoustic session. VRChat and Twitch support immersive, interactive experiences. The diversity signifies the importance of designing and selecting platforms that are adaptable and responsive to artists' goals and audience preferences. In doing so, it can enhance engagement, encourage authentic connections, and create more memorable experiences.

5.5.2 When and what spontaneity to seek for?

Facilitating spontaneous interactions is crucial for engaging audiences in remote music settings, offering the unpredictability and liveliness associated with live music events [190]. Traditional concerts are rich with spontaneous moments – unexpected encores, improvisations, and unplanned interactions – that create memorable experiences and deepen the emotional connection between artists

and audiences [167, 272, 498]. The surprises and imperfections, occurring before, during, and after performances, make each event unique and it resonates with attendees long after it concludes.

In contrast, remote events sometimes offer fewer opportunities for spontaneous interaction, which can impact the overall audience experience. Moreover, the immediacy of accessing a virtual performance with a single click further bypasses the traditional audience journey where memorable experiences often happen [181]. Without spontaneity, virtual performances can feel scripted and less engaging, limiting the unexpected joys characteristic of live music. Research shows that spontaneity in entertainment is perceived as more authentic than scripted experiences, adding dynamic energy that counters the predictability of virtual performances, even if it may suggest lower production quality [383]. Our results indicate that expectations for spontaneity in remote music performances vary based on the event format (fully remote vs. hybrid) and event style (informal vs. formal), influencing how audiences prefer to interact with the platform and the performance itself. This aligns with findings of studies in different live-streaming contexts, such as in gaming, that found that the type of interactivity audiences and streamers seek for is dependant on the stream type [274].

In **fully remote, informal events** (i.e., events where the artist performs in an informal setting – perhaps their bedroom) which mostly take place on platforms like Twitch, Instagram live or VRChat, the platform becomes the primary venue, taking on the role of both the physical and social environment of the event. Here, audiences actively seek both audience-driven spontaneity (e.g., real-time chat, live reactions, playful interactions) and artist-driven spontaneity (e.g., unscripted shout-outs, unexpected setlist changes) to replicate the communal and lively energy of a live event. To enhance the audience journey in these settings, designers and artists can incorporate pre-event activities to build anticipation, such as interactive countdowns, teasers, or behind-the-scenes glimpses. During the event, platforms should prioritise flexibility of interactive tools that allow both audiences and artists to engage in real time, including live chat, adaptable visuals, and audience feedback options, to recreate the unpredictable atmosphere of an in-person experience. Moreover, platforms could consider multi-modal and non-textual modes of interaction [157] such as sketches [293], snapshot-based interactions [522] even audiences being able to participate in the event as avatars [99]. Flexibility of interaction within platforms for audiences and musicians alike could amplify engagement and nurture playfulness [5] and spontaneity, giving users power to shape their experiences either at an individual or collective level [226], similar to other livestreaming contexts such as outdoor streaming [292] or e-sports [278].

In **fully remote, formal events** (i.e., events that are specifically staged and curated), which often take

place on bespoke streaming platforms like Veeps and StageIt, our results suggest that audiences expect a polished, consistent experience over spontaneity. In these settings, structured interactions are more suitable, allowing viewers to feel as though they are watching from the venue. Selected moments of spontaneity, such as an artist's acknowledgment of the online audience, can connect without detracting from the formality [204]. For formal, fully remote events, platforms could focus on high-quality streaming and limited but meaningful spontaneous interactions, such as curated Q&A sessions or artist acknowledgments, to maintain the formality and polish expected in these settings. For example, Oxjam's virtual festival design demonstrated how integrating dedicated volunteer roles can enhance the remote audience journey by managing technical support, guiding new audience members, and facilitating live chat – elements that helped recreate the organic interactions typical of in-person experiences [41]. Volunteers acted as the "invisible" infrastructure that connected artists and audiences, responding in real-time to queries and enhancing the social aspects of the event.

In **hybrid events** (i.e., events that take place physically but are streamed remotely too), on platforms like YouTube or VoD when there is both an in-person and a remote audience, our data showed that spontaneity expectations tend to be lower for remote viewers, who often see their role as spectators of the in-person experience. This is in line with Lai and Hespanhol [265]'s work on hybrid cultural spaces, which suggests that remote audiences in hybrid contexts often engage as observers instead of active participants, expecting a polished experience rather than frequent interaction. However, we found that during such events remote viewers sometimes create "micro-festival" environments at home, with thematic decorations or even small watch parties to capture a shared ambiance, and the screen the live-stream is played on becoming a focal point the experience centres around [415]. Platforms for can support this audience preference by focusing on high-quality streaming, with optional AR-driven customisation kits [489] that allow viewers to personalise their spaces without relying on high interaction from the platform – a strategy that can enable co-located interactions while enhancing the overall event experience, similar to the one proposed by Reig et al. [377].

Through integrating considerations of the audience journey and tailoring strategies to each event type, designers and artists can enhance spontaneity and create more engaging and authentic remote music experiences. Recognising that memorable events are not solely about sensory immersion but also about shared stories, unexpected interactions, and the overall journey can bridge the gap between virtual and in-person performances, ensuring that even in a remote setting, audiences feel a genuine connection, capturing the essence of live events.

5.5.3 Audience size matters

Audience size in remote music events fundamentally alters the dynamics of engagement [496]. On smaller events, especially on platforms like Twitch and VRChat, viewers have more time to interact and build virtual communities through regular participation [188]. This fosters a deeper connection with the artist, enabling easier *shout-outs*, that take the form of reading out comments, re-posting stories or, in the case of VRChat, a nod. Such moments, fleeting as they might be, can amplify the sense of connection and in turn can make the experience feel more intimate, which in turn could lead to attending more events [181, 372].

On the contrary, during larger events, individual interactions can become transient, often lost in the sea of comments. On platforms like YouTube, comments tended to be shorter and repetitive, often seemingly unrelated to each other. For some, this type of interaction accommodates for a different kind of coherence, dubbed by Ford et al. [155] as a 'crowdspeak' that prioritises crowd-based interactions over interpersonal conversations. For others, this could lead to interaction being 'less meaningful' and random, and to events being considered by some scholars as "unsuccessful large-scale interaction rituals" [481]. Moreover, as events scale up in size, the *"feeling seen and heard by the performer"*, although more exciting, becomes a challenge. In larger events, the sheer volume of attendees makes individual shout-outs impractical. Recently, platforms like Twitch have automated their shout-out systems [423] to assist the performers with managing their interaction with the audience, but the impersonal nature of automation could dilute the value of such recognition.

To mitigate some of the challenges that come as audience numbers grow, designers could draw inspiration from events like Eurovision, where fans often create their own local viewing parties and think about grouping participants into smaller communities or 'viewing pods'. Platforms could facilitate the formation of such groups based on interests, location, or mutual connections [349]. A similar approach was taken by Kiswe during the BTS "Permission to Dance Onstage" livestream which was watched by more than a million viewers and was received positively by fans[45]. This can also extend to group shout-outs by the performer. Platforms like VOLTA XR are already experimenting with this approach, with some of their events having *accumulative effects* (i.e., effects that trigger on the screen behind after a number of audience members input commands together and are visible by the performer who then has the ability to acknowledge the group). Such collective acknowledgements could ensure that fans experience a feeling of social connectedness [450] and belonging.

[45] `https://www.fastcompany.com/90694362/kiswe-livestreaming-bts`

5.5.4 The illusion of closeness between audiences and artists

The findings reveal a discrepancy between the perceived intimacy audiences feel during remote music events and the actual level of connection with the artists. Current digital platforms offer audiences a chance to engage in a 'one-and-a-half' sided relationship, where they message artists in real time and occasionally receive a direct response [261]. Participants talked enthusiastically about moments when artists acknowledged them (e.g., reading out their usernames or fulfilling song requests), which enhanced the feeling of a one-to-one connection. This was further amplified when artists actively invited fans to become part of the creative process (e.g., by suggesting lyrics).

However, the sense of intimacy in remote music streaming can be questioned. This reflects the concept of parasocial relationships, where audiences form emotional bonds with media figures, who remain unaware of their individual fans [220]. The ease of digital communication can blur the lines between genuine engagement and the illusion of a personal relationship. Even when participants recognised they were 'just a username', the emotional impact of being acknowledged was significant. The pursuit of intimacy also drives monetisation on platforms like Twitch, where viewers pay for shout-outs or to have messages highlighted, capitalising on fans' desire for personal connection. While this enhances interactivity, it may exploit fans' emotional investment, raising ethical concerns about commodifying personal interaction [211]. To address this, platforms and artists could further promote community-building features that encourage fan interactions, shifting focus from direct artist-to-fan engagement. Transparency from artists about the nature of digital interactions could help set appropriate expectations. These approaches can enrich the remote music experience, ensuring it remains positive and mentally healthy for audiences.

5.5.5 Limitations

My research, while providing valuable insights into the world of remote music events from the lens of audiences, has certain limitations that need to be acknowledged. Firstly, remote music events are diverse, with countless ways for individuals to engage. My study's limited sample size means we have not captured all possible experiences. While I aimed for a comprehensive view, my findings may not represent every audience type or experience. In addition, I focused on specific digital platforms, which do not encompass the entire landscape. This might leave out nuances from unexplored platforms. Moreover, since the study was about the broader design space I did not go deep to the

platforms presented, so there are aspects of those platforms that I did not examine. Lastly, despite my efforts to engage varied demographics, most participants were adults embedded in Western context with good digital access. While these participants are among those more likely to access and attend remote music events, it is important to acknowledge that the insights that came from the study are, to a certain extent, a reflection of their socio-economic privileges. In addition, this means that we have overlooked the practises of audiences from other regions such as East Asia where platforms like BiliBili are popular for live streaming including music, and practices such as those of VTubers are much more prominent [494, 497]. Future research should look into the practises of those audiences, specifically related to remote music events [269]. I discuss more in depth the limitations of the work in Chapter 6.

5.6 Conclusion and future work

In this chapter, I took an exploratory approach, where I focused on remote music audiences and the platforms they use to attend remote music performances. My findings point out to insights, which I hope, could provoke designers and researchers to investigate this space. I see value in sharing this work now, when the research landscape remains relatively unexplored but interest in this space is nevertheless evolving rapidly, especially after the massive shifts brought by the COVID-19 pandemic.

Chapter 6

Remote Rhythms. Audience-informed inspiration for designing remote music events

Building on the findings from Chapter 5, this chapter explores how we can design technology that aligns with the kinds of remote music events audiences truly desire. The previous study revealed that remote music events address different needs compared to in-person experiences. Nevertheless, on many occasions, audiences still long for experiences that leave a lasting impact on them. In this chapter, I aim to unpack the desire to shift remote music events from content consumed and watched to content that is lived and experienced. Firstly, I draw upon the data from Chapter 5 to identify a list of elements people value in their music event-related experiences that can guide and inspire designers in this domain. To enrich this understanding, I introduce a participatory design workshop conducted with a diverse group of stakeholders. Participants were provided with some of the original data from Chapter 5 and were encouraged to embody and instantiate them by developing their own design concepts. The resulting concepts, together with a subsequent discussion, are mapped to the identified design elements with an analysis of how each idea aligns with, challenges, or expands them. I conclude by discussing the implications of these findings for future technology development in remote music experiences. I articulate specific design insights, encapsulating the insights from the previous study and the workshop. I also reflect on the work conducted in the two chapters and the methods I followed. Overall, I hope this chapter provides inspiration to designers who want to design remote music experiences, taking inspiration from audiences that already engage with them.

6.1 Methodology in a nutshell

The work presented in this chapter consisted of two phases. I began with the aim of identifying the things people desire when attending remote music events. For this, in **Phase 1**, I utilised the qualitative data gathered in Chapter 5, to extract a set of recurrent elements with inspirational value for designing remote music experiences. The analysis surfaced a list of 17 elements, grouped into four themes, that people deemed important for engaging in remote music events that transcend watching to become immersive experiences. **Phase 2** involved an in-person participatory workshop where I invited diverse stakeholders to imagine the future of remote music experiences, using our original data as starting points. The aim was to explore the potential and challenges in this space, while also identifying any critical lenses or viewpoints we might have overlooked. I was interested in: (i) understanding how different individuals interpreted our initial data, (ii) uncovering new perspectives and insights, (iii) validating the identified elements, and (iv) gaining a comprehensive understanding of their utilisation by stakeholders. I then looked into the ideas generated during the workshop, analysing how they emerged and how they relate to the elements identified in Phase 1. This phase involved a detailed discussion of each idea, examining how it aligns with, challenges, or extends the identified elements, thereby offering an understanding of the design opportunities in this domain. The process was enriched by discussions with stakeholders, which highlighted certain elements as more or less significant and brought forth new elements that had not been previously considered. The culmination of these phases led to the synthesis six overarching design insights.

6.2 Phase 1: A list of design elements for remote music experiences

Phase 1 builds directly on the findings from Chapter 5, where I explored audience perspectives on remote music events. The themes identified in that chapter provided a foundational understanding of what audiences value in these experiences, such as social connection and meaningful engagement. The themes reflected broader dimensions representing aspects of audience desires.

To translate these themes into actionable prompts for design, I conducted a secondary, design-oriented analysis of the original dataset (interviews, surveys, and field observations). My aim was to extract recurring ideas that could inspire future technological interventions: frustrations with current platforms, imagined features, or desires for more immersive interaction. This process focused on a

subset of participants who expressed a clear wish to engage more actively in remote events and cited the lack of such engagement as a key reason why these events often feel less enjoyable or memorable than in-person ones. I undertook this analysis collaboratively. I discussed the emerging groupings with Dr. Alexandra Covaci, my collaborator Dr. Boyd Branch, and an undergraduate research assistant who had previously supported the study. Together, we iteratively refined the categories, discussing whether the patterns I observed reflected meaningful distinctions, and where thematic overlap could be resolved or used constructively. The conversations ensured the elements were not developed in isolation but were shaped through dialogue and interdisciplinary feedback.

The result is a list of 17 design elements, clustered into four overarching themes. In the section that follows each element is introduced with a summary and supported by indicative quotes. Interview participants are named as **PI1-25** and survey participants are named as **PS1-67**. I chose to present the data in this way, not quantified, because the goal of this phase was not to generalise statistically, but to inspire design. Rather than trying to determine how many people said a particular thing, I focused on what kinds of things they said that pointed to possibilities or unresolved tensions. The quotes I included are representative of broader patterns across the dataset, but they are also chosen for their clarity and potential to prompt reflection or action. This was a deliberate methodological choice. The aim here is not generalisation but generation: to open up possibilities for designing remote music experiences that better reflect what audiences hope such events could become. This approach also aligns with practices in design research and HCI, where user stories and evocative examples are used to communicate insights with design relevance [6, 7, 8].

6.2.1 Social connectedness

The analysis suggests that remote music events are creating opportunities for a new kind of online community. However, the potential for genuine social connectedness remains underdeveloped due to the limited availability of tools specifically designed to support these interactions. While current platforms use features like live chatrooms and social media integration, participants expressed a strong interest in more meaningful interpersonal connections within the context of music. Interviews and observations revealed a desire to explore each other's musical preferences, engage in collaborative activities, and enable spontaneous social exchanges. Unlike traditional online communities, which often form around forums or private groups, or gaming communities, the community that emerges around remote music events is largely situational and embodied. It forms during the live event, shaped by the performance's energy and the shared experience of real-time interaction

(through emotes, chat, avatars, or collective rituals). Such connections are emotionally resonant and socially rewarding, driven by a shared atmosphere rather than sustained conversation or achievement. The community is fluid, anchored in the moment of the event rather than persistent across time.

These findings align with research by Onderdijk et al. [347], which explored how agency, presence, and social context shape audience experiences in virtual concerts. That study emphasised the value of shared agency and the role of visual and social cues in creating a sense of connection. Platforms like Zoom, which allow visual interaction among participants, were found to enhance the feeling of social presence and strengthen relationships within the audience. Building on these insights, my work identifies the untapped potential of existing digital platforms to support community-building while emphasising the need for new approaches. Based on the findings, I have identified four elements in Table 7 that are essential for creating deeper social connections during remote music events.

6.2.2 Interaction with the artist

Remote settings offer unique opportunities to enhance and evolve the relationship between artists and their audiences, as highlighted by Leshem and Schober [273], who showed that empathetic concern allowed listeners of an improvised jazz concert to experience emotions similar to the performer's emotions when listening to the audio recording online, although it did not facilitate shared emotions in the live concert setting. This seems to indicate that empathetic concern may facilitate greater emotional understanding in digital environments. Currently, audiences leverage digital platform features such as live chats, reactions, and social media integration to engage with artists, and this fosters a sense of connection and agency during virtual events. Previous research identified various elements that enhance this connection. For instance, Onderdijk et al. [347] found an increased artist-audience connection when audiences hear their favourite songs or attend VR concerts. My findings expand on these insights by identifying additional elements that contribute to deepening this bond such as providing opportunities for co-creation, and insider access to behind-the-scenes content. While existing digital features provide a foundation for interaction, there is scope for the development of new tools and features, as revealed by our participants. The four key elements identified for enhancing the connection audience-artist are detailed in the Table 8.

Table 7: Design elements and design recommendations for fostering social connectedness in remote music events

#1 Tune in to 'kindred' connections
Audiences reported an enriched experience when they were able to connect with others who share commonalities, whether through shared comments or digital experiences. This fostered valuable outcomes, such as user-generated music recommendations, friendly exchanges, and prolonged discussions within the online musical community. Nevertheless, on current platforms, the task of identifying commonalities and forging connections can present significant challenges.
Participants said: *"The fact that other audience members can participate and say things or ask questions, or do reactions that you also might be feeling.[...] I think that helps [...], you kind of connect with that reaction as well from the other person (PI15)."*; *"watching it together [...] I felt like I was part of the group, in it, in the tribe (PI4)"*; *"I've made so many friends (online) that I just want to hang out with [...] exactly the same reason why I would go out with friends in real life (PI10)."*
Designers could enhance the sense of community within remote music platforms by enabling users to easily identify and bond with people who share their musical preferences. The goal is to foster a sense of camaraderie and belonging that extends beyond the duration of the performance, turning virtual concerts into hubs of shared experiences and lasting connections.
#2 Orchestrate synchronised engagement
A core part of the communal experience at many performances comes in the form of synchronised action. Although digital contexts lack the inherent physicality of in-person concerts, audiences mentioned appropriating existing features within digital platforms (i.e., using the same emojis simultaneously) as resourceful means to encourage synchronisation.
Participants said: *"A lot of streamers have created their own emotes now to inside community jokes and stuff like that [...] Something bad happens, everyone spams an emote, they're like, making fun of everything. Something good happens, they, again, spam and hype the thing up (PI2)"*; *"There's a snowflake emoji that people throw at the DJ if they really think it was a good set (PI5)."*
Designers could amplify synchronised actions in virtual music experiences by incorporating interactive features that foster coordination among participants, either by empowering fans to initiate and coordinate synchronised actions among themselves or by providing tools for artists to initiate such actions in ways that are meaningful to their performance.
#3 Encourage play
There is natural inclination for audiences and artists to seek and create their own entertaining experiences during remote music performances. Audiences often appropriated features of existing digital platforms for playful interactions, engaging in impromptu activities both among themselves and with the performers.
We observed various forms of emergent play including: spontaneous interactions such as play with words during chat conversations; emoji patterns and chants; and structured forms of play such as fans and artists creating their own games and challenges during the performance. **Participants said:** *"There's also a YouTuber [...] who asks audiences to give him three to five words and raps using those three to five words (PI2)."*
Designers could facilitate play, perhaps by creating more open-ended and flexible features within the digital event space that allow both audiences and artists to engage in playful behaviours. This would enhance the enjoyment of the event, creating a sense of community and shared creativity, turning the remote music event into dynamic, interactive, and playful experiences.
#4 Freedom for self expression
In remote music performances, attendees have a multitude of creative tools at their disposal, including avatars and pseudonyms, that allow them to explore and express facets of their personalities. Nevertheless, enhanced freedom of expression brings its own challenges, notably in managing disruptive behaviour.
Participants said: *"People can definitely express themselves more [...] people who because of different reasons, don't want to go out in real life [...] can just be in a safe space basically (PS40)"*; *" I can be more myself here. I have my avatar, they have their avatar, they can be a woman or a man, they can be whatever [...] it doesn't really matter (PI4)."*
Designers could encourage constructive and respectful self-expression while mitigating potential disruptive behaviours such as creative moderation tools; integration of subtle prompts within events encouraging positive interactions and discouraging disruptive behaviour; or introduction of digital etiquette guides.

Table 8: Design elements and design recommendations for encouraging interaction with the artist

#5 Intimate encounters
Audiences frequently emphasised the importance of creating a sense of closeness with the artist, a dynamic they viewed as distinct from in-person events. Unlike traditional live events where the scale and setting might limit personal interaction, remote events were seen as an opportunity for fans to feel a personal connection with the artist.
Participants said: *"I think the strength of remote technology for music events is exactly the creation of the feeling of a one-to-one connection with the artist and the intimacy that comes with it! (PS42)"*; *"It's just you and them, you see them up close and personal even if you are miles away [...] you have your own emotional moment with the artist (PI18)."*; *"It actually felt really indulgent because you just had that person in your living room. It felt like a personal concert, there was no one else watering that down (PI12)."*
Designers could emotionally resonate with the audience and foster intimate moments between them and the performer, making each remote music event feeling like a special, tailor-made experience for every attendee.
#6 Feeling 'seen' and 'heard'
When attending a music performance (whether offline or online) a highly valued aspect reported by audience members is receiving recognition from the performer such as a "shout out", which could be attributed to (i) the audience's wish to feel a closer connection to the performer and (ii) the desire for recognition and a sense of importance.
Participants said: *"The fact I could just tap on my phone and send the artist I'm watching a message, and I know it's going to pop up in front of his face at some point. Knowing that you are almost like apprehensive about touching your phone in the wrong way, in case you accidentally send the wrong emoji or whatever. I think that was quite exciting (PI15)."*
Designers could enhance audience engagement by amplifying the perceived rewards of participation and deepening the perceived one-to-one connection between audiences and performers. Designers could think about introducing features that expand the variety, visibility, and scalability of shout outs from the performer.
#7 Co-creation and collaborative artistry
Audiences can directly contribute to the creative process, from influencing setlists to submitting original content. This collaborative approach is highly valued by audiences, as it deepens their connection with the artist, making them active participants in the artistic experience rather than passive consumers.
We observed various forms of emergent play including: spontaneous interactions such as play with words during chat conversations; emoji patterns and chants; and structured forms of play such as fans and artists creating their own games and challenges during the performance. **Participants said:** *"Snow Patrol... had Saturday Sessions where he would... interact with the audience on Instagram lives. He would ask the audience for lyrics, and a song emerged from that, crafted from the lyrics provided by their fans (PI9)."*
Designers could actively encourage audience participation, integrating features that allow audiences to contribute to the performance in real-time, such as providing lyrics, influencing visuals, or even affecting the music itself.
#8 Behind the scenes and origin stories
Reflecting the dynamic relationship between artists and their audiences, the desire for deeper contextual understanding and interaction is evident among music enthusiasts, The digital space offers unparalleled opportunities for deepening the artist-audience connection through behind the scenes and background stories.
Participants said: *"Sometimes I'd like maybe a bit more information about the artist or something. Not lots, but just something, rather than just the actual concert. A bit of background (PI12)."*
Designers could enable artists to share their stories and background information more easily and interactively during performances incorporating features like live chat, Q&A sessions, and behind-the-scenes content seamlessly.

6.2.3 Redefining the here and now

Digital platforms like Twitch, Instagram Live, and VRChat are redefining the concept of 'live' in music performances. They offer dynamic participation in live events, unbound by physical presence or traditional temporal constraints. Audience engagement varies: some viewers stay synchronised with real-time broadcasts, while others utilise the flexibility to pause or rewind. This flexibility reshapes what 'live' means, allowing to pause a live stream and dissect, discuss, and deeply engage with specific moments as they unfold. My observation supports the idea from Hammelburg [190] that the meaning of 'live' in a mediated, digital context is constantly evolving and being re-defined. The ephemeral nature of remote live music brings unique opportunities as it challenges the limitations of the physical world, but at the same time, it can make remote music events feel less memorable as they could be considered *less of an experience*. In Table 9, I present four elements that point to areas of intervention in the context of temporal and spatial fluidity, as emerging from our data.

6.2.4 Sensory and emotional immersion

Traditional live music is a deeply multisensory experience, enveloping attendees in vivid sights, sounds, temperatures, and even smells. The *scent* of a venue, *"the kick of the drums in your chest and the bass and the flow of the people"* – all of these combine to create lasting memories. In contrast, remote music events often lack this sensory richness, leading to what can be termed as 'sensory paucity'. This gap in digital environments can significantly diminish the depth and impact of the experience. The importance of sensory engagement is echoed in studies like the work of Phillips and Krause [359], which examines the future of classical music livestreaming and highlights how sensory elements enhance digital engagement. Similarly, Hu and Ma [223] explores how sensory language (e.g., words like 'tasty' or 'smooth') used by virtual streamers can shape consumer responses, reinforcing the role of sensory input in online interactions. My findings reveal a similar longing among audiences for deeper, more immersive experiences in remote music events. Participants expressed a desire for holistic engagement – an experience that goes beyond simply hearing and watching to truly captivate the senses and emotions. The craving for sensory and emotional depth underscores the unique power of music when it engages multiple facets of human perception and feeling. It also points to the need for remote music events that are not only seen and heard but truly felt. Under this theme, I identified five key elements, which are presented in Table 10.

Table 9: Design elements and design recommendations for temporal and spatial fluidity in remote music performances

#9 Remote liveness
The concept of liveness in remote music experiences is not a binary of "live" or "not live." Instead, it exists on a spectrum, ranging from fully pre-recorded concerts to interactive, real-time performances that can be accessed from anywhere. This significantly influences audience behaviour by offering distinct opportunities for interaction, shaping how audiences participate, connect, and derive meaning from these digital performances.
Participants said: *"Once you start immersing yourself in the possibility space you have the ability to start sort of layering levels of reality on top of each other, like this sort of layering of temporally things that happened in the past happening alongside what you're experiencing right now and sort of layering on previous audiences onto the experience for example (PI6)."*
Designers could explore the flexibility of this space. For instance, they can enable users to leave messages, reactions, or digital artefacts for future audiences or for themselves to revisit during anniversary events, creating a layered experience of past, present, and future interactions.
#10 Discovery and recommendation
The broad access to digital performances can sometimes lead to an overwhelming choice for audiences. Navigating this digital terrain often requires insider knowledge, especially in platforms like VRChat. Participants in our study mentioned the need for more intuitive guides and curatorial tools that can help streamline the discovery process.
Participants said: *"There was no event calendar and thousands of things are going on. That's the complaint of new users. Where do I go? [...] so the organisation of the actual interface to allow people finding events and people that they want to engage with, that's very important (PI8)."*
Designers could implement more nuanced discovery and recommendation systems, which strike a balance between suggesting events based on a user's established preferences and introducing them to new genres and artists, enhancing their musical exploration without overwhelming them.
#11 Concept performances
Participants in our study reported on attending innovative, technology-driven concept performances that transcend the abilities of live in-person events. For instance some attended Fatboy Slim's EatSleepRaveRepeat VR concert, where they were driving in a roller coaster through the artist's mind.
Participants said: *"You could create these really cool concepts and then share them as an online event, which you wouldn't be able to do on a stadium tour. So, [...] if they shifted the goal to be like, okay, virtual events are going to be more technological and more conceptual and they don't have to deal with the practical issues of crowd control or rain (PS61)."*
Designers could allow artists to create and craft unique experiences that would not be possible in the physical space, but are distinct, memorable, and engaging in their own right,creating a new genre of digital performance art.
#12 Accessible performances
Digital platforms have addressed live music accessibility concerns such as costs and physical constraints, making it feasible for individuals who may have otherwise been unable to attend such events. As highlighted by our participants remote music performances democratised access to live music.
Participants said: *"Live events are often held in locations that can be challenging to access[...] So you can see it whenever you are, you just a Wi-Fi connection (PI11)." "It is really good that we do have technology options available to make it more accessible for people that would be really anxious [...] or if there was a disability that prohibited them going (PI7)."*
Designers could create more inclusive digital concert experiences that cater to diverse audiences, for example by developing adaptable user interfaces that can be easily customised to meet individual needs with includes options for larger text, high-contrast colour schemes, and simplified navigation for users with visual or cognitive impairments.

Table 10: Design elements and design recommendation for encouraging sensory and emotional immersion

#13 Maintain physicality
While digital platforms offer convenience and accessibility, they frequently lack the tangible, physical elements and sensory experiences that are intrinsic to live music events. This also extends to a lack of tangible memorabilia like tickets or the inability to buy physical merchandise to remember the performance.
Participants said: *"When you go to a live event, you just have print your tickets, you have the possibility to buy some gadgets or maybe just have the flyer. It's something silly, but there's a tangible proof that you were there. On online events, it's quite different because how can you have a tangible thing back? I don't know if they can improve something like you participated in this event, we're going to send you something physical, maybe some things you like a key chain or something (PI9)."*
Designers could infuse physical elements into the digital music experience, for example by distributing specially designed kits to the audience before the event that include items that are synchronised with the performance, such as wristbands that vibrate with the bass, LED lights that change with the music's rhythm, or scented candles that correspond with the concert's theme.
#14 Engage the senses
Remote settings often fall short of replicating this level of sensory engagement, with the experience being limited to what can be seen and heard through a screen and speakers, leaving other sensory dimensions untapped.
Participants said: *"It's more of a sensory experience with live music, online music it's more just you seeing and hearing it (PI18)"*; *"Watching a live stream is more just a visual and audio experience and even the visual part is just staring at a screen rather than having, I dunno, pyrotechnics, and sure, you get that on TV, but when it's in real life, you feel the heat coming from the flames (PI2)."*
Designers could engage the audience's senses beyond sight and sound. By embracing multisensory design, designers can transform remote music events from experiences that are heard and seen into fully embodied journeys that transport the audience to a deeper level of connection with the performance.
#15 Embrace the home space
Attending a remote music event from ones own own space was considered one of the affordances of the digital space; one that in-person events can not offer. Nevertheless, participants commented on the many distractions they encounter when watching events from home which stop them from fully immersing themselves in the performance.
Participants said: *" I watch them on the TV with the lights off and warm clothes on my couch with my blanket, which was very comfortable (PI9)"*; *"It's very easy to get up mid-song and go make a cup of tea if you want to, whereas you would never do that in a live performance (PI15)."*
Designers could mitigate distractions and enhance the sense of presence and engagement during the performance for example by integrating a smart home integration system with a focus mode that limits non-urgent device notifications and suggests an optimal viewing setup, like dimming the lights or suggesting comfortable seating arrangements.
#16 From couch to the concert
Remote music events often lack this element of pre-event preparation, with attendees simply tuning in from their homes at a designated time. This ease of access can inadvertently diminish the overall experience. The absence of transitional rituals can also lead to a lesser emotional investment in the event.
Participants said: *"So people may RSVP. They may say that they're going to go and then they forget about it in a way that you simply wouldn't do if you had bought tickets [...] You plan your whole day around that. And the sort of intangibility of the remote event means that I think it is the perceived value is less and therefore the skipability or forget ability, I won't, didn't even think to put a reminder in my calendar for it (PI6)."*
Designers could incorporate elements of pre-event preparation to help fans transition into a performance-ready state. Designers could introduce features that encourage anticipation and preparation, such as virtual lobbies where fans can 'gather' before the show, or customisable avatars that attendees can dress up.
#17 Exclusivity matters
Digital events democratise access, offering a more uniform experience to a broader audience. However, because the content of digital events often remains available long after they have ended, this can reduce their sense of uniqueness and worth.
Participants said: *" If there was exclusive benefits from it, maybe bonus prizes or rewards, its difficult because there is so much free content out there, that there needs to be something that stands out for me to consider paying (unless I really support the performance or am a big fan) (PI1)."*
Designers could promote a sense of scarcity and value perhaps through availability only for a limited period or by offering extra content to a restricted number of virtual attendees. Moreover, attracting a more engaged audience willing to pay for premium experiences or tiered access could increase the revenue potential for artists.

6.3 Phase 2: Stakeholder engagement in a co-design workshop

6.3.1 The co-design workshop

In **Phase 2** of our project, I conducted a co-design workshop aimed at exploring and refining the design elements for online music performance technologies that were identified in Phase 1. The workshop brought together participants from different relevant backgrounds to interpret, ideate and discuss, using our data. With the workshop, I wanted to empower stakeholders to contribute to the research as co-design partners, actively involving them in the creative process of our research.

In organising this workshop, a strategic decision was made not to present the stakeholders with the pre-identified design elements. Instead, I provided them with *"how might we"* questions and selected portions of the raw data. The *"how might we"* questions were formulated by abstracting the key insights or challenges that have emerged from the data. These are:

- How might we encourage shared audience experiences during remote music events?
- How might we preserve the atmosphere of live performance during remote music experiences?
- How might we enable meaningful interactions between audiences and musicians during remote music events?
- How might we make remote music events more memorable?

This approach was designed to foster unbiased engagement with the data, encouraging stakeholders to form fresh perspectives and original interpretations. It was also intended to stimulate creative thinking and minimise confirmation bias, avoiding the influence of our own analysis on the stakeholders' ideation process. More importantly, our methodology allowed me to observe whether certain elements we had identified would naturally emerge in the stakeholders' discussions, highlighting which elements were most resonant and significant to the stakeholders, and providing a deeper understanding of the most prevalent aspects in designing for experiential engagement in remote music events. By involving stakeholders in this manner, I aimed to value their insights and promote a sense of ownership in the research outcomes, ensuring that the outcomes were organic and reflective of a diverse range of experiences and perspectives.

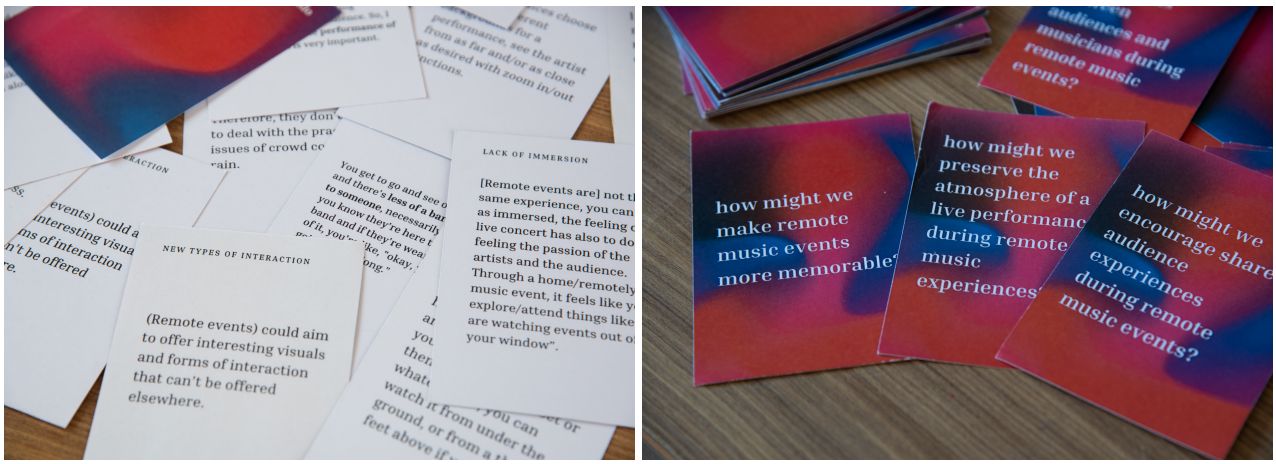


Figure 28: Deck of cards used at the remote music audiences workshop with stakeholders that featured bits of data.

Creation of data card deck. To provide participants with the *"how might we"* questions and the raw data, I devised an approach based on insights gained from prior workshops I facilitated, such as the one described in [118]. In these previous workshops, I observed that participants struggled with ideating speculative ideas from scratch when provided only with guidelines but no tangible material. To address this challenge and facilitate more productive discussions and idea generation, I took a proactive step and I designed a deck of cards based on the *"how might we"* questions and the raw data. This card deck was designed to serve as starting points, thus aiding participants in navigating conversations surrounding our data and offering essential support for their ideation and prototyping processes (refer to Figure 28). The deck includes 44 cards [46]:

- Four cards with the *How might we...?* questions that emerged from our data. On the reverse side of each card, I included curated quotes sourced directly from participants.
- Five sub-groups of cards, one for each of the following broad data categories: i) *challenges*; ii) *opportunities*; iii) *aspects to consider* when designing technology for remote music experiences; iv) *technology* and v) *ideas*. Each group contained 8 cards. These cards were designed with the category name displayed on the front, while on the back, they had participant quotes extracted from the most prevalent codes that had emerged from our data analysis.

Participant recruitment. I recruited 12 participants (ages between 18-40, 5 male, 6 female, 1 non-binary) for the co-design workshop through personal and professional networks (see Table 11. I reached out to people that I believed would be able to contribute meaningfully to the discussions around my work as well as bring a diversity of perspectives. Moreover, I selected people who were able to attend an in-person workshop. These included remote music audiences, musicians, DJs, de-

[46] the workshop materials are uploaded here: https://shorturl.at/ejDEW

signers, digital artists, researchers (in multisensory experiences, VR, AI and media) and event organisers. All participants self-declared as frequent concert-goers and had experience attending remote music performances. Moreover, their diverse involvement in the music industry, ranging from performing to organising, enriched the depth of perspectives and insights they brought to the workshop (see details about the occupation and relevance to the study of our participants in Table 11). Participants had diverse cultural and professional backgrounds. They came from 8 countries including Taiwan, the United Kingdom, South Korea, China, Romania, France, Portugal and the Philippines. All participants are currently living in the UK. Table 11 gives a detailed description of participant occupations, their relevance to the study, and the groups they were assigned to. Two additional researchers were present at the workshop: myself, as the workshop facilitator and a researcher who documented the process.

Table 11: Participants and groups for the remote music audience co-design workshop.

Group	**P.ID**	**Occupation**	**Relevance to the study**
Group 1: Shared audience experiences	P01	VR Researcher	Avid watcher of Twitch streams
	P02	Designer	Digital Arts student, experience with remote music audiences
	P03	Undergraduate student	Aspiring musician
Group 2 Atmosphere Preservation	P04	AI Music researcher/ developer	Occasional DJ, relevant research
	P05	Filmmaker	Organises and documents music events
	P06	User Experience designer	Works at live-streaming platform, research on musician-audience interaction
Group 3 Audience-Musician Interactions	P07	Media Studies student	In-person and remote concert goer
	P08	Postgraduate student	Part-time musician
	P09	Media Studies researcher and designer	DJ and creative technologist
Group 4 Memorable Experiences	P10	Multisensory XR researcher	Researches remote music experiences
	P11	VR developer	Worked with musicians to develop immersive experiences
	P12	Engineer and developer	Former musician, Eurovision fan

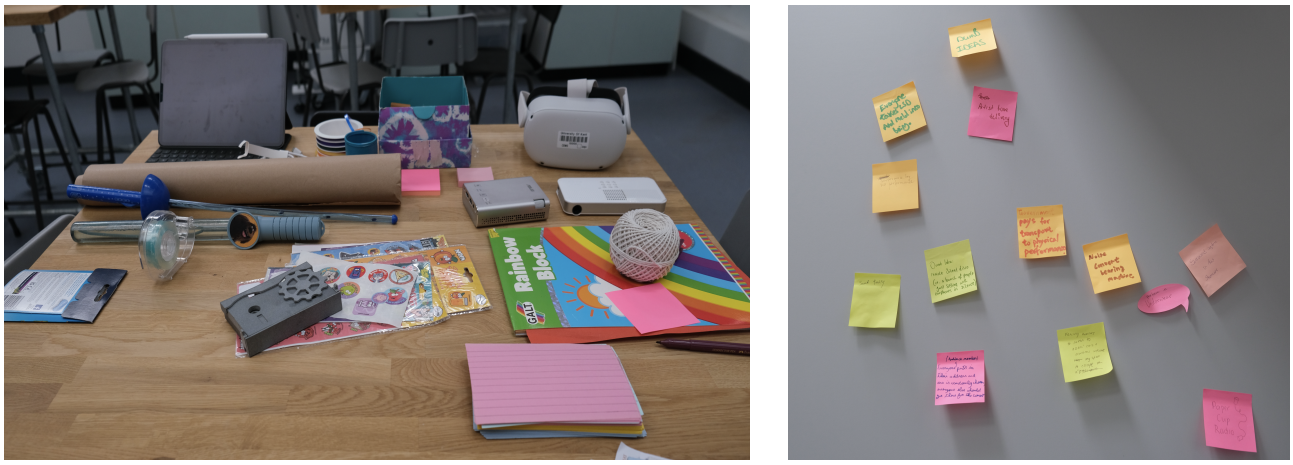
Workshop format.

The three-hour workshop was structured as follows:

Introduction - 10 mins. Participants were welcomed to the space, signed consent forms and were introduced the aim of the day.

Ice-breaker - 10 mins. To warm the group up and get them familiar with each other we started with an ice-breaker activity; participants had 1 minute to think of the worst idea they could propose around the theme of remote music experiences. Each participant had to write their idea on a post-it note and share it with the others, as well as introduce themselves to the group (see Figure 29b). The aim was to encourage dialogue and reduce self-censorship during the workshop.

Setting the context - 10 mins. The ice-breaker activity was followed by a 10 minute presentation on the study itself presenting how the *"How might we?"* questions emerged from the data and of their observations from the remote events they attended and the data gathered during Phase 1.



(a) Some of the materials used at the workshop.

(b) Worse idea ever activity.

Figure 29: Stills from the workshop.

Crazy eights - 15 mins. Participants were divided into four groups of three and each group was given a *"How might we...?"* question and a deck of data cards. Participants had 7 minutes to browse through the cards for some inspiration and to quickly familiarise themselves with the data. We then ran a crazy eights activity where participants had 8 minutes to sketch 8 ideas, addressing the *"How might we...?"* question they were given and inspired by the cards they looked at. The purpose of this was to get participants into a creative mindset and start getting them to think outside of the box.

Ideation and prototyping - 1 hour (with a 15 min break in the middle). Participants had 1 hour to ideate based on the *"How might we...?"* question of their group and develop a Wizard of Oz prototype that they would then showcase to the group. Participants were free to divide their time how they wanted during this session. Besides the card-deck, various materials were available: pens, post-its and paper for the ideation; and theatre props, projectors, VR headsets, musical instruments and smell stickers for the prototyping stage (see Figure 29a).

Enacting - 30 mins. Participants were asked to enact the prototypes they developed in front of the group, followed by a short presentation to explain their thought process and how they got to the idea they presented (see participants enacting their ideas in Figure 31).

Discussion - 30 mins. For the last part of the workshop an open discussion amongst everyone was facilitated, where they were able to unpack their experiences, comment on the ideas provided, as well as point out concerns and opportunities around the future of remote music audiences.

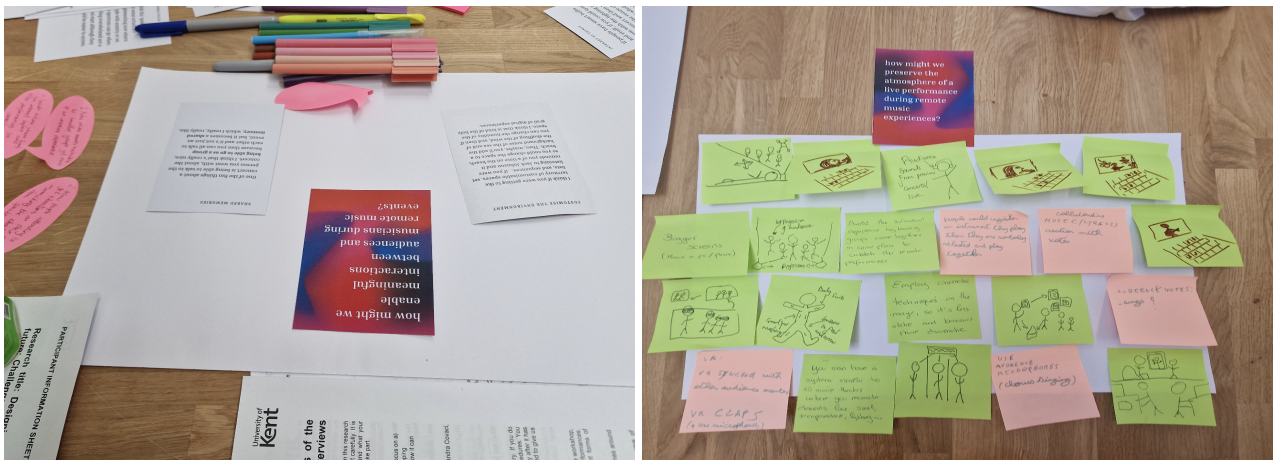


Figure 30: Stills from the workshop.

Final thoughts. At the end, participants were asked to anonymously write a final thought about the day such as feedback about the workshop or what stayed with them.

Data collection. Videos of the four enactment presentations and the discussion were taken and then transcribed for further analysis. Moreover, the post-it notes, drawings and prototypes from all participants were also used as data points. Notes were also taken during the workshop where possible, to support the data collection.

I examined the material developed during the workshop, including the four ideas and the data they originated from. This analysis was aimed at understanding the types of interactions stakeholders envisioned for remote music events and how they conceptualised these contexts. The next step involved mapping the workshop data back to the elements identified in Phase 1, to assess how the workshop ideas and discussions corresponded to, expanded upon, or contrasted with the original design elements, as well as investigating how those elements can respond to the four *"How might we...?"* questions we originally identified. During this phase I also remained open for the emergence of any new elements with inspirational value. This process was iterative, with the insights refined and further interpreted through discussions and reflections with other researchers. I discuss the findings of this phase in the discussion section. There, I take the outcomes of my research a step further, interpreting and articulating them as design directions, exemplifying them with existing work done in the space.

6.3.2 A portfolio of ideas for experiential engagement in remote music events

The four experiences that emerged from the workshop are presented here. I describe the design's premise, the experience, its features it uses and I highlight the design elements it points to.

(a) Participant enacting their idea, which includes food delivery while being in VR and enjoying the event.

(b) A "music box" prototype that features a projector which projects other audiences around the space.

Figure 31: Stills from the workshop

Digital harmony hubs

Group 1 (P01 – P03) had as a starting point the question *How might we encourage shared audience experiences during remote music events?* For this, they proposed a design for enhancing personal connections during the entire concert journey – before, during, and after the show – while also providing a sense of belonging to a broader community. Their concept promoted *a fully immersive experience*, where the *audience participates as avatars*. The design integrated the following features, which we detail below and discuss in the light of the elements resulted from Phase 1.

Private interconnected virtual spaces: Users should have the option to reserve a virtual space that mimics a VIP stadium booth. This feature would allow them to experience the event alongside friends who are in different locations. Participants can attend the performance with their selected group but also have the ability to see the booths of other audiences. This would allow for smaller, more meaningful interactions between audiences and artists while maintaining the feeling of a large crowd attending the event, pointing towards elements #1 and #2. Each space should include a stage where the performance occurs, creating an intimate setting that makes each group feel as if the performance is tailored specifically for them, pointing to elements #5 and #17.

Custom artist designs: The virtual spaces for each performance should be unique and based on the aesthetic of the artist performing, giving the audiences the feeling that they are stepping into the musician's world and strengthening the bond between them and their fans (elements #8 and #11).

Audience lobby: Before the performance starts, users would have the opportunity to enter a fan lobby using their avatars (element #4). Here, they can meet other fans from all over the world (element #1) and make new friends whom they might want to share their space with, thereby fostering new friendships and community ties. This space also acts as a social hub for organic discovery, where attendees can learn about new artists or performances from fellow fans (element #10).

Synchronised dining experience: The concept includes a synchronised food delivery system. Before the experience, the artist curates a food menu that attendees could opt to have delivered to their homes from their local restaurants (see Figure 31a). This way even in different locations attendees can share the same food, mimicking the shared dining experience one would have at a physical venue. Moreover, this adds a tangible, real-world element (elements #13, #14).

Merchandise and artist interaction: The concept also incorporates a virtual merchandise shop where audiences can buy items they like, which will then be physically delivered to their place. Here, the artist can hold signing events and meet-and-greet sessions for their fans (elements #6, #8, #13).

The sensory music box

Group 2 (P04 – P06) approached the *How might we preserve the atmosphere of a live performance during remote music experiences?* question through an experience meant to engage users on multiple sensory levels. They proposed a physical object designed for home use, which created an immersive concert experience beyond the screen (see Figure 31b). In doing so, the design sought to transform the remote music experience from a predominantly passive, observational activity into an interactive, multisensory journey. The following design features were proposed:

360-degree environmental projection: The device projects a live, atmospheric environment around the user, offering a panoramic view of the performance. Users can walk around it, engaging with the performance from various angles. They can also pause it, or replay it experiencing the same moment from different perspectives (element #5). In addition, this projection creates an immersive sound backdrop, complementing the visual experience (element #14).

Olfactory stimulation module: Equipped with scent cartridges, the device releases fragrances aligned

how might we encourage shared audience experiences during remote music events?

LIMINAL SPACES

When you go to a music event and you are in a space with a bunch of strangers and you're all just fans and the lights and the noise are funny, it feels very much like a liminal space. **It doesn't feel like part of the real world**, and then you leave and then the world is normal again. I find that so cool, and I think it's really hard to replicate that in your house.

CONCEPT PERFORMANCES

You could do things like **exclusive concept performances**, and create these really cool concepts and then share them as an online event, which you wouldn't be able to do on a stadium tour.

SHARED MEMORIES

One of the fun things about a concert is being able to talk to the person you went with, about the concert. I think that's really nice, **being able to go as a group** because then you can all talk to each other and it's not just an event, but it becomes a **shared memory**, which I really, really like.

BEYOND THE SCREEN

Well, I think that things would become more three-dimensional. They wouldn't be on a flat screen. So I would hope maybe you could walk around the actual event, hanging in your room rather than sitting on a surface in your room. So it'd be far more immersive. And I said maybe our environment would change at the same time.

LACK OF PRE AND POST EVENT RITUALS

It's a different experience. Live shows are not just "the show time" itself but everything around it: getting ready, planning, the "race for the tickets", the tension before the start. Things that a "at home" concert cannot provide.

Figure 32: Cards participants used to develop their idea around the question “How might we encourage shared audience experiences during remote music events”

with the concert's theme, enhancing the thematic immersion. This links to elements #11 and #14.

Haptic feedback system: To replicate the sensation of live music, the device integrates a sophisticated vibration system. This technology allows users to feel the music in a tactile manner, simulating the vibrations one would experience at a live venue, thus adding a physical dimension to the auditory experience and pointing towards elements #13 and #14.

Audience holograms: For users desiring a more communal experience, the device can project holograms of other audience members into their space. This feature fosters a sense of shared experience by visually and virtually connecting individuals in different locations (element #1).

Concert connect app

Responding to the question *How might we enable meaningful interactions between audiences and musicians during remote music events?*, Group 3 (P07 – P09) proposed an app-based concept to strengthen the interaction between artists and their audience in virtual music events, by giving audiences a voice in shaping the concert experience. The design includes the following features:

Audience-driven setlists: Through the app, attendees can use polls to vote for their favourite songs, ensuring the performance reflects their preferences (element #6, #7).

Co-writing music: The chat function allows for real-time collaboration between the artist and audience with attendees being able to contribute lyrics while the musician plays, fostering a playful co-creation process where the song evolves during the performance (elements #3, #7).

Unique merchandise: Unique merchandise, either virtual or physical, is available exclusively through the app. Artists can 'hand out' these items during the show, making the experience memorable. Physical merchandise could be delivered to the attendee's home before or after the event as a tangible memento (element #13).

Enhanced pre- and post-event engagement: Leveraging the virtual format, the app offers Q&A sessions with the artist before and after the performance, allowing fans to share the experience beyond just the music, building anticipation and prolonging the post-event connection (elements #1, #6, #16).

Accessibility features: Recognising the importance of inclusivity, the app incorporates features like close captioning, ensuring that the event is accessible to a diverse audience, including those with auditory impairments (element #12).

Dancing home appliances series

Group's 4 (P10 – P12) idea features an Internet of Things intervention which modifies the home space according to the concert involving the appliances one has at their home. Designed to immerse the audience in the music and enhance the connection to the virtual event, the smart home appliances become dance partners, turning the living room into a pulsating dance floor by receiving information about the show and responding to it (see Figure 33). Moreover, the concept proposes a series of multisensory abilities for the devices and a feature that randomly replays the best moments after the show. Central to this concept is the idea of engaging with things that people have at home, leveraging the physical space rather than transporting the user to a virtual environment. This way the home creates a new experience every time users attend an event, making each concert unique and memorable.

Figure 33: Participants enacting the dancing home appliance series

The design has the following features:

The groovy fridge: A fridge that has a built-in sound recognition system and a set of tiny robotic legs. When it detects music playing it starts swaying and displays colourful LED lights that sync with the music, creating an ambient light show that enhances the mood of the concert (element #14, #15).

Rhythmic washer and dryer duo: These appliances are activated during remote music events and are equipped with sensors that detect the rhythm of the music, synchronising their spin cycles to match the beat (element #14).

Pet engagement device: a "DJ Dog Toy" that reacts to the music, providing entertainment for pets and integrating them into the experience. These toys vibrate, light up, or play modified sounds in harmony with the concert (element #15).

Smart vacuum dance mode: Event experiences are saved and whenever the user vacuums the cleaner randomly replays music from past events but also performs a dance routine, turning a mundane cleaning session into an entertaining show (element #9).

Selective replay control for appliances: Each smart appliance can be individually programmed to respond to selected replay moments. For example, the user might want the Groovy Fridge to light up and sway to a particular song's chorus or release a specific scent during a memorable guitar solo (element #9).

6.4 Design insights for remote music experiences

My investigation into audiences participating in remote music events revealed important elements that are valuable when designing technology for remote music performances. They show the challenges and unmet desires from those who attend them, but also the opportunities audiences and designers see in technology for addressing them. Moreover, they enrich the previous work through their practical value – they offer actionable information about users that could be easily considered by remote music performance designers.

During the workshop even though participants did not have access to the 17 elements themselves, I found that the features of the speculative design ideas proposed invariably connected resonated with at least one of the elements, underscoring their pervasiveness and relevance. This is not to say that the list is comprehensive, but it points towards the usefulness of the elements and their potential to be used by designers. They serve as a bridge between theoretical understanding and practical application, providing designers with an audience-centric blueprint for crafting technology for remote music performances.

In the sections below I take the key outcomes of our research a step further, interpreting and articulating them as design insights, exemplifying them with our results, the discussions of the workshop as well as existing work done in the space with the aim to to offer practical advice (See Table 12 for a mapping of the insights with the elements and Ideas). The design insights were developed through conversations with my collaborators; namely Dr. Alexandra Covaci and Dr. Boyd Branch.

Table 12: Mapping of design insights to corresponding design elements and speculative design ideas.

Design Insight	**Related Design Elements**	**Associated Design Ideas**
#1 Redefining liveness – from *real-time* to *my time*	#9 Remote liveness, #14 Engage the senses	Sensory Music Box, Dancing Home Appliances
#2 Enhance audience experiences across event phases	#1 Tune in to kindred connections, #13 Maintain physicality, #16 From couch to the concert, #17 Exclusivity matters	Digital Harmony Hubs, Concert Connect App
#3 Balancing artist control and audience interaction	#6 Feeling 'seen' and 'heard', #7 Co-creation and collaborative artistry, #3 Encourage play, #4 Freedom for self-expression	Concert Connect App
#4 Balancing technology and authenticity	#5 Intimate encounters, #8 Behind the scenes and origin stories, #13 Maintain physicality, #14 Engage the senses	Digital Harmony Hubs, Dancing Home Appliances
#5 Creating *magic circles* in home settings	#14 Engage the senses, #15 Embrace the home space, #16 From couch to the concert	Digital Harmony Hubs, Sensory Music Box, Dancing Home Appliances
#6 Designing for multisensory immersion	#13 Maintain physicality, #14 Engage the senses, #15 Embrace the home space	Sensory Music Box, Dancing Home Appliances, Digital Harmony Hubs

6.4.1 Design insight #1: Redefining liveness – from *real-time* to *my time*

Liveness [17] is a defining characteristic of in-person events, which captivate audiences with their raw energy and unpredictable twiss. However, within the digital space, liveness becomes mediated and its meaning is constantly being re-defined by audiences [190]. Audiences have greater agency over their viewing experience: some stay synchronised with real-time music broadcasts, while others utilise the flexibility to pause or rewind. This means that not all viewers are experiencing the event in the same temporal frame. Yet, the shared content and the communal nature of the digital space ensures that audiences remain connected to a sense of a 'live' experience, bound by their collective interest in the event. In this context, *liveness* is less about temporal simultaneity and more about the depth of engagement and the shared experience, even if temporally staggered. This transformation has be outlined by Benford et al. [40], who discusses this fluidity of *liveness* in the context of the ethnographic account of two traditional folk clubs going live.

In addition, we found that even pre-recorded music performances can evoke a strong sense of *liveness* among viewers. Therefore, the perception of *liveness* becomes a combination of the viewer's belief, which is anchored by specific markers and cues within the content, and their active interactions with both the performance and other audience members. Nevertheless, this perception can vary. A viewer might feel a performance is 'live' due to real-time chat, even if the music is pre-recorded. Conversely, a lack of audience interaction or artist responsiveness might make a real-time

performance feel like a replay. Yet, such discrepancies highlight the multifaceted nature of live experiences: pointing to the need to explore how audiences perceive time during a performance, whether they value synchronous interactions with fellow viewers or the artist, or how they might switch roles - from a passive viewer to an active participant. The dynamic interaction with time has the potential to unlock novel creative avenues for performers and designers and help them craft experiences that truly resonate with the audience's evolving definition of *live*. The *sensory music box* design idea capitalises on this by proposing a projected environment around the user which they can pause, walk around and replay enabling them to dissect the performance how they see fit and view it multiple times from multiple perspectives. On a more general level we encourage designers to leverage this fluidity of liveness. They have the opportunity to craft experiences that, while not live in the conventional sense, still convey a sense of immediacy and shared presence. For example, designers could think about embracing the non-linear nature of digital experiences, offering viewers the ability to pause, rewind, or view asynchronously while still maintaining a sense of shared experience.

6.4.2 Design insight #2: Enhance audience experiences across event phases

In in-person music events, the audience's journey is a rich narrative, extending beyond the performance – from the anticipation leading up to it, the rituals of preparation, the travel to the venue, and the shared moments with other audiences. Within the event itself, there are *peak experiences* [167, 272], *the unexpected encores* [498], and the quieter reflective moments. This multifaceted journey, with its ups and lows creates memories that linger after the event concludes. However, with the advent of remote events, there is an immediacy to the engagement, which, while convenient, often hinders the audience's journey. The click of a button transports attendees directly into the event, bypassing the traditional build-up and rituals; events do not feel like occasions anymore [181]. Our study revealed that while the convenience of remote events is appreciated, the absence of a journey –like experience results in events feeling less special. The *Digital harmony hubs* idea showcased the importance of the event journey with the team focusing on other activities before, during and after (e.g., audience lobby, merchandise, eating) rather than the event itself. Participants argued that the importance of the activities surrounding an event are as important as the actual performance.

To recreate the depth and richness of live events in a remote setting, designers should think of the fan experience as an expansive journey, encompassing pre-event, live event, and post-event phases, each offering distinctive opportunities to deepen engagement and foster a sense of community [92]. In the pre-event phase, cultivating anticipation is crucial [512]. Strategies might include augmenting

the multisensory aspects of the event by distributing tangible objects associated with it, or involving the target audience in a co-design process to collaboratively develop an event blueprint that can be shared in advance. During the live event phase, designers should focus on triggering peak moments that mirror the highs and reflective pauses of traditional event experiences by accounting for spontaneous interactions or unexpected surprises, coupled with spaces for individual reflection [342]. Following the event, designers could think of including virtual lounges where attendees can interact, exclusive content releases that recount the highlights of the event, or Q&A sessions with the artist.

6.4.3 Design insight #3: Balancing artist control and audience interaction

The artist and their music are one of the main motivations for audiences to attend live music events [327]. The bond formed between the audience and performer is important, and studies have identified it as a significant factor not only for ensuring a pleasant experience but also for enticing audiences to return to future events [327, 372]. Our findings suggest that remote music audiences long for opportunities to interact during the performance and to co-create, wanting to have an impact on the music and the experience. The *Concert connect* design idea reflected this by proposing interactive set lists and collaborative lyrics writing. Nevertheless, during the discussion at the end of the workshop, one participant asked *"But what about the artist? What about their vision?."*

Indeed, when designing technology for remote music performances it is imperative to recognise the diversity in artists' preferences for audience interaction. While co-creation and audience participation are beneficial, there is also a risk of diluting the artist's original vision. If every aspect of a performance is open to change based on audience preferences, it might stray from the artist's intended narrative or emotional journey. Some musicians may embrace collaborative artistry with their audience, while others might prefer to maintain control over their artistry. Therefore, when designing technology for remote music performances it is important to ensure that the integration of audience interaction complements, rather than overshadows the artist's creative vision. The audience's participation should enrich the artistic narrative rather than redefine it.

Data from interviews and workshops also indicate that while participants welcome opportunities for collaboration, they also appreciate when the final output reflects a cohesive artistic vision rather than a fragmented patchwork of audience-driven choices. This balance can be informed by examining when and how users interact with creative elements. Participants expressed enjoyment in shaping certain aspects – like background visuals, minor setlist adjustments, or thematic prompts – when

these contributions felt like enhancements rather than overhauls. This suggests that designers can offer structured frameworks that invite audience contributions in predefined areas, allowing them to influence but not overshadow the artist's creative core, allowing artists to choose how much they want to involve their audience in the creative process and how [337]. To translate these findings into actionable strategies, designers might consider implementing tiered participation models, where the audience is encouraged to interact most intensely with peripheral or variable elements. These levels can range from low-interaction formats, where the audience's role is mainly observational, to highly interactive formats, including real-time polls for song choices or collaborative creative processes. Additionally, where audience interaction is present, it could be framed as a contribution to the artist's creative process, rather than a direct influence on the art itself, respecting the artist's primary role in the creative journey. Clear boundaries around key artistic decisions, combined with transparent communication about what aspects are open for influence, can ensure that freedom for self-expression does not erode the artist's narrative.

6.4.4 Design insight #4: Balancing technology and authenticity

Our participants expressed that for them, remote music events are distinct opportunities for novel engagement – with the other audiences, the artist and the performance itself. Audiences' desires to go beyond the usual boundaries of traditional concerts are not driven by nostalgia but by interest for diverse and forward-looking experiences. Our findings indicate that technology is not just an enabler, but rather a driving force for delivering extraordinary and seemingly impossible experiences [484]. Moreover, for artists themselves, technology presents an opportunity to overcome the constraints of the physical environments (e.g., venue size, logistical challenges, or budget constraints). This transformation is particularly valuable for smaller artists or those performing from home, who may have previously been restricted in their ability to deliver visually captivating performances.

Despite this, our audiences also yearned for the emotional depth and authenticity of in-person events, frequently making direct comparisons and highlighting the limitations of technology in capturing the feeling of live music. Their perspectives underscore a critical observation: technology, for all its advancements, is still often perceived as *intermediary* – a lens through which we access experiences rather than a space where authentic, standalone experiences reside [373]. Indeed, the concerns about remote events not fully replicating the aura of in-person ones [336], suggest that experiences are not just about sensory immersion; they are about the stories we tell, the memories we create, and the shared cultural and emotional contexts [282]. Data from speculative designs like

the Digital harmony hubs and the Dancing home appliances suggest that authenticity may emerge from familiar cultural gestures, small personal activities integrated into the event, and playful appropriation of everyday objects. Rather than relying solely on advanced graphics or intricate interaction patterns, authenticity can stem from how well the experience resonates with participants' own lives and social habits. This implies that authenticity may be better supported by features that acknowledge existing contexts [447], rather than forcing unfamiliar or overly engineered scenarios.

For designers, this brings a multifaceted challenge. While there is merit in curating technologically advanced and highly polished performances, there is also a need to embrace spontaneity and imperfection. These are elements that lend a unique character to the live event, contributing to 'liveness'. As found in [372], authenticity and how 'believable' and 'real' a performance feels, plays a huge factor in audience satisfaction. Instead of replicating in-person experiences, designers should aim to craft authentic digital experiences that celebrate these spontaneous moments.

6.4.5 Design insight #5: Creating *magic circles* in home settings

Our study's exploration into remote music experiences highlighted the need to redefine the role of physical space in enhancing audience engagement. Traditionally, music events serve as liminal spaces - thresholds between the ordinary and the extraordinary - where attendees transition from their everyday reality into a shared, heightened sensory world. This aligns with the concept 'magic circle' [256] in gaming, where a temporary, immersive environment is created for players where players willingly suspend disbelief. Audiences at a concert experience a similar feeling, embracing an alternate reality governed by its unique rules, making it easier for them to fully engage and lose themselves in the experience. In remote settings, especially within the confines of one's home, replicating this transformation of space presents unique challenges and opportunities. Our participants noted that while remote settings (i.e., homes) offer a comfortable and cocooning environment for music enjoyment [54], they often lack the distinct boundary between the ordinary (e.g., home chores, distractions, daily routines) and the extraordinary (the music event) that in-person events provide.

The shift towards remote music experiences necessitates rethinking how audiences interact with their physical surroundings during a concert, perhaps focusing on transforming the audience's home into an integral component of the performance. The goal is to turn ordinary spaces like living rooms, into *sacred*, immersive environments that transcend the typical associations these spaces might have with daily routines or distractions. Interestingly, three of the four design ideas proposed ways

to transform this physical space either by fully changing it into a virtual space (*Digital harmony hubs*); by augmenting it (*The sensory music box*); or by using existing elements of the environment such as electronic appliances (*Dancing home appliances series*). During the workshop discussion, participants elaborated on their choice of focusing on the environment/atmosphere of their ideas rather than the music itself. One participant noted that the home is where people view these remote experiences and probably where they struggle to connect because it is associated with daily life so when you go to a concert the space does not feel sacred anymore. Changing the environment can help the audience connect with the performance by making it feel like a special moment.

Building upon the "magic circle" analogy within this context, it becomes evident that the home offers a canvas for individuals to cocoon themselves in comfort while simultaneously crafting an immersive, event-specific space. Unlike the fixed boundaries typically defined by event organisers in traditional gatherings, the home introduces an element of adaptability and personalisation. The *Dancing home appliances* design idea exemplified this through the proposal of smart electronic appliances that respond to each performance. Here, attendees take on the role of creators, establishing their magic circle and establishing its boundaries by actively reshaping their living space in anticipation of the event. This act of self-driven creation could facilitate a deeply personal experience, where the magic circle's boundaries can be reshaped for each event. The challenge, then, is to fortify the magic circle against the distractions, interruptions, and the very familiarity of the home setting, ensuring that the music event's reality remains intact. Designers could think about developing applications or devices that allow audiences to customise their immediate surroundings, such as smart lighting systems that change according to the music's tempo or mood, or virtual reality overlays that transform the look and feel of a room. Moreover, another approach would be to provide audiences with sensory kits that can be used to enhance the concert experience at home. These could include items like scented candles to emulate the concert atmosphere, wearable haptic devices for tactile feedback, or DIY decoration kits to visually transform the space. Lastly, designers could think about utilising spatial audio technology to create an enveloping soundscape that transforms the acoustics of a home space, making it feel more like a concert venue.

6.4.6 Design insight #6: Designing for multisensory immersion

Our Phase 1 data showed a need of audiences for deeper immersion that engages multiple sensory modalities beyond traditional audio-visual formats. Moreover, during Phase 2, all four ideas generated by participants in our workshop included various elements of sensory immersion irrespective

of the *how might we* question they were given to address.

From a technological standpoint, the quest for deeper immersion suggested by participants can be met by creating innovative technology-mediated audience participation systems that go beyond mere screen interactions. This approach is supported by emerging research in mulsemedia [117], which explores the integration of touch, taste, and smell with sight and sound, thereby transforming the media consumption landscape. Designers are now challenged to leverage this multi-multi perspective, where multiple types of media engage multiple senses, to significantly enhance the quality of experience for audiences. This shift not only promises more engaging and immersive remote music experiences but also sets a new standard for how designers can create environments that fully captivate the audience's sensory faculties. For example, designers could consider integrating immersive lighting control with smart systems that dynamically adjust to the music's tempo or emotional tone, using interactive dance mats that allow users to interact with the performance, and incorporating scent diffusion systems that release fragrances aligned with the mood or theme of the music can add an olfactory dimension, making the event even more immersive and memorable, via systems like the ones described in [392, 466, 485].

6.5 Some reflections

6.5.1 Lessons learned from engaging with music audiences

Looking back at the approach I took in these two chapters, there is a clear contrast between the work described here and my earlier explorations in Chapters 3 and 4. There, I started from a more traditional perspective: understanding a user, identifying a problem, designing a technological intervention, and testing it with users. It was a straightforward, solution-driven process, where the technology often took centre stage, even if that was not my intention. Here, however, I deliberately chose a different route. Instead of jumping straight to designing new tools, I wanted to understand the situation as it currently stands – to observe how people already engage with remote music performances across a variety of platforms. The shift in perspective meant leaning into a more open-ended form of research. Rather than working from a predefined "problem to solve", I let the participants' experiences, both positive and negative, guide the inquiry. From their rich stories and my own observations, I identified a set of design elements that capture what people value, what frustrates them, and where opportunities for new experiences lie. In doing so, I allowed the data to lead me

towards insights that might otherwise have gone unnoticed. To test the relevance and resonance of these elements, I facilitated a co-design workshop where participants developed speculative ideas. Although the outcomes were intentionally futuristic and not immediately implementable, they were grounded in the real wants, needs, and behaviours of actual audiences. By working in this way, I could confirm that the design elements were not just abstract concepts but tangible stepping stones towards future designs that people might genuinely appreciate.

Of course, this approach was not without its imperfections. For one, relying on existing platforms and real-world practices meant I had to grapple with messy, complex scenarios. Audiences are not uniform; their motivations and tastes differ. The content they engage with is influenced by countless variables, from platform-specific affordances to personal circumstances. The data I collected, while extensive and multi-faceted, could never be complete and the way I presented it could never be complete. I could have written an entire PhD thesis only on that data. I had to make choices about which experiences to highlight and which perspectives to prioritise. Moreover, the workshop's speculative nature sometimes made it challenging to determine how the ideas might translate into real-world applications. Still, this more open approach offered a kind of richness that a purely solution-driven path might have missed as I discovered insights that come from lived experiences rather than assumptions. The results now serve as a foundation, not just for me but also for others who want to build upon a human-centred understanding of remote music performances.

What can others learn from this? First, that stepping back from a purely "problem-solution" mindset can open up new creative opportunities. When we stepped back from making new tools to see what's already out there, we find that the solutions people organically create can be more specific and adaptable than what we might invent on our own. Remote music audiences are not waiting passively for someone to hand them the perfect platform. They're actively repurposing tools, appropriating features, and blending different environments to craft experiences that meet their needs. Observing these practices feels like pulling back a curtain – behind it, there were layers of complexity and creativity we might not anticipate but we can learn a lot from. Second, that embracing the complexity of how people currently use technology can generate more meaningful insights than starting with a blank slate. Finally, that speculative activities grounded in real user data can help ensure that even your most imaginative ideas remain tethered to genuine human needs and desires. By honouring what audiences are already doing, I ended up with insights that feel both imaginative and realistically attuned to the people who will ultimately use these technologies.

6.5.2 Lessons learned from a stakeholder workshop

HCI research has long acknowledged the importance of working with a wide range of stakeholders, not just end users [94, 109, 313, 436]. Such engagements often bring in new views or opportunities that might not emerge if researchers only speak to users or rely on their own interpretations . This involvement has taken the shape of interviews, expert consultations, and conversations at different stages: for example to gather design requirements [364], evaluate systems [244, 379], comment on and contextualise the findings [518] or comment on catalogues of ideas [7]. As the field evolves, we see more collaborative and hands-on approaches. Co-design workshops, for example, encourage participants to take an active role, going beyond the classic "designer as interpreter" model and letting stakeholders themselves shape the direction of a project.

In my workshop, I aimed to experiment with this principle by giving stakeholders direct access to raw user data, rather than a neatly packaged set of conclusions. I wanted to see what would happen if participants had the chance to handle the data themselves: raw quotes, observations, and feedback from remote music audiences. Instead of me sorting it all out in advance, I asked them to interpret and build on what they found. The hope was that confronting them with material still brimming with ambiguity would prompt a level of creativity and authenticity that might not surface otherwise.

I offered the data in the form of physical cards, each containing a participant quote or a piece of insight. The **tangibility of data** turned out to be important, which aligns with findings from other researchers using cards as ideation materials [4, 219] . Having something concrete to move around, rearrange, and combine made it easier for groups to think about multiple angles. Participants actively referred back to the cards when explaining ideas to one another as explained by one of the participants during the workshop discussion *"For example, one of us might try to describe an idea, and use a card that describes something related for the others to use as an origin point of imagination. I think the cards were useful because the ideation was looking so far into the future, and a lot of it was intangible. It gets complex to explain similar ideas with VR, AR, XR, on top of the other technologies we were proposing, and these cards helped us keep track (P07)."* This hands-on approach allowed them to use the cards both as evidence and as starting points for speculation, blending what they knew about the data with their own experiences and expertise.

Although this tactic opened up new possibilities, it was not without its challenges. The sheer amount of data at times felt overwhelming. Some participants got stuck on a single detail or struggled to see the bigger picture. Others became so focused on aligning ideas with particular quotes that they

missed the chance to think more broadly. While giving participants raw data can spark new insights, it also calls for careful curation and pacing. This can be addressed in future workshops, by introducing data in layers, starting with a small set of quotes and letting participants move to a second, more detailed layer only when they are ready. Moreover, scheduled moments of reflection might help groups step back, repositions their ideas, and decides what matters most. Structuring the process in such way could prevent people from becoming overwhelmed or drifting too far into the weeds.

The choice to make the workshop **playful and performative** added another dimension. Instead of just talking about their concepts, participants acted them out. One team became appliances in a home responding to the music of a remote concert (see Figure 33). Another group integrated VR technology to simulate meeting spaces and backstage lounges. By physically enacting their ideas, they tested their feasibility and clarified what still felt too vague. Moving around and using props helped them think about sensory details and practicality. This performative approach lowered the formality of the setting and encouraged people to engage personally, rather than feeling they were simply evaluating a researcher's plan. Yet, too much playfulness can sometimes lead to overthinking and over-discussion. Some groups spent a lot of time interpreting a single quote or perfecting a small detail of their scenario, making it hard to reach a clear decision. In retrospect, introducing shorter time frames, breaking tasks into smaller chunks, or guiding participants past sticking points would have helped maintain momentum and prevented unnecessary tension. Although deep engagement is valuable, striking a balance is key.

Diversity in the participant pool also proved invaluable. Mixing audience members with designers, VR developers, and even a musician led to more comprehensive ideas. One participant questioned whether we were paying enough attention to the artist's perspective, a concern that had not emerged when looking only at user data. This moment underlined the importance of including different types of stakeholders. Audiences brought real-life experiences of attending remote concerts, while experts contributed technical knowledge and strategic thinking. This combination surfaced viewpoints that would likely remain hidden in a more uniform group. However, this diversity also made consensus harder, showing that setting up a structure for decision-making or having a facilitator gently guide discussions might be helpful when participants get stuck.

In addition, **introducing technology into the workshop environment** – VR headsets, smell prototyping, projectors—helped connect speculative ideas with real-world possibilities. By experimenting with these tools, participants began to envision not just the form or function of their ideas, but also the potential interplay with contemporary technologies. For instance, while a card drawing

represents a concept, a VR headset could bring that concept to life, connecting it stronger with its real-world application. As seen in Figure 31a, one of the groups used the VR headsets to convey that each person was in a different physical location but in the same virtual space. Another group chose to simulate the smell of a concert in their idea, using the smell prototyper by Brooks and Lopes [77], with one participant commenting during their final thoughts notes *"Using other senses will 100% help audiences to have memorable experiences [in remote music events]. (I feel like I still have lavender smell!)."* Additionally, the use of sound and projection further enriched the prototypes (see Figure 31b), allowing for a multisensory exploration of ideas. Integrating technology expanded the scope of prototyping and allowed participants to imagine future technologies. It also nudged them to consider the multifaceted ways in which existing technology can enhance user experiences.

Overall, the workshop lead to ideas and insights that go far beyond what we might have found through a more traditional, top-down approach. The data cards gave them something to hold on to; the performative aspects gave them freedom to experiment; and the diversity in the group made sure multiple angles were considered. Of course, the process was not perfect. I had to accept that not every group would reach a polished conclusion and that some discussions might drift off course. But this slightly messy approach felt valuable precisely because it revealed what people cared about and how they thought about the data. Sometimes the best way forward is to trust participants to wrestle with the complexity and come out with something meaningful.

I learned a lot from the workshop and I hope others can learn from my lessons too. When involving stakeholders directly with raw data, it is wise to manage the amount of information, provide opportunities for reorientation, and allow for moments when participants can reflect and regroup. Encouraging playful, performative activities can bring energy and fresh thinking to the session, but it's important to keep an eye on the pacing to avoid over-analysis. Technology can help participants imagine what their concepts might look like in practice, while ensuring the group is diverse and balanced can improve both the quality of ideas and the range of perspectives considered. Although the prototypes generated were conceptual and imperfect, they triggered discussions that led to deeper understanding of the user data and paved the way for future developments. Overall, the approach – handing over the interpretive role to participants and letting them engage with raw data – is not a one-size-fits-all solution, but it worked well in this context. I hope other researchers and designers consider trying something similar. The experience demonstrated that opening up the research process, letting people in on the data and the messiness that comes before conclusions, can spark creativity and deliver insights that more controlled methods might miss.

6.6 Limitations

This research, while providing valuable insights into the design space of remote music performances from the lens of audiences, has certain limitations that need to be acknowledged.

Sample size and scope: Remote music events are diverse, with countless ways for individuals to engage. Our study's limited sample size means we could not capture all possible experiences. While I aimed for a comprehensive view, the findings may not represent every audience type or experience. We also focused on specific digital platforms, which do not encompass the entire landscape. This might leave out nuances from unexplored platforms. Moreover, since our study was about the broader design space, there might be some platform-specific aspects we did not explore.

Generalisability: Our findings might not be necessarily universally applicable, as the elements identified and the resulting speculative design ideas are grounded in the existing practices of our participants and the events we observed. Some might not apply beyond the contexts where they were found, and there could be more elements on our list had we explored other settings.

Demographic limitations: Despite my efforts to engage a varied demographic, most participants were adults embedded in Western context with good digital access and familiarity. This demographic profile means that the insights of the study are, to a certain extent, a reflection of their socio-economic privileges. While these participants are among those likely to access remote music events, it is crucial to understand that their experiences might not be representative of the broader global audience.

6.7 Conclusion

In this chapter, I went beyond specific platforms to start investigating the design of technology that enables immersive remote music performances. My findings point out design insights, which I hope could provoke designers and researchers to explore this area. The scope of the studies in this part of my thesis was broad, covering a wide range of audiences, necessitating future work that is perhaps more targeted to certain types of events. Moreover, in this work, I focus on audiences rather than the artists themselves. Therefore, there is an opportunity for future research to build on mine by investigating the design space from the musicians' perspective and bridging the two key stakeholders.

Part IV

Bringing it all Together

In the final part of this thesis, I find myself looking back on both the journey and the work it has produced. When I started this research, I was driven by a desire to explore how we can design technology that supports the feeling of immersion that makes music performance so meaningful in remote and digital contexts. Over time, my goal expanded as I navigated the challenges of designing for a space where technology and human experience intersect in such interesting ways: musicians and audiences often appropriate technologies in ways that go beyond their intended purpose, seeking engagement, personalisation, and creativity rather than efficiency or user-friendliness [217]. The way they use technology tends to be personal, subjective, instrument or performance-specific, and difficult to generalise into specific recommendations for informing future designs [37]. Subjectivity means that any design framework or set of suggestions cannot be universal or draw definite conclusions of what would work and what would not. It should serve as a flexible starting point to inspire new explorations.

In this part of my thesis, I bring everything together, inviting others to reflect, question, and imagine what comes next. I synthesise the findings from my work and expand them into actionable design dimensions and directions. I also step back to reflect on the broader implications of my research, its messiness, and the personal journey it represents, and how it might inspire others in the field. In Chapter 7, I present a design toolkit for remote music performances, developed from what I learned and informed by related research. The toolkit introduces four design dimensions, offering rough areas to think about when designing technologies for this space. I then propose design directions to inspire designers exploring this field, exemplified through other work I or others have done. These are not meant to be exhaustive or definitive; they are starting points drawn from my experiences for further exploration. The toolkit represents my attempt to sketch a foundation that others can adapt and extend to suit their own contexts and needs. Chapter 8 shifts focus to the researcher's journey, something I feel is often overlooked in academic work. This chapter is deeply personal, as it reflects on what I have learned – not just through the research outcomes but through the process itself. It is a chapter about recognising the value of the journey, however messy it might be, and finding ways to embrace it as part of the process. Finally, Chapter 9 brings this thesis to a close by revisiting the research questions, summarising the contributions of my work, and discussing its limitations. I also outline opportunities for future research, acknowledging that this thesis is just one step in a much larger conversation. The work I present here does not offer all the answers, nor does it aim to. Instead, it opens up new ways of thinking about remote music performances and invites others to continue exploring and building on this foundation.

Chapter 7

A designer's toolkit for remote music performances

In this chapter, I synthesise the findings of my research into a design toolkit for remote music performances, inspired by the work of Malloch et al. [302] who proposed a design workbench for interactive music systems. The toolkit aims to provide starting points for designing remote music experiences, drawing from the insights I gathered through working with musicians and audiences. While rooted in the context of music, the ideas presented here have the potential to inspire design across other domains, such as other types of performance, entertainment, and remote collaboration. The chapter begins by presenting design dimensions that can ground and direct considerations for creating immersive remote music performances, where the experience is thought about first and technology follows. I then propose design opportunities that highlight the different roles technology can play in the context of remote music performances by offering specific pathways for innovation in this space. I demonstrate these with references to existing examples in the design, entertainment, and media spaces, or examples given by my research participants. I hope this chapter empowers others to take the next steps in the design space of remote music performances.

7.1 Dimensions for designing 'immersive' remote music performances

In this section, I propose a set of four dimensions for designing remote music performance. The dimensions are aimed to encourage designers to think about the kind of experiences they want to create *before* deciding on the technological means to achieve them. The dimensions draw inspira-

tion from Hammelburg's work Hammelburg [190], which examines how *'liveness'* and the feeling of *'being there live'* are constructed and experienced in contemporary cultural events, particularly those mediated by technology. Her research frames 'liveness' as **'being now here together'** – emphasising active engagement (*being*), shared temporal moments (*now*), layered spatiality (*here*), and social connection (*together*). She notes that people actively construct their experiences through media, shifting the focus from technological mediation to human interaction with the event itself.

While Hammelburg's work [190] centres on liveness and in-person cultural events mediated by technology, I brought these ideas into the remote music performance design space, where the interplay of technology mediation and experience becomes even more complex, as technology not only mediates liveness but also facilitates it. No technology = no access to the event = no liveness. The context of my work is not limited to 'live' events, but also encompasses other forms of musical interaction, including rehearsals and creative sessions, where the performance aspect is central to their occurrence. As a common thread throughout these distinct forms of musical interaction, performance itself inherently involves an element of 'happening' and, therefore, it is 'live', as the musicians need to play their instrument or sing for it to be a performance [432, 511]. Even when watching a recording of a performance, one watches with the knowledge that it was once 'live' at some point in the past. This differs from many studio recordings or digitally engineered pieces of music or other art, as these pursue the perfection of high level production over the potential for 'liveness', meaning that simultaneity of both music-making and/or audience reception is a defining component of all performances considered here, whether in-person or remote [449]. This influences my discussion of immersive experiences rather than live experiences, as I argue that for an experience to feel immersive, it needs, in some capacity, to feel 'live'. Those being immersed need to feel that they are participants of the experience; they need to feel present and in the moment, connected to the music, their surroundings, and, if applicable, others. Therefore, Hammelburg's dimensions still provide a good starting framework for thinking about immersive experiences as experiences where participants feel immersed through their interactions.

In the following sections, I apply Hammelburg's dimensions to the context of designing *immersive* experiences for remote music performances. While there will be some consistent elements, it is also important to recognise that this is not a one-size-fits-all recipe for someone to feel immersed in an experience. Experiences are subjective; they are personal and context-dependent, influenced by many factors [201, 309]. Hence, the dimensions I present are not prescriptive or universal (i.e., if considered, would lead to truly immersive experiences) but are meant to inspire and provoke.

7.1.1 Being - Presence

In Hammelburg's work [190], *being* signifies an active state of presence and engagement, involving both the event itself and fellow participants, emphasising active participation over passive observation. She argues that event-goers "inhabit space" through their media practices, using technology to anchor their physical presence in the event and create a sense of place. For example, actions such as visual presencing (sharing photos and videos that show "you are there"), locative practices (check-ins, location tags), and livestreaming, all contribute to this embodied experience of *being* at the event, even for those joining remotely. In the context of remote music performances, *being* can be understood as an active state of engagement or a state of feeling fully present, where participants interact with the performance (whether performing it or experiencing it), the environment, and, potentially, other audience members and musicians [201]. While discussions of presence in remote settings could be associated with technologies like VR [285, 427], *being* in this context does describe the same feeling but is not confined to VR environments or any environments in fact. It is about *feeling* 'in' the performance, whether that entails feeling in the environment or feeling in the moment when using the technological tool used to access the performance. Hence *being* is about evoking a sense of defined place with and through the performance [105], in a way that creates emotional, sensory, and experiential engagement, regardless of the medium [428].

For musicians, *being* denotes feeling fully present in their craft and the performance environment – virtual or physical –, including rehearsals, live performances, and creative collaborations, where the musician's engagement is tied to their ability to focus on their artistry and others' responses to their artistry [432]. This could mean inhabiting spaces or making use of tools in ways that support their creative flow and authenticity, free from distractions or disruptions that would take them out of it [403]. They need to feel both present and engaged [440]. For instance, the musicians I worked with emphasised the importance of being 'in the zone', [304] and described moments where they felt fully present when the technology faded into the background, allowing them to focus entirely on the music and the virtual space. When distractions arose, it was important that these distractions were not of the kind that would make them fully unable to play (e.g., the weight of the headset) but were the kind that could fuel creativity when they adapted to it (even latency). The first kind significantly altered their sense of *being* and made it non-existent, while the second kind, even if initially frustrating, was a type of distraction that they were able to adapt to and find ways around by thinking creatively. This was due to the fact that the virtual environment also facilitated a sense of *being* in and of itself, with latency as a function and characteristic of that environment. The

extent and nature of the latency is a factor here, as a slight degree facilitates creativity and lateral thinking, whereas excessive latency could generate too many practical and experiential issues and thus become a distraction that prohibits a sense of *being* [505]. In any case, whatever the purpose of the performance is, designing for *being* for musicians is about supporting them to feel immersed in their craft and empowered to adapt the performance variables to their needs, ensuring that the virtual or physical space or the tool supports their artistic expression.

For audiences, *being* involves cultivating a sense of presence and connection with the music and others in attendance [359]. Unlike traditional live events, remote experiences require intentional efforts to create a sense of *being there*, as it often competes with the distractions of everyday life, as seen from my data. Nevertheless, my research revealed that audiences crave for this sense of *being* and they adopt different strategies to achieve it. For instance, they actively shape their physical environments – adjusting lighting, using quality speakers, or even creating festival-like atmospheres – in order to feel more immersed or generate greater potential for immersion. When this sense of *being* lacks in VR, audiences there too, have tried to find ways to improve it, whether this is through investing in expensive equipment like high quality headsets, body tracking, and even haptic vests. Moreover, *being* also comes from moments of interaction with the artist or with other audience members. Active participation supports this sense of feeling present and in the experience or performance even if the sense of *being* in the space is not strong. As a result, participation can be used to compensate for, or mitigate a lack of physical immersion, when trying to create a sense of *being*.

This observation raises an interesting question: should *being* in remote music performances shift to *doing*? In remote contexts, participants often take on a more active role than in traditional live settings where presence can simply mean being in the physical space. In a remote or virtual environment, participants frequently 'do' things to achieve their sense of *being* [14] – whether it is performing, setting up their space, engaging with interactive features, or modifying their experience through platform tools. For example, audiences on platforms like Twitch or VRChat engage in interactive elements like chat, avatar customisation, or even influencing the performance itself [481]. Similarly, musicians may customise virtual environments or adapt their performance styles to fit the medium [403]. In this sense, *doing* perhaps becomes integral to achieving *being*. However, it is important to avoid reducing *being* to purely task-oriented actions. Musical experiences do involve moments of absorption, reflection, and emotional resonance [14], even from home. Audiences described moments of being at home *"just them, the artist and their music"*. Therefore, designing for remote music performances should balance opportunities for active engagement with spaces for contemplation

and connection, ensuring that the experience remains meaningful, allowing participants to fully inhabit the moment in the way they choose to [13]. In this case then the *being* dimension becomes about crafting experiences that support presence and engagement in all its forms.

The *being* dimension asks designers to consider how technology can enable musicians to feel immersed in their craft and audiences to feel connected to the event, regardless of physical location. In VR, *being* might mean feeling like you are in a concert hall alongside other attendees. On a livestreaming platform, it could involve real-time communication with artists or fellow viewers, where the shared experience creates a sense of belonging. Therefore I encourage you to ask: *How do we design experiences that allow participants to feel deeply connected to the music, the environment, and others involved? How do we account for the different ways people achieve this sense of presence, whether through interaction, customisation, or simply being immersed in the music?*

7.1.2 Now - Temporality

Now refers to the temporal dimension of liveness, emphasising the significance of experiencing a shared moment in time. Drawing on the concept of *kairos* [382] as a critical, opportune, or pivotal moment, Hammelburg [190] argued that the *now* of liveness is not confined to strict real-time simultaneity but instead encompasses a dynamic interplay of past, present, and future. She described how event-goers engage in practices such as 'pre-living' (anticipating future memories), documenting the present, and 'reliving' past moments through media [189, 191]. This fluid understanding of *now* acknowledges the multifaceted temporalities of mediated experiences, recognising that how we perceive and engage with the present is shaped by both the past and the future. Our present-day actions may too be shaped by past-oriented awareness of previous experiences and future-oriented thoughts of how we might remember the present event once it has become part of the past. Applying this into the context of remote music performances, *now* becomes equally fluid, shaped by how participants – both musicians and audiences – engage with time in order to enhance their connection to music. While in Hammelburg's work [190] the *now* is flexible, it still revolves around how attendees perceive and experience one singular moment in time, the moment of the performance. In online settings, that singular moment in time also becomes flexible [177]. For example, audiences may perceive a performance as being in the *now* even when it is pre-recorded but accompanied by real-time interactions. Musicians, too, may perform in the *now* while their audience engages asynchronously. Therefore, *now* in remote settings is in some ways co-created [115], balancing synchronous and asynchronous elements to shape a meaningful but perceived sense of immediacy.

My research revealed that for musicians, *now* involves engaging with their craft in real time, even when that time is disrupted or reshaped by technological constraints like latency. While latency can interrupt the immediacy of performance, musicians often creatively adapt to these challenges. Some musicians incorporated latency as a structural element in their music, using it to experiment with staggered rhythms or harmonies. Others reinterpreted familiar compositions, treating latency as an opportunity for innovation rather than an obstacle. Such examples demonstrate how musicians can reframe "temporal disruptions" as opportunities for creativity [505]. For creative musical practice, the fluid *now* could provide opportunities to reconceptualise time as a creative tool. Technology could offer features such as temporal manipulation, enabling artists to rehearse and perform in ways that are not possible in traditional contexts going beyond audio loopers to embodied practises and layering of experiences [252]. For instance, slowing down a section to refine technique, looping specific passages, or pausing to reflect on artistic choices could transform the rehearsal process into a more adaptive and iterative experience. In performances, temporal features like audience feedback loops or adaptive pacing could allow musicians to tailor the flow of the event dynamically. Such practices and intentionality could redefine the immediacy of performance, where the *now* becomes an adaptable and creative resource rather than a fixed and potentially constrictive point in time, while still allowing the musician to be in their physical *now*.

For audiences, the *now* dimension is shaped by platform affordances and individual preferences, offering a spectrum of temporal engagement [177, 359]. Digital platforms allow both synchronous and asynchronous interactions, enabling audiences to engage in ways that suit their needs [380]. Some may participate in real-time, interacting with artists and fellow viewers through live chats, while others pause, rewind, or revisit moments, experiencing the performance at their own pace. This flexibility blurs the lines between 'live' and 'recorded', focusing on the depth of engagement rather than strict simultaneity [190]. My research revealed that even pre-recorded performances can evoke liveness when accompanied by *doing* real-time interactions, such as audience chats or artist responses. Conversely, a lack of interactivity can make a real-time performance feel static [449]. Features that promote connection – such as live chats, responsive artists, or communal moments – anchor audiences to a collective *now*, even when their temporal experiences differ [482].

Here, an avenue for future research emerges: does the sense of *now* derive from a lack of 'pausability', as in, does the sense of existing in shared temporality with others partly come from the fact that you cannot 'pause' the flow of time in interactions with musicians and audiences? These real-time, unpauseable elements like live chats may succeed in generating the *now* of liveness insofar

as they are able to replicate the unpausability of live in-person events - do pre-recorded videos of live performances that lack these features feel less *live* and *now* because of their ability to be paused if one needs to refill a water bottle or answer the front door, without worrying about missing something? Remote events can thus generate *now*-ness [190] by experimenting with these feelings of immediacy and concurrent experience for musicians and audiences alike, suggesting that some degree of real-time element is important to generate the *now*. Recent anthropological research into videogame sociality has highlighted the importance of temporality, exploring how perceptions of time may be significantly altered by differing levels of engagement with digital environments [358] and developing novel methodologies such as 'chronotypology' through which to understand the different temporalities evoked by games [228]. This opens up the space for experimenting with the gaps and overlaps between 'real time' and the temporality of the performance and/or platform.

Overall, designing for the *now* dimension involves embracing the fluidity of time in digital spaces while creating presence and immediacy. For musicians, this could mean creating tools that enable temporal adaptation. For audiences, it requires balancing personalised engagement with shared temporal experiences. This could include tools that allow audiences to pause and explore the performance from multiple perspectives while preserving a sense of shared presence; making sure that asynchronous engagement does not detract from the ephemerality and uniqueness of the experience. The goal is to create moments that translate well into treasured memories, or moments that those experiencing view as worth being in and remembering [474]. I ask: *How can we design immersive experiences that allow musicians and audiences to experience time in ways that feel immediate and connected? How can tools and platforms amplify the immediacy of now moments while embracing the fluidity of digital interactions?*

7.1.3 Here - Spatiality

In Hammelburg's work [190] *here* represents a multi-layered spatial experience shaped by media. She argued that media technologies do not simply diminish spatial borders but create a plurality of event locales. This means that the *here* of an event can encompass: (i) the physical event location itself; (ii) various mediated spaces, such as livestreams, social media platforms, and even personal screens; and (iii) transformed home spaces that become dedicated 'eventspheres' for remote participation [492]. Moreover, *here* involves constantly navigating proximity and distance. What feels near or far to the event is not predetermined but is shaped by individual media practices of event attendees. Building on this, my research applies the concept of *here* into the context of remote music

performances, particularly in virtual and hybrid settings. In these performances, *here* is no longer tied to the physical location of the performance itself and the plurality of event locales is able to proliferate without physical limitation. The *here* becomes a flexible construct shaped by technological affordances and human interaction. In many cases, the *here* even becomes the tool or platform that facilitates the performance, such as VR environments or livestream platforms. The tool itself allows for the user to feel a perceived sense of proximity, despite a physical distance, either through interaction with others, the music, or the virtual space. This perspective encourages designers to focus on how spaces and tools – both physical and virtual – can support engagement and immersion, transforming spaces (literal or metaphorical) into meaningful places [105, 198].

For musicians, *here* is closely tied to their sense of connection to the performance environment. Virtual spaces, such as those provided by *VR Rehearse & Perform*, allowed musicians to rehearse in iconic venues or fantastical spaces [266, 364]. These environments helped musicians feel 'present' even when physically at home, turning virtual spaces into places through interaction and creativity. The process of transforming space into place depended on sensory and embodied engagement. Musicians emphasised the importance of auditory feedback, noting that spaces lacking good sound felt incomplete and detached. For some, when their headphones were off and the sound of the virtual space was blending with that of the physical space, the sense of being *here* was diminished. For others, the blending of the two made the *here* stronger, because the sound was reflecting in a physical environment as well. This highlights how the auditory dimension shapes spatial experiences, but still remains subjective.

Moreover, musicians described virtual environments as both instruments and stages, where their interactions actively defined the space's spatial and auditory qualities [258, 400]. Just as physical venues are shaped by their materiality and history, virtual spaces (whether visual or not) influence musicians' creative processes [104]. When designing tools for musicians for a remote *here*, it could be argued that facilitating a sense of auditory connection with the performance environment is more important than the visual one – whether that is the physical or virtual space they are playing in or even the tool their sound comes to them through [14]. Nevertheless, it is important to note that the sense of *being here* might deteriorate if the audio and visual do not match – i.e., the space sounds different than it looks like. Even though in theory this is something that could trigger creativity, I found that musicians felt really uncomfortable having a big reverberation in a small room or vice-versa. While a person without an attuned ear might not have noticed, for musicians it was important and this sense of connection or coherence between the visual and sonic was key.

For audiences, *here* is shaped by their engagement with physical, virtual, and platform-specific environments [177]. Audiences in livestreaming platforms reported a stronger sense of *here* when they could interact with others, transforming digital spaces like Twitch from a passive setting experienced through a screen into a shared, active place where viewers collectively engaged with the performance, creating a shared focus and redefining spatiality [454]. For others, their own homes were the *here*, particularly when they prepared their space specifically for the performance, whether that involved a complicated set up like a mini festival in the garden or a simple set up with dimmed lights, a glass of wine, and a blanket. For Social VR audiences the *here* was the virtual space. However, interestingly in the cases where there was more than one iteration of the event, the *here* was the one with the 'real' artist or artists in it, not the one with the recorded instance of the artist, even if in both occasions the artist looked exactly the same. The *here* without the real artist felt not 'live' even if in the other dimensions it was.

Both musicians and audiences turned spaces into places, achieving a sense of *here* by engaging with the performances meaningfully through their patterns of use, shared understanding, and social or embodied interactions [139, 198]. This resonates with Hammelburg [190]'s argument that media practices become acts of "embodied placemaking", through which people actively "inhabit space", transforming locations into meaningful event locales. Similarly, online, through their interactions, whether embodied or not, users engage in digital "placemaking" practices, that turn the performance 'space' into a meaningful event locale. Moreover, this aligns with Benford and Giannachi [37]'s idea where participants collaborate co-produce meaningful event geographies. *What if we, as designers, leverage every aspect of the digital space (soundscapes, visual design, interactive elements) as raw material for placemaking, guiding participants to turn music performances into deeply resonant, memorable places?*

7.1.4 Together - Sociality

Hammelburg [190] stressed that a sense of 'being *together*' is crucial to experiencing liveness. Without a social context, connections to unfolding events lack significance and meaning. *Together* is not a given but is actively constructed through the interplay of people and technologies. Social media practices, like tagging friends, using hashtags, or live streaming, shape and are shaped by concrete socialities in eventspheres. In this context, media practices become performances of social identity and relatedness, allowing individuals to express belonging and connect with others who share their values or interests [407]. Within my own work, sociality is also one of the factors that appears to

contribute to an experience being immersive. In remote music contexts, sociality emerges through text chats, emojis, voice interactions, avatar gestures, or even subtle audience-to-audience acknowledgements [481, 483]. This communal sense of co-presence draws on insights from music sociology [433] and digital fandom studies [35], which reveal how audiences form micro-communities and musicians respond to and riff off these collective energies. It also relates to how participants negotiate their roles, whether as performers, active contributors, or silent onlookers who still affect the group dynamic simply by 'being there'. Within the remote context, *together* dimension is about crafting opportunities for participants to co-create an atmosphere that feels engaging and meaningful.

While in my first two chapters on musicians I focused on individual musical practice, *together* was a key element that musicians felt that they were missing from *VR Rehearse & Perform*. The isolation imposed by COVID-19 and its disruption of in-person creative practices brought to the surface how essential social ties are to their artistry and wellbeing [85, 414, 443]. During interviews, many musicians described struggling with remote collaboration tools, pointing out the loss of spontaneous exchanges and the emotional charge that comes from playing *together* with other musicians or audiences. Although latency issues, poor sound quality, and missed non-verbal cues complicated remote musical interactions, artists still sought opportunities to connect through the tools they had available to them and even those who were generally opposed to the integration of technology embraced it for the sake of maintaining social connection [40]. My prototype, *VR Rehearse & Perform*, did focus on solo practice, but its potential for supporting collaborative features was clear. Musicians I worked with expressed interest in immersive platforms where they could rehearse, improvise, or experiment side by side with others, virtually inhabiting the same environment, hearing and responding to each other's playing in ways that feel natural and immediate. This was something that I emulated artificially in the third iteration of the software by adding pre-recorded musicians, but it was not the same. Playing *together* is also the first thing that comes to mind when I talk to any musician about my work on remote music performance.

For audiences, *together* is perhaps the most important dimension of the four, whether this is understood as being *together* with other audience members or being *together* with the artist [454]. In remote music performances, the audience were active participants who co-created the event's social atmosphere. Even when the performance was not live but pre-recorded, the audience *together* created the sense of being through interacting with each other. Each interaction amplifies the sense that everyone is immersed in a common experience unfolding before them, even if they are physically apart.

In these remote experiences, *togetherness* is about forging and sustaining emotional and social ties across distances. Designers should consider how to design for trust, camaraderie, and empathy among participants who may never meet in person. Interactions – whether synchronous or asynchronous – become moments of shared cultural production, generating communal memories and reinforcing a collective identity bound up with the musical experience [481]. As participants engage with one another, they bring their personal contexts, cultural references, and emotional states, ultimately shaping the community's narrative and making the experience feel meaningful and immersive. The inside jokes and evolving rituals that emerge in these digital eventspheres create a communal energy that cannot be replicated by technology alone. Social cues also enhance immersion. Audiences reported feeling more present and emotionally invested when they noticed others reacting in real time, even if they themselves were not interacting. Moreover, *togetherness* extends beyond the digital space. In physical settings, when participants adjusted their environments to match the event they were watching, it was never a solitary act [454]. These changes were made to share the experience and attend the event *together* with others.

Designing for *together* means treating remote music technologies as fertile ground for social connection [359]. This could involve implementing features that encourage collective co-creation – such as collaborative playlists, audience-driven set lists, interactive polls, or breakout rooms where small groups discuss the show. It might mean enabling micro-interactions (e.g., a nod, a clap, a short message) that remind participants they are all part of a living, breathing cultural moment. Immersion, in this sense, stems not only from how participants feel about the music itself, but also from how they feel about each other, linked by a shared emotional landscape that deepens their involvement. So the question then is: *How can we shape remote music environments so that participants feel genuinely immersed in each other's company, rather than as isolated observers of a distant event?*

7.1.5 Interweaving the dimensions

Being, *now*, *here*, and *together* do not operate in isolation. They overlap and influence each other as participants negotiate presence, time, space, and relationships [190], echoing Dourish [139]'s argument that social and cultural practices shape how we interact with technology. Each dimension, when considered with sensitivity to personal and collective meaning, encourages designers to prioritise human experience and interpretation over technological capacities or specifics, focusing on crafting experiences that feel alive – experiences where participants are truly *being*, fully in the *now*, embedded in a meaningful *here*, and genuinely *together*. Rather than focusing on what technol-

ogy can do, these dimensions prompt designers to ask questions [309] like *"How should technology feel?"* or *"What type of participation do we want to enable?"* *"How might we cultivate meaningful interactions between people, music, and place for remote music performances?"*

In this context, technology becomes a means to an experiential end, not the driver of the experience itself. I encourage designers to think about experiences that feel alive and *human*, no matter how advanced the underlying technologies are. Instead of seeking a perfect technical solution, designers could find value in trading off features that serve minimal or no experiential purpose. For instance, instead of focusing on ultra-realistic 3D graphics, they might invest time in improving audience-to-performer communication tools or refining the spatial acoustics that matter more to musicians and listeners. Similarly, rather than forcing everyone to experience the event simultaneously, designers might embrace asynchronous participation if it better serves reflection and inclusion. These dimensions do not guarantee immersion, but they help designers think about remote musical experiences as lived situations rather than technical outputs. By asking how to support *being*, shape the *now*, cultivate a meaningful *here*, and promote genuine *togetherness*, designers can create remote music performances that feel immersive and worthwhile in their own right.

7.2 Design opportunities for remote music experiences

The dimensions discussed so far offer a perspective for thinking about remote music experiences from an experience-first standpoint. They prompt reflection on presence, time, place, and social connection, encouraging a shift away from technology-led approaches. To move from reflection to action, this section proposes a series of short and focused design opportunities. Each opportunity acts as a practical lens to address specific challenges or opportunities within remote contexts. Some were directly inspired by ideas and suggestions shared by participants throughout this research. Where relevant, I have included indicative quotes to show how these ideas connect to participant reflections, though these quotes are not presented as results. I refer to musician participants as M-PID and to audiences as A-PID. Other opportunities emerged from my own synthesis of the research findings, my positionality as a designer working in this space, and insights from related projects and published work. For example, topics such as accessibility reflect broader design concerns that were less central in participant discussions but are nonetheless important to consider. The opportunities are intentionally concise, avoiding extensive discussion or references back to scholarship or my original data, so that designers and researchers can easily adapt them to different contexts. They serve

as inspirational starting points rather than prescriptive findings, inviting experimentation and iteration, ensuring that future work can explore diverse paths and refine approaches based on emerging findings and evolving needs. The section is organised according to different purposes or priorities that designers may have to facilitate ease of use.

Designing for music training. Musicians in the interviews identified the potential of VR to enhance musical training. Remote platforms could support music education by enabling learners to connect with professional musicians, attend masterclasses, or receive personal feedback regardless of location. Artists in training might practice by stepping into their teacher's role virtually, observing technique and style from a first-person perspective. For example, the VR experience I created for the RCM Percussion Festival allowed young people to play a drumset alongside professional musicians[47] (see Section 8.2.2 for more information). Moreover, technology could provide a safe environment for tackling performance anxiety [56]. Simulating a stage setting with adjustable crowd sizes or acoustics could help musicians build confidence in varied scenarios [16]. One participant suggested that technology could *"help [musicians] see how they are performing something, either recording it or in real-time becoming an audience member. So, seeing myself performing, rather than seeing from my POV. For me, watching myself perform as I'm performing could be quite useful. Because I could choreograph and try out things (M-P1)".* Platforms might record performances from multiple angles, allowing musicians to analyse instrument handling and sound balance from different corners of the venue – including hearing themselves from an audience seat, observing subtle technique details close up, or experiencing the acoustics from afar. An example of these possibilities in action is the immersive experience by the Philharmonia Orchestra conducted by Esa-Pekka Salonen[48]. Through the app, users were able to move on the stage exploring the various sectors of the orchestra, stand near the conductor, see the backstage, or enjoy the performance from the usual seats. Moreover, features like mirrors, similar to those in VRChat [164], or the musicians' mirror by Arthur Carabott[49], could assist learners in refining their technique by observing themselves in real-time.

Designing for collaborative artistry. The findings from Chapters 5 and 6 show that audiences want active participation in music performances, seeking involvement that goes beyond simple acknowledgment from artists. Participants highlighted examples of artist-audience collaborations on platforms like Twitch and Instagram, where remote audiences could contribute to performances in real

[47] `https://shorturl.at/22MKf`
[48] `https://shorturl.at/G8VnI`
[49] `https://www.arthurcarabott.com/musicians-mirror/`

time. This interest suggests that remote spaces enable new forms of collaboration, reshaping performance dynamics. Designers could create tools that allow audiences to influence creative and technical elements, such as shaping musical content, contributing visuals, or voting on performance opportunities. Examples of such interactions are already emerging. One participant described Snow Patrol's collaborative songwriting on Instagram, where audience-submitted lyrics via the chat were incorporated into songs, creating a sense of shared ownership. On Twitch, extensions enable audiences to vote, receive shoutouts, or influence on-screen activities, tools that artists are increasingly adopting[50]. Similarly, platforms like VOLTA XR let audiences adjust visuals during performances through phone apps or live chat. This could also enhance hybrid performances, allowing remote audiences to control elements like projections in physical venues, strengthening their connection to the event. Interfaces like voting systems could further blur the lines between performer and audience, enabling degrees of co-creation previously unattainable.

Designing impossible experiences. Musicians and audiences in my studies highlighted how technology can create experiences impossible in real life. Musicians imagined performing in fantastical or unattainable locations, like floating stages or sacred concert halls, or experimenting with unconventional environments designed to challenge their focus and creativity. One participant suggested, *"It would be interesting to perform in environments totally not conducive to music, like a city street or a traffic island in New York, to test how well you can focus and adapt".* For audiences, technology offers the chance to stand beside their favourite artists during performances or see a concert from the artist's unique perspective. Designers can tap into this potential by creating dynamic stages that morph to the music, gravity-defying platforms, or ephemeral venues that exist only for a single performance. Interactive environments could even let audiences influence the performance narrative, adding a participatory layer to the experience. Real-world examples showcase this potential. Fatboy Slim's VR experience transported audiences into surreal, mind-bending environments while allowing the artist to anonymously join the audience and experience his music from their perspective[51], [52]. Imogen Heap's VR performance took audiences to a magical reimagining of her childhood home, blending personal history with immersive visuals[53]. Embracing the impossible, can help designers create performances that redefine artistic boundaries, offering memorable experiences for both musicians and audiences.

[50] `https://www.twitch.tv/p/en/extensions/`
[51] `https://engagevr.io/fatboy_slim_concert/`
[52] `https://voicesofvr.com/1215-fatboy-slims-groundbreaking-trippy-vr-concert-on-engagexr/`
[53] `https://www.theverge.com/2018/8/23/17769166/imogen-heap-concert-oculus-vr-headset-thewavevr`

Designing for physical experiences. Participants in the interviews noted that the lack of tangibility in remote music performances often made them less memorable. Some suggested physical artefacts as a way to address this, with one participant saying: *"You could maybe receive something after attending an event at home, like a flyer, or a key chain, or something. Just so you say you attended this. It's something silly but something that is proof that you went there (A-P106)"*. Participants in the workshop (Chapter 6) further envisioned integrating physical devices into remote performances, highlighting that not all innovations need to remain on-screen. Tangible artefacts such as sensory kits, wearable instruments, or interactive devices could connect audiences to the performance's tactile elements. For instance, a device might emit vibrations synchronised with the bass line, or smart lighting systems could adapt to tempo changes, transforming the living room ambiance to match the music's mood. These ideas blur the line between remote and live experiences, reconnecting audiences with the physicality of music. Inspiration for such designs can be drawn from existing trends. Gaming communities often use colour-changing LED light strips that synchronise with on-screen visuals to create immersive atmospheres. A participant imagined how syncing smart bulbs to concert lighting could enhance the experience: *"If you could sync them with the lighting on the concert and then when you see the venue change colour, your whole room does. That's cool because it gets you more in the atmosphere (A-P107)"*. Physical festivals like Tomorrowland 2024 have also explored this, through some of their on-site installations offering attendees the chance to customise private spaces with personalised lights, ambiance, and scents for intimate rave experiences. Similarly, K-pop concerts increasingly use synchronised light sticks that change colour in unison with the music, creating a shared experience for both in-person and remote audiences. For example, IU's concerts allow light sticks to sync via Wi-Fi, connecting fans globally. Integrating physical and digital elements can help designers of remote music performances create experiences that resonate both emotionally and physically and, therefore, become memorable.

Designing for accessibility. As seen from my results, remote music experiences can reach far beyond the physical constraints of a traditional venue, making performances accessible to those who face barriers to in-person attendance. While traditional venues often incorporate features for mobility access[54], challenges such as travel difficulties, fatigue, or the need for medical equipment can still impede participation, as seen in research on the difficulties that disabled audience members may face in attending outdoor music festivals [31]. Additionally, individuals with auditory or visual disabilities may encounter obstacles that hinder their enjoyment of live performances. While Wembley

[54] `https://shorturl.at/ABWg9`

Stadium integrates British Sign Language interpreters, audio descriptive commentary, and hearing aid induction loops, remote performances could go even further to enhance experiences of those with auditory and optical challenges [69]. Interfaces could provide captions for lyrics or visual representations of sound for hearing-impaired participants. Sensory feedback tools—tactile or haptic devices—could let participants feel the beat through vibrations or see the music represented visually. Such approaches align with inclusive design principles [418].

Designing for cross-cultural exchange. Remote music performances enable connections across cultures, allowing audiences to explore traditions, instruments, and styles from around the globe. Participants in the audience study shared how these performances helped them connect with artists from other cultures, like the Korean boy band BTS. This often inspired them to learn more about the cultural context of the music, demonstrating the power of music to transcend borders and foster curiosity. The cross-cultural potential of remote performances extends beyond audiences and musicians to broader opportunities for cultural exchange. Designers could create features like integrated chat translation tools for real-time communication, or interactive maps tied to performances to situate music within its geographical and cultural context, enhancing understanding and appreciation. Such tools can break down stereotypes and encourage richer dialogue, as supported by research in intercultural communication and cultural psychology [202]. Examples of the appetite for cross-cultural exchange are already visible in digital spaces. Belgian creator Ed People's Teach Me Your Favourite Dance Move series, where he learns and shares local dance steps from different cultures, has garnered millions of followers and is celebrated for fostering a sense of belonging across divides[55]. Similarly, music platforms could offer features like virtual call-and-response sessions inspired by global traditions, or highlight unique cultural events such as folk festivals, drumming circles, or classical concerts. Integrating these tools, platforms can enable users to attend a folk festival in Reykjavik, or a street performance in Mexico City – all from home.

Designing for sustainability. In-person music events often require significant travel, energy-intensive lighting and sound systems, and large-scale infrastructure, all of which contribute to carbon emissions and resource consumption [475]. Participants in my study noted that remote music performances could help reduce some of these environmental impacts by cutting down on travel, waste, resource usage, and venue operations. However, remote events are not entirely free of environmental costs, as hosting them requires energy to run servers, stream high-quality audio and video, and

[55] https://www.socialnationnow.com/ed-people-brings-people-together-through-dance

power devices [305]. Additionally, the proliferation of short-lived equipment, such as VR headsets with limited longevity, further contributes to environmental strain [331]. Designers could create tools to inform users about their environmental impact. For instance, a streaming platform might display how much carbon emissions were saved compared to attending in person or provide tips for reducing digital footprints, such as opting for lower-bitrate streams when possible [370]. Energy-efficient rendering of virtual stages, promoting modular hardware upgrades to extend device life, and supporting eco-friendly hosting services[56] could further minimise environmental costs [153]. In this way, remote music platforms could reduce some environmental burdens of traditional shows and inspire participants to make conscious choices about their digital consumption.

Designing for monetisation. During my interactions with musicians amid the COVID-19 pandemic, I heard first-hand accounts of the financial challenges they faced. Years after the lockdowns, many have taken on additional jobs alongside their musical pursuits to sustain themselves. This reflects a broader shift in the industry, where the pandemic exposed the precariousness of creative work and forced musicians to adapt in diverse ways [85, 413, 414]. These challenges are compounded by ongoing changes in the traditional music economy. Once driven by record sales and album releases, the industry now relies heavily on streaming services, which often provide minimal revenue for artists. As a result, many musicians are turning to experiences such as live performances and remote engagements as a key source of income[57]. Remote music performances present opportunities to capitalise on the growing importance of experiences in the industry. Research on fan communities highlights that audiences value opportunities to engage closely with artists, especially when they feel part of a shared event [35]. Designers could develop monetisation tools that empower musicians, such as exclusive sessions, subscription-based access to rehearsals, interactive performances, or behind-the-scenes virtual tours. Integrated tipping (such as Twitch bits), audience-driven set lists (where fans sponsor a song), or 'VIP' rehearsal passes can create new revenue streams that encourage a sense of connection and participation. For example, on Twitch, fans can donate to streamers money or Twitch bits to support them, with some streamers having leaderboards and awarding viewers with specific perks[58]. Platforms must also reconsider their role in sustaining musicians. This could include fairer revenue-sharing models, sponsorship opportunities tailored to independent creators, or features that prioritise audience-artist engagement. Examples of these efforts already exist. Twitch's subscription tiers allow artists to earn directly from their audiences[59], while Bandcamp waives plat-

[56] https://www.thegreenwebfoundation.org/tools/directory/
[57] https://www.ukmusic.org/wp-content/uploads/2024/11/TIM-Report-2024-reduced.pdf
[58] https://jinglejam.tiltify.com/
[59] https://www.twitch.tv/creatorcamp/en/paths/monetize-your-content/twitch-basics/

form fees every Friday to support musicians[60]. Platforms like VOLTA XR offer free software to artists and enable monetisation through audience contributions or events themselves[61]. Shifting monetisation from selling commodities to creating unique, participatory encounters can help platforms and tools better meet the evolving needs of artists in the post-pandemic landscape.

7.3 Closing thoughts

Designing immersive remote music experiences involves more than translating live events into pixels and streams. It calls for embracing human-centred practices, creativity, and curiosity in ways that recognise the fluid boundaries between physical and digital [93]. Audiences and musicians do not enter these virtual spaces or use the tools as blank slates; they carry expectations, insecurities, tastes, and emotions shaped by their everyday lives. At the same time, their experiences with technology often return to influence their offline perspectives. This reciprocal relationship – where actions and emotions flow back and forth between worlds – demands a design approach that respects and celebrates the complexities of being human. A thoughtful designer might ask how new technologies can balance innovation with users' well-being. Experimental platforms can inspire new art forms and build communities, but they may also lead to unsettling or addictive experiences. Imagine a future where immersive virtual venues overshadow small local music scenes, or where the social fabric of physical gatherings erodes in favour of more controllable but less spontaneous digital events. There is a risk that immersive features, if not handled with care, push people toward isolation, or encourage reliance on intangible experiences that slowly eclipse lived connections. Yet there is promise here too. Approached ethically, immersive remote performances could offer people worldwide access to musical communities once limited by geography. They might enable musicians to reach fans who would never step into a physical venue, or create new opportunities for personal growth and learning. The point is not to replace reality, but to understand that digital and physical worlds interweave, shaping each other continuously. This perspective encourages us to be cautious yet open-minded when designing new platforms and interactions. Designing for immersion requires iteration. This involves careful observation, regular engagement with users, and flexibility to adjust. It is about balancing creativity with potential risks to offer experiences that are not just innovative but also respectful of diverse human needs.

[60] https://daily.bandcamp.com/features/bandcamp-fridays-in-2024
[61] https://www.volta-xr.com/

Chapter 8

Beyond remote music performances. Reflections from conducting HCI research

As I approached the end of this thesis, it became necessary to offer a personal account of the lessons learned and the challenges I experienced over the past five years. In this chapter, I move away from the domain-specific discussions of remote music performances that have characterised the previous sections and I pause and reflect on the journey that has brought me here. As researchers, we tend to focus more on the outcomes of our work rather than the journey we have been through. However, I believe that reflecting on this personal journey is important too, especially for other young researchers struggling to navigate the complexities and find their voice in the crowded academic space [335]. Through the various failures and successes of the past few years, I have grown as a researcher and as a person. Towards the end of my PhD, I began to find my voice in the space where I operate and to better understand my work and my own values. Here, I take the opportunity to reflect on some of these learnings, hoping to share a first-person perspective that others might find valuable, as well as things I wish someone had told me when I started or even during the countless failures I had to face. On a personal level, these reflections set the tone on the kind of researcher I want to be coming out of this PhD.

In the sections that follow, I reflect on the inherent 'messiness' of research work [391] and the tension that often arises between technocentric and human-centric approaches – particularly in contexts where technological innovation is more valued than human understanding. I also look back on the importance of embracing alternative research outcomes (AROs) – creative, non-traditional formats of disseminating academic work that may not align directly with original goals but offer unexpected

contributions nonetheless [526]. Through developing AROs and speaking with others about AROs, I actually had the most important moments of clarity regarding the value of my work. Additionally, I write about seeing myself as someone positioned 'in between' disciplines, technologies, and perspectives – a position that enabled me to bridge gaps, create (or break) collaborations, and approach problems from multiple angles. Lastly, I explore the emotional dimensions of conducting research and I share my experiences of working while grieving – a challenge that profoundly shaped my perspective on being a human-centred researcher. Grieving while trying to write this thesis brought into focus the significance of care and empathy – not only with users but also within the research community and with ourselves as researchers.

Including this chapter may seem unconventional in the context of a PhD thesis; it might seem like a diary entry of some sort or just a space where I put 'everything else'. Depending on who is reading this, it might come across as a critique, it might seem like an unnecessary addition, or it could be the most relatable part of the thesis. All perspectives are valid, as my intention is to offer a personal reflection, hoping to encourage readers to reflect and more importantly start sharing their own journeys. I note here that although there might be a lot of research that supports what I say here, my reflections are not extensively situated within a wider body of work, since my goal is not to situate my work within the research space but rather to situate myself within my work. Nevertheless, I occasionally reference researchers and collaborators who significantly influenced my thinking. In putting this chapter together and sharing my experiences – both the triumphs and the struggles – I aim to provide a resource for others who may be navigating similar paths and to inspire them to approach their work with curiosity, criticality, openness, and a willingness to embrace uncertainty. I hope to encourage reflection – not just on the research itself but on the journey we each undertake in our professional and personal lives.

8.1 Where is the 'Human' in HCI?

In HCI and in general technology-oriented domains, the pursuit of technological novelty often dominates. Grant assessments, academic outputs, and industry collaborations frequently emphasise the creation of new tools, systems, or platforms. This focus can lead to a technocentric approach, where the question becomes, *"What new thing can we make"* or *"What can we do with this technology?"* rather than *"What do people actually need?"* When I started my PhD, this mindset heavily influenced me: we do XR, so let's identify a problem and solve it with XR. While this approach aligns with the

technical rigour of an engineering school, it left me feeling alienated. The work I was doing felt disconnected from the realities of the people I wanted to help and I started despising designing new techology. My friend Boyd often jokingly referred to me as 'technophobic', and while that label might be exaggerated, it reflected the discomfort I felt with what I was doing at the time.

In my early work, I focused on building VR tools to support musicians, which is what caused me to begin questioning whether this work genuinely addressed their needs. The musicians I interviewed had so many problems caused by the pandemic, such as lack of income, mental health problems and so on, that it seemed impossible that such a population, would be able to access VR equipment or have the infrastructure to adopt some of the things I was proposing, even in the near future. On the other hand, when I turned my attention to online communities like those who attend raves in VRChat, I encountered people deeply embedded in virtual spaces, using technology creatively and intentionally to meet their needs, not the technology we, as researchers, forced on them to fix their problems. Social VR users had the means to afford such technologies and were appropriating, adapting, and reshaping them to enhance their experiences. The contrast between the two worlds forced me once more to confront my assumptions and re-think my love-hate relationship with technology.

Technology can solve problems, and new innovations are necessary. However, solving problems effectively requires an understanding of the humans who will engage with that solution or that technology. In theory, this idea seems obvious, but in practice, this is often not the case. Many HCI projects fall into the trap of designing solutions that do not fully align with users realities, and therefore would not apply to real life situations outside of research. For instance, chatbots for people with dementia or VR training for people in wheelchairs, or in our case VR to replace performance spaces of musicians, all sound really promising on paper (and would probably be catchy both for a CHI conference publication or a fancy research grant), but do they truly consider the complexities of the users' lived experiences? On the opposite end of the spectrum, ideas produced through more 'designerly' methods can sometimes feel too far removed from the context they aim to address, too philosophical rather than practical and applicable, which is something I observed when my my work had reach the other extreme. I think the real answer lies in balancing these extremes when the goal is to design technology for humans (because often the goal may be other things). As researchers and designers, we must ask, *"Who are we designing for?"* and, *"What can we design for them that can make their lives better, more fun, more productive (or unproductive), more anything...?"*

8.1.1 Who are we designing for? Who are we excluding?

Reflecting on my research, I have come to see how important it is to question, not just what we are designing, but who we are designing for and, importantly, who we might be excluding in the process. At the outset of this work, I was designing for musicians – creators navigating unique challenges and aspirations. I realised that my assumptions about their needs and my excitement for what technology could offer them often shaped the solutions I pursued. I was imagining how musicians could use technology, rather than starting with an understanding of what they actually needed or the barriers they faced. This created an unavoidable tension between the technology I was building and the realities of those I aimed to serve.

For instance, while I envisioned VR as a tool for musicians to rehearse and perform in immersive environments, the cost of VR equipment immediately excluded many of the musicians I actually worked with. During the pandemic, several participants faced significant financial instability, making VR an impractical solution for their day-to-day lives [443]. Although some found value in the prototypes, it became clear that I was designing for a niche group, potentially excluding those most in need of accessible tools. This realisation forced me to question myself: *"Was I doing work that truly mattered, or was I inadvertently creating technology that reinforced existing inequalities?"*. Therefore, I then turned my focus people who were already using technology, looking at how I could design for them. But even then, the question remained: *"Who gets to participate in these emerging technological spaces, and who is left behind?"*. While the promise of new technologies like VR is often framed as inclusive and accessible, the reality is more complicated. It caters to musicians and audiences with the financial means and equipment to access the technologies and experiences we design. Meanwhile, for example grassroots musicians and audiences, particularly those from economically or socially marginalised groups [308, 343], often lack the resources to participate in these advancements, while they are the ones who need them the most. This is something I pondered upon for quite sometime, questioning who benefits from the innovations we design and who risks being erased or overlooked in the process.

During the second part of my research, though my perspective changed, and this tension, while still there, was confronted in a different way. When I shifted my focus from creating new tools to studying how people were already using existing technologies, I came across communities like those on VRChat, which proved to be a turning point in my understanding of who I was designing for. Initially, I approached these spaces with preconceptions, imagining VRChat users as isolated "computer geeks".

I had read literature on harassment in virtual spaces, so I really was envisioning the worse [59, 162]. At that stage, I was already grappling with my existential crisis about the value of using VR to solve the world's problems as much research was doing, so I had a hard time understanding why people would spend so much time in virtual spaces. Regardless, because of the nature of my research, it was important to engage with this community – they were the ones attending events remotely on a regular basis.

Figure 34: Selfie with friends in the "MoonLit Wanderings" world in VRChat

Despite my misconceptions, what I discovered was a vibrant, socially engaged group of people using VR, not for escapism, but as a platform for creativity and connection (see Figure 34 for some of the friends I made there). For example, they organised jam sessions and Drum N Bass raves. Their practices revealed a depth of engagement that challenged my earlier assumptions and made me rethink the value of VR as a medium. For these users, VR was not a frivolous addition to their lives but a meaningful extension of their social worlds [303]. Many had specific reasons for inhabiting virtual spaces, including sensory sensitivities, social anxiety, or neurodivergent traits that made physical spaces challenging [128]. For some of the most extreme cases, the real world with all its inequalities had really failed them. In VR, they found opportunities to build confidence and social skills, often improving their offline lives in ways that I found fascinating [128]. They also had the means to use the technology and were technologically literate enough to test its boundaries. Engaging with the VRChat community made me realise that technology is not inherently the problem or the solution – it depends entirely on who is using it, why, and in what context. For VRChat ravers, the technology addressed a genuine need, and they had the resources and desire to engage with it fully. It is not enough to create something that could be useful or fun; we need to ask whether it is useful or fun for the right people in the right context. This also made me aware of how easily we exclude people, or make assumptions about them, even unintentionally. If we do not take time to understand who our designs serve and who they leave behind, we risk reinforcing barriers rather than breaking them.

8.1.2 Technology for technology's sake

Another thing I have learned in the past five years is the value of looking beyond the 'new and shiny'. Innovation is often equated with creating something entirely original, but this way of thinking can sometimes blind us to the ingenuity already happening around us. Chasing novelty for its own sake often results in superficial tools or ideas that remain just that – superficial, used one time for that one experiment. What if we spent more time studying the organic ways people already use technology? We researchers might find we have much to learn.

Observing existing practices with curiosity is as critical as building new tools. Without it, we risk designing solutions that are redundant or disconnected from real needs. When I developed VR for musicians, I aimed to address gaps I assumed existed. But after I engaged with VRChat communities, I saw a different reality. These users were already performing in surreal virtual spaces, creatively adapting tools to play instruments, jam, and connect[62]. Their ingenuity far surpassed what I was designing. This was humbling. I realised I had spent years creating something these communities had already figured out, just in their own way. Innovation does not always mean starting from scratch. Some of the most impactful insights come from engaging with what people are already doing and applying that knowledge to new contexts. For example, VRChat allows people to share virtual spaces that can be almost anything. Why do we need to build new VR apps each time that replicate the same basic functionality? Instead of overlooking existing platforms, we could repurpose them for research and experimentation [389, 390], expanding on the creativity already at work, rather than duplicating efforts with redundant solutions which stay within the context of that one paper.

As designers, our curiosity should extend beyond the desire to come up with new ideas to include a willingness to look closely at the systems and behaviours already in place, and to recognise the ingenuity in what people are doing without our intervention. This does not diminish the importance of innovation; it strengthens it. By understanding the ecosystems people have built for themselves, we can create interventions that are more aligned with their needs and contexts. This can reduce 'solution' waste and encourage the development of more sustainable and impactful work. Observation reveals not only what is missing but also what is thriving, what can be supported, and what can inspire our work. In the case of VRChat, the community did not need me to design a groundbreaking platform – they were already performing and connecting in extraordinary ways. What they needed, perhaps, was recognition of their creativity, and what we needed was to learn from them.

[62] Resident Advisor 2022. The music, venues and creators driving virtual reality clubbing. `https://www.youtube.com/watch?v=Z5kiPAmgKpY`

8.2 The value of Alternative Research Outcomes (AROs)

In 2023, as I was flying to Pittsburgh for the DIS conference, I found myself stranded in New York due to flight cancellations. While in the airport queue to change my flight, I met an HCI researcher who was also heading to DIS for a workshop on AROs. I had no idea what that term meant, so he explained that AROs are research outcomes (not outputs) that go beyond traditional academic papers [526, 527]. They can include exhibitions [101, 365], documentaries [281, 525], and other creative forms of dissemination. Ironically, my suitcase at the time was filled with art created by individuals living with dementia as part of a research project. I was planning to exhibit those at DIS as an art installation because I felt that just a paper would not have done justice to the work. After many cancelled flights and a series of bus trips, I finally reached Pittsburgh. There, I met MinYoung Yoo (Min), the main organiser of the workshop, and we had several conversations about AROs. Our discussions made me realise that AROs were a significant part of my research practice and I had been engaging with them all along without naming them as such. Since that first encounter, Min and I have engaged in ongoing dialogue about the potential of AROs to reshape research dissemination. Our discussions have made me reflect on how the AROs I have created throughout my work have shaped it as well.

8.2.1 So what are Alternative Research Outcomes?

We defined AROs as *uniquely situated, dedicated research activities or artifacts that emerge as new endpoints in the research timeline that aim to translate, communicate, or disseminate research insights in an accessible and engaging form tailored to an intended audience.* AROs hold unique value in HCI and design research by offering pathways to share insights with diverse communities in ways traditional written publications cannot [526]. Traditional academic papers are limited by their dense language and accessibility barriers. These constraints often alienate non-academic audiences and fail to capture the richness of lived experiences or the sensory and embodied aspects of research [120]. AROs, in contrast, allow research to diverge from conventional timelines and formats – such as workshops, exhibitions, and DIY tutorials – resonating with the communities they target. They prioritise the accessibility, contextuality, and experiential nature of research, opening up new avenues for connection and impact. Looking back at the work of this thesis, I have worked on projects that stemmed from my research but ended up as AROs that took on their own trajectories, reaching audiences in unique ways. Below, I reflect on three AROs and the impact they had on my work.

8.2.2 Three AROs that came from remote music performances

Figure 35: Top: Illustrations by Greg Stobbs. Bottom: Stills from the VR experience

Tingbao: an interdisciplinary project celebrating the beauty of nature

Tingbao [365] is an ongoing interdisciplinary collaboration involving the Dreamsailors Collective – Richard Navarro, Paul Cheneour, and Cass XuXin – along with myself, visual artist Greg Stobbs, VR developer Yun Jung Jang, and other HCI researchers, technologists, and musicians. Tingbao tells the tale of a grandfather who travels through time to find his old memories, re-tracking his past through the eyes of a young version of himself. The story celebrates the natural world, and in particular, the ability of plants and animals to stimulate our imaginations [439]. It was inspired by the watery landscapes of Hambrook Marshes in Kent, UK, an important site for biodiversity which in recent times came under threat from arsonists and development projects[63]. The narrative is an allegory for the fragility of our natural world and a better, more protected future like the one that Tingbao dreams into being. The project started in 2019 as a music collaboration between composer and performer Richard and flautist Paul. During the pandemic, as the musicians' live shows were cancelled, the project took a turn into the digital world with more people joining. Together, we created different ways to share the story of Tingbao, such as a musical podcast, a series of illustrations, a live theatre performance with interactive visuals, and a VR experience[64] (see Figures 35, 36). In bringing us together, Tingbao showcases how different mediums and people can come together to tell stories about topics that matter. The music of Tingbao was created long before the pandemic; however, the idea to expand its reach emerged after Richard and Paul engaged with me while I was doing my research on musicians.

[63] https://www.kentlive.news/news/kent-news/hambrook-marshes-canterbury-beauty-spot-4697779
[64] https://linktr.ee/tingbao-dreamsailors

Through talking with me and seeing the potential of technology, the musicians started thinking about ways to expand the impact of their music. My role in Tingbao was more than that of a connector, I brought together ideas and talents to realise a shared vision.

Figure 36: Stills from the live show

While Tingbao is not directly part of my thesis, it emerged from my research and I have been working on the project throughout. More importantly, Tingbao became an integral link to the music community, linking me to the people I work for in many ways. I recently showcased the VR experience at CHI PLAY in Tampere and the Work in Progress (WIP) art festival in Cyprus. These exhibitions enabled me to communicate my research to academic and public audiences in ways that traditional academic outputs never could. Without Tingbao, I would not have engaged with as many people or reached such diverse audiences. While a project like Tingbao could have existed outside my research, it became what it is nowadays because my research and my involvement in its early stages shaped its trajectory. My work would also have existed outside of Tingbao but I would never have gotten to see practical manifestations of it. Also the performance of Tingbao was my first live show where I got to contribute to the show itself - as a performer in some ways, even if that was just a midi keyboard to trigger visuals.

Figure 37: Tingbao at WIP Show Cyprus (left and middle picture) and at CHI Play demo track in Tampere (right).

VR for percussion training

The second ARO I want to mention is a VR experience I developed for percussion training in collaboration with performance scientists from the Royal College of Music (RCM) and researchers from the Creative Computing Institute at University of Arts London (UAL). This project was built upon our earlier work on the *VR Rehearse & Perform* project and was created as part of ongoing discussions about innovative possibilities for music education. At the time, RCM was preparing for its annual Percussion Festival, a major event attracting thousands of attendees. They wanted to have an inspiring installation for young people to spark their interest in percussion instruments.

We began with a workshop involving RCM percussionists to explore ideas. It became clear that simply showcasing instruments would not sufficiently engage young participants. With fewer young people taking up music, we needed a creative approach that demonstrated both the beauty of percussion and the potential within themselves to learn and excel. Inspired by my research, we considered creating a remote, immersive training tool that could guide learners without requiring an instructor's physical presence, but also that would not just be a screen. After an initial brainstorming session, I went home to refine the concept and returned with a range of ideas for the percussionists to test. Using a VR headset and some other technology available to me, such as portable projectors, I demonstrated existing applications, including a piano training app that utilised the passthrough technology of the Oculus to instruct how to play the keys. However, the concept still felt uninspired. Through further discussion, we realised that the most compelling approach would involve exposing young people to professional percussionists themselves. This led us to imagine a VR experience that captured the perspective of an expert musician and allowed the user to be in the musician's shoes.

Figure 38: Photos from the workshops with performance scientists where I exposed them to different VR applications that could inspire them.

Together with Yuni, we filmed 360-degree videos of professional percussionists performing and integrated them with a VR setup. The experience mapped a physical drum to the ones being played in the video, allowing users to feel as though they were part of the performance. This interactive and immersive tool was showcased at the Percussion Festival, where it resonated strongly with attendees. Participants, especially young people, were captivated by the opportunity to step into a musician's perspective and observe their technique up close, while also being able to play alongside them. Just imagine putting on a VR headset and seeing your teacher from their perspective, being able to follow their technique. This VR experience was such a simple idea that perhaps could not have been a novel research application but it did its job, it engaged the public both with the potential of percussion but also with the potential of remote music performances for music training.

Figure 39: Photos from the RCM Percussion Festival exhibition with attendees being able to play drums with famous musicians in VR.

Audiences of the future workshops

The Audiences of the Future workshops is a series of workshops I ran with my collaborators at UAL, Dr. Vali Lalioti and Dr. Bea Wohl. Inspired by the *VR Rehearse & Perform* project and a workshop I previously conducted at IMX on Performances of the Future [363], we aimed to showcase existing technologies to artists and encourage them to imagine how these tools could transform their work. Our goal was to spark ideas for performances that could engage audiences in new ways, whether by creating more immersive experiences or connecting with people across distances.

We conducted two workshops, the first with eight artists and the second with ten, held in two stunning theatres in London. We intentionally chose these spaces to provide an inspiring and familiar environment, ensuring the participants felt grounded in a setting that related them to their practice. The workshops were simple in structure: we introduced the kind of work we were doing and then presented a range of technologies for them to explore. These included not only VR but also apps

on iPads and laptops (such as the software version of VOLTA XR), mini projectors, and other accessible tools. From there, we gave the artists free rein to experiment. The results were beautiful! They envisioned performances that leveraged technology to co-create with audiences, extend their reach to remote viewers, and innovate how they could tell stories on stage. These imaginative exercises revealed the immense potential of these tools to inspire both artists and audiences alike.

Figure 40: Stills from the Audiences of the Future workshops with participants using portable projectors and VR headsets to prototype how they envisioned performances.

These workshops also impacted my own work. They inspired me to focus more on audience engagement for the second part of my thesis. Additionally, the approach we used – providing an open-ended, exploratory space for creativity – shaped how I structured the workshop in Chapter 6. This ARO exemplified how creating spaces for play and experimentation can not only support others' creativity but also feed back into our own research and personal practices.

8.2.3 Reflecting on AROs

Reflecting on these AROs, I see how they came organically from my research but took on lives of their own. They enabled me to connect with the communities I serve and reminded me that research should not only be about knowledge production for other researchers. It should be about knowledge production (or sharing more like) for everyone. The success of the AROs was in their ability to connect with diverse audiences, encourage collaboration, and open pathways for new ideas. In the end, each ARO also gave back to me, and without these projects, my work would not have been what it is today. They allowed me to tap into my strengths as a designer, artist, and researcher, blending my skills in ways that traditional academic outputs could not. Each project inspired me, offering new perspectives and driving me to think differently about the role of research in creating impact.

Nevertheless, developing AROs brought its own challenges, such as issues around authorship and evaluation. For example, Tingbao involved numerous collaborators – musicians, artists, and technologists, whose contributions were crucial. Yet, academic structures offered limited ways to credit

them adequately when presenting the project at conferences like CHI PLAY. While I included their names in the abstract (something I do a lot recently with work, where people who help do not have ORCID IDs), this gesture felt insufficient to reflect their integral roles. AROs resist conventional evaluation metrics. Their impact is not measured by citations but by their ability to inspire and engage. While conferences like DIS and CHI PLAY, with their demo and exhibition tracks, are starting to recognise these contributions, they remain anchored in academic contexts, often culminating in a written paper. This tension highlights a need for more inclusive systems that value experiential, situated knowledge within our communities.

Through my conversations with Min, I gained the vocabulary to frame AROs as distinct research outcomes rather than 'side projects'. Having this understanding has helped me articulate their significance and position them within my academic journey. By including this reflection in my thesis, I hope to foreground the role of AROs and advocate for their continued recognition within HCI and design research communities.

8.3 Being the in-between

In July 2024, at the DIS conference in Copenhagen, I introduced a senior HCI researcher I had met the year before at the same conference to my advisor, Dr. Alexandra Covaci. Alexandra asked about their specialisation. The response was, *"I am not really good at one specific thing; what I'm really good at is bringing things together like puzzle pieces, being an in-between"*. Their passing comment stayed with me and got me to reflect on my own identity as a researcher and the broader value of occupying the 'in-between' space. HCI is inherently interdisciplinary, blending amongst others design, engineering, and social science to explore and create new possibilities [58]. Researchers in this field often adapt their identities based on the context – they might be technologists, designers, or theorists depending on the task at hand. That one comment helped me realise that my ability to move between things, between disciplines, between theory and practice, and between people, is at the core of my work.

When I began my PhD, I was a designer trying to position myself as a technologist and an XR researcher. In the School of Engineering, surrounded by peers and advisors with technical expertise, I often felt like an imposter. I questioned my place in a context that seemed to value outputs that were functional, measurable, and productive. But I tried to take on this identity and my early work

reflected this – I focused on solving problems and creating tools, working within the expectations of the environment I was in. My attempts to conform to this mindset left me disconnected from my own strengths and values, but I also felt disconnected from the new identity I was trying to adopt.

A year in, this changed when I came across work by Ferran Altarriba Bertran, and through him I discovered the space of *designerly* HCI [7, 170, 341]. Framing design, not as an adjunct to technology, but as a central method for exploring and creating new possibilities, resonated with my background as a designer and encouraged me to start tapping into it again. I began to view design in HCI not as a process of solving predefined problems, but as a means of generating questions, encouraging creativity, and exploring emerging spaces. Inspired by this, I tried to start positioning myself as a design researcher, aligning my work more closely with the practices and principles of researchers within designerly HCI and communities like DIS. Yet, even in this space, I often felt like I did not fully belong. I was not a trained design researcher and my work was too practical, too technical, not crazy or provocative enough. I struggled to reconcile the technical aspects of my PhD with the open-ended, generative ethos of designerly HCI. This left me feeling once again like I was straddling two worlds – neither fully a technologist nor fully a design researcher.

8.3.1 Embracing halfness

Being an 'in-between' made me struggle quite a lot when trying to position myself within established academic or professional frameworks. I often felt like I knew a little bit of everything but not enough of anything to be able to fit in. What could I contribute to a department that had so many people being able to make VR, or to a design team with plenty of trained designers? Nevertheless, over time, I came to realise that this 'in-between' identity is not a limitation but a strength. I am, by necessity and by choice 'half' or less of everything – a designer, a technologist, an XR researcher and many other things. My halfness allows me to adapt to diverse contexts and bring together perspectives that might otherwise remain disconnected. It has enabled me to work across a range of fields and projects, from music and theatre performance to human-food interaction, dementia care, heritage and Social VR. For example, in the Tingbao project mentioned in the previous section, being in the middle was exactly my role. I did not create the music, nor the art, nor the VR, but rather, I brought the people who did all those things together and exposed them to ideas and possibilities, which resulted in the diversity of outcomes we had. Where something that someone else could not do was needed, I filled that role, e.g., I animated the illustrations and made them audio reactive for the performance or I brainstormed with Yuni about developing the VR. If all these other people were

not there, none of the diverse outcomes of Tingbao would have existed. But if I was not there the intersections between all the people and outcomes would not have been there.

My thesis itself further reflects my in-betweenness. While, as PhD candidates, our work should be in-depth and focused, mine is a little bit of everything (and maybe a lot of nothing) – it is not a design thesis, a music thesis, an engineering thesis, or an XR thesis, but a blend of all. This might make it appear fragmented to some and dilute its focus, but it also renders it accessible to a wide audience. I would like to think that designers, technologists, XR developers, and musicians can all find something of value within it. A designer reading this might not learn from my human-centred design methods but they might learn from my approach to technology design. A computer scientist or even a musician will find my technological contribution insignificant, but then they might learn from my methods.

An example of this is the CHI paper that was published based on Chapters 3 and 4. When I tried to submit it as a technology contribution to VRST, the technology part was found not novel enough; when I tried to submit it as a designerly contribution to DIS, the design methodology aspect again was not strong enough. However, when I submitted it as a CHI paper that had a little bit of both but not too much of one or the other, it was accepted and quite well received. When later, Lucas Turchet, one of the people leading the Internet of Sounds community, which is highly musical and highly technical, read my work he contacted me and remarked that while he didn't learn much technologically or musically from my work - things were obvious to him as a musician and technologist - he found my approach and the way I conceptualised technology thought-provoking and human. This comment reinforced my belief that the value of my work lies not in advancing a single discipline but in bridging the gaps in between. My bridging role is also evident in how I collaborated with people throughout this research. Working with artists, technologists, audiences, and musicians required me to find a shared language and create mutual understanding, which I would like to think I have done well. My thesis is as much of my participants and the people i worked with as much as its mine.

8.3.2 Lessons learned from the middle

Working as an "in-between" researcher has revealed both the challenges and value of navigating across disciplinary spaces. One of the most important lessons I have learned is that identity in research is fluid. Many of us come into academia with a clear sense of who we are—or who we think we need to be; whether as designers, technologists, or theorists. But over time, these roles shift.

They are shaped by the work we do, the people we meet, and the environments we navigate. I began this PhD as a practising designer, then tried to become a technologist, and later tried to return to design. But even then, I never fully fit. The truth is, very few of us do. Most of us operate on a spectrum, leaning more toward one side or the other depending on the context, or simply hovering somewhere in the middle.

Being in-between has allowed me to bridge ideas, people, and methods that may not naturally meet. In my own work, this has meant combining design and technology to explore remote performance in ways that made sense to musicians, artists, and collaborators. It also meant helping collaborators from very different backgrounds understand one another, and finding the common ground between them. I have learned to communicate across roles, to translate language between domains, and to create space for different types of expertise to be heard and valued. This bridging role might seem intangible, but it is a significant contribution in fields like HCI, where interdisciplinary thinking is really important for tackling complex challenges, but frequently work still seems to fall either on one side or the other – e.g., sometimes design work is too designerly and intangible for technologists to learn from and technology work is too technological for designers to tap into. There is a big difference between work that simply combines fields and work that genuinely connects them. I have tried to hold that connection space.

At the same time, working in-between means becoming comfortable with uncertainty [437]. Neither fully technical nor fully designerly or artistic spaces feel like a perfect fit. Engineering-focused environments can sometimes lack the openness needed to explore emerging questions. Designerly spaces, while rich in creativity, can feel detached from implementation and impact. Being in-between means holding these tensions and trying to navigate them carefully, making sure the work remains imaginative but also grounded in the contexts and people it hopes to support. That has shaped how I approached this thesis, how I designed the studies, and how I collaborated with others. I have tried to balance vision with practicality in ways that feel relevant, not just to academia, but to the people I worked with along the way.

Some of what I write here might sound familiar to those who already work in interdisciplinary spaces. But are they? Is being in-between the same as being interdisciplinary? I'm not sure "interdisciplinary" fully captures what I mean. Interdisciplinarity often implies drawing from two or more established disciplines – typically from a position of being trained in at least one of them. That is not the case for me. I did not come into this work as a trained designer, a computer scientist, or an engineer. I do not hold formal qualifications in any of those areas, and I was not educated in their theories or methods.

While I contribute to conversations in HCI, design, and technology, and publish in their venues, I have never really belonged to any of those communities. My academic background is in Digital Arts, which at the time focused mainly on creative software. Although I've worked as a designer, I never received training in design research or design methods. My PhD, although situated in a School of Engineering, did not include HCI or technical training. The title I received, PhD in Digital Arts, does not reflect at all what the work actually is, and it often works against me in professional contexts.

This is not just a matter of confidence or experience. It is also structural. In Cyprus, for example, I am currently not eligible for faculty positions in HCI or Interaction Design in public universities because I do not have a degree in computer science or design. These exclusions are reminders that disciplinary belonging is shaped not only by what we do, but by how institutions recognise and categorise us. And it shows up informally too; in how I speak with designers or technologists, or in the feeling that I lack the theoretical or technical backbone to be fully part of either group. But that position, on the edge of several disciplines, also brings advantages. It has made me flexible and open to ambiguity. It has helped me listen better, connect ideas across gaps, and support others in working together. I may not have disciplinary authority, but I can help build conditions where collaboration is possible. I can join dots that others might not even realise are connected.

So while there are overlaps between being in-between and being interdisciplinary, I believe they are not the same. Interdisciplinarity can mean moving between clear points. Being in-between means working in the spaces where those points blur. It is more fluid, less defined, and sometimes more isolating, but also full of potential. More and more researchers are coming into these fields from unconventional paths, and I want this thesis to speak to them. Not as a guide for moving from one discipline to another, but as a reminder that valuable work can emerge from the middle; from the uncertain, unsettled, and sometimes messy space in between. This thesis is a product of that space. It does not sit neatly in one domain and it does not even relate to the title I get from it, since it has little to do with Digital Arts. But that is also what makes it accessible. It may not advance a single discipline, but it contributes by helping others see what can happen when people, questions, and methods come together and reshape one another. That is the strength of the in-between.

8.4 What happens when a researcher cannot think?

The PhD journey is often described as one of the most demanding academic paths, characterised by isolation, uncertainty, and intense self-discipline [371]. Research highlights the alarming prevalence of mental health challenges in academia, including high rates of depression, anxiety, burnout and suicide among doctoral students and early career researchers [88, 144, 397]. I could probably cite 100 different papers that talk about this mental health crisis, but I will keep it light on them. However, it is a well-established fact that academia is hard; researchers very often struggle because we are the type of people who think a lot and question a lot [329]. These struggles are amplified by a culture that equates productivity with worth [434, 459], leaving little room for vulnerability [19]. When personal crises intersect with these existing pressures, the impact on a researcher's ability to think, communicate, and produce knowledge can be extensive.
In a space where our primary task is to think, what happens when thinking becomes impossible [369]?

In July 2023, I had completed the data collection phase of my PhD and planned to spend the remainder of the year writing, aiming for a December submission. Despite earlier challenges – including the absence of a research community, academic politics, and lack of funding – I was confident I could finish. Leaving behind the environment that I associated with many of these struggles, I relocated to Athens, envisioning myself writing in vibrant little cafes. It felt so exciting! Life, however, took an unexpected turn. Over the following months, a series of personal crises derailed my plans. My long-term relationship ended. My grandmother, who is central in my life, was diagnosed with breast cancer. My responsibilities in Cyprus, a place I had never envisioned living in, began to grow. I had to move back to a home that never felt like home to take care of the people I loved. Balancing caregiving responsibilities and working to be able to sustain myself left little room for the PhD. Later, as I slowly attempted to regain my footing, further challenges came up. A second close family member was diagnosed with breast cancer. My grandmother was diagnosed with a second cancer. My grandfather, who had been battling health issues for the past year, unexpectedly passed away. And my grandmother fell into such deep depression, expressing suicidal thoughts on a daily basis. I was left emotionally and mentally drained. I had to process my own grief for losing one of the two people who practically raised me, while being in constant fear that I might lose the other one. I also had to be there for a family battling grief, cancer, and mental illness all at once.

The thesis became a symbol of everything I had sacrificed; it became a thing of hate. Opening the

document reminded me of the calls I had not picked up because I was working and the Christmases I had missed because travelling would be too distracting. I thought about all the times I had said,*"No I can't come for lunch, I need to work on my thesis".* Now, I would never have lunch with my grandparents again. How could I have prioritised this thing over them? Writing felt impossible. Some days, I sat in front of the document for hours without typing a word. The strain extended to my broader academic responsibilities. Due to my mental fog, I found it increasingly difficult to communicate effectively, affecting my ability to contribute to joint projects or meaningfully interpret feedback. Panic attacks and an overwhelming sense of unworthiness made even professional tasks feel impossible. For example, at the DIS 2024 conference, I nearly walked out of the hall instead of presenting my paper and a workshop I was supposed to lead fell apart due to my inability to manage it, leaving some of my collaborators disappointed. I became so unreliable that collaborators stopped wanting to work with me.

The mental toll was compounded by my strong feelings of shame and inadequacy. I postponed my submission date multiple times and turned down postdoctoral opportunities, which further amplified a sense of failure. People around me kept asking why I could not *"just write"* as my data collection had been finished for so long and *"I just had to put things together"*. Why couldn't I just do it? Their inability to understand mirrored and intensified my own internalised doubts. The internalised narrative of weakness, coupled with academia's culture of silence and expectations to 'just finish', made me feel isolated, incapable and unfit for academic work. In reflecting on this period, I see how it forced me to confront the limitations of my resilience and question how academia supports – or fails to support – those who keep it running. The expectation to 'push through' is not only unrealistic but harmful, especially when mental clarity is critical to what we do. *If the very act of thinking and interpreting is compromised, how can we be expected to produce valuable academic work?*

8.4.1 The impact of grief on my research

The nature of research, particularly qualitative research, demands not only intellectual rigour but also emotional and cognitive engagement [386]. Analysing data, developing insights, and shaping arguments require focus, creativity, and emotional balance. When the mind is clouded by grief or mental fatigue, these processes become extraordinarily difficult. For a time, I could not see how I could continue, let alone complete, this thesis.

As I navigated my struggles, I became acutely aware of the lack of infrastructure within academia to

support researchers in times of crisis. Even before my personal challenges, I had found institutional support insufficient. Mental health services were overstretched, often requiring long wait times, and there were no dedicated resources for doctoral students grappling with the unique pressures of academia. These deficiencies became even more pronounced during my grief. Balancing caregiving responsibilities, financial pressures, and academic demands left me without the time or energy to seek the help I needed. The expectation to "push through" felt crushing. I relied on personal strategies – therapy (a lot of it), martial arts, peer support, and community engagement – to regain my footing. But it took a lot of time and money. These helped me find balance and begin to reconnect with my work. However, I recognise how fortunate I was to access these resources independently; not everyone has the means or time to do so.

While working through these challenges I noticed a shift in how I related to my research. The act of putting myself over my work to be able to find balance gave me the clarity to confront deeper questions about what I wanted this PhD to represent. Grief heightened my sensitivity to the human dimensions of my research, helping me articulate what my work was about all along – the humans not the technology. My research has never been about contributing new technology within a design space, rather it is more about amplifying the human experience within it.

Had I finished this PhD a year ago, this thesis would not have been mine. I would have written it but it would not have my voice in it. Grief changed me. It matured my perspective and helped me find my voice. It also gave me the confidence I needed to adopt a reflective and personal writing style. Writing in this way, particularly in the context of the School of Engineering, felt unconventional and risky. Yet, leaning into vulnerability felt necessary. Through this process, I found not only my voice but also the courage to use it. I came to understand that my contribution to the research community is in creating work that speaks to the realities and complexities of the people it seeks to serve, irrespective of whether that work is novel or not. My thesis, shaped by my grief and my growth, is a reflection of who I have become and the values I now want to bring to my work.

8.4.2 Starting a conversation

Before beginning my PhD, I was deeply engaged in mental health advocacy. I championed the importance of speaking out, delivering talks in schools across the UK[65], addressing researchers in India[66], and organising creative workshops between university students and mental health hospital residents

[65] http://www.sppali.com/work.html#cbp=ajax/toolkit.html
[66] http://www.sppali.com/work.html#cbp=ajax/india.html

in Singapore. Even my master's thesis explored the stigma surrounding suicide[67]. Part of this work involved being open about my own mental health struggles. I believed that sharing my experiences could encourage others to do the same and challenge the stigma surrounding mental health.

However, upon entering academia, I felt silenced. The culture prioritised competition and productivity, leaving little room for vulnerability. The topics I had been so passionate about suddenly felt taboo. I noticed many peers grappling with impostor syndrome, anxiety, and burnout – so common, in fact, that I cannot think of anyone who did not struggle at some point. Yet, everyone maintained a brave face. This unspoken expectation of stoicism created an isolating environment where it felt unsafe to share struggles. Academia, particularly at the PhD level, is inherently isolating [19]. Without meaningful avenues for support, personal challenges often amplify professional pressures.

This silence harms not only individuals but also the research they produce. The emotional toll of our work is inseparable from the intellectual process, yet academia often fails to acknowledge this reality [434, 459]. Some institutions offer counselling or coaching, but these resources are often underfunded and inaccessible. For me, this isolation was heightened as I worked in an institution where few others conducted HCI research. Most of the meaningful support I received came from conversations with people I met at conferences. Peers shared their struggles and coping strategies, making me feel less alone and more capable of continuing. These exchanges were invaluable, but they also highlighted how much is left to chance. I was lucky to attend conferences and build a network; what about those who lack the funding or opportunities to do so?

Adding this section to my thesis – even though it is deeply personal and might make others uncomfortable – is my way of starting a conversation. Through sharing my story, I discovered how common these challenges are among researchers: a colleague who got off a plane to care for a sick child, another who navigated experiments while undergoing chemotherapy, and yet another who battled panic attacks before every presentation. These stories revealed a shared vulnerability that remains largely unspoken, further isolating those who are struggling. Academia must address mental health challenges openly and systematically. If our work demands clarity, creativity, and focus, we need structures that support these qualities, especially during crises. As an HCI community, we must also recognise our responsibility to support the humans behind the research. Institutions cannot bear this burden alone, especially when their efforts often fall short. We need spaces where researchers can connect, not just about their work, but as people navigating the challenges of academia. These spaces should extend beyond institutions or costly conferences.

[67] `http://www.sppali.com/work.html#cbp=ajax/suicide.html`

If HCI prides itself on centring the human experience, we must care for the humans who make the field what it is.

We must normalise discussions about mental health and acknowledge the personal challenges that shape our work. Why should we feel alone when so many share these struggles? In HCI, where the human experience is central, we have an opportunity and a responsibility to lead by example. How can we design systems that better support researchers? How can we create environments that prioritise care and connection, not just with our participants but also within our academic communities? These questions require collective effort and a willingness to challenge the status quo. Through therapy, conversations, and reconnecting with what matters most to me, I found ways to continue this work. But these journeys are not linear, nor are they always successful in conventional terms. My aim is not to provide solutions but to invite further discussion. If this thesis, shaped by personal struggle and growth, can serve as a starting point for conversations about mental health in academia, then its value extends far beyond its specific contributions to the field of remote music performance.

8.5 Reflecting on reflecting

By reading this chapter, you, the reader of this thesis, have learned about me – my challenges, my growth, and the perspectives that shaped this thesis. My journey as a researcher is inseparable from the research itself. The ideas, arguments, and findings presented in this thesis did not arise in isolation; they were influenced by my experiences, my doubts, and my evolving perspectives. In reflecting on some parts of my journey, I have been able to look at my work from different angles, strengthening my understanding of what it represents and why it is as it is. I hope that by sharing my reflections, I also helped others do the same.

Without this chapter, I would not be present in this thesis. My existence as a researcher would have been reduced to a name on the title page. You would not know the personal context that influenced the choices I made, the tensions I grappled with, or the shifts in perspective that defined my work. This chapter provides insight into why this thesis exists in its current form and how it came to be. It connects the knowledge produced here to the person who produced it. Knowledge production is as much about the researcher as it is about the data. We interpret data, define problems, and shape findings through the lens of our own understanding. When that understanding shifts, so does the knowledge we produce. This can lead to new insights, even from the same material.

Reflection is, therefore, not just a personal exercise; it is an important part of research. It allows us to contextualise our work and revisit its purpose, often uncovering new dimensions in the process. Research is not static, nor is it ever fully objective. It evolves alongside the researcher, shaped by our choices, assumptions, and experiences. Recognising this relationship can enrich how we approach and evaluate research. Understanding the human element behind knowledge production reveals the origins of the methods we choose, the problems we address, and the perspectives that shape our approach.

For example, consider research on chatbots for people with dementia. Did the idea originate from a fascination with the technology, later applied to the context of dementia? Or did it come from a need identified from working with a community, with technology serving as the tool? These origins matter. They provide insight into the purpose of the research; whether the problem drove the technology or the technology generated the problem. Both are valid, but understanding the origins allows us to evaluate the technology appropriately. Is it a potential tool for addressing broader issues, or is it a solution designed specifically for a predefined problem? Without this context, we risk evaluating outcomes without fully understanding their intent or purpose, potentially missing the bigger picture.

This chapter is an invitation to consider the human context behind knowledge. It is a reminder that the work we produce is never detached from the people who create it. Reflection helps us situate knowledge within the realities of those who generate it. This practice not only deepens our understanding of the research but also fosters greater transparency in how problems are framed, methods are chosen, and knowledge is shaped. It pushes us to move beyond surface-level evaluations of outcomes and to critically assess purpose, origin, and intent. By reflecting on my own process, I have come to see my work in a new light. Reflection has allowed me to uncover new dimensions in my research, not by generating new data but by revisiting what was already there with a different perspective. I hope this chapter encourages you to think about the human in research – not just in my work, but in the work you encounter.

Chapter 9

Conclusion

Concluding this thesis is both a reflective and fulfilling moment. I began this research with a simple yet challenging guiding question: *how can we capture the magic and connection of live music in digital spaces?* As someone greatly moved by music but not a musician, I was curious how technology could bridge the emotional and creative gaps that surfaced when physical spaces became inaccessible. My work explores the design space of remote music performances through the perspectives of musicians and audiences. Throughout this thesis, I have investigated the lives of musicians adapting their creative practices when traditional spaces were out of reach, and I have listened to audiences seeking meaningful experiences in virtual concerts, longing for the connection that live events bring. Along the way, I have dealt with the complexities of navigating the entanglement of designing technologies that prioritise human experience while also embracing technological possibilities.

This work has aimed to provide domain-specific and methodological insights into how we might design for immersive remote music performances. My research responds to gaps in holistic approaches in this space, where existing work focuses narrowly on either musicians or audiences, specific technologies, or isolated use cases [464, 468, 481]. By integrating these perspectives, I sought to contribute a more practice-oriented understanding of this design space. In this final chapter, I revisit the research questions that guided my work, summarising key findings and insights. I also acknowledge the limitations of my work and what future work can investigate. I hope my work guides other researchers and designers to continue this exploration and inspires them to approach digital experiences with creativity, care, and human-centred thinking.

9.1 Revisiting the research questions

When I started this thesis, I sought to investigate how remote music performances could be understood, designed, and enhanced through human-centred approaches. For this, I posed four research questions I wanted to explore throughout my work (see Section 1.2). The research questions guided my journey through the design space of remote music performances through the eyes of musicians and audiences, as well as through my own position in the research and its evolvement. Having completed this work, I return to these questions, reflecting on how they have been addressed and situating the answers within the broader contributions claimed in Chapter 1.

RQ1: How do musical creative practices and performances adapt to remote contexts, and what is the role of technology in facilitating this adaptation?

In this thesis, I explored how musicians and audiences adapt to remote music experiences, focusing on the challenges and opportunities these contexts present. I examined how technologies, such as spatial audio systems, livestreaming, and VR environments, shaped their approaches to remote performance and engagement. In Chapter 2, I highlighted how the COVID-19 pandemic forced musicians and audiences to embrace technology as a tool for maintaining musical connection. While technology facilitated adaptation, musicians and audiences prioritised retaining the human essence of musicking [432, 433]. They found creative ways to overcome physical separation, preserving a sense of shared experience. In Chapters 3 and 4, I focused on musicians and showed how immersive technologies, particularly VR, can support creative musical practices. Well-designed tools enabled musicians to rehearse and perform in virtual spaces when physical venues were unavailable. Features such as virtual acoustics and visual feedback allowed musicians to experiment creatively, adapt techniques, and reimagine their performances. Chapters 5 and 6 examined audience perspectives, revealing how remote attendance expanded participation and connection beyond traditional in-person events. Audiences engaged with livestreams, VR concerts, and other digital platforms, each offering unique interaction dynamics. Technology served as a bridge, connecting geographically dispersed people to music and each other.

RQ2: What are the needs and desires of musicians and audiences experiencing music performances remotely?

Through in-depth interviews, workshops, and observations, I identified the needs and desires of musicians and audiences in remote music contexts. Musicians value technology that integrates seamlessly into their workflows, offering flexibility and supporting their creative processes. They require access to varied spaces – both real and virtual – with adjustable acoustics that mimic performance environments. Emotional triggers that inspire creativity and interfaces that do not interfere with handling instruments are also essential [364]. Audiences, on the other hand, seek deeper connections – with performers, with each other, and with the sense of a shared 'live' experience. They want remote performances to go beyond passive consumption, desiring active participation that fosters a sense of 'being' [191, 367]. My findings highlight that remote performances should not simply replicate in-person events. Instead, they should embrace their digital nature to deliver unique benefits aligned with user values. For musicians, this includes addressing technical issues like latency and creating tools that enable, rather than hinder, creativity [85, 403]. For audiences, this means promoting engagement, community, and emotional resonance. By combining insights from both groups, I demonstrated that musicians and audiences desire immersive, meaningful experiences where technology acts as a bridge for connection. Based on this in Chapter 7, I proposed four design dimensions that prioritise the experience first and allow technology to follow.

RQ3: How do musicians and audiences perceive the opportunities and challenges of technology in remote music performances, and what implications do these perceptions have when we design technology for them?

Throughout my work I have uncovered a diversity of perceptions. For example in Chapters 3 and 4, on the one hand, musicians appreciated the freedom to rehearse in once – inaccessible acoustical environments, to experiment with creative prompts, and to integrate elements that inspire playful improvisation. On the other hand, technical limitations – such as audio latency, sound quality and headset discomfort – introduced new challenges. In Chapter 5 I saw that audiences are open the potential for shared experiences across geographical divides but also faced fragmented ecosystems of platforms, complexities in interaction design, and uncertainty about long-term engagement. Overall, what I found is that people are open to technology if it aligns with their needs and resources and addresses their desires. At the same time, many are unaware of the possibilities these tools offer,

making it essential to expose users to emerging technologies to spark interest and understanding. My work shows that to support adoption, designs need to bridge the gap between user expectations and the technical capabilities of these systems. This highlights the value of human-centred design in ensuring that technology meets real-world needs and creates meaningful experiences.

RQ4: How can we use human-centred design methodologies to inform and co-create technology with musicians and audiences that enhance the remote music experience?

To address RQ4, I employed participatory methods – interviews, workshops, prototypes, and user evaluations – to anchor the research process in the lived realities of the people involved. In developing *VR Rehearse & Perform* (Chapters 3 and 4), I engaged directly with musicians to understand their needs and develop a technology that aims to meet them. This approach provided valuable insights into how immersive technologies can support creative practice but also revealed tensions. Nevertheless, the complexity of VR occasionally shifted the focus from users to the technology itself, highlighting the importance of examining how decisions at every stage shape outcomes and agency. In Chapters 5 and 6, I shifted my approach, prioritising learning from existing practices over designing. I observed how audiences engage with remote music performances on existing platforms, and explored what these experiences reveal about their desires and challenges. Both of the approaches I followed (design-led and exploratory) had merits and limitations, but together they pointed towards the importance of focusing on the human experiences at the core of remote music performances. This reflection led to the proposal of the dimensions and and design opportunities in Chapter 7, emphasising that designing for this space requires prioritising the lived realities and values of the people involved.

An important part of this process was recognising that my own position in the research mattered. I did not try to stand apart as a neutral observer; instead, I treated my evolving perspective as part of the research process itself. Realising this opened space to question my own assumptions and biases more openly, adjusting the direction of the work when I recognised certain limitations. In Chapter 8 I offered a deeper insight into this by stepping back on the research and reflecting on my own journey. I talked about my tensions when it came to technology design, I articulated the importance of AROs and I described what it means to exist in-between disciplines, never fully at home in one space. I also described my experiences of doing research while grieving, being faced the difficult truth that academia often fails to support us when we are at our best, let alone at our worst. My reflections

were not separate from the rest of the project; they shaped how I made decisions, how I related to participants, how I designed and how I wrote. They were part of the human-centredness of the work. Asking "Where is the human in HCI?" is not only about users. It is also about acknowledging the humanity of the researcher. Bringing that into view makes the research process more transparent and, in many ways, more honest. It helps frame human-centred design not just as a method for building better systems, but as a way of working that values lived experience of participants and researchers alike.

9.2 So who does this work speak to?

Although my work is heavily grounded in HCI, this thesis was never meant to speak only to HCI researchers, I would like to think that its contributions extend across multiple communities. Rather than addressing one clearly defined field, I aimed to create connections across disciplines and practices. Each part of the research was shaped by different people and conversations, and I hope different readers find something they can take from it; whether that's a design method, a practical insight, or a sense of recognition.

For **interaction design researchers and HCI scholars**, the thesis provides methodological and conceptual tools for working in complex or experiential domains. It demonstrates how human-centred and participatory approaches can surface overlooked needs and tensions, especially in emerging design spaces like remote performance. It also contributes to ongoing discussions about experience-centred and care-oriented approaches to technology design, showing how immersive technologies can be shaped around lived experience rather than novelty or technical performance alone. The work speaks first to interaction design and HCI researchers who are working in emerging or hard-to-define spaces. Through a mix of methods—including prototyping, workshops, speculative prompts, and open-ended interviews, I show how we can work with complexity without trying to reduce it.

For **musicians and artists**, the work offers reflections on how creative practices adapt in digital settings. The prototype work in Chapters 3 and 4 is directly shaped by musicians' own practices, while Chapters 6 and 7 offer ideas for thinking through the challenges and opportunities of remote and hybrid engagement: from presence and play to accessibility and creative control. The intention is not to offer solutions, but prompts for reflection and experimentation. I hope the work shows that remote music performance does not need to replicate what is lost, but can create something different

and meaningful in its own right.

For **audience experience researchers and industry professionals**, particularly those working in streaming, events, or platform development, the findings highlight how audiences engage emotionally, socially, and practically with digital music formats. The work shows that audience participation is not passive or generic; it is shaped by platform constraints, personal rituals, and expectations of liveness and connection. Such insights are especially relevant for designing future audience-facing tools and experiences that feel responsive rather than one-size-fits-all.

For **policy makers, funders, and institutions**, the thesis highlights the cultural and emotional role of music, especially in contexts of disruption. Understanding what people value in remote formats, beyond scale or reach, is important when shaping inclusive and sustainable futures for creative practice. This work offers insight into how digital and hybrid performance formats are not just stopgaps, but potential long-term spaces for connection and experimentation.

For **early-career researchers and those working across disciplines or navigating personal challenges**, I hope this thesis offers something beyond its research content. Chapter 8 reflects on how grief, shifting perspectives, and a sense of not fully belonging in any one discipline shaped the kind of work I was able to do. It also explores how embracing AROs helped me reimagine what research can look like – valuing process, dialogue, relevance to real contexts and accessibility alongside traditional outputs. I tried to hold space for contradiction and complexity in my methods, collaborations, and writing, because research never happens in isolation from life. The academic process is often presented as objective and linear, but in reality, it is always entangled with who we are and what we are going through. With my work I speak to those who have felt pressure to separate the personal from the academic, those who feel like they constantly need to translate themselves to be understood as well as those who always feel like they do not fit in. With adding a strong personal touch to my work I want to remind them that research does not have to fit neatly into a box; and neither do us as researchers. It is possible to produce rigorous and reflective work that is also honest about where it comes from. And for those who move between roles, methods, or communities – my work shows that such in-betweenness is not a weakness, but a place from which important and original work can emerge. I hope others in similar positions find something here that feels familiar, and that encourages them to approach their work in ways that are honest, situated, and meaningful.

Finally, this thesis speaks to anyone interested in designing technology in ways that feel more human. Whether a developer, a creative technologist, a festival organiser, or someone experimenting with

digital forms of performance, the work provides starting points, questions, and ideas to build on; or to resist. Remote music performance is not a substitute for live performance. It is a different medium entirely, with its own possibilities. And that space is still unfolding.

9.3 Limitations and future work

Like all researchers, I would like to believe that my work is 'future proof'; but I doubt it is. No research is without its limitations, and this thesis is no exception. Therefore, it is important to acknowledge the shortcomings that underlie my work, beyond the study-specific ones. Here, I reflect on some of the limitations, framing them as opportunities for future inquiries, encouraging others to build on what I have started.

Limited scope on user perspectives. One key limitation of this work lies in the range of perspectives included. Remote music performance encompasses diverse experiences shaped by cultural, geographic, and technological factors. It spans professional orchestras streaming complex pieces, hobbyists performing from their bedrooms, and global online audiences. I aimed to find common threads, yet the perspectives included in this thesis reflect only a tiny portion of the vast landscape. Many voices remained out of reach due to constraints in time, resources, and access. Some underrepresented communities may have offered valuable insights into how remote music is performed and experienced in different contexts. For example, individuals in areas with limited internet infrastructure might innovate in unexpected ways, and cultural norms could shape how people engage with virtual musical experiences. Future work could broaden the scope, embracing a richer set of perspectives and giving a more complete view of the landscape.

Balancing breadth and depth. The field of remote music performance is inherently vast and interdisciplinary. While on the outside it might seem like a new topic that surfaced during the pandemic, on the inside it is a topic that draws on so many different fields from HCI, engineering, and design to performance science, sociology, and musicology, to name a few. Each of these fields has its own huge body of research relevant (directly or indirectly) to remote music performance. The methodologies I used to conduct this research also have their own huge bodies of work. Given the expansive scope, it was not feasible to address and engage with every relevant work in detail, and undoubtedly, many key contributions were overlooked. Moreover, due to the vastness of the music landscape within and outside of HCI, I also did not engage in depth with work from other performance fields such as

theater or dance, which might have given me interesting insights. Nevertheless, this limitation also reflects my approach as a designer and a researcher. I thrive in being 'in-between'; adapting across disciplines and synthesising ideas rather than specialising in any single field. While this adaptability gives me the ability to work on many different topics, it inherently means my engagement with specific domains may lack the exhaustive depth of a specialist. Within my work, I have aimed to strike a balance, prioritising literature and perspectives most aligned with the core questions of this thesis and my position within the research. Future work could build upon the foundations I set, going into specific areas to further open up this emerging design space.

Rapidly evolving technology. Another limitation is the rapid pace of technological change in remote music performance. By the time I began writing this thesis, several of the tools and platforms I initially explored had already been replaced or significantly updated. This constant evolution made it difficult to anchor findings to specific technologies without them quickly feeling outdated. Instead, I focused on principles and experiences that go beyond individual tools, such as the emotional connections and challenges of performing remotely. However, this approach inevitably sacrifices some of the specificity that could be valuable for practitioners and researchers working in the present. This limitation also brings up a tension inherent in studying fast-moving fields: as soon as you think you have caught up, the goalposts shift. While I recognise the need to contextualise my findings within the technologies available at the time, I also accept that this work will need re-contextualisation as innovations emerge. As a designer, I see this as both a challenge and an opportunity – it reminds me that research like mine is part of an ongoing conversation. I hope this thesis provides a foundation others can build on, revisiting its ideas in light of future technological advancements.

Reliance on qualitative methods. One additional important limitation of my work is the reliance on qualitative methods without the integration of quantitative analysis. This was a conscious decision, rooted in the exploratory and generative nature of the research. My aim was to engage deeply with the lived experiences, values, and creative processes of both musicians and audiences – elements that are often too complex, contextual, or fluid to be meaningfully captured through predefined measures. Working in an emergent design space where there are no established frameworks for what immersive remote music performance "should" look like, I found qualitative methods, such as open-ended interviews, observations, and participatory workshops, essential for allowing participants to express their needs, expectations, and challenges in their own terms. Such methods also aligned with my constructivist and human-centred approach, which focused on co-creating knowledge rather than testing specific hypotheses.

That said, I acknowledge that this approach has its limitations. Without complementary quantitative data, there are fewer opportunities to generalise findings across larger populations, compare preferences statistically, or assess the measurable impact of specific interventions (such as particular features in the VR Rehearse & Perform prototype). For instance, evaluating perceived presence or creative flow in a more structured way could have added another layer of evidence to support some of the qualitative observations made during testing. A mixed-methods approach could have supported triangulation and added breadth to the depth achieved through qualitative work. However, the reality of this design process was often messy, iterative, and shaped by unexpected developments(e.g, constraints, scheduling challenges, and the evolving interests of participants). Flexibility was essential. At times, the complexity of what was being designed did not lend itself to easy quantification. Still, I see the potential value of integrating mixed methods in future work that builds on this research. Quantitative approaches could be particularly useful in testing specific design principles at scale, identifying platform-level behavioural trends, or validating emerging design frameworks. They might also help evaluate long-term engagement or user retention—important aspects that sit outside the scope of this thesis but are critical for sustainable design in this space.

Romanticising music performance. A further limitation of this thesis is the asymmetry in how the constructed and professionalised nature of music performance is examined from the perspectives of audiences versus musicians. In the audience-focused work, themes such as branding, monetisation, rehearsal, and the carefully curated nature of performance were explicitly addressed; partly because they were raised unprompted by participants and were then explored through follow-up questions. Audience members often spoke about the 'illusion of connection' and their awareness that performances were mediated and managed. In contrast, the musician studies focused more heavily on creativity and the emotional experience of playing music in virtual or remote settings. At the time those interviews were designed and conducted, my interest lay in understanding how VR might support creative practice, and this shaped the framing of the study. I did not include direct prompts about the pressures or performative dimensions of musicianship. Although a few participants touched on ideas of formality, expectations, or performance anxiety, these were not systematically followed up. Looking back, this choice reflects not only the early stage of the research but also my own positioning. I approached the work from a perspective that sought to support emotional connection and wellbeing, and this shaped what I saw and prioritised. However, music performance is not just a site of creative exploration; it is also work. It is rehearsed, branded, sometimes transactional, and often bound up in complex forms of labour and professional identity. By not actively engaging with these aspects during the musician studies, I may have contributed to a romanticised view of performance,

one that risks overlooking the realities that shape how musicians present themselves, make a living, and navigate mediated environments. Future work should take a more deliberate look at the tensions musicians face in remote and hybrid contexts, not only around creativity and immersion but also around professionalism, audience expectation, self-presentation, and sustainability. Criticality in such aspects is essential for designing technologies that respond to the full scope of what music performance entails.

9.4 Conclusion

With my dissertation, I have explored the design space of remote music performances, presenting both the outcomes of my doctoral research as well as the methodologies that guided my exploration. I hope to empower designers to create new technologies in the space, and in doing so, enhance the experiences of those engaged in it. I also wanted to influence other stakeholders who are involved in the field, such as developers, event organisers, platform designers, and so on. Overall, my goal was to contribute to the growing body of work in the field of remote music performance, hoping that this will lead to the development of technologies and experiences that leverage the possibilities that exist within the space but remain human and satisfy those who use them.

Appendix 1: Portfolio of Work

List of relevant publications

Part II

|PAPER| **Sophia Ppali**, Vali Lalioti, Boyd Branch, Chee Siang Ang, Andrew J. Thomas, Bea S. Wohl, and Alexandra Covaci. 2022. Keep the VRhythm going: A musician-centred study investigating how Virtual Reality can support creative musical practice. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems (CHI '22)*. Association for Computing Machinery, New York, NY, USA, Article 220, Pages 1–19. `https://doi.org/10.1145/3491102.3501922` [364]

|PAPER| Vali Lalioti*, **Sophia Ppali***, Andrew J. Thomas, Ragnar Hrafnkelsson, Mick Grierson, Chee Siang Ang, B. S. Wohl, and Alexandra Covaci. 2021.VR Rehearse & Perform - A platform for rehearsing in Virtual Reality. In *Proceedings of the 27th ACM Symposium on Virtual Reality Software and Technology (VRST '21)*. Association for Computing Machinery, New York, NY, USA, Article 107. `https://doi.org/10.1145/3489849.3489896` (*first equal co-author) [266]

|POLICY BRIEF| Aaron Williamon, George Waddell, Neta Spiro, Rosie Perkins, Caitlin Shaughnessy, Aifric Campbell, Marisa Miraldo, Vali Lalioti, and **Sophia Ppali**. 2022. HEartS professional: the Health, Economic and Social impact of COVID-19 on Professionals in the arts: findings and policy implications for cultural recovery. In *The Pandemic and Beyond*. `https://doi.org/10.24379/RCM.00002303` [504]

Part III

|PAPER| **Sophia Ppali**, Elena Ppali, Alberto Boem, Luca Turchet, Boyd Branch, Sloe Scorer, Chee Siang Ang, and Alexandra Covaci. 2025. The Virtual Concert-goer: Audience Perspectives on Remote Music Performances. In *Proceedings of the ACM on Human-Computer Interaction (CSCW '25)*. Association for Computing Machinery, New York, NY, USA.

|PAPER| Jihae Han*, Yu Sun*, **Sophia Ppali***, Alexandra Covaci, and Andrew Vande Moere. 2025. To Cuddle, Mingle, Venture, or Guide: How Architectural Affordances Influence the Experience of Social VR Places. In *Proceedings of the 2025 ACM Designing Interactive Systems Conference* (DIS '25). Association for Computing Machinery, New York, NY, USA. (*first equal co-author) `https://doi.org/10.1145/3715336.3735772` [192]

|PAPER| **Sophia Ppali**, Max Scorer, Elena Ppali, Boyd Branch, and Alexandra Covaci. 2024. Remote Rhythms: Audience-informed insights for designing remote music performances. In *Proceedings of the 2024 ACM Designing Interactive Systems Conference (DIS '24)*. Association for Computing Machinery, New York, NY, USA, Pages 2675–2690. `https://doi.org/10.1145/3643834.3660719` [367]

Part IV

|PAPER| MinYoung Yoo, **Sophia Ppali**, William Odom, Yumeng Zhuang, Kritika Kritika, Wyatt Olson, Catherine Wieczorek, Heidi Biggs, Arne Berger, Audrey Desjardins, Ron Wakkary, and Kathryn E. Ringland. 2025. Translating HCI Research to Broader Audiences: Motivation, Inspiration, and Critical Factors on Alternative Research Outcomes. *In Proceedings of the 2025 CHI Conference on Human Factors in Computing Systems (CHI '25)*. Association for Computing Machinery, New York, NY, USA, Article 455, Pages 1–24. `https://doi.org/10.1145/3706598.3713884` [527]

|WORKSHOP| **Sophia Ppali**, Marios Constantinides, Fotis Liarokapis, Jaydon Farao, Soraya S. Anvari, MinYoung Yoo, Ferran Altarriba Bertran, Shannon Rodgers, Jihae Han, Rina R. Wehbe, Margot Brereton, and Alexandra Covaci. 2025. Cite Your Well-being First: What Happens When Personal Life, Mental Health, and HCI Research Become Entangled? In *Companion Publication of the 2025 ACM Designing Interactive Systems Conference (DIS '25 Companion)*. Association for Computing Machinery, New York, NY, USA. `https://doi.org/10.1145/3715668.3734181` [369]

|DEMO PAPER| Sophia Ppali, Yun Jung Jang, Marina Pasia, Andreas Papallas, Panayiotis Zaphiris, and Alexandra Covaci. 2024. Tingbao: A musical Immersive Experience Inspired by Environmental Themes. In *Companion Proceedings of the 2024 Annual Symposium on Computer-Human Interaction in Play (CHI PLAY Companion '24)*. Association for Computing Machinery, New York, NY, USA, Pages 318–323. `https://doi.org/10.1145/3665463.3678836` [365]

Other

|DOCTORAL CONSORTIUM PAPER| **Sophia Ppali**. 2023. Music from Anywhere & Everywhere: Exploring the design space of remote music performance. In *Companion Publication of the 2023 ACM Designing Interactive Systems Conference (DIS '23 Companion)*. Association for Computing Machinery, New York, NY, USA, Pages 45–49. `https://doi.org/10.1145/3563703.3593067` [362]

|WORKSHOP| **Sophia Ppali**, Boyd Branch, Alexandra Covaci, Bea Wohl, and Vali Lalioti. 2022. *Performances' 22: A Workshop on Designing the Performances of the Future at IMX 2022*. In *Adjunct Proceedings of the 2022 ACM International Conference on Interactive Media Experiences (IMX '22)*, Aveiro, Portugal, Pages 159-162. `10.6084/m9.figshare.20069453.v1` [363]

Alternative research outcomes

|EXHIBITION| *Tingbao* at the Work in Progress Festival at CYENS Centre of Excellence, Nicosia, 2024. Music & Narration: Richard Navarro, Paul Chenneour, Cass XuXin, Visuals: Greg Stobbs, VR experience: Yun Jun Jang, Technology consultant & Exhibition setup: **Sophia Ppali**

|WORKSHOP| *Designing the Performances of the future workshops* run through Knowledge Exchange Funding by the Creative Computing Institute at the University of Arts London, 2022. Led by: Vali Lalioti. Facilitators: **Sophia Ppali**, Bea Wohl, Yun Jung Jang, Alex Newson.

|EXHIBITION| *XR for Percussion Training* at the Royal College of Music Percussion Festival, 2022. Initiative by: George Waddell. Workshops facilitation: Sophia Ppali, Vali Lalioti. VR experience: **Sophia Ppali**, Yun Jung Jang. Exhibition support: Bea Wohl, Yun Jun Jang.

|GUEST MODULE| *Performances of the Future brief* for the Collaborative and Collective Practices module at the Wimbledon College of Arts, University of Arts London, 2022. Module leader: Paul Franklin, Brief delivery, teaching and workshops: **Sophia Ppali**

|LIVE SHOW| *Tingbao* at The Malthouse Theatre as part of the Canterbury Festival, 2021. Music & Narration: Dreamsailor collective (Richard Navarro, Paul Chenneour, Cass XuXin), Visuals: Greg Stobbs, Animation and interactive visuals: **Sophia Ppali**

List of other publications produced during the PhD research

|PAPER| **Sophia Ppali***, Ethan Cheung*, Alexandra Covaci, Wan-Jou She, and Chee Siang Ang. 2025. Creating with Care: Co-Designing Immersive Experiences through Art-Making with People Living with Dementia. In *Proceedings of the 2025 CHI Conference on Human Factors in Computing Systems (CHI '25)*. Association for Computing Machinery, New York, NY, USA, Article 673, Pages 1–18.
Honourable Mention Paper Award `https://doi.org/10.1145/3706598.3714101` (*first equal co-author) [368]

|PAPER| Boyd Branch, Piotr Mirowski, Kory Mathewson, **Sophia Ppali**, and Alexandra Covaci. 2024. Designing and Evaluating Dialogue LLMs for Co-Creative Improvised Theatre. In *Proceedings of the 15th International Conference on Computational Creativity (ICCC '24)*.
`https://doi.org/10.48550/arXiv.2405.07111` [71]

|PAPER| Alexandra Covaci, Khawla Alhasan, Mayank Loonker, Bernardine Farrell, Luma Tabbaa, **Sophia Ppali**, and Chee Siang Ang. 2023. No Pie in the (Digital) Sky: Co-Imagining the Food Metaverse. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems (CHI '23)*. Association for Computing Machinery, New York, NY, USA, Article 501, Pages 1–17.
`https://doi.org/10.1145/3544548.3581305` [118]

|PAPER| Mayank Loonker, **Sophia Ppali**, Rocio von Jungenfeld, Christos Efstratiou, and Alexandra Covaci. 2022. "I was Holding a Magic Box": Investigating the Effects of Private and Projected Displays in Outdoor Heritage Walks. In *Proceedings of the 2022 ACM Designing Interactive Systems Conference (DIS '22)*. Association for Computing Machinery, New York, NY, USA, Pages 1565–1580.
`https://doi.org/10.1145/3532106.3533468` [286]

|WORKSHOP| **Sophia Ppali**, Marina Pasia, Sara Wolf, Jihae Han, Reese Muntean, Minyoung Yoo, Kasper Rodil, Arne Berger, Andreas Papallas, Luigina Ciolfi, John Stevens, and Alexandra Covaci. 2024. Sensing Heritage: Exploring Creative Approaches for Capturing, Experiencing and Safeguarding the Sensorial Aspects of Cultural Heritage. In *Companion Publication of the 2024 ACM Designing Interactive Systems Conference (DIS '24 Companion)*. Association for Computing Machinery, New York, NY, USA, Pages 445–448.
`https://doi.org/10.1145/3656156.3658400` [366]

|EXTENDED ABSTRACT - ART EXHIBITION SUBMISSION| Ethan Cheung, **Sophia Ppali**, Boris Otkhmezuri, Clare L. Thomas, and Alexandra Covaci. 2023. Co-creating Meaningful Spaces: Stepping into Virtual Worlds Crafted by People Living with Dementia. In *Companion Publication of the 2023 ACM Designing Interactive Systems Conference (DIS '23 Companion)*. Association for Computing Machinery, New York, NY, USA, Pages 81–85. `https://doi.org/10.1145/3563703.3596645` [101]

|WORK IN PROGRESS| Ethan Cheung, **Sophia Ppali**, Anna Xygkou, Alexandra Covaci, Hiba H Jawharieh, Clare L. Thomas, and Chee Siang Ang. 2023.Meaningful Spaces, Meaningful Places: Co-creating VR Experiences with People Living with Dementia. In *Companion Publication of the 2023 ACM Designing Interactive Systems Conference (DIS '23 Companion)*. Association for Computing Machinery, New York, NY, USA, Pages 217–221. `https://doi.org/10.1145/3563703.3596624` [102]

|LATE BREAKING WORK| Boyd Branch, Piotr Mirowski, **Sophia Ppali**, Rocio Von Jungenfeld, Paul Allain, and Christos Efstratiou. 2023. Mirror Placement Matters in Remote Collaboration. In *Extended Abstracts of the 2023 CHI Conference on Human Factors in Computing Systems (CHI EA '23)*. Association for Computing Machinery, New York, NY, USA, Article 207, Pages 1–8.
`https://doi.org/10.1145/3544549.3585798` [70]

|WORKSHOP PAPER| Ethan Cheung, Chee Siang Ang, Panote Siriaraya, **Sophia Ppali**, Kieran Breen, and Sarrah Fatima. 2022. VRPassport: Travel the world in Virtual Reality for people with Dementia. Presented at the CHI 2022 workshop: *The Future of Emotion in Human-Computer Interaction (EMOCHI '22)*. `https://kar.kent.ac.uk/id/eprint/99778` [100]

Appendix 2: Interview guide for musicians

This guide was used to support semi-structured interviews conducted in 4. The questions and prompts below served as thematic anchors during the sessions rather than a strict script. The purpose of the interviews was to get musicians reflect on their experiences of using *VR Rehearse & Perform* and gather feedback across several themes

- **System experience.**
  - How would you describe your overall experience of playing music in VR?
  - Which parts did you enjoy or find frustrating? What could be improved?
  - How did the VR sound environment feel to you? (e.g. reverberation, spatial acoustics)
  - What kind of music did you choose to play in VR and why?
- **Sense of presence.**
  - Did you feel as if you were "actually there" in the virtual space? Why or why not?
  - How did the different environments affect your playing or mood?
  - Did you think about being in the virtual space while you were playing?
- **Instrument interaction.**
  - How did you experience playing your instrument in VR?
  - Was it difficult not being able to see your hands or the instrument?
  - How did the relationship between the physical and virtual space affect your playing?
- **Flow and focus.**
  - Were you focused while playing or distracted by elements in VR?
  - How long did you feel like you were playing? (Followed by comparison to actual time)
  - How would you rate your performance quality in VR? What influenced that?
- **Comparisons with real-world practice.**
  - How did playing in VR compare to playing without the headset?
  - In what ways did it feel similar or different to practicing in a real venue?
  - What aspects felt better or worse, and why?
- **Future applications.**
  - Could you imagine using this in your regular practice? If so, for what?
  - Are there other uses of VR in your artistic practice that you could envision?

Appendix 3: Interview guide for audiences

This interview guide was developed to explore how audiences experience music performances remotely using digital technologies. Questions and prompts were used flexibly to allow participants to shape the conversation based on their own experiences.

- **Background & Listening Habits.**
  - Tell me a bit about yourself and your music preferences.
  - How important is music in your life? What types of music do you enjoy seeing live?
  - How often do you attend live music events? Can you describe a particularly memorable live music experience?
- **Experience with remote performances.**
  - How frequently do you attend online or remote music events?
  - Can you describe your experience attending musical performances from home?
  - How does attending a remote concert differ from being there in person?
- **Journey & ecosystem.**
  - What influences your decision to attend a remote or livestreamed event?
  - How do you usually find out about upcoming livestreamed performances?
  - What device or setup do you typically use (e.g. laptop, TV, phone)?
  - Do you prefer to attend alone or with others (friends, family)?
  - Have you used any live chat or online interaction features during a remote event? If so, how did that affect your experience?
- **Attitudes & behaviours.**
  - Can you describe a memorable online live music performance? What stood out to you?
  - What makes a remote music performance engaging or enjoyable?
  - Have you interacted with the artist or other audience members during a remote performance? How did you feel about it?
  - How important is it for you to feel part of a community during a remote music experience?
  - What challenges or frustrations have you encountered when watching live performances from home?
  - Are there aspects of remote performances that consistently fall short for you?
- **Opportunities & future directions.**
  - Should remote performances replicate or reinvent in-person concerts?
  - What elements are essential for remote performances to feel meaningful or immersive?
  - How do you think technology could be used to improve the at-home concert experience?
  - Are there any features you've seen, or would like to see, that might help remote performances feel more social or emotionally impactful?

Bibliography

[1] A. Adams and A. L. Cox. Questionnaires, in-depth interviews and focus groups. In P. Cairns and A. L. Cox, editors, *Research Methods for Human-Computer Interaction*, pages 17–34. Cambridge University Press, 1 edition, Aug. 2008. doi: https://10.1017/CBO9780511814570.003.

[2] S. Agrawal, A. Simon, S. Bech, K. Bærentsen, and S. Forchhammer. Defining Immersion: Literature Review and Implications for Research on Audiovisual Experiences. *Journal of the Audio Engineering Society*, 68(6):404–417, 2020. doi: https://doi.org/10.17743/jaes.2020.0039.

[3] I. Alfarone and U. Merlone. The show must go on: Pandemic consequences on musicians' job insecurity perception. *Psychology of Music*, 50:1976–2000, 2022. doi: https://doi.org/10.1177/03057356221081553.

[4] T. Alshehri, R. Kirkham, and P. Olivier. Scenario Co-Creation Cards: A Culturally Sensitive Tool for Eliciting Values. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*, pages 1–14. ACM, 2020. doi: https://doi.org/10.1145/3313831.3376608.

[5] F. Altarriba Bertran, E. Márquez Segura, and K. Isbister. Technology for Situated and Emergent Play: A Bridging Concept and Design Agenda. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*, pages 1–14. ACM, Apr. 2020. doi: https://doi.org/10.1145/3313831.3376859.

[6] F. Altarriba Bertran, A. Pometko, M. Gupta, L. Wilcox, R. Banerjee, and K. Isbister. The Playful Potential of Shared Mealtime: A Speculative Catalog of Playful Technologies for Day-to-day Social Eating Experiences. *Proceedings of the ACM on Human-Computer Interaction*, 5(CHI Play):267:1–267:26, Oct. 2021. doi: https://doi.org/10.1145/3474694.

[7] F. Altarriba Bertran, L. Bisbe Armengol, C. Cooke, I. Chen, V. Dong, B. Dastoor, K. Tadano, F. Dean, J. Wang, A. Altarriba Bertran, J. Duval, and K. Isbister. Co-Imagining the Future of Playable Cities: A Bottom-Up, Multi-Stakeholder Speculative Inquiry into the Playful Potential of Urban Technology. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems*, pages 1–19. ACM, Apr. 2022. doi: https://doi.org/10.1145/3491102.3501860.

[8] F. Altarriba Bertran, O. O. Buruk, V. Spors, and J. Hamari. Playful Inspiration for a New Wave of Joyful Forest Technology. In *Proceedings of the 2023 ACM Designing Interactive Systems Conference*, pages 1886–1903. ACM, 2023. doi: https://doi.org/10.1145/3563657.3596015.

[9] K. Andersen and R. Wakkary. The Magic Machine Workshops: Making Personal Design Knowledge. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, pages 1–13. ACM, 2019. doi: https://doi.org/10.1145/3290605.3300342.

[10] T. H. Andersen. *Interaction with Sound and Pre-recorded Music: Novel Interfaces and Use Patterns*. PhD thesis, University of Copenhagen, 2005.

[11] T. Anne-Marie, N. Chau, and K. Kimppa Kai. Ethical questions related to using netnography as research method. *The ORBIT Journal*, 1(2):1–11, 2017. doi: https://doi.org/10.29297/orbit.v1i2.50.

[12] T. Arterbury and G. M. Poor. 3D Positional Movement Interaction with User-Defined, Virtual Interface for Music Software: MoveMIDI. In *Extended Abstracts of the 2019 CHI Conference on Human Factors in Computing Systems*, pages 1–4. ACM, 2019. doi: https://doi.org/10.1145/3290607.3313267.

[13] J. Atherton and G. Wang. Curating Perspectives: Incorporating Virtual Reality into Laptop Orchestra Performance. In *Proceedings of the International Conference on New Interfaces for Musical Expression*, pages 154–159, 2020. doi: https://doi.org/10.5281/zenodo.4813290.

[14] J. Atherton and G. Wang. Doing vs. Being: A philosophy of design for artful VR. *Journal of New Music Research*, 49(1):35–59, 2020. doi: https://doi.org/10.1080/09298215.2019.1705862.

[15] L. Aufegger and D. Wasley. Virtual reality feedback influences musicians' physical responses and mental attitude towards performing. *Music and Medicine*, 12(3):157–166, 2020. ISSN 1943-863x. doi: https://10.47513/mmd.v12i3.732.

[16] L. Aufegger, R. Perkins, D. Wasley, and A. Williamon. Musicians' perceptions and experiences of using simulation training to develop performance skills. *Psychology of Music*, 45(3):417–431, 2017. doi: https://doi.org/10.1177/0305735616666940.

[17] P. A. Auslander, Philip. *Liveness: Performance in a Mediatized Culture*. Routledge, 2 edition, 2008. doi: https://doi.org/10.4324/9780203938133.

[18] A. Ayobi, K. Stawarz, D. S. Katz, P. Marshall, T. Yamagata, R. Santos-Rodríguez, P. A. Flach, and A. O'Kane. Co-Designing Personal Health? Multidisciplinary Benefits and Challenges in Informing Diabetes Self-Care Technologies. *Proceedings of the ACM on Human-Computer Interaction*, 5:1–26, 2021. doi: https://doi.org/10.1145/3479601.

[19] Z. J. Ayres. *Managing your mental health during your PhD: a survival guide*. Springer, 2022. doi: https://doi.org/10.1007/978-3-031-14194-2.

[20] D. Ayton, T. Tsindos, and D. Berkovic. *Qualitative Research – a practical guide for health and social care researchers and practitioners*. Monash University Library, Mar. 2023. doi: https://doi.org/10.60754/chqr-dn78.

[21] S. Baharloo, P. A. Johnston, S. K. Service, J. Gitschier, and N. B. Freimer. Absolute Pitch: An Approach for Identification of Genetic and Nongenetic Components. *The American Journal of Human Genetics*, 62(2):224–231, 1998. doi: https://doi.org/10.1086/301704.

[22] W. Bailey and B. Fazenda. The effect of visual cues and binaural rendering method on plausibility in virtual environments. In *Audio Engineering Society Convention 144*. Audio Engineering Society, 2018.

[23] M. Balaam, R. Comber, R. E. Clarke, C. Windlin, A. Ståhl, K. Höök, and G. Fitzpatrick. Emotion Work in Experience-Centered Design. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, pages 1–12. ACM, 2019. doi: https://doi.org/10.1145/3290605.3300832.

[24] L. Bannon. Reimagining HCI: toward a more human-centered perspective. *Interactions*, 18(4):50–57, 2011. doi: https://doi.org/10.1145/1978822.1978833.

[25] L. Bannon, J. Bardzell, and S. Bødker. Reimagining participatory design. *Interactions*, 26(1):26–32, 2018. doi: https://doi.org/10.1145/3292015.

[26] L. J. Banton. The Role of Visual and Auditory Feedback during the Sight-Reading of Music. *Psychology of Music*, 23(1):3–16, 1995. doi: https://doi.org/10.1177/0305735695231001.

[27] A. Barbosa and J. Cordeiro. The influence of perceptual attack times in networked music performance. In *Audio Engineering Society Conference: 44th International Conference: Audio Networking*. Audio Engineering Society, 2011.

[28] F. Barcellini, L. Prost, and M. Cerf. Designers' and users' roles in participatory design: What is actually co-designed by participants? *Applied Ergonomics*, 50:31–40, 2015. doi: https://doi.org/10.1016/j.apergo.2015.02.005.

[29] S. Bardzell. Feminist HCI: taking stock and outlining an agenda for design. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 1301–1310. ACM, 2010. doi: https://doi.org/10.1145/1753326.1753521.

[30] A. R. Bargum, D. Kandpal, O. I. Kristjansson, S. R. Mosen, J. Andersen, and S. Serafin. Virtual Reconstruction of a the Ambisonic Concert Hall of the Royal Danish Academy of Music. In *2021 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW)*, pages 99–102. IEEE, 2021.

[31] D. Barrera-Fernández and M. Hernández-Escampa. Inclusion of people with reduced mobility in festivals: Perceptions and challenges at the Guelaguetza Festival, Mexico. In *Accessibility, Inclusion, and Diversity in Critical Event Studies*. Routledge, 2018.

[32] C. Bartlette, D. Headlam, M. Bocko, and G. Velikic. Effect of network latency on interactive musical performance. *Music Perception*, 24(1):49–62, 2006.

[33] A. Bartolome, N. B. Ha, and S. Niu. Investigating multimodal interactions and parasocial attractiveness in YouTube ASMR videos. In *Companion Publication of the 2021 Conference on Computer Supported Cooperative Work and Social Computing*, pages 14–18, 2021.

[34] V. Bauer and T. Bouchara. First Steps Towards Augmented Reality Interactive Electronic Music Production. In *2021 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW)*, pages 90–93. IEEE, 2021.

[35] N. K. Baym. Fans or friends?: seeing social media audiences as musicians do. *Matrizes*, 7(1):13, June 2013. ISSN 1982-8160, 1982-2073. doi: https://doi.org/10.11606/issnnn.1982-8160.v7i1p13-46.

[36] A. Behr, M. Brennan, M. Cloonan, S. Frith, and E. Webster. Live Concert Performance: An Ecological Approach. *Rock Music Studies*, 3 (1):5–23, 2016. doi: https://doi.org/10.1080/19401159.2015.1125633.

[37] S. Benford and G. Giannachi. *Performing mixed reality*. MIT Press, 2011.

[38] S. Benford, G. Giannachi, B. Koleva, and T. Rodden. From interaction to trajectories: designing coherent journeys through user experiences. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 709–718. ACM, 2009. doi: https://doi.org/10.1145/1518701.1518812.

[39] S. Benford, C. Greenhalgh, A. Hazzard, A. Chamberlain, M. Kallionpää, D. M. Weigl, K. R. Page, and M. Lin. Designing the audience journey through repeated experiences. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*, pages 1–12, 2018.

[40] S. Benford, P. Mansfield, and J. Spence. Producing Liveness: The Trials of Moving Folk Clubs Online During the Global Pandemic. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*. ACM, 2021. doi: https://doi.org/10.1145/3411764.3445125.

[41] S. Benford, K. Manninen, S. Martindale, A. Hazzard, J. P. Martinez Avila, P. Tennent, J. Spence, T. Castle-Green, P. Brundell, P. Barnard, et al. Infrastructures for Virtual Volunteering at Online Music Festivals. *Proceedings of the ACM on Human-Computer Interaction*, 7 (Cscw1):1–26, 2023.

[42] A. Bennett. *Music scenes: Local, translocal and virtual*. Vanderbilt University Press, 2004.

[43] J. Bennington and D. Ko. Physical Controllers vs. Hand-and-Gesture Tracking: Control Scheme Evaluation for VR Audio Mixing. In *Audio Engineering Society Convention 147*. Audio Engineering Society, Audio Engineering Society, 2019.

[44] C. E. Benzecry. *The opera fanatic: Ethnography of an obsession*. University of CHIcago Press, 2019.

[45] L. Beranek. *Concert halls and opera houses: music, acoustics, and architecture*. Springer Science & Business Media, 2012.

[46] A. Bergman. 'Wherever You Are Whenever You Want': Captivating and Encouraging Music Experiences when Symphony Orchestra Performances are Provided Online. *Open Library of Humanities*, 7(2), 2021. doi: https://doi.org/10.16995/olh.4679.

[47] A. Berkowitz. *The Improvising Mind: Cognition and Creativity in the Musical Moment*. OUP Oxford, 2010.

[48] F. Berthaut, M. Desainte-Catherine, and M. Hachet. Drile: an immersive environment for hierarchical live-looping. In *Proceedings of the Conference on New Interfaces for Musical Expression*, pages 192–199, 2010.

[49] F. Berthaut, M. Hachet, and M. Desainte-Catherine. Piivert: Percussion-based interaction for immersive virtual environments. In *IEEE Symposium on 3D User Interfaces*, pages 15–18. IEEE, 2010.

[50] F. Berthaut, M. Desainte-Catherine, and M. Hachet. Interacting with 3D reactive widgets for musical performance. *Journal of New Music Research*, 40(3):253–263, 2011.

[51] F. Berthaut, V. Zappi, and D. Mazzanti. Scenography of immersive virtual musical instruments. In *2014 IEEE VR Workshop: Sonic interaction in virtual environments (SIVE)*, pages 19–24. IEEE, 2014. doi: https://doi.org/10.1109/sive.2014.7006285.

[52] F. A. Bertran, A. Pometko, M. Gupta, L. Wilcox, R. Banerjee, and K. Isbister. Designerly Tele-Experiences: A New Approach to Remote Yet Still Situated Co-Design. *ACM Transactions on Computer-Human Interaction*, 29(5):1–30, 2022. doi: https://doi.org/10.1145/3506698.

[53] M. Biasutti and L. Frezza. Dimensions of Music Improvisation. *Creativity Research Journal*, 21:232–242, 2009. doi: https://doi.org/10.1080/10400410902861240.

[54] K. Bijsterveld. Acoustic cocooning: How the car became a place to unwind. *The Senses and Society*, 5(2):189–211, 2010.

[55] A. Birhanu and S. Rank. KeynVision: exploring piano pedagogy in mixed reality. In *Extended Abstracts Publication of the Annual Symposium on Computer-Human Interaction in Play*, pages 299–304, 2017.

[56] J. Bissonnette, F. Dubé, M. Provencher, and M. Moreno Sala. Virtual reality exposure training for musicians: Its effect on performance anxiety and quality. *Medical problems of performing artists*, 30(3):169–177, 2015.

[57] E. Bjögvinsson, P. Ehn, and P.-A. Hillgren. Design Things and Design Thinking: Contemporary Participatory Design Challenges. *Design Issues*, 28(3):101–116, 2012. doi: https://doi.org/10.1162/DESI_a_00165.

[58] A. F. Blackwell. HCI as an Inter-Discipline. In *Proceedings of the 33rd Annual ACM Conference Extended Abstracts on Human Factors in Computing Systems*, pages 503–516. ACM, 2015. doi: https://doi.org/10.1145/2702613.2732505.

[59] L. Blackwell, N. Ellison, N. Elliott-Deflo, and R. Schwartz. Harassment in Social Virtual Reality: Challenges for Platform Governance. *Proceedings of the ACM on Human-Computer Interaction*, 3(Cscw):1–25, 2019. doi: https://doi.org/10.1145/3359202.

[60] A. E. Blandford. Semi-structured qualitative studies. In M. Soegaard and R. Dam, editors, *In: Soegaard, M and Dam, R, (eds.) The Encyclopedia of Human-Computer Interaction. Interaction Design Foundation: Denmark. (2013)*. Interaction Design Foundation, 2013.

[61] J. Bleecker. Design Fiction: A Short Essay on Design, Science, Fact, and Fiction. In S. Carta, editor, *Machine Learning and the City*, pages 561–578. Wiley, 1 edition, 2022. doi: https://doi.org/10.1002/9781119815075.ch47.

[62] S. Bødker. When second wave HCI meets third wave challenges. In *Proceedings of the 4th Nordic conference on Human-computer interaction: changing roles*, pages 1–8. ACM, 2006. doi: https://doi.org/10.1145/1182475.1182476.

[63] S. Bødker. Third-wave HCI, 10 Years Later—participation and Sharing. *Interactions*, 22(5):24–31, 2015.

[64] S. Bødker and M. Kyng. Participatory Design that Matters–Facing the Big Issues. *ACM Transactions on Computer-Human Interaction*, 25(1):1–31, 2018. doi: https://doi.org/10.1145/3152421.

[65] S. Bødker, C. Dindler, O. S. Iversen, and R. C. Smith. What Is Participatory Design? In S. Bødker, C. Dindler, O. S. Iversen, and R. C. Smith, editors, *Participatory Design*, pages 5–13. Springer International Publishing, 2022. doi: https://doi.org/10.1007/978-3-031-02235-7_2.

[66] L. Boer and J. Donovan. Provotypes for participatory innovation. In *Proceedings of the Designing Interactive Systems Conference*, pages 388–397. ACM, 2012. doi: https://doi.org/10.1145/2317956.2318014.

[67] L. O. Bonde, K. Juel, and O. Ekholm. Associations between music and health-related outcomes in adult non-musicians, amateur musicians and professional musicians–Results from a nationwide Danish study. *Nordic Journal of Music Therapy*, 27(4):262–282, 2018.

[68] D. Borgo. Beyond performance: Transmusicking in cyberspace. *Taking it to the Bridge: Music as Performance*, pages 319–348, 2013.

[69] A. Bossey. Accessibility all areas? UK live music industry perceptions of current practice and Information and Communication Technology improvements to accessibility for music festival attendees who are deaf or disabled. *International Journal of Event and Festival Management*, 11(1):6–25, 2020. doi: https://doi.org/10.1108/ijefm-03-2019-0022.

[70] B. Branch, P. Mirowski, S. Ppali, R. Von Jungenfeld, P. Allain, and C. Efstratiou. Mirror Placement Matters in Remote Collaboration. In *Extended Abstracts of the 2023 CHI Conference on Human Factors in Computing Systems*, pages 1–8. ACM, Apr. 2023. doi: https://doi.org/10.1145/3544549.3585798.

[71] B. Branch, P. Mirowski, K. Mathewson, S. Ppali, and A. Covaci. Designing and Evaluating Dialogue LLMs for Co-Creative Improvised Theatre, May 2024.

[72] T. Bratteteig and I. Wagner. Disentangling power and decision-making in participatory design. In *Proceedings of the 12th Participatory Design Conference: Research Papers - Volume 1*, pages 41–50. ACM, 2012. doi: https://doi.org/10.1145/2347635.2347642.

[73] V. Braun and V. Clarke. Reflecting on reflexive thematic analysis. *Qualitative Research in Sport, Exercise and Health*, 11(4):589–597, Aug. 2019. ISSN 2159-676x. doi: https://doi.org/10.1080/2159676x.2019.1628806.

[74] V. Braun and V. Clarke. One size fits all? What counts as quality practice in (reflexive) thematic analysis? *Qualitative Research in Psychology*, 18(3):328–352, 2021. ISSN 1478-0895. doi: https://doi.org/10.1080/14780887.2020.1769238.

[75] G. Breakwell and R. Jaspal. Identity processes and musicians during the COVID-19 pandemic. *Musicae Scientiae*, 26:777–798, 2022. doi: https://doi.org/10.1177/10298649221102526.

[76] J. Broderick, J. Duggan, and S. Redfern. The Importance of Spatial Audio in Modern Games and Virtual Environments. In *2018 IEEE Games, Entertainment, Media Conference (GEM)*, pages 1–9, 2018. doi: https://doi.org/10.1109/gem.2018.8516445.

[77] J. Brooks and P. Lopes. Smell & Paste: Low-Fidelity Prototyping for Olfactory Experiences. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*, pages 1–16. ACM, 2023. doi: https://doi.org/10.1145/3544548.3580680.

[78] E. Brown and P. Cairns. A grounded investigation of game immersion. In *CHI '04 Extended Abstracts on Human Factors in Computing Systems*, pages 1297–1300. ACM, 2004. doi: https://doi.org/10.1145/985921.986048.

[79] S. C. Brown and D. Knox. Why go to pop concerts? The motivations behind live music attendance. *Musicae Scientiae*, 21(3):233–249, 2017.

[80] A. Bryman. *Social research methods*. Oxford University Press, 2005.

[81] M. Buchenau and J. F. Suri. Experience prototyping. In *Proceedings of the 3rd conference on Designing interactive systems: processes, practices, methods, and techniques*, pages 424–433. ACM, 2000. doi: https://doi.org/10.1145/347642.347802.

[82] J. Burgess and J. Green. *Youtube: online video and participatory culture*. Polity Press, second edition edition, 2018.

[83] C. Burton-Hill. Is watching opera in the cinema just as good? URL https://www.bbc.com/culture/article/20150114-opera-in-the-cinema-blasphemy.

[84] M. Butterfield. Participatory Discrepancies and the Perception of Beats in Jazz. *Music Perception*, 27(3):157–176, 2010. doi: https://doi.org/10.1525/mp.2010.27.3.157.

[85] C. J. Cai, M. Carney, N. Zada, and M. Terry. Breakdowns and Breakthroughs: Observing Musicians' Responses to the COVID-19 Pandemic. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*, pages 1–13. ACM, May 2021. doi: https://doi.org/10.1145/3411764.3445192.

[86] C. Çakmak and R. Hamilton. Composing Spatial Music with Web Audio and WebVR. In *Proceedings of the Web Audio Conference*, 2019.

[87] C. Çakmak, A. Çamcı, and A. Forbes. Networked Virtual Environments as Collaborative Music Spaces. In *Proceedings of the International Conference on New Interfaces for Musical Expression*, pages 106–111, 2016.

[88] F. Campbell, L. Blank, A. Cantrell, S. Baxter, C. Blackmore, J. Dixon, and E. Goyder. Factors that influence mental health of university and college students in the UK: a systematic review. *BMC Public Health*, 22(1):1778, 2022. doi: https://doi.org/10.1186/s12889-022-13943-x.

[89] B. Carey. SpectraScore VR: Networkable virtual reality software tools for real-time composition and performance. In *International conference on New Interfaces for Musical Expression*, 2016.

[90] B. Carey and B. Ulas. VR'SPACE OPERA': Mimetic Spectralism in an Immersive Starlight Audification System. *arXiv preprint arXiv:1611.03081*, 2016.

[91] A. Carôt and C. Werner. Fundamentals and principles of musical telepresence. *Journal of Science and Technology of the Arts*, pages 26–37 Páginas, Jan. 2009. doi: https://doi.org/10.7559/citarj.v1i1.6.

[92] D. Catapult. Immersive Audience Journey Report. Technical report, Digital Catapult, 2020.

[93] D. J. Chalmers. *Reality+: Virtual worlds and the problems of philosophy*. Penguin UK, 2022.

[94] A. Chamberlain, A. Crabtree, and M. Davies. Community engagement for research: contextual design in rural CSCW system development. In *Proceedings of the 6th International Conference on Communities and Technologies*, pages 131–139. ACM, 2013. doi: https://doi.org/10.1145/2482991.2483001.

[95] A. Chamberlain, S. Benford, and A. Dix. Re-Thinking Immersive Technologies for Audiences of the Future. In *Proceedings of the Audio Mostly 2018 on Sound in Immersion and Emotion*, pages 1–3. 2018.

[96] H. Chapin, K. Jantzen, J. A. S. Kelso, F. Steinberg, and E. Large. Dynamic Emotional and Neural Responses to Music Depend on Performance Expression and Listener Experience. *Plos One*, 5(12):e13812, 2010. doi: https://doi.org/10.1371/journal.pone.0013812.

[97] J.-P. Charron. Music Audiences 3.0: Concert-Goers' Psychological Motivations at the Dawn of Virtual Reality. *Frontiers in Psychology*, 8(May):8–11, 2017. ISSN 1664-1078. doi: https://doi.org/10.3389/fpsyg.2017.00800.

[98] L.-X. Chen and C.-T. Sun. Self-regulation influence on game play flow state. *Computers in Human Behavior*, 54:341–350, 2016.

[99] Q. Chen, J. Gan, A. Bellucci, and G. Jacucci. "I Felt Everyone Was a Streamer": An Empirical Study on What Makes Avatar Collective Streaming Engaging. *Proc. ACM Hum.-Comput. Interact.*, 8(Cscw1), Apr. 2024. doi: https://doi.org/10.1145/3637344.

[100] E. Cheung, C. S. Ang, S. Siriaraya, Panoteeand Ppali, K. Breen, and S. Fatima. VRPassport: Travel the world in Virtual Reality for people with Dementia, Mar. 2022.

[101] E. Cheung, S. Ppali, B. Otkhmezuri, C. L. Thomas, and A. Covaci. Co-creating Meaningful Spaces: Stepping into Virtual Worlds Crafted by People Living with Dementia. In *Designing Interactive Systems Conference*, pages 81–85. ACM, 2023. doi: https://doi.org/10.1145/3563703.3596645.

[102] E. Cheung, S. Ppali, A. Xygkou, A. Covaci, H. H. Jawharieh, C. L. Thomas, and C. S. Ang. Meaningful Spaces, Meaningful Places: Co-creating VR Experiences with People Living with Dementia. In *Companion Publication of the 2023 ACM Designing Interactive Systems Conference*, pages 217–221. ACM, July 2023. doi: https://doi.org/10.1145/3563703.3596624.

[103] A. CHIrico, S. Serino, P. Cipresso, A. Gaggioli, and G. Riva. When music "flows". State and trait in musical performance, composition and listening: a systematic review. *Frontiers in Psychology*, 6:906, 2015. doi: https://doi.org/10.3389/fpsyg.2015.00906.

[104] M. Ciciliani. Virtual 3D environments as composition and performance spaces. *Journal of New Music Research*, 49(1):104–113, 2020.

[105] L. Ciolfi. Understanding spaces as places: extending interaction design paradigms. *Cognition, Technology & Work*, 6(1):37–40, 2004. doi: https://doi.org/10.1007/s10111-003-0139-6.

[106] T. Clark and A. Williamon. Evaluation of a mental skills training program for musicians. *Journal of Applied Sport Psychology*, 23(3): 342–359, 2011. doi: https://doi.org/10.1080/10413200.2011.574676.

[107] E. F. Clarke. Creativity in performance. *Musicae Scientiae*, 9(1):157–182, 2005. doi: https://doi.org/10.1177/102986490500900106.

[108] V. J. Clemente-Suárez, A. A. Dalamitros, A. I. Beltran-Velasco, J. Mielgo-Ayuso, and J. F. Tornero-Aguilera. Social and Psychophysiological Consequences of the COVID-19 Pandemic: An Extensive Literature Review. *Frontiers in Psychology*, 11:580225, 2020. doi: https://doi.org/10.3389/fpsyg.2020.580225.

[109] J. Coenen, P. Biedermann, S. Claes, and A. Vande Moere. The Stakeholder Perspective on Using Public Polling Displays for Civic Engagement. In *Proceedings of the 10th International Conference on Communities & Technologies - Wicked Problems in the Age of Tech*, pages 61–74. ACM, 2021. doi: https://doi.org/10.1145/3461564.3461585.

[110] S. Cohen and J. Ginsborg. The Experiences of Mid-career and Seasoned Orchestral Musicians in the UK During the First COVID-19 Lockdown. *Frontiers in Psychology*, 12, 2021.

[111] S. Cohen and J. Ginsborg. One Year on: The Impact of COVID-19 on the Lives of Freelance Orchestral Musicians in the United Kingdom. *Frontiers in Psychology*, 13, 2022. doi: https://doi.org/10.3389/fpsyg.2022.885606.

[112] A. Corrêa, B. Lemos, M. Nascimento, and R. Lopes. AR Musical App for CHIldren's Musical Education. In *IEEE International Symposium on Consumer Electronics*, pages 125–126. IEEE, 2016.

[113] N. N. Correia, D. Castro, and A. Tanaka. The Role of Live Visuals in Audience Understanding of Electronic Music Performances. In *Proceedings of the 12th International Audio Mostly Conference on Augmented and Participatory Sound and Music Experiences*, pages 1–8. ACM, 2017. doi: https://doi.org/10.1145/3123514.3123555.

[114] W. Costa, L. Ananias, I. Barbosa, B. Barbosa, A. De'Carli, R. Barioni, L. Figueiredo, V. Teichrieb, and D. Filgueira. Songverse: a music-loop authoring tool based on Virtual Reality. In *IEEE Symposium on Virtual and Augmented Reality*, pages 216–222. IEEE, 2019.

[115] N. Couldry. Liveness, "Reality," and the Mediated Habitus from Television to the Mobile Phone. *The Communication Review*, 7(4): 353–361, 2004. doi: https://doi.org/10.1080/10714420490886952.

[116] P. Coulton and J. G. Lindley. More-Than Human Centred Design: Considering Other Things. *The Design Journal*, 22(4):463–481, 2019. doi: https://doi.org/10.1080/14606925.2019.1614320.

[117] A. Covaci, L. Zou, I. Tal, G.-M. Muntean, and G. Ghinea. Is Multimedia Multisensorial? - A Review of Mulsemedia Systems. *ACM Computing Surveys*, 51(5):91:1–91:35, Sept. 2018. ISSN 0360-0300. doi: https://doi.org/10.1145/3233774.

[118] A. Covaci, K. Alhasan, M. Loonker, B. Farrell, L. Tabbaa, S. Ppali, and C. S. Ang. No Pie in the (Digital) Sky: Co-Imagining the Food Metaverse. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*, pages 1–17. ACM, Apr. 2023. doi: https://doi.org/10.1145/3544548.3581305.

[119] C. Cox, B. Hicks, and J. Gopsill. Improving Mixed-Reality Prototyping through a Classification and Characterisation of Fidelity. *Proceedings of the Design Society*, 2:353–362, 2022. doi: https://doi.org/10.1017/pds.2022.37.

[120] R. Cox, A. Irving, and C. Wright, editors. *Beyond text? critical practices and sensory anthropology*. Manchester University Press, first published edition, 2016.

[121] I. Cross. Music, cognition, culture, and evolution. *Annals of the New York Academy of Sciences*, 930:28–42, 2001. doi: https://doi.org/10.1111/j.1749-6632.2001.tb05723.x.

[122] M. Csikszentmihalyi and M. Csikzentmihaly. *Flow: The psychology of optimal experience*, volume 1990. Harper & Row New York, 1990.

[123] M. Csikszentmihalyi and J. LeFevre. Optimal experience in work and leisure. *Journal of personality and social psychology*, 56(5):815, 1989.

[124] M. Cuevas-Rodríguez, L. Picinali, D. González-Toledo, C. Garre, E. de la Rubia-Cuestas, L. Molina-Tanco, and A. Reyes-Lecuona. 3D tune-in toolkit: An open-source library for real-time binaural spatialisation. *PLoS ONE*, 14(3):e0211899, 2019. doi: https://doi.org/10.1371/journal.pone.0211899.

[125] R. E. Cytowic and D. Eagleman. *Wednesday is indigo blue: Discovering the brain of synesthesia*. Mit Press, 2011.

[126] H. Daffern, K. Balmer, and J. Brereton. Singing Together, Yet Apart: The Experience of UK Choir Members and Facilitators During the Covid-19 Pandemic. *Frontiers in Psychology*, 12, 2021.

[127] T. Daikoku. Musical creativity and depth of implicit knowledge: spectral and temporal individualities in improvisation. *Frontiers in computational neuroscience*, 12:89, 2018.

[128] M. T. Deighan, A. Ayobi, and A. A. O'Kane. Social Virtual Reality as a Mental Health Tool: How People Use VRChat to Support Social Connectedness and Wellbeing. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*, pages 1–13. ACM, 2023. doi: https://doi.org/10.1145/3544548.3581103.

[129] I. Deliège and G. A. Wiggins. *Musical creativity: Multidisciplinary research in theory and practice*. Psychology Press, 2006.

[130] J. Delrue, A. Mouratidis, L. Haerens, G.-J. De Muynck, N. Aelterman, and M. Vansteenkiste. Intrapersonal achievement goals and underlying reasons among long distance runners: Their relation with race experience, self-talk, and running time. *Psychologica Belgica*, 56(3):288, 2016.

[131] J. Denk, A. Burmester, M. Kandziora, and M. Clement. The impact of COVID-19 on music consumption and music spending. *PLoS ONE*, 17(5):e0267640, 2022. doi: https://doi.org/10.1371/journal.pone.0267640.

[132] T. DeNora. *Music in everyday life*. Cambridge university press, 2000.

[133] L. Devendorf, K. Andersen, and A. Kelliher. The Fundamental Uncertainties of Mothering: Finding Ways to Honor Endurance, Struggle, and Contradiction. *ACM Trans. Comput.-Hum. Interact.*, 27(4):26:1–26:24, 2020. doi: https://doi.org/10.1145/3397177.

[134] A. d'Hoop and J. Pols. 'The game is on!'Eventness at a distance at a livestream concert during lockdown. *Ethnography*, page 14661381221124502, 2022.

[135] Digital Catapult and UK Reseach and Innovation. An overview of audience insights and perspectives on immersive art, culture, and entertainment. Technical report.

[136] G. A. Dingle, L. S. Sharman, Z. Bauer, E. Beckman, M. Broughton, E. Bunzli, R. Davidson, G. Draper, S. Fairley, C. Farrell, L. M. Flynn, S. Gomersall, M. Hong, J. Larwood, C. Lee, J. Lee, L. Nitschinsk, N. Peluso, S. E. Reedman, D. Vidas, Z. C. Walter, and O. R. L. Wright. How Do Music Activities Affect Health and Well-Being? A Scoping Review of Studies Examining Psychosocial Mechanisms. *Frontiers in Psychology*, 12:713818, 2021. doi: https://doi.org/10.3389/fpsyg.2021.713818.

[137] C. DiSalvo, J. Lukens, T. Lodato, T. Jenkins, and T. Kim. Making public things: how HCI design can express matters of concern. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 2397–2406. ACM, 2014. doi: https://doi.org/10.1145/2556288.2557359.

[138] A. Doucet. "From Her Side of the Gossamer Wall(s)": Reflexivity and Relational Knowing. *Qualitative Sociology*, 31(1):73–87, 2008. doi: https://doi.org/10.1007/s11133-007-9090-9.

[139] P. Dourish. *Where the Action Is: The Foundations of Embodied Interaction*. The MIT Press, Sept. 2001. doi: https://doi.org/10.7551/mitpress/7221.001.0001.

[140] S. Dow, B. MacIntyre, J. Lee, C. Oezbek, J. Bolter, and M. Gandy. Wizard of Oz support throughout an iterative design process. *IEEE Pervasive Computing*, 4(4):18–26, 2005. doi: https://doi.org/10.1109/mprv.2005.93.

[141] H. L. Dreyfus and S. E. Dreyfus. The ethical implications of the five-stage skill-acquisition model. *Bulletin of Science, Technology & Society*, 24(3):251–264, 2004.

[142] A. Dunne. *Speculative Everything: Design, Fiction, and Social Dreaming*. MIT Press, 2013.

[143] P. Ehn. Scandinavian Design: On Participation and Skill. In *Participatory Design*. CRC Press, 1993.

[144] R. Eleftheriades, C. Fiala, and M. D. Pasic. The challenges and mental health issues of academic trainees. *F1000Research*, 9:104, 2020. doi: https://doi.org/10.12688/f1000research.21066.1.

[145] S. Elsayed-Ali, E. M. Bonsignore, and J. Chan. Exploring Challenges to Inclusion in Participatory Design From the Perspectives of Global North Practitioners. *Proceedings of the ACM on Human-Computer Interaction*, 7:1–25, 2023. doi: https://doi.org/10.1145/3579606.

[146] C. Elsden, D. Chatting, A. C. Durrant, A. Garbett, B. Nissen, J. Vines, and D. S. Kirk. On Speculative Enactments. *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*, pages 5386–5399, 2017. doi: https://doi.org/10.1145/3025453.3025503.

[147] S. Engeser and F. Rheinberg. Flow, performance and moderators of challenge-skill balance. *Motivation and Emotion*, 32(3):158–172, 2008.

[148] K. A. Ericsson, R. T. Krampe, and C. Tesch-Römer. The role of deliberate practice in the acquisition of expert performance. *Psychological Review*, 100(3):363–406, 1993. doi: https://doi.org/10.1037/0033-295x.100.3.363.

[149] E. Fallowfield and P. Gomez. An etude for post-pandemic practice: The impact of the COVID-19 pandemic on practice methods and instrumental technique. *Frontiers in Psychology*, 13, 2022. doi: https://doi.org/10.3389/fpsyg.2022.846953.

[150] Y. Fanger, K. Pfeuffer, U. Helmbrecht, and F. Alt. PIANX – A Platform for Piano Players to Alleviate Music Performance Anxiety Using Mixed Reality. In *19th International Conference on Mobile and Ubiquitous Multimedia*, pages 267–276. ACM, 2020. doi: https://doi.org/10.1145/3428361.3428394.

[151] V. Fernández and B. Gerasimova. *IRL to URL: Digitalization in the live music scene during and post-COVID-19 : A platform-driven study of the live music scene and its approaches*, volume 2. Curran Associates, Inc., 2022.

[152] J. R. Ferreira, H. C. N. Carrer, M. M. Cid, and A. B. Oliveira. Relationship of Musculoskeletal Symptoms and Musical Practice Intensity among Musicians During the COVID-19 Pandemic: A Descriptive Questionnaire Study. *Medical problems of performing artists*, 37 4: 242–248, 2022. doi: https://doi.org/10.21091/mppa.2022.4029.

[153] P. Ferreira. Metaverse Sustainability: The Green Challenge of Virtual Worlds, 2023.

[154] A. Følstad, M. Skjuve, and P. B. Brandtzaeg. Different chatbots for different purposes: towards a typology of chatbots to understand interaction design. In *Internet Science: INSCI 2018 International Workshops, St. Petersburg, Russia, October 24–26, 2018, Revised Selected Papers 5*, pages 145–156. Springer, 2019.

[155] C. Ford, D. Gardner, L. E. Horgan, C. Liu, a. m. tsaasan, B. Nardi, and J. Rickman. Chat Speed OP PogChamp: Practices of Coherence in Massive Twitch Chat. In *Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems*, pages 858–871. ACM, May 2017. doi: https://doi.org/10.1145/3027063.3052765.

[156] N. R. Fram, V. Goudarzi, H. Terasawa, and J. Berger. Collaborating in isolation: assessing the effects of the Covid-19 pandemic on patterns of collaborative behavior among working musicians. *Frontiers in Psychology*, 12, 2021.

[157] C. A. Fraser, J. O. Kim, A. Thornsberry, S. Klemmer, and M. Dontcheva. Sharing the Studio: How Creative Livestreaming can Inspire, Educate, and Engage. In *Proceedings of the 2019 on Creativity and Cognition*, pages 144–155. ACM, June 2019. doi: https://doi.org/10.1145/3325480.3325485.

[158] T. Fraser, A. H. D. Crooke, and J. W. Davidson. "Music Has No Borders": An Exploratory Study of Audience Engagement With YouTube Music Broadcasts During COVID-19 Lockdown, 2020. *Frontiers in Psychology*, 12, 2021.

[159] C. Frauenberger, J. Good, G. Fitzpatrick, and O. S. Iversen. In pursuit of rigour and accountability in participatory design. *International Journal of Human-Computer Studies*, 74:93–106, 2015. doi: https://doi.org/10.1016/j.ijhcs.2014.09.004.

[160] E. L. Frederick, C. H. Lim, G. Clavio, and P. Walsh. Why we follow: An examination of parasocial interaction and fan motivations for following athlete archetypes on Twitter. *International journal of sport communication*, 5(4):481–502, 2012.

[161] G. Freeman, S. Zamanifard, D. Maloney, and A. Adkins. My Body, My Avatar: How People Perceive Their Avatars in Social Virtual Reality. In *Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems*, pages 1–8. ACM, Apr. 2020. doi: https://doi.org/10.1145/3334480.3382923.

[162] G. Freeman, S. Zamanifard, D. Maloney, and D. Acena. Disturbing the Peace: Experiencing and Mitigating Emerging Harassment in Social Virtual Reality. *Proceedings of the ACM on Human-Computer Interaction*, 6(Cscw1):1–30, 2022. doi: https://doi.org/10.1145/3512932.

[163] S. Frith. *Performing rites: On the value of popular music*. Harvard University Press, 1996.

[164] K. Fu, Y. Chen, J. Cao, X. Tong, and R. LC. "I Am a Mirror Dweller": Probing the Unique Strategies Users Take to Communicate in the Context of Mirrors in Social Virtual Reality. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*, pages 1–19. ACM, 2023. doi: https://doi.org/10.1145/3544548.3581464.

[165] C. J. Fullagar, P. A. Knight, and H. S. Sovern. Challenge/Skill Balance, Flow, and Performance Anxiety. *Applied Psychology*, 62(2): 236–259, 2013. doi: https://doi.org/10.1111/j.1464-0597.2012.00494.x.

[166] A. Gabrielsson. Music Performance Research at the Millennium. *Psychology of Music*, 31(3):221–272, 2003.

[167] A. Gabrielsson, J. Whaley, and J. Sloboda. Peak Experiences in Music. In S. Hallam, I. Cross, and M. H. Thaut, editors, *The Oxford Handbook of Music Psychology*, page 0. Oxford University Press, Jan. 2016. doi: https://doi.org/10.1093/oxfordhb/9780198722946.013.44.

[168] J. Garcia, T. Carpentier, and J. Bresson. Interactive-compositional authoring of sound spatialization. *Journal of New Music Research*, 46(1):74–86, 2017.

[169] P. Garcia and M. Cifor. Expanding Our Reflexive Toolbox: Collaborative Possibilities for Examining Socio-Technical Systems Using Duoethnography. *Proc. ACM Hum.-Comput. Interact.*, 3(Cscw):190:1–190:23, 2019. doi: https://doi.org/10.1145/3359292.

[170] W. Gaver. What should we expect from research through design? In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 937–946. ACM, May 2012. doi: https://doi.org/10.1145/2207676.2208538.

[171] W. W. Gaver, J. Beaver, and S. Benford. Ambiguity as a resource for design. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 233–240. ACM, 2003. doi: https://doi.org/10.1145/642611.642653.

[172] A. M. Geeves, D. J. McIlwain, and J. Sutton. Seeing yellow: 'Connection' and routine in professional musicians' experience of music performance. *Psychology of Music*, 44(2):183–201, 2016. doi: https://doi.org/10.1177/0305735614560841.

[173] E. Gerber and M. Carroll. The psychological experience of prototyping. *Design Studies*, 33(1):64–84, 2012. doi: https://doi.org/10.1016/j.destud.2011.06.005.

[174] J. Giacomin. What Is Human Centred Design? *The Design Journal*, 17(4):606–623, 2014. doi: https://doi.org/10.2752/175630614x14056185480186.

[175] R. Graham and S. Cluett. The Soundfield as Sound Object: Virtual Reality Environments as a Three-Dimensional Canvas for Music Composition. In *Audio Engineering Society Conference: 2016 AES International Conference on Audio for Virtual and Augmented Reality*. Audio Engineering Society, Audio Engineering Society, 2016.

[176] W. Greeff. *The influence of perception latency on the quality of musical performance during a simulated delay scenario*. PhD thesis, University of Pretoria, 2016.

[177] B. Green. Splendour XR: Place, Experience and Liveness at a Virtual Music Festival. *Leisure Sciences*, pages 1–18, 2023.

[178] S. A. Gross and G. Musgrave. *Can Music Make You Sick?: Measuring the Price of Musical Ambition*. University of Westminster Press, 2020.

[179] D. J. Gunkel. The Relational Turn: Third Wave HCI and Phenomenology. In M. Filimowicz and V. Tzankova, editors, *New Directions in Third Wave Human-Computer Interaction: Volume 1 - Technologies*, pages 11–24. Springer International Publishing, 2018. doi: https://doi.org/10.1007/978-3-319-73356-2_2.

[180] D. Hackl and C. Anthes. HoloKeys-An Augmented Reality Application for Learning the Piano. In *Forum Media Technology*, pages 140–144, 2017.

[181] J. Haferkorn, B. Kavanagh, and S. Leak. Livestreaming Music in the UK. A report for musicians. Technical report, Economic and Social Research Council, May 2021.

[182] R. Hajika, K. Gupta, P. Sasikumar, and Y. S. Pai. HyperDrum: Interactive Synchronous Drumming in Virtual Reality using Everyday Objects. In *SIGGRAPH Asia 2019 XR*, pages 15–16. ACM, 2019. doi: https://doi.org/10.1145/3355355.3361894.

[183] K. Halskov and P. Dalsgård. Inspiration card workshops. In *Proceedings of the 6th conference on Designing Interactive systems*, pages 2–11. ACM, 2006. doi: https://doi.org/10.1145/1142405.1142409.

[184] K. Halskov and N. B. Hansen. The diversity of participatory design research practice at PDC 2002–2012. *International Journal of Human-Computer Studies*, 74:81–92, 2015. doi: https://doi.org/10.1016/j.ijhcs.2014.09.003.

[185] R. Hamilton. Coretet: a 21st Century Virtual Interface for Musical Expression. In *International Symposium on Computer Music Multidisciplinary Research*, pages 1010–1021, 2019.

[186] R. Hamilton. Mediated musical interactions in virtual environments. In *New Directions in Music and Human-Computer Interaction*, pages 243–257. Springer, 2019.

[187] R. Hamilton and C. Platz. Gesture-based collaborative virtual reality performance in carillon. In *Proceedings of the International Computer Music Conference*, pages 337–340, 2016.

[188] W. A. Hamilton, O. Garretson, and A. Kerne. Streaming on twitch: fostering participatory communities of play within live mixed media. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 1315–1324. ACM, Apr. 2014. doi: https://doi.org/10.1145/2556288.2557048.

[189] E. Hammelburg. Live event-spaces: Place and space in the mediatized experience of events. In *Locating Imagination in Popular Culture*. Routledge, 2020.

[190] E. Hammelburg. *Being There Live: How Liveness is Realized Through Media Use at Contemporary Cultural Events*. PhD thesis, Dec. 2021.

[191] E. Hammelburg. Being There Live: An Ethnographic Approach for Studying Social Media Use in Mediatized Live Events. *Social Media + Society*, 7(1):2056305120984454, Jan. 2021. ISSN 2056-3051. doi: https://doi.org/10.1177/2056305120984454.

[192] J. Han, Y. Sun, S. Ppali, A. Covaci, and A. Vande Moere. To Cuddle, Mingle, Venture, or Guide: How Architectural Affordances Influence the Experience of Social VR Places. In *Proceedings of the 2025 ACM Designing Interactive Systems Conference*. ACM, July 2025. doi: https://doi.org/10.1145/3715336.3735772.

[193] N. C. Hansen, J. M. G. Treider, D. Swarbrick, J. S. Bamford, J. Wilson, and J. K. Vuoskoski. A crowd-sourced database of coronamusic: documenting online making and sharing of music during the COVID-19 pandemic. *Frontiers in Psychology*, 12:684083, 2021.

[194] D. Haraway. Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspective. *Feminist Studies*, 14 (3):575–599, 1988. doi: https://doi.org/10.2307/3178066.

[195] J. Hardy, S. Wyche, and T. Veinot. Rural HCI Research. *Proceedings of the ACM on Human-Computer Interaction*, 3:1–33, 2019. doi: https://doi.org/10.1145/3359298.

[196] M. A. Harley. *Space and spatialization in contemporary music: History and analysis, ideas and implementations*. Lulu. com, 2016.

[197] D. J. Harris, K. L. Allen, S. J. Vine, and M. R. Wilson. A systematic review and meta-analysis of the relationship between flow states and performance. *International Review of Sport and Exercise Psychology*, pages 1–29, 2021.

[198] S. Harrison and P. Dourish. Re-place-ing space: the roles of place and space in collaborative systems. In *Proceedings of the 1996 ACM conference on Computer supported cooperative work*, pages 67–76. ACM, 1996. doi: https://doi.org/10.1145/240080.240193.

[199] S. Harrison, P. Sengers, and D. Tatar. Making epistemological trouble: Third-paradigm HCI as successor science. *Interacting with Computers*, 23(5):385–392, 2011. doi: https://doi.org/10.1016/j.intcom.2011.03.005.

[200] J. Haynes and L. Marshall. Beats and tweets: Social media in the careers of independent musicians. *New Media & Society*, 20(5): 1973–1993, 2018.

[201] C. Heeter. Being There: The Subjective Experience of Presence. *Presence: Teleoperators and Virtual Environments*, 1(2):262–271, 1992. doi: https://doi.org/10.1162/pres.1992.1.2.262.

[202] S. J. Heine. *Cultural psychology*. W.W. Norton & Company, fourth edition, international student ediction edition, 2020.

[203] I. Héroux. Creative Processes in the Shaping of a Musical Interpretation: A Study of Nine Professional Musicians. *Frontiers in Psychology*, 9:665, 2018. doi: https://doi.org/10.3389/fpsyg.2018.00665.

[204] D. Hesmondhalgh. Is music streaming bad for musicians? Problems of evidence and argument. *New Media & Society*, 23(12): 3593–3615, 2021.

[205] J. Hill. Developing Creativity-Enabling Skills. In J. Hill, editor, *Becoming Creative: Insights from Musicians in a Diverse World*, page 0. Oxford University Press, 2018. doi: https://doi.org/10.1093/oso/9780199365173.003.0002.

[206] C. Hine. Ethnography and the Internet: Taking Account of Emerging Technological Landscapes. *Fudan Journal of the Humanities and Social Sciences*, 10(3):315–329, 2017. doi: https://doi.org/10.1007/s40647-017-0178-7.

[207] O. Hödl. *The design of technology-mediated audience participation in live music*. 2016. doi: https://doi.org/10.34726/hss.2016.37385.

[208] O. Hödl, F. Kayali, and G. Fitzpatrick. Designing interactive audience participation using smart phones in a musical performance. In *Proceedings of the International Computer Music Conference*, 2012.

[209] O. Hödl, G. Fitzpatrick, and F. Kayali. Design Implications for technology-mediated audience participation in live music. In *Proceedings of the Sound and Music Computing Conference*, pages 28–34, 2017.

[210] O. Hödl, F. Kayali, G. Fitzpatrick, and S. Holland. TMAP Design Cards for Technology-Mediated Audience Participation in Live Music. In S. Holland, T. Mudd, K. Wilkie-McKenna, A. McPherson, and M. M. Wanderley, editors, *New Directions in Music and Human-Computer Interaction*, pages 41–59. Springer International Publishing, 2019. doi: https://doi.org/10.1007/978-3-319-92069-6_3.

[211] C. A. Hoffner and B. J. Bond. Parasocial relationships, social media, & well-being. *Current Opinion in Psychology*, 45:101306, 2022. ISSN 2352-250x. doi: https://doi.org/https://doi.org/10.1016/j.copsyc.2022.101306.

[212] I. Holeman and D. Kane. Human-centered design for global health equity. *Information Technology for Development*, 26(3):477–505, 2020. doi: https://doi.org/10.1080/02681102.2019.1667289.

[213] S. Holland, K. Wilkie, P. Mulholland, and A. Seago, editors. *Music and Human-Computer Interaction*. Springer, 2013 edition, 2013.

[214] S. Holland, K. Wilkie, P. Mulholland, and A. Seago. *Music and Human-Computer Interaction*. Springer Science & Business Media, 2013.

[215] S. Holland, A. P. McPherson, W. E. Mackay, M. M. Wanderley, M. D. Gurevich, T. W. Mudd, S. O'Modhrain, K. L. Wilkie, J. W. Malloch, J. Garcia, et al. Music and HCI. In *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems*, pages 3339–3346, 2016.

[216] S. Holland, T. Mudd, K. Wilkie-McKenna, A. McPherson, and M. M. Wanderley, editors. *New directions in music and human-computer interaction*. Springer International Publishing, 1 edition, 2019.

[217] S. Holland, T. Mudd, K. Wilkie-McKenna, A. McPherson, and M. M. Wanderley, editors. *New Directions in Music and Human-Computer Interaction*. Springer International Publishing, 2019. doi: https://doi.org/10.1007/978-3-319-92069-6.

[218] K. Holtzblatt and H. Beyer, editors. *Contextual Design: design for life*. Morgan Kaufmann, second edition edition, 2017.

[219] E. Hornecker. Creative idea exploration within the structure of a guiding framework: the card brainstorming game. In *Proceedings of the fourth international conference on Tangible, embedded, and embodied interaction*, pages 101–108. ACM, 2010. doi: https://doi.org/10.1145/1709886.1709905.

[220] D. Horton and R. Richard Wohl. Mass communication and para-social interaction: Observations on intimacy at a distance. *psychiatry*, 19(3):215–229, 1956.

[221] N. Horvat, T. Martinec, I. Uremović, and S. Škec. Use it early: The effect of immersion on spatial and design space aspects in team-based mechanical design reviews. *Advanced Engineering Informatics*, 59:102270, 2024. doi: https://doi.org/10.1016/j.aei.2023.102270.

[222] N. Howell, A. Desjardins, and S. Fox. Cracks in the Success Narrative: Rethinking Failure in Design Research through a Retrospective Trioethnography. *ACM Trans. Comput.-Hum. Interact.*, 28(6):42:1–42:31, 2021. doi: https://doi.org/10.1145/3462447.

[223] H.-h. Hu and F. Ma. Human-like bots are not humans: The weakness of sensory language for virtual streamers in livestream commerce. *Journal of Retailing and Consumer Services*, 75:103541, 2023.

[224] S. Hu, Z. Liang, K. Zhou, D. Veríssimo, T. M. Lee, X. Ruan, and A. Hinsley. Applying a co-design approach with key stakeholders to design interventions to reduce illegal wildlife consumption. *People and Nature*, 5(4):1234–1244, 2023. doi: https://doi.org/10.1002/pan3.10492.

[225] R. Hupke, D. Jan, N. Werner, and J. Peissig. Latency and Quality-of-Experience Analysis of a Networked Music Performance Framework for Realistic Interaction. In *Audio Engineering Society Convention 152*, pages 1–10. Audio Engineering Society, 2022.

[226] K. Isbister, E. Márquez Segura, and E. F. Melcer. Social Affordances at Play: Game Design Toward Socio-Technical Innovation. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*, pages 1–10. ACM, Apr. 2018. doi: https://doi.org/10.1145/3173574.3173946.

[227] M. Jackson. *Distracted: Reclaiming our focus in a world of lost attention*. Rowman & Littlefield, 2018.

[228] D. Jayemanne. Chronotypology: Literature and video games: beyond stereotypes
. 2018.

[229] M. S. Jeannotte. When the gigs are gone: Valuing arts, culture and media in the COVID-19 pandemic. *Social Sciences & Humanities Open*, 3(1):100097, 2021. doi: https://doi.org/10.1016/j.ssaho.2020.100097.

[230] H. Jenkins. *Convergence culture: where old and new media collide*. New York University Press, 2006.

[231] C. Jennett, A. L. Cox, P. Cairns, S. Dhoparee, A. Epps, T. Tijs, and A. Walton. Measuring and defining the experience of immersion in games. *International Journal of Human-Computer Studies*, 66(9):641–661, 2008. doi: https://doi.org/10.1016/j.ijhcs.2008.04.004.

[232] H. Jodén and J. Strandell. Building viewer engagement through interaction rituals on Twitch.tv. *Information, Communication & Society*, 25(13):1969–1986, Oct. 2022. ISSN 1369-118x. doi: https://doi.org/10.1080/1369118x.2021.1913211.

[233] D. Johnson and G. Tzanetakis. VRMin: using mixed reality to augment the theremin for musical tutoring. In *Proceedings of the International Conference on New Interfaces for Musical Expression*, pages 151–156, 2017.

[234] M. R. Johnson and J. Woodcock. 'It's like the gold rush': the lives and careers of professional video game streamers on Twitch. tv. *Information, Communication & Society*, 22(3):336–351, 2019.

[235] A. Jones and R. J. Bennett. *The Digital Evolution of Live Music*. Chandos Publishing, 2015.

[236] M. J. Jones. How to Have Humor in an Epidemic: Musicking, Pandemic Palimpsests, and Public Health Pedagogy in the Age of COVID-19. *Americas: A Hemispheric Music Journal*, 29(1):90–98, 2020.

[237] T. Joshi, H. Biggs, J. Bardzell, and S. Bardzell. Who is "I"?: Subjectivity and Ethnography in HCI. In *Proceedings of the 2024 CHI Conference on Human Factors in Computing Systems*, pages 1–15. ACM, 2024. doi: https://doi.org/10.1145/3613904.3642727.

[238] K. Jung, S. Kim, S. Oh, and S. H. Yoon. HapMotion: motion-to-tactile framework with wearable haptic devices for immersive VR performance experience. *Virtual Reality*, 28(1):13, 2024.

[239] M. Jung and I. Clester. Hack the Show: Design and Analysis of Three Interaction Modes for Audience Participation. *Journal of the Audio Engineering Society*, 71(11):769–779, 2023.

[240] P. N. Juslin. Five Facets of Musical Expression: A Psychologist's Perspective on Music Performance. *Psychology of Music*, 31(3):273–302, 2003. doi: https://doi.org/10.1177/03057356030313003.

[241] P. N. Juslin and D. Västfjäll. Emotional responses to music: the need to consider underlying mechanisms. *The Behavioral and Brain Sciences*, 31(5):559–575; discussion 575–621, 2008. doi: https://doi.org/10.1017/s0140525x08005293.

[242] J. Kabat-Zinn. Mindfulness-based interventions in context: Past, present, and future. *Clin. Psychol. (New York)*, 10(2):144–156, 2003.

[243] N. Kang, W.-P. Brinkman, M. B. van Riemsdijk, and M. Neerincx. The design of virtual audiences: noticeable and recognizable behavioral styles. *Computers in Human Behavior*, 55:680–694, 2016.

[244] J. Kangas, Z. Li, and R. Raisamo. Expert Evaluation of Haptic Virtual Reality User Interfaces for Medical Landmarking. In *Extended Abstracts of the 2022 CHI Conference on Human Factors in Computing Systems*, pages 1–7. ACM, 2022. doi: https://doi.org/10.1145/3491101.3519671.

[245] C. Kapadia. Doing more in less time: How multitasking increases creativity. In *Academy of Management Proceedings*, volume 2016, page 17543. Academy of Management Briarcliff Manor, NY 10510, 2016.

[246] C. Kapadia and S. Melwani. More tasks, more ideas: The positive spillover effects of multitasking on subsequent creativity. *Journal of Applied Psychology*, 106(4):542, 2021.

[247] B. F. Katz, B. N. Postma, D. Poirier-Quinot, and J. Meyer. Experience with a virtual reality auralization of Notre-Dame Cathedral. *The Journal of the Acoustical Society of America*, 141(5):3454–3454, 2017.

[248] F. Kayali, O. Hödl, G. Fitzpatrick, P. Purgathofer, A. Filipp, R. Mateus-Berr, U. Kühn, T. Wagensommerer, J. Kretz, and S. Kirchmayr. Playful Technology-Mediated Audience Participation in a Live Music Event. In *Extended Abstracts Publication of the Annual Symposium on Computer-Human Interaction in Play*, pages 437–443. ACM, 2017.

[249] M. Kaytoue, A. Silva, L. Cerf, W. Meira Jr, and C. Raïssi. Watch me playing, I am a professional: a first study on video game live streaming. *WWW'12 - Proceedings of the 21st Annual Conference on World Wide Web Companion*, May 2012. doi: https://doi.org/10.1145/2187980.2188259.

[250] L. Kent, C. Snider, J. Gopsill, and B. Hicks. Mixed reality in design prototyping: A systematic review. *Design Studies*, 77:101046, 2021. doi: https://doi.org/10.1016/j.destud.2021.101046.

[251] O. Khlystova, Y. Kalyuzhnova, and M. Belitski. The impact of the COVID-19 pandemic on the creative industries: A literature review and future research agenda. *Journal of Business Research*, 139:1192–1210, Feb. 2022. ISSN 0148-2963. doi: https://doi.org/10.1016/j.jbusres.2021.09.062.

[252] P. Kiliboz and C. Erkut. Multimodal Looper: A Live-Looping System for Gestural and Audio-visual Improvisation. In *Proceedings of the 9th International Conference on Movement and Computing*, pages 1–8. ACM, 2024. doi: https://doi.org/10.1145/3658852.3659068.

[253] F. Kiss, S. Mayer, and V. Schwind. Audio VR: did video kill the radio star? *Interactions*, 27(3):46–51, 2020.

[254] Y. Kjus and A. Danielsen. Live islands in the seas of recordings: The music experience of visitors at the Øya Festival. *Popular Music and Society*, 37(5):660–679, 2014.

[255] Y. Kjus and A. Danielsen. Live Islands in the Seas of Recordings: The Music Experience of Visitors at the Øya Festival. *Popular Music and Society*, 37(5):660–679, 2014. doi: https://doi.org/10.1080/03007766.2014.929322.

[256] J. H. Klabbers. The magic circle: Principles of gaming & simulation. In *The Magic Circle: Principles of Gaming & Simulation*. Brill, 2009.

[257] O. M. Kleinmintz, P. Goldstein, N. Mayseless, D. Abecasis, and S. G. Shamay-Tsoory. Expertise in Musical Improvisation and Creativity: The Mediation of Idea Evaluation. *Plos One*, 9(7):e101568, 2014. doi: https://doi.org/10.1371/journal.pone.0101568.

[258] d. ko and w. woszczyk. virtual acoustics for musicians: subjective evaluation of a virtual acoustic system in performance of string quartets. *journal of the audio engineering society*, 66(9):712–723, 2018. doi: https://doi.org/https://doi.org/10.17743/jaes.2018.0038.

[259] M. Kob, S. V. Amengual Garí, and Z. Schärer Kalkandjiev. *Room Effect on Musicians' Performance*, pages 223–249. Springer International Publishing, 2020. doi: https://doi.org/10.1007/978-3-030-00386-9_9.

[260] I. Koskinen, J. Zimmerman, T. Binder, J. Redström, and S. Wensveen. 1 - Constructive Design Research. In I. Koskinen, J. Zimmerman, T. Binder, J. Redström, and S. Wensveen, editors, *Design Research Through Practice*, pages 1–13. Morgan Kaufmann, 2012. doi: https://doi.org/10.1016/b978-0-12-385502-2.00001-8.

[261] R. Kowert and E. Daniel Jr. The one-and-a-half sided parasocial relationship: The curious case of live streaming. *Computers in human behavior reports*, 4:100150, 2021.

[262] D. Kralik. Reflexivity: A Practical Guide for Researchers in Health and Social Sciences. *Journal of Advanced Nursing*, 50(2):227–227, 2005. doi: https://doi.org/10.1111/j.1365-2648.2005.03416_2.x.

[263] R. Kronenburg. Typological trends in contemporary popular music performance venues. *Arts Marketing: An International Journal*, 1 (2):136–144, 2011. doi: https://doi.org/10.1108/20442081111180359.

[264] N. C. Krotz. *Media Events in a Global Age*. Routledge, 2009.

[265] Z. Lai and L. Hespanhol. An investigation on strategies for remote interactions with cultural spaces. In *Proceedings of the 33rd Australian Conference on Human-Computer Interaction*, pages 170–175, 2021.

[266] V. Lalioti, S. Ppali, A. J. Thomas, R. Hrafnkelsson, M. Grierson, C. S. Ang, B. S. Wohl, and A. Covaci. VR Rehearse & Perform - A platform for rehearsing in Virtual Reality. In *Proceedings of the 27th ACM Symposium on Virtual Reality Software and Technology*, pages 1–3. ACM, Dec. 2021. doi: https://doi.org/10.1145/3489849.3489896.

[267] A. Lamont. University students' strong experiences of music. *Music Sci.*, 15(2):229–249, 2011.

[268] H. Lee, J. Launay, and L. Stewart. Signals through music and dance: Perceived social bonds and formidability on collective movement. *Acta Psychologica*, 208:103093, 2020.

[269] S. Lee and J. Lee. "Ju. T'aime" My Idol, My Streamer: A Case Study on Fandom Experience as Audiences and Creators of VTuber Concert. *IEEE Access*, 11:31125–31142, 2023. doi: https://doi.org/10.1109/access.2023.3252563.

[270] S. W. Lee, A. Willette, D. Koutra, and W. S. Lasecki. The effect of social interaction on facilitating audience participation in a live music performance. In *Proceedings of the 2019 Conference on Creativity and Cognition*, pages 108–120, 2019.

[271] Y. Lee, J. J. Y. Chung, J. Y. Song, M. Chang, and J. Kim. Personalizing ambience and illusionary presence: How people use "study with me" videos to create effective studying environments. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*, pages 1–13, 2021.

[272] T. W. Leong and P. Wright. Understanding 'tingle' in opera performances. In *Proceedings of the 25th Australian Computer-Human Interaction Conference: Augmentation, Application, Innovation, Collaboration*, pages 43–52. ACM, Nov. 2013. doi: https://doi.org/10.1145/2541016.2541026.

[273] O. Leshem and M. Schober. Empathic listeners identify musically expressed emotion more accurately in improvised Jazz. In *Proceedings of the 13th International Conference of Student of Systematic Musicology (SysMus20)*, pages 55–56, 2020.

[274] P. Lessel, M. Altmeyer, J. Sahner, and A. Krüger. Streamer's Hell - Investigating Audience Influence in Live-Streams Beyond the Game. *Proc. ACM Hum.-Comput. Interact.*, 6(CHI Play), Oct. 2022. doi: https://doi.org/10.1145/3549515.

[275] D. J. Levitin. *This is your brain on music: the science of a human obsession*. Dutton, 2006.

[276] M. Levstek, R. M. Barnby, K. L. Pocock, and R. Banerjee. "It All Makes Us Feel Together": Young People's Experiences of Virtual Group Music-Making During the COVID-19 Pandemic. *Frontiers in Psychology*, 12, 2021.

[277] J. Li, J. Guo, and G. Leshed. Meditating in Live Stream: An Autoethnographic and Interview Study to Investigate Motivations, Interactions and Challenges. *Proceedings of the ACM on Human-Computer Interaction*, 8:1–33, 2024. doi: https://doi.org/10.1145/3637417.

[278] L. Li, J. Uttarapong, G. Freeman, and D. Y. Wohn. Spontaneous, Yet Studious: Esports Commentators' Live Performance and Self-Presentation Practices. *Proceedings of the ACM on Human-Computer Interaction*, 4(Cscw2):1–25, 2020.

[279] Y.-K. Lim, E. Stolterman, and J. Tenenberg. The anatomy of prototypes: Prototypes as filters, prototypes as manifestations of design ideas. *ACM Trans. Comput.-Hum. Interact.*, 15(2):7:1–7:27, 2008. doi: https://doi.org/10.1145/1375761.1375762.

[280] R. B. Lind, V. Milesen, D. M. Smed, S. P. Vinkel, F. Grani, N. C. Nilsson, L. Reng, R. Nordahl, and S. Serafin. Sound design in virtual reality concert experiences using a wave field synthesis approach. In *2017 IEEE Virtual Reality (VR)*, pages 363–364, 2017. doi: https://doi.org/10.1109/vr.2017.7892327.

[281] J. Lindley and D. P. Green. Permission to Muck About, Knowledge, and the Grammar of Intuition. In *Proceedings of the Halfway to the Future Symposium*, pages 1–8. ACM, 2024. doi: https://doi.org/10.1145/3686169.3686175.

[282] Y. Liu. The Secret of Attending Music Concerts in Post- Pandemic: A Thought of Enhancing Well-Being Performing Art's Events During and Post Pandemic. *Online Journal of Complementary & Alternative Medicine*, 8:1–2, Aug. 2023. doi: https://doi.org/10.33552/ojcam.2023.08.000699.

[283] J. M. Loaiza. Musicking, embodiment and participatory enaction of music: outline and key points. *Connection Science*, 28(4):410–422, 2016. doi: https://doi.org/10.1080/09540091.2016.1236366.

[284] K. K. Loh and S. W. H. Lim. Positive associations between media multitasking and creativity. *Computers in Human Behavior Reports*, 1:100015, 2020.

[285] M. Lombard and T. Ditton. At the Heart of It All: The Concept of Presence. *Journal of Computer-Mediated Communication*, 3(2):0–0, 1997. doi: https://doi.org/10.1111/j.1083-6101.1997.tb00072.x.

[286] M. Loonker, S. Ppali, R. von Jungenfeld, C. Efstratiou, and A. Covaci. "I Was Holding a Magic Box": Investigating the Effects of Private and Projected Displays in Outdoor Heritage Walks. In *Designing Interactive Systems Conference*, page 1565–1580. ACM, 2022. doi: https://doi.org/10.1145/3532106.3533468.

[287] B. Loveridge. Networked Music Performance in Virtual Reality: Current Perspectives. *Journal of Network Music and Arts*, 2(1):2, 2020.

[288] C. H. Low. Assessing the Future IP Landscape of Music's Cash Cow: What Happens When the Live Concert Goes Virtual. *New York University Law Review*, 91:33, 2016.

[289] Z. Lu. Live streaming in CHIna for sharing knowledge and promoting intangible cultural heritage. *Interactions*, 27:58–63, 2019. doi: https://doi.org/10.1145/3373145.

[290] Z. Lu, S. Heo, and D. J. Wigdor. StreamWiki: Enabling Viewers of Knowledge Sharing Live Streams to Collaboratively Generate Archival Documentation for Effective In-Stream and Post Hoc Learning. *Proc. ACM Hum.-Comput. Interact.*, 2(Cscw), Nov. 2018. doi: https://doi.org/10.1145/3274381.

[291] Z. Lu, M. Annett, M. Fan, and D. J. Wigdor. "I feel it is my responsibility to stream": Streaming and Engaging with Intangible Cultural Heritage through Livestreaming. *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, 2019. doi: https://doi.org/10.1145/3290605.3300459.

[292] Z. Lu, M. Annett, and D. Wigdor. Vicariously experiencing it all without going outside: A study of outdoor livestreaming in CHIna. *Proceedings of the ACM on Human-Computer Interaction*, 3(Cscw):1–28, 2019.

[293] Z. Lu, R. H. Kazi, L.-y. Wei, M. Dontcheva, and K. Karahalios. StreamSketch: Exploring Multi-Modal Interactions in Creative Live Streams. *Proc. ACM Hum.-Comput. Interact.*, 5(Cscw1):58:1–58:26, Apr. 2021. doi: https://doi.org/10.1145/3449132.

[294] Z. Lu, C. Shen, J. Li, H. Shen, and D. Wigdor. More Kawaii than a Real-Person Live Streamer: Understanding How the Otaku Community Engages with and Perceives Virtual YouTubers. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*. ACM, 2021. doi: https://doi.org/10.1145/3411764.3445660.

[295] A. Lucero, A. Desjardins, C. Neustaedter, K. Höök, M. Hassenzahl, and M. E. Cecchinato. A Sample of One: First-Person Research Methods in HCI. In *Companion Publication of the 2019 on Designing Interactive Systems Conference 2019 Companion*, pages 385–388. ACM, 2019. doi: https://doi.org/10.1145/3301019.3319996.

[296] G. Luck and P. Toiviainen. Ideal singing posture: evidence from behavioural studies and computational motion analysis. pages 15–19, 2007.

[297] E. Lybrand. *Community in the Crowd: Motivations for Commenting on Twitch.tv Live Streams*. PhD thesis, Clemson University, 2019.

[298] R. MacDonald, C. Byrne, and L. Carlton. Creativity and flow in musical composition: an empirical investigation. *Psychology of Music*, 34(3):292–306, 2006. doi: https://doi.org/10.1177/0305735606064838.

[299] F. Macedo. Investigating Sound in Space: Five meanings of space in music and sound art. *Organised Sound*, 20(2):241–248, 2015.

[300] J. Mackrill. Situated design methods. *Ergonomics*, 60(9):1316–1317, 2017. doi: https://doi.org/10.1080/00140139.2017.1325163.

[301] T. Mäki-Patola, J. Laitinen, A. Kanerva, and T. Takala. Experiments with virtual reality instruments. In *Proceedings of the 2005 conference on New interfaces for musical expression*, pages 11–16. National University of Singapore, 2005.

[302] J. Malloch, J. Garcia, M. M. Wanderley, W. E. Mackay, M. Beaudouin-Lafon, and S. Huot. A Design Workbench for Interactive Music Systems. In S. Holland, T. Mudd, K. Wilkie-McKenna, A. McPherson, and M. M. Wanderley, editors, *New Directions in Music and Human-Computer Interaction*, pages 23–40. Springer International Publishing, 2019. doi: https://doi.org/10.1007/978-3-319-92069-6_2.

[303] D. Maloney and G. Freeman. Falling Asleep Together: What Makes Activities in Social Virtual Reality Meaningful to Users. In *Proceedings of the Annual Symposium on Computer-Human Interaction in Play*, pages 510–521. ACM, Nov. 2020. doi: https://doi.org/10.1145/3410404.3414266.

[304] M. Marin and J. Bhattacharya. Getting into the musical zone: trait emotional intelligence and amount of practice predict flow in pianists. *Frontiers in Psychology*, 4, 2013.

[305] L. U. Marks, J. Clark, J. Livingston, D. Oleksijczuk, and L. Hilderbrand. Streaming Media's Environmental Impact. *Media+Environment*, 2(1), 2020. doi: https://doi.org/10.1525/001c.17242.

[306] R. G. M. Masu, P. Bala, M. A. Ahmad, N. N. Correia, V. Nisi, N. Nunes, and T. Romão. VR Open Scores: Scores as Inspiration for VR Scenarios. *Proceedings of the International Conference on New Interfaces for Musical Expression, NIME 2020*, pages 109–114, 2020.

[307] J. May. *Pilgrims On Tour: Collective Effervescence in Concerts*. Thesis, 2010.

[308] E. Mazierska, L. Gillon, and T. Rigg, editors. *The future of live music*. Bloomsbury Academic, 2020.

[309] J. McCarthy and P. Wright. Technology as experience. *interactions*, 11(5):42–43, 2004.

[310] M. McCurdy, C. Connors, G. Pyrzak, B. Kanefsky, and A. Vera. Breaking the fidelity barrier: an examination of our current characterization of prototypes and an example of a mixed-fidelity success. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 1233–1242. ACM, 2006. doi: https://doi.org/10.1145/1124772.1124959.

[311] N. McDonald, S. Schoenebeck, and A. Forte. Reliability and Inter-rater Reliability in Qualitative Research: Norms and Guidelines for CSCW and HCI Practice. *Proceedings of the ACM on Human-Computer Interaction*, 3(Cscw):1–23, 2019. doi: https://doi.org/10.1145/3359174.

[312] H. McIntosh. Charity Benefit Concerts and the One World: Together at Home Event. *Rock Music Studies*, 8(1):76–82, 2021. doi: https://doi.org/10.1080/19401159.2020.1852773.

[313] M. L. McKittrick. Climate Change Games as Boundary Objects: Moving Toward Dialogic Communication in Stakeholder Engagement. In *Proceedings of the 40th ACM International Conference on Design of Communication*, pages 32–41. ACM, 2022. doi: https://doi.org/10.1145/3513130.3558975.

[314] A. Mcmahan. Immersion, engagement, and presence: A method for analyzing 3-D video games. *The Video Game Theory Reader*, pages 67–86, 2003.

[315] J. McVeigh-Schultz, M. Kreminski, K. Prasad, P. Hoberman, and S. S. Fisher. Immersive Design Fiction: Using VR to Prototype Speculative Interfaces and Interaction Rituals within a Virtual Storyworld. In *Proceedings of the 2018 Designing Interactive Systems Conference*, pages 817–829. ACM, 2018. doi: https://doi.org/10.1145/3196709.3196793.

[316] J. McVeigh-Schultz, E. Márquez Segura, N. Merrill, and K. Isbister. What's It Mean to "Be Social" in VR?: Mapping the Social VR Design Ecology. In *Proceedings of the 2018 ACM Conference Companion Publication on Designing Interactive Systems*, pages 289–294. ACM, May 2018. doi: https://doi.org/10.1145/3197391.3205451.

[317] J. McVeigh-Schultz, A. Kolesnichenko, and K. Isbister. Shaping Pro-Social Interaction in VR: An Emerging Design Framework. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, pages 1–12. ACM, May 2019. doi: https://doi.org/10.1145/3290605.3300794.

[318] L. Men and N. Bryan-Kinns. LeMo: Supporting Collaborative Music Making in Virtual Reality. In *IEEE VR Workshop on Sonic Interactions for Virtual Environments*, 2018.

[319] L. Men and N. Bryan-Kinns. LeMo: exploring virtual space for collaborative creativity. In *Proceedings of the Conference on Creativity and Cognition*, pages 71–82. 2019.

[320] K. J. Messick. Music industry in crisis: The impact of a novel coronavirus on touring metal bands, promoters, and venues, June 2020.

[321] B. Moens, C. Muller, L. Van Noorden, M. Franěk, B. Celie, J. Boone, J. Bourgois, and M. Leman. Encouraging spontaneous synchronisation with D-Jogger, an adaptive music player that aligns movement and music. *PloS one*, 9(12):e114234, 2014.

[322] A. Moore, M. Howell, A. Stiles, N. Herrera, and R. McMahan. Wedge: A musical interface for building and playing composition-appropriate immersive environments. In *IEEE Symposium on 3D User Interfaces*, pages 205–206. IEEE, 2015. doi: https://doi.org/10.1109/3dui.2015.7131772.

[323] E. Morgan-Ellis. "Like Pieces in a Puzzle": Online Sacred Harp Singing During the COVID-19 Pandemic. *Frontiers in Psychology*, 12, 2021.

[324] Y. Motokawa and H. Saito. Support system for guitar playing using augmented reality display. In *IEEE/ACM International Symposium on Mixed and Augmented Reality*, pages 243–244. IEEE, 2006. doi: https://doi.org/10.1109/ismar.2006.297825.

[325] M. Mouratidis, S. Rüller, K. Aal, S. Y. Lazem, A. N. Peters, N. Boulus-Rødje, S. Holdermann, V. Vlachokyriakos, A. Light, D. Randall, and V. Wulf. Coping with Messiness in Ethnography: Authority, Bias and Immersion in ethnographic Fieldwork in the non-Western World. *Extended Abstracts of the 2021 CHI Conference on Human Factors in Computing Systems*, 2021. doi: https://doi.org/10.1145/3411763.3441328.

[326] T. Mudd. Playing with Feedback: Unpredictability, Immediacy, and Entangled Agency in the No-input Mixing Desk. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*, pages 1–11. ACM, 2023. doi: https://doi.org/10.1145/3544548.3580662.

[327] M. Mulder and E. Hitters. Visiting pop concerts and festivals: measuring the value of an integrated live music motivation scale. *Cultural Trends*, 30(4):355–375, Aug. 2021. ISSN 0954-8963. doi: https://doi.org/10.1080/09548963.2021.1916738.

[328] M. Mulder and E. Hitters. Constructing the live experience at pop music concerts. *Music Percept.*, 41(1):36–58, 2023.

[329] A. Müller. Mental health disorders: prevalent but widely ignored in academia? *The Journal of Physiology*, 598(7):1279–1281, 2020. doi: https://doi.org/10.1113/jp279386.

[330] M. J. Muller. Participatory design: the third space in HCI. In *The human-computer interaction handbook: fundamentals, evolving technologies and emerging applications*, pages 1051–1068. L. Erlbaum Associates Inc., 2002.

[331] R. Muntean, K. Hennessy, C. Mills, and A. N. Antle. Untangling Cables: A Case Study of the Life & Afterlife of Digital Devices in Academic Research. In *Proceedings of the 2024 ACM Designing Interactive Systems Conference*, pages 653–667. ACM, 2024. doi: https://doi.org/10.1145/3643834.3661540.

[332] J. H. Murray. *Hamlet on the holodeck: the future of narrative in cyberspace*. MIT Press, 1998.

[333] D. Murthy. Digital Ethnography: An Examination of the Use of New Technologies for Social Research. *Sociology*, 42(5):837–855, 2008. doi: https://doi.org/10.1177/0038038508094565.

[334] G. Musgrave. Music and wellbeing vs. musicians' wellbeing: examining the paradox of music-making positively impacting wellbeing, but musicians suffering from poor mental health. *Cultural Trends*, 32(3):280–295, 2023.

[335] M. Nartey. Navigating the doctorate: a reflection on the journey of 'becoming' a PhD in applied language sciences. *Cogent Education*, 8(1):1994360, 2021. doi: https://doi.org/10.1080/2331186x.2021.1994360.

[336] L. nation. COVID-19 Impact from live music fans. Technical report, May 2020.

[337] A. Newson and S. Ervi. Performances 4 - Performative Journeys: Ensuring the Relevance of Grassroots Venue Experiences. In *Performances'22 : A Workshop on Designing the Performances of the Future at IMX 2022 - ACM International Conference on Interactive Media Experiences*, 2022. doi: https://doi.org/10.6084/m9.figshare.20069528.v1.

[338] N. C. Nilsson, R. Nordahl, and S. Serafin. Immersion Revisited: A review of existing definitions of immersion and their relation to different theories of presence. *Human Technology*, 12(2):108–134, 2016. doi: https://doi.org/10.17011/ht/urn.201611174652.

[339] D. Norman. *The design of everyday things: Revised and expanded edition*. Basic Books (AZ), 2013.

[340] W. Odom, J. Zimmerman, S. Davidoff, J. Forlizzi, A. K. Dey, and M. K. Lee. A fieldwork of the future with user enactments. In *Proceedings of the Designing Interactive Systems Conference*, pages 338–347. ACM, 2012. doi: https://doi.org/10.1145/2317956.2318008.

[341] W. Odom, R. Wakkary, Y.-k. Lim, A. Desjardins, B. Hengeveld, and R. Banks. From Research Prototype to Research Product. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, pages 2549–2561. ACM, 2016. doi: https://doi.org/10.1145/2858036.2858447.

[342] W. T. Odom, A. J. Sellen, R. Banks, D. S. Kirk, T. Regan, M. Selby, J. L. Forlizzi, and J. Zimmerman. Designing for slowness, anticipation and re-visitation: a long term field study of the photobox. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 1961–1970, 2014.

[343] M. of london. Cultural Infrastructure plan. Technical report, 2019.

[344] R. Oldenburg. Our vanishing third places. *Planning commissioners journal*, 25(4):6–10, 1997.

[345] P. G. Oliver and S. Lalchev. Digital Transformation in the Music Industry: How the COVID-19 Pandemic Has Accelerated New Business Opportunities. In G. Morrow, D. Nordgård, and P. Tschmuck, editors, *Rethinking the Music Business: Music Contexts, Rights, Data, and COVID-19*, pages 55–72. Springer International Publishing, 2022. doi: https://doi.org/10.1007/978-3-031-09532-0_4.

[346] K. E. Onderdijk, F. Acar, and E. Van Dyck. Impact of Lockdown Measures on Joint Music Making: Playing Online and Physically Together. *Frontiers in Psychology*, 12, 2021.

[347] K. E. Onderdijk, D. Swarbrick, B. Van Kerrebroeck, M. Mantei, J. K. Vuoskoski, P.-J. Maes, and M. Leman. Livestream experiments: the role of COVID-19, agency, presence, and social context in facilitating social connectedness. *Frontiers in psychology*, 12:647929, 2021.

[348] K. E. Onderdijk, L. Bouckaert, E. V. Dyck, and P.-J. Maes. Concert experiences in virtual reality environments. *Virtual Reality*, pages 1–14, 2023.

[349] D. Palea, A. Guo, A. Nair, R. Anderson, N. Charagulla, N. M. Su, and D. T. Lee. Forming Shared Interest Pods: Barriers to Self-Assembly of Interest-Based Small Groups, and Dynamics of Retaining and Giving up Control to Find Collective Fit. *Proc. ACM Hum.-Comput. Interact.*, 8(Cscw2):445:1–445:50, Nov. 2024. doi: https://doi.org/10.1145/3686984.

[350] J. Palomäki, A. Kunnari, M. Drosinou, M. Koverola, N. Lehtonen, J. Halonen, M. Repo, and M. Laakasuo. Evaluating the replicability of the uncanny valley effect. *Heliyon*, 4(11):e00939, 2018. doi: https://doi.org/10.1016/j.heliyon.2018.e00939.

[351] J. Palomäki, T. Tammi, N. Lehtonen, N. Seittenranta, M. Laakasuo, S. Abuhamdeh, O. Lappi, and B. U. Cowley. The link between flow and performance is moderated by task experience. *Computers in Human Behavior*, 124:106891, 2021. doi: https://doi.org/https://doi.org/10.1016/j.chb.2021.106891.

[352] L. F. Panton. *Investigating auditorium acoustics from the perspective of musicians*. PhD thesis, University of Tasmania, 2017.

[353] S. Park. ARLooper: Collaborative Audiovisual Experience with Mobile Devices in a Shared Augmented Reality Space. In *Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems*, pages 1–4, 2020.

[354] E. Passarotto, F. Preckel, M. Schneider, and D. Müllensiefen. Deliberate practice in music: Development and psychometric validation of a standardized measurement instrument. *Psychology of Music*, 50(5):1637–1655, 2022. doi: https://doi.org/10.1177/03057356211065172.

[355] M. T. Pearce and G. A. Wiggins. Auditory expectation: the information dynamics of music perception and cognition. *Topics in cognitive science*, 4(4):625–652, 2012.

[356] H. Persson, H. Åhman, A. Yngling, and J. Gulliksen. Universal design, inclusive design, accessible design, design for all: different concepts–one goal? On the concept of accessibility–historical, methodological and philosophical aspects. *Universal Access in the Information Society*, 14, 2014. doi: https://doi.org/10.1007/s10209-014-0358-z.

[357] V. Peters, J. Bissonnette, D. Nadeau, A. Gauthier-Légaré, and M.-A. Noël. The impact of musicking on emotion regulation: A systematic review and meta-analysis. *Psychology of Music*, 52(5):548–568, 2024. doi: https://doi.org/10.1177/03057356231212362.

[358] P. Petridis, E. Stouraitis, and M. Patiniotis. Many times: The perception of temporality in digital environments. 5:35–49, 2022.

[359] M. Phillips and A. E. Krause. 17. Audiences of the Future–How Can Streamed Music Performance Replicate the Live Music Experience? *Classical Music Futures: Classical Music Futures*, 2024.

[360] R. Piitulainen, P. Hämäläinen, and E. D. Mekler. Vibing Together: Dance Experiences in Social Virtual Reality. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems*, pages 1–18. ACM, Apr. 2022. doi: https://doi.org/10.1145/3491102.3501828.

[361] K. Pires and G. Simon. YouTube Live and Twitch: A Tour of User-Generated Live Streaming Systems. *Proceedings of the 6th ACM Multimedia Systems Conference, MMSys 2015*, pages 225–230, Mar. 2015. doi: https://doi.org/10.1145/2713168.2713195.

[362] S. Ppali. Music from Anywhere & Everywhere: Exploring the design space of remote music performance. In *Companion Publication of the 2023 ACM Designing Interactive Systems Conference*, pages 45–49. ACM, July 2023. doi: https://doi.org/10.1145/3563703.3593067.

[363] S. Ppali, B. Branch, A. Covaci, B. Wohl, and V. Lalioti. Performances' 22: A Workshop on Designing the Performances of the Future at IMX 2022. 2022.

[364] S. Ppali, V. Lalioti, B. Branch, C. S. Ang, A. J. Thomas, B. S. Wohl, and A. Covaci. Keep the VRhythm going: A musician-centred study investigating how Virtual Reality can support creative musical practice. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems*, pages 1–19. ACM, Apr. 2022. doi: https://doi.org/10.1145/3491102.3501922.

[365] S. Ppali, Y. J. Jang, M. Pasia, A. Papallas, P. Zaphiris, and A. Covaci. Tingbao: A musical Immersive Experience Inspired by Environmental Themes. In *Companion Proceedings of the 2024 Annual Symposium on Computer-Human Interaction in Play*, pages 318–323. ACM, 2024. doi: https://doi.org/10.1145/3665463.3678836.

[366] S. Ppali, M. Pasia, S. Wolf, J. Han, R. Muntean, M. Yoo, K. Rodil, A. Berger, A. Papallas, L. Ciolfi, J. Stevens, and A. Covaci. Sensing Heritage: Exploring Creative Approaches for Capturing, Experiencing and Safeguarding the Sensorial Aspects of Cultural Heritage. In *Companion Publication of the 2024 ACM Designing Interactive Systems Conference*, pages 445–448. ACM, July 2024. doi: https://doi.org/10.1145/3656156.3658400.

[367] S. Ppali, M. Scorer, E. Ppali, B. Branch, and A. Covaci. Remote Rhythms: Audience-informed insights for designing remote music performances. In *Proceedings of the 2024 ACM Designing Interactive Systems Conference*, pages 2675–2690. ACM, July 2024. doi: https://doi.org/10.1145/3643834.3660719.

[368] S. Ppali, E. Cheung, A. Covaci, W.-J. She, and C. S. Ang. Creating with Care: Co-Designing Immersive Experiences through Art-Making with People Living with Dementia. In *Proceedings of the 2025 CHI Conference on Human Factors in Computing Systems*, pages 1–18. ACM, Apr. 2025. doi: https://doi.org/10.1145/3706598.3714101.

[369] S. Ppali, M. Constantinides, F. Liarokapis, J. Farao, S. Anvari, M. Yoo, F. A. Bertran, S. Rodgers, J. Han, R. Wehbe, M. Brereton, and A. Covaci. Cite Your Well-being First: What Happens When Personal Life, Mental Health, and HCI Research Become Entangled? In *Companion Publication of the 2025 ACM Designing Interactive Systems Conference*. ACM, July 2025. doi: https://doi.org/10.1145/3715668.3734181.

[370] C. Preist, D. Schien, and P. Shabajee. Evaluating Sustainable Interaction Design of Digital Services: The Case of YouTube. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, pages 1–12. ACM, 2019. doi: https://doi.org/10.1145/3290605.3300627.

[371] M. A. Quijada. My Mental Health Struggle in Academia: What I Wish All Business School Faculty, Students, and Administration Knew. *Journal of Management Education*, 45(1):19–42, 2021. doi: https://doi.org/10.1177/1052562920958433.

[372] J. Radbourne, K. Johanson, H. Glow, and T. White. The Audience Experience: Measuring Quality in the Performing Arts. *International Journal of Arts Management*, 11(3):16–29, 2009. ISSN 1480-8986.

[373] D. A. Rahilly. A Phenomenological Analysis of Authentic Experience. *Journal of Humanistic Psychology*, 33(2):49–71, Apr. 1993. ISSN 0022-1678. doi: https://doi.org/10.1177/0022167893332007.

[374] T. Rautiainen-Keskustalo. Embodiment through digital intangibility: Infrastructures of musicking. *Journal of New Music Research*, 50(2):147–154, 2021. doi: https://doi.org/10.1080/09298215.2021.1899248.

[375] S. Reeves, S. Benford, C. O'Malley, and M. Fraser. Designing the spectator experience. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 741–750. ACM, 2005. doi: https://doi.org/10.1145/1054972.1055074.

[376] D. J. Reichenbach. Losing time and space: Experiencing immersion. In *Space, Time and the Limits of Human Understanding*, pages 503–512. Springer International Publishing, 2017.

[377] S. Reig, E. Principe Cruz, M. M. Powers, J. He, T. Chong, Y. J. Tham, S. Kratz, A. Robinson, B. A. Smith, R. Vaish, et al. Supporting piggybacked co-located leisure activities via augmented reality. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*, pages 1–15, 2023.

[378] L. Remaggi, H. Kim, P. J. Jackson, and A. Hilton. Reproducing real world acoustics in virtual reality using spherical cameras. In *Audio Engineering Society Conference: 2019 AES International Conference on Immersive and Interactive Audio*. Audio Engineering Society, 2019.

[379] C. Remy, O. Bates, A. Dix, V. Thomas, M. Hazas, A. Friday, and E. M. Huang. Evaluation Beyond Usability: Validating Sustainable HCI Research. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*, pages 1–14. ACM, 2018. doi: https://doi.org/10.1145/3173574.3173790.

[380] J. Rendell. Staying in, rocking out: Online live music portal shows during the coronavirus pandemic. *Convergence*, 27(4):1092–1111, 2021.

[381] M. M. Reybrouck. Musical creativity between symbolic modelling and perceptual constraints: The role of adaptive behaviour and epistemic autonomy. In *Musical Creativity*, pages 58–76. Psychology Press, 2006.

[382] T. Rickert. *Ambient Rhetoric: The Attunements of Rhetorical Being*. University of Pittsburgh Press, 2013. doi: https://doi.org/10.2307/j.ctt5hjqwx.

[383] J. R. Rifkin, K. M. Du, and K. M. Cutright. The preference for spontaneity in entertainment. *Journal of Consumer Research*, 50(3):597–616, 2023.

[384] K. E. Ringland, A. Bhattacharya, K. Weatherwax, T. Eagle, and C. T. Wolf. ARMY's Magic Shop: Understanding the Collaborative Construction of Playful Places in Online Communities. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems*, pages 1–19. ACM, 2022. doi: https://doi.org/10.1145/3491102.3517442.

[385] Y. Rogers. New theoretical approaches for human-computer interaction. *Annual Review of Information Science and Technology*, 38 (1):87–143, 2004. doi: https://doi.org/10.1002/aris.1440380103.

[386] L. E. Ross. An account from the inside: Examining the emotional impact of qualitative research through the lens of "insider" research. *Qualitative psychology (Washington, D.C.)*, 4(3):326–337, 2017. doi: https://doi.org/10.1037/qup0000064.

[387] C. Rottondi, C. Chafe, C. Allocchio, and A. Sarti. An Overview on Networked Music Performance Technologies. *IEEE Access*, 4:8823–8843, 2016.

[388] M.-L. Ryan. *Narrative as Virtual Reality: Immersion and Interactivity in Literature and Electronic Media*. Johns Hopkins University Press, 2003.

[389] D. Saffo, C. Yildirim, S. Di Bartolomeo, and C. Dunne. Crowdsourcing Virtual Reality Experiments using VRChat. In *Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems*, pages 1–8. ACM, 2020. doi: https://doi.org/10.1145/3334480.3382829.

[390] D. Saffo, S. Di Bartolomeo, C. Yildirim, and C. Dunne. Remote and collaborative virtual reality experiments via social VR platforms. In *Proceedings of the 2021 CHI conference on human factors in computing systems*, pages 1–15, 2021.

[391] N. Sakata. Embracing the Messiness in Mixed Methods Research: The Craft Attitude. *Journal of Mixed Methods Research*, 17(3): 288–307, 2023. doi: https://doi.org/10.1177/15586898221108545.

[392] E. B. Saleme, A. Covaci, G. Mesfin, C. A. Santos, and G. Ghinea. Mulsemedia DIY: A survey of devices and a tutorial for building your own mulsemedia environment. *ACM Computing Surveys (CSUR)*, 52(3):1–29, 2019.

[393] A. Salovaara, A. Oulasvirta, and G. Jacucci. Evaluation of Prototypes and the Problem of Possible Futures. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*, pages 2064–2077. ACM, 2017. doi: https://doi.org/10.1145/3025453.3025658.

[394] P. Sanden. Rethinking Liveness in the Digital Age. In D. Trippett, M. M. Ingalls, and N. Cook, editors, *The Cambridge Companion to Music in Digital Culture*, pages 178–192. Cambridge University Press, 2019. doi: https://doi.org/10.1017/9781316676639.017.

[395] E. B.-N. Sanders and P. J. Stappers. Co-creation and the new landscapes of design. *CoDesign*, 4(1):5–18, 2008. doi: https://doi.org/10.1080/15710880701875068.

[396] G. M. A. Sarno, Daniele Palma, editor. *Sounds of the Pandemic: Accounts, Experiences, Perspectives in Times of COVID-19*. Focal Press, 2022. doi: https://doi.org/10.4324/9781003200369.

[397] E. N. Satinsky, T. Kimura, M. V. Kiang, R. Abebe, S. Cunningham, H. Lee, X. Lin, C. H. Liu, I. Rudan, S. Sen, M. Tomlinson, M. Yaver, and A. C. Tsai. Systematic review and meta-analysis of depression, anxiety, and suicidal ideation among Ph.D. students. *Scientific Reports*, 11 (1):14370, 2021. doi: https://doi.org/10.1038/s41598-021-93687-7.

[398] A. A. Sawchuk, E. Chew, R. Zimmermann, C. Papadopoulos, and C. Kyriakakis. From remote media immersion to distributed immersive performance. In *Proceedings of the 2003 ACM SIGMM workshop on Experiential telepresence*, pages 110–120, 2003.

[399] T. Schäfer, M. Smukalla, and S.-A. Oelker. How music changes our lives: A qualitative study of the long-term effects of intense musical experiences. *Psychology of Music*, 42(4):525–544, 2014. doi: https://doi.org/10.1177/0305735613482024.

[400] Z. Schärer Kalkandjiev and S. Weinzierl. The influence of room acoustics on solo music performance: An experimental study. *Psychomusicology: Music, Mind, and Brain*, 25(3):195, 2015.

[401] A. Schiavio and M. Benedek. Dimensions of Musical Creativity. *Frontiers in Neuroscience*, 14, 2020.

[402] C. Schissler, P. Stirling, and R. Mehra. Efficient construction of the spatial room impulse response. In *2017 IEEE Virtual Reality (VR)*, pages 122–130, 2017. doi: https://doi.org/10.1109/vr.2017.7892239.

[403] R. Schlagowski, F. Wildgrube, S. Mertes, C. George, and E. André. Flow with the Beat! Human-Centered Design of Virtual Environments for Musical Creativity Support in VR. In *Proceedings of the 14th Conference on Creativity and Cognition*, pages 428–442. ACM, 2022. doi: https://doi.org/10.1145/3527927.3532799.

[404] R. Schlagowski, D. Nazarenko, Y. Can, K. Gupta, S. Mertes, M. Billinghurst, and E. André. Wish You Were Here: Mental and Physiological Effects of Remote Music Collaboration in Mixed Reality. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*, pages 1–16, 2023.

[405] E. Schreuder, J. van Erp, A. Toet, and V. L. Kallen. Emotional responses to multisensory environmental stimuli: A conceptual framework and literature review. *Sage Open*, 6(1):2158244016630591, 2016.

[406] K. C. Schrøder. Audience Reception Research in a Post-broadcasting Digital Age. *Television & New Media*, 20(2):155–169, Feb. 2019. ISSN 1527-4764. doi: https://doi.org/10.1177/1527476418811114.

[407] R. Schwartz and G. R. Halegoua. The spatial self: Location-based identity performance on social media. *New Media & Society*, 17 (10):1643–1660, 2015. doi: https://doi.org/10.1177/1461444814531364.

[408] J. Seering, S. Savage, M. Eagle, J. Churchin, R. Moeller, J. P. Bigham, and J. Hammer. Audience Participation Games: Blurring the Line Between Player and Spectator. In *Proceedings of the 2017 Conference on Designing Interactive Systems*, page 429–440. ACM, 2017. doi: https://doi.org/10.1145/3064663.3064732.

[409] S. Serafin, C. Erkut, J. Kojs, N. Nilsson, and R. Nordahl. Virtual Reality Musical Instruments: State of the Art, Design Principles, and Future Directions. *Computer Music Journal*, 40(3):22–40, 2016.

[410] S. Serafin, A. Adjorlu, N. Nilsson, L. Thomsen, and R. Nordahl. Considerations on the use of virtual and augmented reality technologies in music education. In *IEEE Virtual Reality Workshop on K-12 Embodied Learning through Virtual & Augmented Reality*, pages 1–4. IEEE, 2017. doi: https://doi.org/10.1109/kelvar.2017.7961562.

[411] S. Serafin, M. Geronazzo, C. Erkut, N. C. Nilsson, and R. Nordahl. Sonic interactions in virtual reality: state of the art, current challenges, and future directions. *IEEE computer graphics and applications*, 38(2):31–43, 2018.

[412] P. Shannon-Baker. Philosophical underpinnings of mixed methods research in education. In R. J. Tierney, F. Rizvi, and K. Ercikan, editors, *International Encyclopedia of Education (Fourth Edition)*, pages 380–389. Elsevier, 2023. doi: https://doi.org/10.1016/b978-0-12-818630-5.11037-1.

[413] C. Shaughnessy, R. Perkins, N. Spiro, G. Waddell, A. Campbell, and A. Williamon. The future of the cultural workforce: Perspectives from early career arts professionals on the challenges and future of the cultural industries in the context of COVID-19. *Social Sciences & Humanities Open*, 6(1):100296, Jan. 2022. ISSN 2590-2911. doi: https://doi.org/10.1016/j.ssaho.2022.100296.

[414] C. Shaughnessy, R. Perkins, N. Spiro, G. Waddell, and A. Williamon. Cultivating progressive development in the cultural industries: challenges and support needs identified by the creative workforce in the United Kingdom. *Cultural Trends*, 0(0):1–18, July 2023. ISSN 0954-8963. doi: https://doi.org/10.1080/09548963.2023.2227850.

[415] S. T.-H. Sher and N. M. Su. From Screens to Projector, Wall, and TVs: Conceptualizing Livestreams as Design Material for Direct and Indirect Viewership Experiences. *Proceedings of the ACM on Human-Computer Interaction*, 7(Cscw1):1–22, Apr. 2023. ISSN 2573-0142. doi: https://doi.org/10.1145/3579489.

[416] D. Shin. How does immersion work in augmented reality games? A user-centric view of immersion and engagement. *Information, Communication & Society*, 22(9):1212–1229, 2019.

[417] M. Shin, S. W. Song, S. J. Kim, and F. Biocca. The effects of 3D sound in a 360-degree live concert video on social presence, parasocial interaction, enjoyment, and intent of financial supportive action. *International Journal of Human-Computer Studies*, 126:81–93, 2019. doi: https://doi.org/10.1016/j.ijhcs.2019.02.001.

[418] K. Shinohara, J. O. Wobbrock, and W. Pratt. Incorporating Social Factors in Accessible Design. In *Proceedings of the 20th International ACM SIGACCESS Conference on Computers and Accessibility*, page 149–160. ACM, 2018. doi: https://doi.org/10.1145/3234695.3236346.

[419] H. Shortt. Liminality, space and the importance of 'transitory dwelling places' at work. *Human Relations*, 68(4):633–658, Apr. 2015. ISSN 0018-7267. doi: https://doi.org/10.1177/0018726714536938.

[420] A. Simeone, R. Cools, S. Depuydt, J. ao Maria Gomes, P. Goris, J. Grocott, A. Esteves, and K. Gerling. Immersive Speculative Enactments: Bringing Future Scenarios and Technology to Life Using Virtual Reality. *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems*, 2022. doi: https://doi.org/10.1145/3491102.3517492.

[421] V. L. Simoens and M. Tervaniemi. Musician–instrument relationship as a candidate index for professional well-being in musicians. *Psychology of Aesthetics, Creativity, and the Arts*, 7(2):171, 2013. doi: https://doi.org/10.1037/a0030164.

[422] N. Singh, J. Mentch, J. Ng, M. Beveridge, and I. Drori. Image2Reverb: Cross-Modal Reverb Impulse Response Synthesis. *arXiv:2103.14201 [cs, eess]*, 2021.

[423] M. Sjöblom, M. Törhönen, J. Hamari, and J. Macey. The ingredients of Twitch streaming: Affordances of game streams. *Computers in Human Behavior*, 92:20–28, Mar. 2019. ISSN 0747-5632. doi: https://doi.org/10.1016/j.chb.2018.10.012.

[424] M. Slater. A noteeon Presence Terminology. *Presence Connect*, 3, 2003.

[425] M. Slater. Place illusion and plausibility can lead to realistic behaviour in immersive virtual environments. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 364(1535):3549–3557, 2009. doi: https://doi.org/10.1098/rstb.2009.0138.

[426] M. Slater. Immersion and the illusion of presence in virtual reality. *British Journal of Psychology*, 109:431–433, 2018. doi: https://doi.org/10.1111/bjop.12305.

[427] M. Slater and M. V. Sanchez-Vives. Enhancing our lives with immersive virtual reality. *Frontiers in Robotics and AI*, 3:74, 2016.

[428] M. Slater and S. Wilbur. A framework for immersive virtual environments (FIVE): Speculations on the role of presence in virtual environments. *Presence: Teleoperators & Virtual Environments*, 6(6):603–616, 1997.

[429] M. Slater, S. Neyret, T. Johnston, G. Iruretagoyena, M. A. d. l. C. Crespo, M. Alabèrnia-Segura, B. Spanlang, and G. Feixas. An experimental study of a virtual reality counselling paradigm using embodied self-dialogue. *Scientific Reports*, 9(1):10903, 2019. doi: https://doi.org/10.1038/s41598-019-46877-3.

[430] M. Slater, C. Cabriera, G. Senel, D. Banakou, A. Beacco, R. Oliva, and J. Gallego. The sentiment of a virtual rock concert. *Virtual Reality*, 27(2):651–675, 2023.

[431] J. A. Sloboda, J. W. Davidson, M. J. Howe, and D. G. Moore. The role of practice in the development of performing musicians. *British journal of psychology*, 87(2):287–309, 1996.

[432] C. Small. *Musicking: the meanings of performing and listening*. Wesleyan Univ. Press [u.a.], 1998.

[433] C. Small. Musicking – the meanings of performing and listening. A lecture. *Music Education Research*, 1(1):9–22, 1999. doi: https://doi.org/10.1080/1461380990010102.

[434] C. Smith and E. Ulus. Who cares for academics? We need to talk about emotional well-being including what we avoid and intellectualise through macro-discourses. *Organization*, 27(6):840–857, 2020. doi: https://doi.org/10.1177/1350508419867201.

[435] K. Snook, T. Barri, M. Bolles, P. Ericson, C. Fravel, J. Goßmann, S. Green-Mateu, A. Luck, M. Schedel, and R. Thomas. Concordia: A musical XR instrument for playing the solar system. *Journal of New Music Research*, 49(1):88–103, 2020. doi: https://doi.org/10.1080/09298215.2020.1714666.

[436] J. Soale and K. Broscheid. Early IT Week: The Expansion of Stakeholder Engagement for a Growing Early IT High School Partnership Program. In *Proceedings of the 23rd Annual Conference on Information Technology Education*, pages 53–56. ACM, 2022. doi: https://doi.org/10.1145/3537674.3554749.

[437] R. Soden, L. Devendorf, R. Y. Wong, L. B. CHIlton, A. Light, and Y. Akama. Embracing Uncertainty in HCI. In *Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems*, pages 1–8. ACM, 2020. doi: https://doi.org/10.1145/3334480.3375177.

[438] R. Soden, P. S. Pathak, and O. Doggett. What We Speculate About When We Speculate About Sustainable HCI. *ACM SIGCAS Conference on Computing and Sustainable Societies*, 2021. doi: https://doi.org/10.1145/3460112.3471956.

[439] H. V. Sørensen. CHIldren's Play and Social Relations in Nature and Kindergarten Playgrounds: Examples from Norway. In L. T. Grindheim, H. V. Sørensen, and A. Rekers, editors, *Outdoor Learning and Play: Pedagogical Practices and CHIldren's Cultural Formation*, pages 79–93. Springer International Publishing, 2021. doi: https://doi.org/10.1007/978-3-030-72595-2_5.

[440] C. Spahn, F. Krampe, and M. Nusseck. Live Music Performance: The Relationship Between Flow and Music Performance Anxiety. *Frontiers in Psychology*, 12, 2021. doi: https://doi.org/10.3389/fpsyg.2021.725569.

[441] C. Spence. Crossmodal correspondences: A tutorial review. *Attention, Perception, & Psychophysics*, 73(4):971–995, 2011.

[442] N. Spiro, R. Perkins, S. Kaye, U. Tymoszuk, A. Mason-Bertrand, I. Cossette, S. Glasser, and A. Williamon. The Effects of COVID-19 Lockdown 1.0 on Working Patterns, Income, and Wellbeing among 1 Performing Arts Professionals in the United Kingdom (April–June 2020). *Frontiers in Psychology*, pages 1–30, 2021. doi: https://doi.org/https://doi.org/10.3389/fpsyg.2020.594086.

[443] N. Spiro, R. Perkins, S. Kaye, U. Tymoszuk, A. Mason-Bertrand, I. Cossette, S. Glasser, and A. Williamon. The Effects of COVID-19 Lockdown 1.0 on Working Patterns, Income, and Wellbeing Among Performing Arts Professionals in the United Kingdom (April–June 2020). *Frontiers in Psychology*, 11, 2021. ISSN 1664-1078.

[444] M. Spychiger. The Sacred Sphere. Its Equipment, Beauty, Functions, and Transformations under Secular Conditions. *Music, Education, and Religion: Intersections and Entanglements*, page 142, 2019.

[445] M. Steen. Tensions in human-centred design. *CoDesign*, 7(1):45–60, 2011. doi: https://doi.org/10.1080/15710882.2011.563314.

[446] A. Striner, A. M. Webb, J. Hammer, and A. Cook. Mapping Design Spaces for Audience Participation in Game Live Streaming. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*. ACM, 2021. doi: https://doi.org/10.1145/3411764.3445511.

[447] N. M. Su and E. Stolterman. A Design Approach for Authenticity and Technology. In *Proceedings of the 2016 ACM Conference on Designing Interactive Systems*, pages 643–655. ACM, June 2016. doi: https://doi.org/10.1145/2901790.2901869.

[448] I. C. Sumaya and E. Darling. Procrastination, flow, and academic performance in real time using the experience sampling method. *The Journal of Genetic Psychology*, 179(3):123–131, 2018.

[449] D. Swarbrick, D. Bosnyak, S. R. Livingstone, J. Bansal, S. Marsh-Rollo, M. H. Woolhouse, and L. J. Trainor. How Live Music Moves Us: Head Movement Differences in Audiences to Live Versus Recorded Music. *Frontiers in Psychology*, 9, 2019.

[450] D. Swarbrick, B. Seibt, N. Grinspun, and J. K. Vuoskoski. Corona Concerts: The Effect of Virtual Concert Characteristics on Social Connection and Kama Muta. *Frontiers in Psychology*, 12, 2021. ISSN 1664-1078.

[451] L. Tabbaa, C. S. Ang, W. J. Siriaraya, Panoteeand She, and H. G. Prigerson. A Reflection on Virtual Reality Design for Psychological, Cognitive and Behavioral Interventions: Design Needs, Opportunities and Challenges. *International Journal of Human–Computer Interaction*, 37(9):851–866, 2021. doi: https://doi.org/10.1080/10447318.2020.1848161.

[452] A. Tanaka. *Sensor-based musical instruments and interactive music*. na, 2009.

[453] A. Tanaka. Embodied musical interaction: body physiology, cross modality, and sonic experience. *New directions in music and human-computer interaction*, pages 135–154, 2019.

[454] I. Taylor, S. Raine, and C. Hamilton. COVID-19 and the UK Live Music Industry: A Crisis of Spatial Materiality. *The Journal of Media Art Study and Theory*, 1(2), 2020. doi: https://doi.org/10.59547/26911566.1.2.12.

[455] T. L. Taylor. *Watch me play: Twitch and the rise of game live streaming*. Princeton University Press, 2018.

[456] N. Teixeira, G. Mello Vianna, R. Lima, C. Jáuregui, L. Furtado, T. Pereira Alberto, and R. Medeiros. Covid-19 Impact on the Music Sector in Belo Horizonte (Minas Gerais, Brazil). *Frontiers in Sociology*, 6, 2021.

[457] M. Thibault. Design Kitsch. In *Companion Proceedings of the 2024 Annual Symposium on Computer-Human Interaction in Play*, pages 285–287. ACM, 2024. doi: https://doi.org/10.1145/3665463.3678867.

[458] D. R. Thomas. A General Inductive Approach for Analyzing Qualitative Evaluation Data. *American Journal of Evaluation*, 27(2):237–246, 2006. doi: https://doi.org/10.1177/1098214005283748.

[459] B. Torrisi. Academic productivity correlated with well-being at work. *Scientometrics*, 94(2):801–815, 2013. doi: https://doi.org/10.1007/s11192-012-0709-6.

[460] F. Tosi. From User-Centred Design to Human-Centred Design and the User Experience. In F. Tosi, editor, *Design for Ergonomics*, pages 47–59. Springer International Publishing, 2020. doi: https://doi.org/10.1007/978-3-030-33562-5_3.

[461] J. Traer and J. H. McDermott. Statistics of natural reverberation enable perceptual separation of sound and space. *Proceedings of the National Academy of Sciences*, 113(48):E7856–e7865, 2016. doi: https://doi.org/10.1073/pnas.1612524113.

[462] M. V. Trust. Understanding small music venues. Technical report, 2015.

[463] K. Tsioutas, G. Xylomenos, and I. Doumanis. An empirical evaluation of QoME for NMP. In *2021 11th IFIP International Conference on New Technologies, Mobility and Security (NTMS)*, pages 1–5. IEEE, 2021.

[464] L. Turchet. Musical Metaverse: vision, opportunities, and challenges. *Personal and Ubiquitous Computing*, pages 1–17, 2023.

[465] L. Turchet, A. McPherson, and C. Fischione. Smart Instruments: Towards an Ecosystem of Interoperable Devices Connecting Performers and Audiences. In *Proceedings of the Sound and Music Computing Conference*, pages 498–505, 2016.

[466] L. Turchet, C. Fischione, and M. Barthet. Towards the Internet of Musical Things. In *Proceedings of the Sound and Music Computing Conference*, pages 13–20, 2017.

[467] L. Turchet, C. Fischione, G. Essl, D. Keller, and M. Barthet. Internet of Musical Things: Vision and Challenges. *IEEE Access*, 6:61994–62017, 2018.

[468] L. Turchet, R. Hamilton, and A. Çamci. Music in Extended Realities. *IEEE Access*, 9:15810–15832, 2021. doi: https://doi.org/10.1109/access.2021.3052931.

[469] L. Turchet, T. West, and M. M. Wanderley. Touching the audience: musical haptic wearables for augmented and participatory live music performances. *Personal and Ubiquitous Computing*, 25(4):749–769, 2021.

[470] K. Ueno and H. Tachibana. Cognitive modeling of musician's perception in concert halls. *Acoustical science and technology*, 26(2): 156–161, 2005.

[471] K. Ueno and H. Tachibana. A consideration on acoustic properties on concert-hall stages. *Building Acoustics*, 18(3-4):221–235, 2011.

[472] K. Ueno, K. Kato, and K. Kawai. Effect of room acoustics on musicians' performance. Part I: Experimental investigation with a conceptual model. *Acta Acustica united with Acustica*, 96(3):505–515, 2010.

[473] M. Union. The Working Musician Report. Technical report, 2012. URL **https://musiciansunion.org.uk/working-performing/education-and-teaching/music-education-policy-and-reports/the-working-musician-report**.

[474] J. van de Goor, A. M. Sools, and G. J. Westerhof. The Emergence of Meaning From Meaningful Moments in Life. *Journal of Humanistic Psychology*, 65(1):192–218, 2025. doi: https://doi.org/10.1177/0022167820967779.

[475] A. van der Hoeven and E. Hitters. Live music and the New Urban Agenda: Social, economic, environmental and spatial sustainability in live music ecologies. *City, Culture and Society*, 32:100490, 2023. doi: https://doi.org/10.1016/j.ccs.2022.100490.

[476] D. van der Linden, M. Tops, and A. B. Bakker. Go with the flow: A neuroscientific view on being fully engaged. *European Journal of Neuroscience*, 53(4):947–963, 2021.

[477] D. van der Schyff and A. Schiavio. Musical Creativity in Performance. In G. E. McPherson, editor, *The Oxford Handbook of Music Performance, Volume 1*, page 0. Oxford University Press, 2022. doi: https://doi.org/10.1093/oxfordhb/9780190056285.013.30.

[478] D. van der Schyff, A. Schiavio, and D. J. Elliott. *Musical Bodies, Musical Minds: Enactive Cognitive Science and the Meaning of Human Musicality*. The MIT Press, Aug. 2022. doi: https://doi.org/10.7551/mitpress/12117.001.0001.

[479] K. Van Es. *The future of live*. John Wiley & Sons, 2017.

[480] D. Van Nort. Distributed Networks of Listening and Sounding: 20 Years of Telematic Musicking. *Journal of Network Music and Arts*, 5(1):6, 2023.

[481] F. Vandenberg. Put Your "Hand Emotes in the Air:" Twitch Concerts as Unsuccessful Large-Scale Interaction Rituals. *Symbolic Interaction*, 45(3):425–448, 2022. ISSN 1533-8665. doi: https://doi.org/10.1002/symb.605.

[482] F. Vandenberg. *All together now: Live (streamed) music as collective practice*. 2023.

[483] F. Vandenberg, M. Berghman, and J. Schaap. The 'lonely raver': music livestreams during COVID-19 as a hotline to collective consciousness? *European Societies*, 23(sup1):S141–S152, 2021.

[484] C. Velasco, F. Barbosa Escobar, O. Petit, and Q. J. Wang. Impossible (Food) Experiences in Extended Reality. *Frontiers in Computer Science*, 3, 2021. ISSN 2624-9898.

[485] T. Venkatesan and Q. J. Wang. Feeling Connected: The Role of Haptic Feedback in VR Concerts and the Impact of Haptic Music Players on the Music Listening Experience. In *Arts*, volume 12, page 148. Mdpi, 2023.

[486] A. H. Vera and H. A. Simon. Situated action: A symbolic interpretation. *Cognitive Science*, 17(1):7–48, 1993. doi: https://doi.org/10.1016/s0364-0213(05)80008-4.

[487] A. P. Vermeeren, E. L.-C. Law, V. Roto, M. Obrist, J. Hoonhout, and K. Väänänen-Vainio-Mattila. User experience evaluation methods: current state and development needs. In *Proceedings of the 6th Nordic conference on human-computer interaction: Extending boundaries*, pages 521–530, 2010.

[488] J. Vervaeke, L. Ferraro, and A. Herrera-Bennett. 24 Flow as Spontaneous Thought: Insight and Implicit Learning. *The Oxford Handbook of Spontaneous Thought: Mind-Wandering, Creativity, and Dreaming*, page 309, 2018.

[489] V. Vinayagamoorthy, M. Glancy, C. Ziegler, and R. Schäffer. Personalising the TV Experience using Augmented Reality: An Exploratory Study on Delivering Synchronised Sign Language Interpretation. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, pages 1–12. Association for Computing Machinery, May 2019. doi: https://doi.org/10.1145/3290605.3300762.

[490] C. Vincent. The impacts of digital initiatives on musicians during COVID-19: examining the Melbourne Digital Concert Hall. *Cultural Trends*, 32(3):247–263, 2023.

[491] J. Vines, R. Clarke, T. Leong, J. McCarthy, O. S. Iversen, P. Wright, and P. Olivier. Invited SIG - participation and HCI: why involve people in design? In *CHI '12 Extended Abstracts on Human Factors in Computing Systems*, pages 1217–1220. ACM, 2012. doi: https://doi.org/10.1145/2212776.2212427.

[492] I. Volkmer and F. Deffner. Eventspheres as Discursive Forms: (Re-)Negotiating the "mediated center" in new network cultures. In *Media Events in a Global Age*. Routledge, 2009.

[493] R. Wakkary, W. Odom, S. Hauser, G. Hertz, and H. Lin. A short guide to material speculation: actual artifacts for critical inquiry. *Interactions*, 23(2):44–48, 2016. doi: https://doi.org/10.1145/2889278.

[494] Q. Wan and Z. Lu. Investigating VTubing as a Reconstruction of Streamer Self-Presentation: Identity, Performance, and Gender. *Proc. ACM Hum.-Comput. Interact.*, 8(Cscw1), Apr. 2024. doi: https://doi.org/10.1145/3637357.

[495] G. Wang, N. R. Fram, L. L. Carstensen, and J. Berger. Characterizing the Relationship Between the COVID-19 Pandemic and U.S. Classical Musicians' Wellbeing. *Frontiers in Sociology*, 7, 2022. doi: https://doi.org/10.3389/fsoc.2022.848098.

[496] M. Wang and D. Li. What motivates audience comments on live streaming platforms? *Plos One*, 15(4):e0231255, Apr. 2020. ISSN 1932-6203. doi: https://doi.org/10.1371/journal.pone.0231255.

[497] P. Wang and Z. Lu. Let's Play Together through Channels: Understanding the Practices and Experience of Danmaku Participation Game Players in CHIna. *Proc. ACM Hum.-Comput. Interact.*, 7(CHI Play), Oct. 2023. doi: https://doi.org/10.1145/3611059.

[498] E. Webster. "One More Tune!" The Encore Ritual in Live Music Events. *Popular Music and Society*, 35(1):93–111, Feb. 2012. ISSN 0300-7766. doi: https://doi.org/10.1080/03007766.2010.538241.

[499] P. R. Webster. Creativity and music education: Creative thinking in music: Advancing a model. *Creativity and music education*, 1(33), 2002.

[500] S. Whiting. The Value of Small Live Music Venues: Alternative Forms of Capital and Niche Spaces of Cultural Production. *Cultural Sociology*, 15(4):558–578, 2021. doi: https://doi.org/10.1177/17499755211021307.

[501] C. Whitley, F. K. Youngblood, and J. Bosse. Musician emotional wellbeing during the pandemic: assessing the impact of external factors, positive life outlook and socio-demographics. *Leisure Studies*, 41:573–586, 2022. doi: https://doi.org/10.1080/02614367.2022.2043419.

[502] S. Willemsen, R. Paisa, and S. Serafin. Resurrecting the Tromba Marina: 17th Sound and Music Computing Conference. *Proceedings of the 17th Sound and Music Computing Conference*, pages 300–307, 2020. doi: https://doi.org/10.5281/zenodo.3898812.

[503] A. Williamon, T. Clark, and M. Küssner. Learning in the spotlight. volume 1, pages 206–221. Oxford University Press, 2017. doi: https://doi.org/10.1093/acprof:oso/9780199346677.003.0014.

[504] A. Williamon, G. Waddell, N. Spiro, R. Perkins, C. Shaughnessy, A. Campbell, M. Miraldo, V. Lalioti, and S. Ppali. Policy brief: HEartS professional: the Health, Economic and Social impact of COVID-19 on Professionals in the ARTs: findings and policy implications for cultural recovery, 2022. Publisher: The Pandemic and Beyond.

[505] R. Wilson. Aesthetic and technical strategies for networked music performance. *Ai & Society*, 38(5):1871–1884, 2023. doi: https://doi.org/10.1007/s00146-020-01099-4.

[506] B. Witmer and A. Steed. Measuring presence in virtual environments: A presence questionnaire. *Presence: Teleoperators and Virtual Environments*, 7(3):225–240, 1998. doi: https://doi.org/10.1162/105474698565686.

[507] D. Y. Wohn, G. Freeman, and C. McLaughlin. Explaining Viewers' Emotional, Instrumental, and Financial Support Provision for Live Streamers. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*, pages 1–13, New York, NY, USA, Apr. 2018. ACM. doi: https://doi.org/10.1145/3173574.3174048.

[508] G. H. Wolff and C. Shen. Audience size, moderator activity, gender, and content diversity: Exploring user participation and financial commitment on Twitch.tv. *New Media & Society*, 26(2):859–881, Feb. 2024. ISSN 1461-4448. doi: https://doi.org/10.1177/14614448211069996.

[509] I. Wollman, C. Fritz, J. Poitevineau, and S. McAdams. Investigating the Role of Auditory and Tactile Modalities in Violin Quality Evaluation. *Plos One*, 9(12):e112552, 2014. doi: https://doi.org/10.1371/journal.pone.0112552.

[510] R. Y. Wong and V. Khovanskaya. Speculative Design in HCI: From Corporate Imaginations to Critical Orientations. In M. Filimowicz and V. Tzankova, editors, *New Directions in Third Wave Human-Computer Interaction: Volume 2 - Methodologies*, pages 175–202. Springer International Publishing, 2018. doi: https://doi.org/10.1007/978-3-319-73374-6_10.

[511] N. Wood, M. Duffy, and S. J. Smith. The Art of Doing (Geographies of) Music. *Environment and Planning D: Society and Space*, 25(5): 867–889, 2007. doi: https://doi.org/10.1068/d416t.

[512] M. Wright. Open Sound Control: an enabling technology for musical networking. *Organised Sound*, 10(3):193–200, 2005. doi: https://doi.org/10.1017/S1355771805000932.

[513] W. J. Wrigley and S. B. Emmerson. The experience of the flow state in live music performance. *Psychology of Music*, 41(3):292–305, 2013. doi: https://doi.org/10.1177/0305735611425903.

[514] Y. Wu, L. Zhang, N. Bryan-Kinns, and M. Barthet. Open Symphony: Creative Participation for Audiences of Live Music Performances. *IEEE MultiMedia*, 24(1):48–62, 2017. doi: https://doi.org/10.1109/MMUL.2017.19.

[515] T. Wulf, F. M. Schneider, and S. Beckert. Watching Players: An Exploration of Media Enjoyment on Twitch. *Games and Culture*, 15(3): 328–346, May 2020. ISSN 1555-4120. doi: https://doi.org/10.1177/1555412018788161.

[516] A. Xambó and G. Roma. Performing audiences: Composition strategies for network music using mobile phones. In *Proceedings of the International Conference on New Interfaces for Musical Expression*, 2020. doi: https://doi.org/10.5281/zenodo.4813191.

[517] X. Xiao, P. Puentes, E. Ackermann, and H. Ishii. Andantino: Teaching CHIldren Piano with Projected Animated Characters. In *Proceedings of the The 15th International Conference on Interaction Design and CHIldren*, pages 37–45. ACM, June 2016. doi: https://doi.org/10.1145/2930674.2930689.

[518] A. Xygkou, A. Siriaraya, Panoteeand Covaci, H. G. Prigerson, R. Neimeyer, C. S. Ang, and W.-J. She. The "Conversation" about Loss: Understanding How Chatbot Technology was Used in Supporting People in Grief. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*, pages 1–15. ACM, 2023. doi: https://doi.org/10.1145/3544548.3581154.

[519] A. Xygkou, C. S. Ang, J. P. Siriaraya, Panoteeand Kopecki, A. Covaci, E. Kanjo, and W.-J. She. MindTalker: Navigating the Complexities of AI-Enhanced Social Engagement for People with Early-Stage Dementia. In *Proceedings of the 2024 CHI Conference on Human Factors in Computing Systems*, pages 1–15. ACM, 2024. doi: https://doi.org/10.1145/3613904.3642538.

[520] H. Yakura and M. Goto. Enhancing Participation Experience in VR Live Concerts by Improving Motions of Virtual Audience Avatars. In *2020 IEEE International Symposium on Mixed and Augmented Reality (ISMAR)*, pages 555–565, Nov. 2020. doi: https://doi.org/10.1109/ismar50242.2020.00083.

[521] T. Yamabe, H. Asuma, S. Kiyono, and T. Nakajima. Feedback design in augmented musical instruments: a case study with an AR drum kit. In *IEEE 17th International Conference on Embedded and Real-Time Computing Systems and Applications*, volume 2, pages 126–129. IEEE, 2011. doi: https://doi.org/10.1109/RTCSA.2011.27.

[522] S. Yang, C. Lee, H. V. Shin, and J. Kim. Snapstream: Snapshot-based Interaction in Live Streaming for Visual Art. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*, page 1–12. ACM, 2020. doi: https://doi.org/10.1145/3313831.3376390.

[523] N. Yeo, M. White, I. Alcock, R. Garside, S. Dean, A. Smalley, and B. Gatersleben. What is the best way of delivering virtual nature for improving mood? An experimental comparison of high definition TV, 360 video, and computer generated virtual reality. *Journal of Environmental Psychology*, 72:101500, 2020. doi: https://10.1016/j.jenvp.2020.101500.

[524] M. Yoo, W. Odom, and A. Berger. Understanding Everyday Experiences of Reminiscence for People with Blindness: Practices, Tensions and Probing New Design Possibilities. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*, pages 1–15. ACM, 2021. doi: https://doi.org/10.1145/3411764.3445212.

[525] M. Yoo, L. Knight, W. Odom, and A. Berger. Storywork & Reciprocity: On the Design of an Audio Documentary that Extends HCI Research back to Participants. In *Proceedings of the 2022 ACM Designing Interactive Systems Conference*, pages 1345–1357. ACM, 2022. doi: https://doi.org/10.1145/3532106.3533539.

[526] M. Yoo, A. Berger, J. Lindley, D. P. Green, Y. Boeva, I. Nicenboim, and W. Odom. Beyond Academic Publication: Alternative Outcomes of HCI Research. In *Companion Publication of the 2023 ACM Designing Interactive Systems Conference*, pages 114–116. ACM, 2023. doi: https://doi.org/10.1145/3563703.3591458.

[527] M. Yoo, S. Ppali, W. Odom, Y. Zhuang, K. Kritika, W. Olson, C. Wieczorek, H. Biggs, A. Berger, A. Desjardins, R. Wakkary, and K. E. Ringland. Translating HCI Research to Broader Audiences: Motivation, Inspiration, and Critical Factors on Alternative Research Outcomes. In *Proceedings of the 2025 CHI Conference on Human Factors in Computing Systems*, pages 1–24. ACM, Apr. 2025. doi: https://doi.org/10.1145/3706598.3713884.

[528] F. K. Youngblood, J. Bosse, and C. Whitley. How can I keep from singing? The effects of COVID-19 on the emotional wellbeing of community singers during early stage lockdown in the United States. *International Journal of Community Music*, 2021. doi: https://doi.org/10.1386/ijcm_00045_1.

[529] K. Zhukov, M. S. Barrett, and A. Creech. The impacts of Covid-19 lockdowns on professional and personal lives of freelance creative collaborative musicians. *Research Studies in Music Education*, 2023. doi: https://doi.org/10.1177/1321103x231186952.