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Study Protocol

Feeling Connected: The Role of Haptic Feedback in VR Concerts and the Impact of Haptic Music Players on the Music Listening Experience

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Abstract: Today, some of the most widely attended concerts are in virtual reality (VR). For example, the videogame Fortnite recently attracted 12.3 million viewers sitting in homes all over the world to a VR Travis Scott rap concert. As such VR concerts become increasingly ubiquitous, we are presented with an opportunity to design more immersive virtual experiences by augmenting VR with other multisensory technologies. Given that sound is a multi-modal phenomenon that can be experienced sonically and vibrationally, we investigated the importance of haptic feedback to musical experiences using a combination of qualitative and empirical methodologies. Study 1 was a qualitative study demonstrating that, unlike their live counterparts, current VR concerts make it harder for audiences to form a connection with artists and their music. Furthermore, VR concerts lack multisensory feedback and are perceived as less authentic than live concert experiences. Participants also identified a variety of different kinds of touch that they receive at live concerts and suggested that ideal VR concerts would replicate physical touch and thermal feedback from the audience, emotional touch, and vibrations from the music. Specifically, users advocated for the use of haptic devices to increase the immersiveness of VR concert experiences. Study 2 isolated the role of touch in the music listening experience and empirically investigated the impact of haptic music players (HMPs) on the audio-only listening experience. An empirical, between-subjects study was run with participants either receiving vibrotactile feedback via an HMP (haptics condition) or no vibrotactile feedback (control) while listening to music. Results indicated that listening to music while receiving vibrotactile feedback increased participants' sense of empathy, parasocial bond, and loyalty towards the artist, while also decreasing participants' feelings of loneliness. The connection between haptics condition and these dependent variables was mediated by the feeling of social presence. Study 2 thus provides initial evidence that HMPs may be used to meet people's need for connection, multisensory immersion, and complex forms of touch in VR concerts as identified in Study 1.

Keywords: haptics; psychological connection; presence; music; virtual reality

Citation: Venkatesan, Tara, and Qian Janice Wang. 2023. Feeling Connected: The Role of Haptic Feedback in VR Concerts and the Impact of Haptic Music Players on the Music Listening Experience. *Arts* 12: 148. https://doi.org/10.3390/arts12040148

Academic Editors: Justin Paterson and Marcelo M. Wanderley

Received: 29 January 2023
Revised: 24 February 2023
Accepted: 16 March 2023
Published: 10 July 2023

1. Introduction

Access to music is greater than it has ever been in human history. Technological advancements have made it possible for us to discover and access millions of songs and artists of every genre within seconds. Today, people spend an average of 2 h a day listening to music via streaming services such as Spotify, Apple Music, and Amazon Music (Moore 2020).

Due to the ubiquity of on-demand streaming, people spend a significant amount of time listening to recorded music as opposed to live music (Charron 2017; Horie et al. 2018). One implication of this is that interaction with recorded music is always mediated via technology—finding and selecting music involves interacting with a digital streaming service or record player, and listening to music requires speakers or headphones

(Prior 2018). We also mainly engage with recorded music via one sensory modality—the auditory modality. While we have access to visual cues in certain contexts, such as when watching music videos or viewing digital album art when we search for music on streaming services, we do not have access to cues such as the artists' facial expressions, posture, and movement when we are simply listening to music (Schutz 2008; Waddell and Williamon 2017; Venkatesan et al. 2020). Because listening to recorded music is less perceptually rich than listening to live music for the reasons listed above, individuals have sought ways to augment the recorded music listening experience.

Over the last decade, there have been major developments in immersive technologies, as there has been a general shift in technology from "access and find" Web 1.0 focused tools to Web 3.0 tools that encourage "immersive collaboration and co-creation" (Kapp and O'Driscoll 2010). The goal of immersive environments is to enable the user to experience a computer-generated world "as if it were real" (Bowman and McMahan 2007). The degree of immersiveness of a technology is the extent to which the technology creates a perceptually rich environment that diminishes the distinction between the mediated environment and reality (Cummings and Bailenson 2016). Thus, immersive technology can make the user feel either as though they have been transported elsewhere or that the digital personalities are sharing the same space as the user (Harper 2015; Holt 2010).

1.1. Immersion and VR Concerts

While many immersive technologies have not been specifically designed for augmenting the experience of listening to music, some of these technologies have music-specific applications, and the music industry has tried to capitalize on this shift in consumer demand towards highly engaging, immersive experiences. Innovation in virtual reality, particularly, has made attending virtual concerts increasingly popular. Virtual reality (VR) is a technology that creates artificially simulated environments, and VR headsets are devices that generate a sense of sensory immersion by creating a visual and auditory barrier between the user and their environment (Bowman and McMahan 2007). As technological advancements improve the affordances of VR, users also experience increased senses of immersion and realism in virtual environments. For example, advances in graphics hardware mean that the visual fidelity of virtual environment displays are high and can feel life-like (Sanchez-Vives and Slater 2005). Improvements in frame-rates and latency allow people to feel that movements in virtual environments are as fluid as in the real world (Sanchez-Vives and Slater 2005). Furthermore, the affordances of VR technology mean that they can capture and communicate the emotions of others via details in an avatar's facial expression and body language (Grant 2016; Janssen et al. 2010; Schultze and Brooks 2019). This aids the user to generate more accurate mental models of the situation and characters depicted in a mediated environment (Blanke 2012).

For these reasons, VR concerts allow users to have immersive musical experiences, transporting them to life-like concert venues and enabling them to share the same virtual space as the artist and other audience members (Esteves 2017). Additionally, VR concerts allow users who might otherwise not be able to travel or purchase tickets for a live event to attend from anywhere in the world without leaving the comfort of their sofas (Hamad and Jia 2022).

VR concerts have become increasingly common. For example, the gaming company Roblox hosted several successful VR concerts in the metaverse for popular artists such as Marshmello and Travis Scott, the latter of which was virtually attended by over 10.7 million people (Hogan 2020). VR concerts allow people to accomplish more than just attend concerts, however—they allow for exploration of new environments and offer other novel experiences such as opportunities for virtual dancing and virtual engagement with behind-the-scenes content. In 2016, the entertainment company LiveNation partnered with NextVR to broadcast a series of concerts in VR. Users watched the artists perform in various venues, such as zoos, and were able to see additional footage of the artist backstage and moving around the virtual space (Citibank 2017). Companies such as MelodyVR create virtual

concert experiences where users can change their viewing angle and even "stand" on stage along with the band (Hanley 2019). Games like Minecraft have hosted virtual concerts where attendees can participate in virtual mosh pits and other forms of virtual dance (Moritzen 2022).

1.2. VR Concerts Are Not as Multisensory as Live Concerts

While VR is indeed more immersive than watching concerts on a laptop or phone, it still only stimulates two senses—vision and audition. Live concerts, on the other hand, are multisensory experiences. The smell of the food and sweat of bodies in the crowd, the feel of people dancing together, and the musical vibrations that reverberate through one's body are all sensations that are missing in VR concerts.

Touch is particularly important to musical experiences because sound is a multi-modal phenomenon that can be experienced both sonically and via vibrations (Trivedi et al. 2016). Sound is usually experienced through the ear drums, but certain frequencies of sound, specifically lower frequencies at intensities that activate mechanoreceptors in the skin, can be felt in the body through the sense of touch (Hove et al. 2020). There is evidence that listening to loud music with high-level low-frequency sounds, such as electronic dance music, can stimulate a vestibular response (Todd and Cody 2000; Todd et al. 2008). Furthermore, high-level low-frequency pure tones can cause human body surface vibration which can be felt in the chest and the abdomen (Takahashi et al. 2005). Vibrations are an extremely important aspect of live musical experiences: they play an important role in both the perception and the enjoyment of music (Merchel and Altinsoy 2014). In fact, evidence suggests that listening to recorded music without vibrotactile feedback is less perceptually rich and immersive (Ideguchi and Muranaka 2007).

There are, however, other ways in which people might experience touch in live concerts such as the feel of bodies touching in a crowd, touch associated with dancing (kinaesthesia), etc. To our knowledge, however, no one has classified the kinds of tactile experiences one receives at a live concert. Thus, one aim of this research is to understand the importance of tactile experiences in live concerts and the different kinds of touch that people experience in live concert settings.

1.3. Replicating Tactile Feedback with Haptic Music Players

The second aim of this research is to understand how haptic feedback may be replicated via technology to make VR concert experiences more immersive and life-like. Before delving into our discussion of haptic music players, we will begin by defining some terms. Touch is complex and consists of several different kinds of experience such as the sensation of temperature, vibrations, and movement. The term haptic refers to the sense of touch and encompasses both kinaesthetic (proprioceptive) and cutaneous (tactile) receptors (Hannaford and Okamura 2016). The ability to discriminate between tactile and proprioceptive stimuli is determined by the size and density of the receptor field and the intensity of the stimulus (Vallgårda et al. 2017). A haptic device employs technology that delivers haptic feedback, i.e., potentially both kinaesthetic and tactile feedback. Haptics have become ubiquitous today and are commonly found in mobile phones and tablet devices (Mazzoni and Bryan-Kinns 2015a).

In the case of music, specific kinds of haptic devices have been designed to pick up on low-frequency sounds from an audio input and translate the sound into vibrotactile feedback (O'Malley and Gupta 2008; Turchet et al. 2020). These haptic devices are called Haptic Music Players (HMPs). Some HMPs have been designed to enable the hearing-impaired to vibrationally "feel" the music while others have been used to enhance the digital musical instrument playing experience (Nanayakkara et al. 2013). In this paper, we are mainly concerned with HMPs that enhance the music listening experience by providing vibrotactile feedback which conveys musical information through contact with the skin (Remache-Vinueza et al. 2021).

While there is a growing body of research on the impact of HMPs on the music listening experience, a large segment of the research is dedicated to understanding how HMPs enhance the listening experiences of the hearing-impaired (e.g., Fletcher 2021; Nanayakkara et al. 2013; Remache-Vinueza et al. 2021). While there are a few papers on the impact of HMPs on the music listening experience for people with unimpaired hearing, most of this research has to do with hedonic enjoyment of the experience (Giroux et al. 2019). To our knowledge, there is no research on HMPs and psychological connection. Drawing from the literature on immersive technologies in non-musical contexts such as gaming and media consumption, this paper hypothesizes that HMPs may increase feelings of psychological connection to the artist when listening to recorded music because they generate a sense of social presence.

1.4. Haptic Devices Generate Feelings of Social Presence

It has been suggested that haptic devices can generate a sense of immersion and social presence. Social presence has been defined as the "degree of salience of the other person in the interaction and the consequent salience of the inter-personal relationships" (Short et al. 1976). Numerous terms fall under the umbrella concept of "presence", including social presence, co-presence, personal presence, and telepresence (Nowak and Biocca 2003; Lee 2004). Presence can refer to the psychological sense of "being there" with others in a virtual environment (Biocca 1997). The "others" in the virtual environment could be people in different physical locations or fictional avatars interacting in the virtual environment (Nowak 2001). Presence can also refer to the "psychological connection of minds" and the awareness that one's behaviour may be monitored by others in a mediated environment (Rettie 2003). Presence may also be defined as the feeling that an individual in the mediated environment is psycho-emotionally there with you in the real world, i.e., the mediated person is sharing the same space as you (Schultze and Brooks 2019). There is very little consistency among sub-definitions of the concept of presence, however, and researchers tend to disagree on just how many sub-divisions of the concept of presence there are. For example, some researchers conflate social presence with co-presence while others draw a clear distinction between the two (Nowak 2001; Schultze and Brooks 2019). Most researchers agree, however, that presence generally relates to the feeling of social and emotional connection to others in a mediated environment (Kim et al. 2019). People perceive mediated others as real instead of abstract or anonymous; thus, interaction with mediated others tends to resemble face-to-face interaction (Lombard and Ditton 1997). In this paper, we refer to social presence as both the feeling that the mediated other is "there" in the real world with you, and the feeling of your "being there" in the virtual environment (Lowenthal and Snelson 2017; Schultze and Brooks 2019).

Haptic devices may generate a feeling of social presence because they manipulate the user's sense of psychological distance to a mediated other, and the feedback from haptic devices mimics human-to-human contact (Hadi and Valenzuela 2014). Haptic devices can convey rich social information, delivering cues about emotions and intentions much like in face-to-face interactions (Mazzoni and Bryan-Kinns 2015a; Mellis and Tichenor 2005; Smith and MacLean 2007). Research suggests that haptic devices can enable the user to experience "mediated social touch" because the feedback generated by these devices increases the salience of others and, therefore, perception of social presence (Baecker et al. 2014; Basdogan et al. 2000; Chang and O'Sullivan 2005; Haans et al. 2014; Sallnäs 2010). People report feeling that mediated others and digital avatars are "there" when interacting in environments with haptic feedback (Basdogan et al. 2000; Sallnäs 2010). People also use different types of touch when interacting with human versus nonhuman objects in digital spaces, e.g., exerting different haptic pressure when touching a human versus picking up a cup (Bailenson and Yee 2008). This indicates that haptic devices are an important part of digital social interaction and that they can convey social information in mediated environments.

1.5. Haptic Devices and Psychological Connection

Physical contact is an important part of socialization that can convey positive impressions about people and improve mood (Burgoon 2002; Crusco and Wetzel 1984; Williams and Kleinke 1993). People similarly form positive evaluations of others and self-report increased positive mood when using haptic devices (Bailenson et al. 2007). One study investigating behavioural measures of loneliness suggested that translating a social partner's heartbeat into felt on the skin via a haptic wearable device might increase intimacy-seeking behaviour, such as standing closer to the social partner (Janssen et al. 2010). Using haptic devices has been shown to increase the perception of togetherness in a collaborative task (Bailenson and Yee 2008; Lee and Kim 2008; Sallnäs 2010). Furthermore, a study that compared haptic feedback and visual feedback in a virtual game of football found that participants demonstrated greater trust among virtual teammates with haptic as opposed to visual feedback (Brave et al. 1998). Conversely, people report decreased feelings of loneliness when engaging with haptic devices (Fumagalli et al. 2019). Haptic devices significantly decrease feelings of loneliness to the extent that they have been recommended as a potential intervention to reduce feelings of isolation in chronically lonely populations such as the elderly (Appel et al. 2020).

1.6. Haptic Devices in Art Experiences

Initial evidence suggests that haptic devices may influence and augment art experiences. Recent field studies have showed that people enjoy tactile experiences of visual artwork (Faustino et al. 2017; Vi et al. 2017). Participants in a study conducted at the Tate Britain gallery in London reported feeling more immersed when experiencing art while using a haptic device (Vi et al. 2017). Another paper argued that haptic enhancements for the visually impaired increased opportunities for learning and increased the enjoyment of learning for visitors at a museum exhibit (Geary 2007). A paper on immersive human–computer interactions detailed a prototype design for a product called SensArt, a device that produces music, vibrations, and temperature changes to translate the emotive qualities of visual art (Faustino et al. 2017). While this was not an empirical study, the intent of the designers was to create an immersive technology to accompany visual artworks with the aim of increasing audience connection with the art.

There is also some research on HMPs suggesting that haptic devices can increase enjoyment of the music-listening experience. For example, one study found that listening to music while sitting in chairs that provide vibrotactile feedback in time with the music increased psychological arousal and greater subjective appreciation for the music (Giroux et al. 2019). Another study found that use of an HMP while playing the video game Dance Dance Revolution increased both enjoyment of the game and game performance (Hodges 2018). One study, however, found that receiving vibrotactile feedback via an HMP while listening to music was an acquired taste as many users initially reported disliking the experience although enjoyment increased over time (Vallgårda et al. 2017). To date, however, no one has investigated the impact of HMPs on feelings of social presence and psychological connection.

1.7. The Studies

The present research has two main aims: (1) to understand the differences between live and VR concert experiences and establish the importance of touch in live concert settings and (2) to investigate the potential for HMPs to augment the music-listening experience. Study 1 used qualitative methodologies to investigate the various ways in which the experience of attending live concerts differed from VR concerts. It also investigated the types and importance of touch—both tactile and kinaesthetic experiences—in live concerts, and where on the body this feedback is most strongly felt. Finally, it asked participants to describe their ideal experiences of touch for VR concerts.

Study 2 then empirically investigated a single aspect of VR concerts—namely the impact of vibrotactile touch on the recorded-music-listening experience. Study 2 was an

exploratory study assessing whether using an HMP that delivers vibrotactile feedback in time with the music can influence feelings of empathy, parasocial bond, and loyalty towards the artist; the hypothesis was that participants would report a greater sense of all three when listening to music with the HMP on (haptics condition) compared to when it was off (control condition). We hypothesized that the main effect of haptics on these dependent variables would be mediated by the feeling of social presence. Taken together, studies 1 and 2 serve as a first step towards validating the use of HMPs to augment VR concert experiences.

2. Study 1

First, an exploratory qualitative study was run to gain greater insight into people's experiences at live and VR concerts. Participants were asked about the ways in which VR concerts differ from live concerts to help us understand the key experiences that VR concerts either lack or provide compared to live concerts. Participants were also asked about the relative importance of five senses—sound, sight, touch, taste, and smell—in live concert settings in order to better understand what kinds of sensory feedback may be prioritized when designing immersive virtual-concert experiences. Participants were then asked to list the ways in which they experience touch in live concert settings so we could codify the various kinds of haptic experiences that one may receive. Finally, participants were asked to remember a time they went to a live concert and recall where they felt vibrations in their body. This set of questions was asked to inform potential haptic device design.

3. Methods

3.1. Participants

Twenty participants (50% Female, M_{age} = 31.20, SD_{age} = 8.32) were recruited on Prolific Academic for payment of £9 per hour. Participants were pre-screened to select for frequent VR users (defined as those having used VR more than 15 times) from both US and UK users. Participants were told that they would be asked questions about their experiences at live concerts and VR concerts.

3.2. Procedure

Participants answered a 20 min survey containing a series of both qualitative free-response and scale-measure questions. Free-response questions were asked in order to empower participants to answer without the biases inherent to interview styles of questionnaires and focus groups (Brown and Knox 2017). Additionally, previous research has established that free-response questions are a good way of capturing rich information when investigating musical experiences (Gabrielsson and Lindström-Wik 2003). Furthermore, minimum sentence requirements were implemented for free-response questions to encourage participants to give more thorough feedback as online study participants tend to be inattentive (Wessling et al. 2017; Zhou and Fishbach 2016).

Participants were asked a free-response question about the differences between live concerts and VR concerts: *What (if any) are the differences between attending a live performance and watching a concert in VR, e.g., on the Oculus? If you have never watched a VR concert, imagine what the experience would be like. (Please write a minimum of 2 sentences).*

Participants were also asked questions about sensations of touch in live concert settings. They were asked to close their eyes and recall a time they attended a live concert. They were asked to rank the senses—sight, sound, smell, taste, and touch—in order of importance to enjoyment of the concert. They were then asked a yes/no question about whether they experienced vibrations on their body at the concert. If they answered "yes", participants were given two short-answer questions about where on their bodies they experienced the strongest/weakest vibrations. Participants were then asked the following free-response question: *What kinds of tactile feedback did you receive from others (e.g., touch, crowd-surfing etc.)? (Please write a minimum of 2 sentences).* They were then asked a multiple-choice question: *When answering these last few questions, what genre of music were you thinking of?* (*pop, EDM,*

hip-hop/rap, rock, classical, folk, jazz, other [please specify]). Finally, participants were asked a free-response question about their ideal tactile experiences in a VR concert setting: *What would be your ideal tactile experience when watching a concert in VR? Think of where you'd like to feel tactile feedback, what kind of tactile feedback, the intensity of the tactile feedback* etc. *(Please write a minimum of 2 sentences).*

The order of the questions about tactile experiences in live concert settings and VR versus live concerts were randomized across participants. At the end of the survey, they were asked questions about their demographics and how often they attended live concerts, how often they watched videos of concerts online, and how often they watched VR concerts.

All free-response questions were collapsed into categorical variables for thematic analysis. This approach has previously been used in media psychology studies and was chosen due to its flexibility and suitability for distilling large quantitates of text from which insights may be drawn (Brown and Knox 2017). First, the primary author coded anything that was considered important. The codes were then grouped based on recurring themes. Lastly, interpretive coding was conducted by both authors based on their memories of live music events (method established by Brown and Knox 2017).

4. Results

Themes for qualitative analysis were identified based on in vivo coding of participant responses and common response patterns (phases of thematic analysis proposed by Braun and Clarke 2006 and applied by Brown and Knox 2017) to study motivations of concert attendance). While this was a largely qualitative study, Likert-scale response measures were also taken into consideration. Additionally, while not a common practice in many qualitative studies, the frequency of themes identified among the 20 participants was represented as a percentage to indicate the relative importance of themes (Vuoskoski and Eerola 2011). The analysis is broken down into the following sections based on the categories of research questions asked: live versus VR concert experiences, and touch in live and VR settings.

4.1. Live vs. VR Concert Experiences

Participants were asked to discuss the ways in which live and VR concerts differed based on either their own or imagined experiences of both. All participants attended more than one concert per year, and the majority of participants attended 1–3 concerts per year. Furthermore, only five participants had never watched a concert in VR, and most people watched 1–3 VR concerts per year. Three participants attended VR concerts more than five times per year. Figure 1 shows a thematic map of the three major differences identified between live versus VR concert experiences.

4.1.1. Connection

The most common theme was a difference in connection between live and VR concerts (65%). Connection can be broken down into two main components: social and emotional connection. One of the main criticisms of VR is that it is a solitary activity: "VR concerts feel isolated in nature". Because VR is solitary, several participants felt that watching concerts in VR felt "a little isolating" and defeated one of the main motivations for attending live concerts, which is to "have fun with other people".

Additionally, it is difficult to replicate complex social interaction with other members of the crowd in VR due to the constraints of the technology. While some degree of social interaction may be possible, many participants felt it was insufficient to truly replicate in-person social interaction, which includes everything from "mosh pits" to interacting with "the performer directly": "*When it comes to interacting with people, it would still be possible, even if limited*". Furthermore, several participants mentioned that VR concerts do not provide the "feeling of being surrounded by thousands of people" which was crucial to the experience of connection in live concerts: "*When watching a VR concert, there is no real interaction with other people in the crowd*".

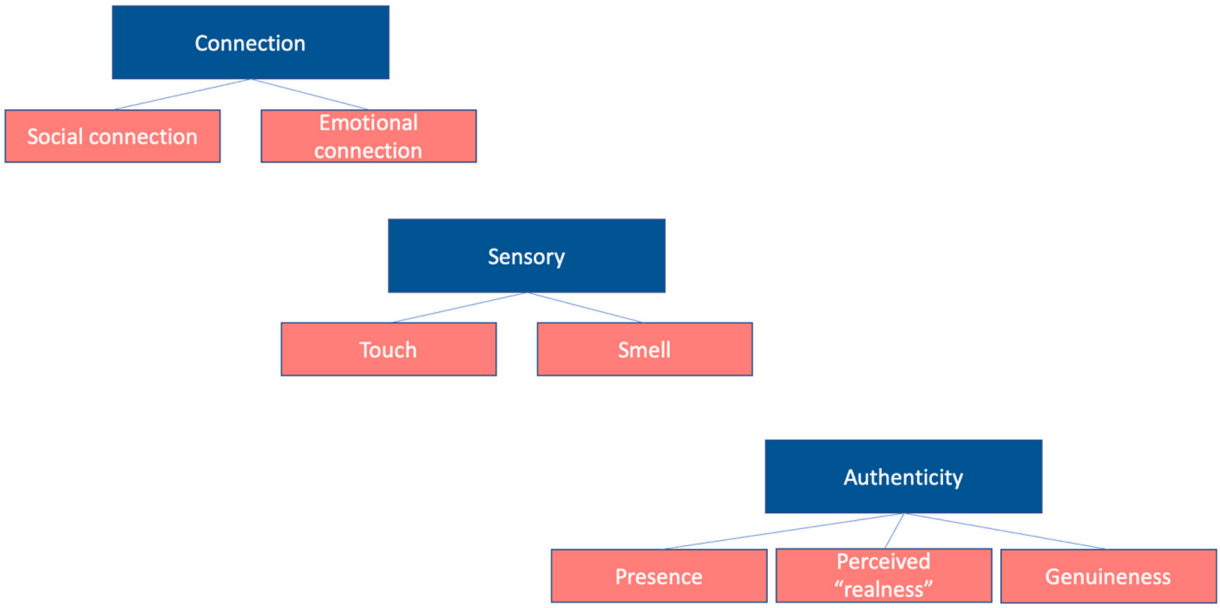

Figure 1. Thematic map of three main differences between live and VR concerts.

VR concert videos do, however, provide a unique opportunity to feel closer to the artists on stage as the artists are filmed up-close and there are no obstructions to the user's view: " . . . *you watch as if you are among the band with no obstruction*". That said, the lack of real-time engagement was a point of frustration as one participant noted that VR concerts are "typically pre-recorded and the artist or band cannot respond to you in real time". Thus, while visual connection creates some feelings of connection, the lack of real-time response renders the artist–VR user engagement superficial.

The second form of connection mentioned was emotional connection to other audience members and the music. While people can "feel and connect" with others in live performance spaces, there is limited ability to do so in VR. Participants mentioned that while it might be possible to "feel some of the emotions like in real life", it is not possible to "experience the same intense feelings as if you were really there". In other words, while VR may generate some emotional response in the user, it is not the same intensity of emotional connection as in live concerts. Participants reiterated that emotional connection is one motivation for attending live concerts and makes the experience "much more enjoyable".

4.1.2. Sensory

The second most reported difference is that a live concert is multisensory whereas a VR one is not (50%). As one participant said, the live concert experience "takes over all your senses" in a way that VR does not. Specifically, participants mentioned a lack of smells and tactile feedback in VR: "*Still wouldn't be the same as you wouldn't get the buzz of being there and get the sensations such as touch, smell etc.*".

One participant suggested using haptic devices to generate artificial sensations of tactility in VR. While this might allow the user to "feel the beat", the haptic device might be less equipped to provide other important kinds of tactile feedback associated with the feeling of being in a crowd: "*Although you do get haptic feedback from using VR devices, it is not the same thing as the physical feeling of being surrounded by thousands of people in person*".

While most people felt that a VR concert is "far less immersive than it would be in person", some people noted that VR concert experiences are "far more immersive . . . than just watching a normal video of the concert". This is in part due to the full visual immersion of the experience, which is much more "realistic" than watching on a phone or laptop screen.

Users can also control how much sensory stimulation they receive on a VR headset. For example, participants mentioned that the ability to control volume settings on the VR headset allows for some customization of the experience, which is positive: "*With live performances, you leave your home for the venue and you can't control the volume and the noises of people in concert*".

One caveat that some users mentioned, however, is that VR concerts can sometimes contain low-quality graphics and sound which contribute to a lower-fidelity sensory experience. As one user who commonly attends VR concerts within games mentioned:

> "*When I envision virtual concerts currently, I am immediately reminded of the virtual concerts that are held in games such as Roblox or Fortnite. Almost immediately, the VR concert experience is lower quality because those games have graphics that do not even come close to mimicking real life, so the immersion of a VR concert is immediately almost close to zero.*"

Other users speculated that sound quality would be difficult to replicate in VR concerts: "*I feel like the vibe and people would be very easy to emulate on a VR headset, but no so much the sound*".

4.1.3. Authenticity

Participants also mentioned that VR concerts are less authentic than live concerts (35%). Authenticity is a slightly broader theme that encompasses feelings of presence which are linked to feelings of genuineness and perceived "realness". It also refers to the novelty of the experience.

Presence was coded as anything that referred to the feeling of "being there". Several people conceded that VR enables users to feel like they are "sort of . . . there", but most said it was not the same. Some people referred specifically to the lack of atmosphere in VR: "*You wouldn't get the buzz of being there*".

Several people mentioned that the experience "doesn't feel genuine". They referred to the VR concert experience as being "manipulated" or "fabricated for the user's perfect experience". In other words, participants felt like there was something inauthentic about the way VR concerts are presented to viewers.

Additionally, simply knowing that the experience is not a live concert event makes the overall experience less real: "*I would imagine VR concerts to be a little isolating and unrealistic*". Several participants referred to the lack of realism without specifying what made the experience unrealistic other than the mere knowledge that it was not a live concert. This suggests that even if the affordances of the technology generate a greater feeling of telepresence, the mere knowledge that the experience is not in-person might influence perceptions of the realness and authenticity of the experience.

The second aspect of authenticity that people mentioned is the novelty of live concerts, which is difficult to replicate in VR concerts. The fact that a VR concert can be watched again means that the experience feels "less special" and less novel:

> "*It doesn't feel genuine and feels like it can be replicated again and again. A live concert gives you an individual, unique experience, as if you've missed [sic] then you've missed it entirely. It feels special.*"

Other participants mentioned that VR did not offer opportunities for spontaneity:

> "*There are real humans to interact with at a live show, and stage diving is fun and dangerous. It would be impossible to be in a mosh pit with VR. I cannot hook up with some hot punk rock guy in VR. (well I could but it's not the same).*"

Other participants felt that the experience was disingenuous because the lack of spontaneity meant that the experience was somehow manufactured or "fabricated for the user's perfect experience".

4.2. Experiences of Touch in Live and VR Concerts

Participants were asked to recall a time they attended a live concert and recall how important tactile experiences were to the concert experience. As can be seen in Figure 2, sound was ranked the most important, followed by sight, smell/touch, and taste. There was no significant difference between ranking for smell and touch; 19 out of 20 participants responded that they remembered feeling vibrations on their body at the concert. Figure 3 indicates where on their bodies people experienced the strongest vibrations. Most people reported feeling the strongest vibrations in the upper body (chest/torso and stomach) and in the feet.

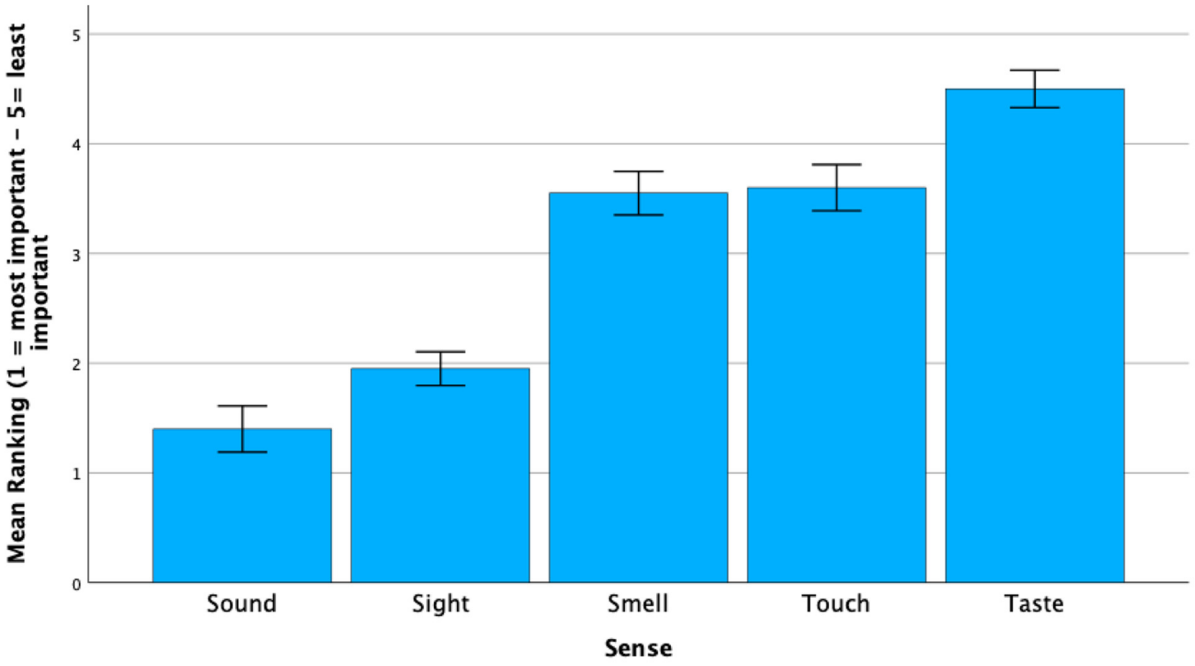

Figure 2. Mean ranking of the five senses ±1 standard deviation.

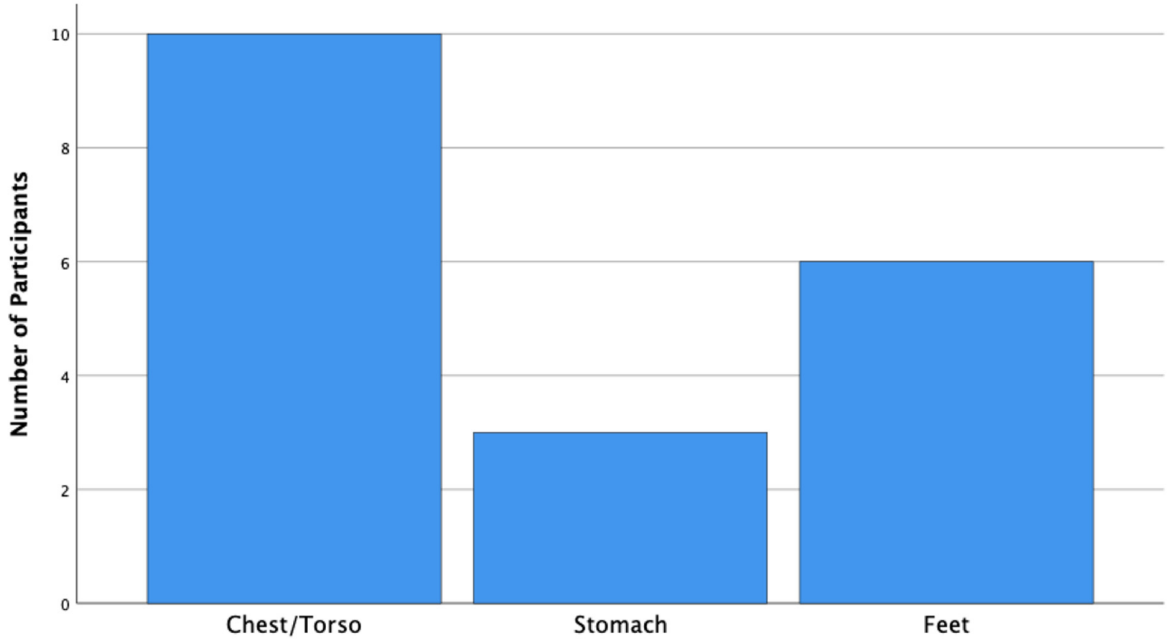

Figure 3. Location of strongest vibrations on body during concert.

Questions about the kinds of touch that participants receive at live concerts and ideal experiences of touch when watching VR concerts revealed four major kinds of touch: *touch from the audience, emotional "touch", vibrations*, and *thermal feedback*. Percentages were calculated as the number of times a theme was mentioned for the two questions relating to tactile experiences. If a participant mentioned the same theme twice within a response to a question, it was counted only once.

4.2.1. Touch from the Audience

The most common form of touch that people received at live concerts was touch from other audience members (85%). There were two main forms of touch. Firstly, there was accidental touching resulting from people standing in close proximity to one another, which included "*people bumping into me*", "it was crowded so there was a lot of touching and pushing", and "*people touched me and brushing alongside me in the crowd as I was stood up and close to other people*". Secondly, there was intentional touching, which occurred as a part of social interaction with other audience members in group choreography and movement: "*We held hands and rocked and swayed*". Where touch was experienced as a consequence of movement, it may be considered to be kinaesthetic feedback.

While touch from the audience was the most common form of touch in live performance, it was not the most desired tactile experience in VR (35%). A smaller group of people mentioned wanting to experience tactile feedback to simulate social engagement, e.g., touch related to "*artist or band engage[ing] with the audience in real time*". Several participants mentioned wanting kinaesthetic feedback by way of coordinated group dancing in VR:

> "*My ideal tactile experience would be being able to touch other people and dance with them. I would like to be able to hold hands with whoever I'm attending the concert with.*"

Most people, however, wanted to simulate the touch associated with being in a crowded environment such as the "*feel of being shoved and pushed around*" and "*the feeling of bumping into people*".

4.2.2. Vibrations

The second most common form of touch that people reported experiencing at live concerts was vibrations (25%). People either experienced vibrations from the music or, more commonly, appeared to experience vibrations due to the movements of the crowd: "*The rump and stamp of their feed rocked the podium and through my whole body*".

When watching concerts in VR, vibrations were the most common form of tactile feedback that people wished to experience (35%). Participants mentioned wanting to feel the vibrations of the music itself to augment the musical experience, thus making the VR experience more immersive and realistic.

> "*The only way VR can improve this is if they somehow find a way to replicate the vibrations of the music like you were in a concert (i.e., the whole body sensation of "feeling the music")*"

People were specific about how and where they would prefer receiving this vibrational feedback. For example, some people reported wanting to "*feel the touch and vibrations on my skin*" and "*feeling vibrations at your feet*". Based on the varied responses, it is not clear that people want to experience vibrations in the same way. Two people suggested a solution for experiencing vibrations in VR and proposed integrating "*vibrations from some kind of haptic device*".

4.2.3. Emotional Touch

A small group of people specifically mentioned emotional connection when asked about touch at live concerts (10%). Participants mentioned that they "*very synced with the crowd*" and one participant mentioned that they "*felt the love from the artists*". While not a

form of tactile feedback, it appears that some participants interpreted emotional connection as a form of touch.

People also reported a need for feeling emotional touch via VR (15%). Participants suggest that recreating emotional connection in a VR concert may make the experience more life-like: "*I think I would want to connect with the music they are using and to feel the realest of it as if I am watching it live*". One participant described the need for emotional touch to help transmit the emotional states of others in the virtual audience: "*seeing and experiencing that other people in the crowd share the same intense happy feelings as you are experiencing yourself during the concert*".

4.2.4. Thermal Feedback

A minority of participants mentioned wanting to receive thermal feedback as a form of touch when watching VR concerts (10%). Two participants indicated that they wished to feel a "*rise in temperature*" to simulate the feeling of heat flowing from a crowd: "*Feeling vibrations at your feet and the heat radiating from other people around you would feel more authentic*".

10% of participants indicated that they did not want to experience any kind of touch when watching concerts in VR.

Finally, participants were asked about the musical genre of the concert that they were recalling to answer the questions about touch (Figure 4). We asked about the genre of the concert to contextualize the data collected. For example, it is customary for people to stand near one another at a pop concert but not at a classical concert, where the audience tends to be seated.

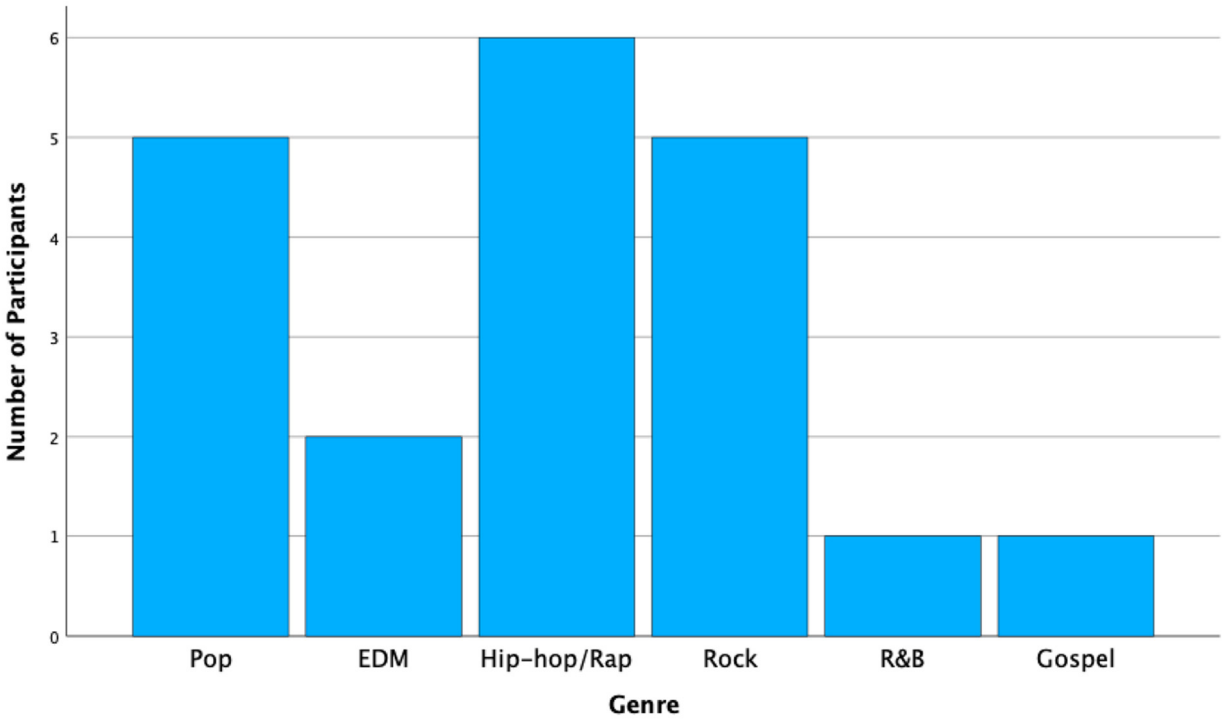

Figure 4. Musical genre of concert in participant memory task.

5. Discussion

In summary, the results of Study 1 showed that people feel less connected and less sensorially immersed in VR concerts than in live concerts. They also perceive VR concerts to be less authentic experiences than live concerts. Participants suggested that technological interventions, such as haptic devices, can mimic physical contact, enable people to feel more socially connected, and generate vibrations in time with the music which may be used to increase sensorial immersion. Participants also cautioned, however, that the mere knowledge that the experience is virtual and not live may contribute to the lack of

authenticity, and it is therefore possible that no intervention may be able to surmount this bias. That said, as the affordances of immersive technologies improve, it might be possible to generate a greater feeling of presence which may allow people to perceive the experience as more authentic (Nowak and Biocca 2003).

Furthermore, an in-depth exploration of tactile experiences in live concert settings revealed that people receive a variety of different forms of touch. Participants also indicated that they would like to feel these varied forms of tactile experience when watching VR concerts. Participants specifically brought up a need for physical touch, emotional touch, vibrations, and thermal feedback. Interestingly, participants described emotional connection as a tactile experience. This is in line with research suggesting that physical touch is processed by both a-beta fibres, responsible for the discriminative properties of tactile sensation, and CT afferents, which may be responsible for transmitting information about the subjective emotional experience of touch (McGlone et al. 2007). Additionally, participants referred to the thermal feedback generated by the heat of the crowd as a form of tactile feedback. This is in line with research suggesting that temperature is an aspect of touch perception as the trigeminal nerve carries information on touch, texture, and temperature to the primary somatic sensory cortex of the brain (Simon et al. 2006; Viana 2011). Vibrational feedback was also an important part of the tactile experience in live-concert events, and people mentioned feeling that vibrational feedback occurred mainly in their chests, feet, and stomach. Interestingly, none of those areas are associated with physical touch from other audience members, suggesting that vibrational feedback is mainly from the music and occasionally from the jumping of the audience, as one participant mentioned.

As this was a qualitative study, it was subject to some of the limitations endemic to qualitative research. Due to the small sample size and online format of the study, the results were prone to bias. As this was an online study conducted on Prolific, responses were perfunctory and may have been less detailed than interview-style questionnaires (Newman et al. 2021). Furthermore, not all participants had attended VR concerts, and thus some answers were based on speculation. Three participants had never attended VR concerts and were thus imagining the VR concert experience instead of basing their answers on their own experiences. Additionally, when asked about tactile experiences at live concerts, participants reported a wide range of touch types. This is, however, probably limited to concert experiences of very specific musical genres. For example, the kinds of touch one might receive at a seated classical-music concert without amplification might be very different from the tactile feedback one receives at a rock concert. As none of the participants listed attending jazz or classical concerts, it is possible that the scope of the results is limited to non-classical genres of music.

Finally, a major limitation of this study is that participants were asked to recall their experiences of touch in live concerts. This is potentially problematic as research suggests that the retrieval and storage of information related to touch is not as strong as for auditory or visual information (for reviews, see Gallace and Spence 2009). Some studies have suggested that people perform less well on touch than visual-recognition tasks when both tactile and visual stimuli are presented for the same length of time (see Walk and Pick 1981 for review). Future research may wish to conduct qualitative research in actual live-concert settings to obtain more accurate data about experiences of touch.

6. Study 2

While Study 1 provided an overview of the role and importance of touch in live versus VR concerts, Study 2 narrowed the scope of investigation to a particular form of touch and its impact on one aspect of VR concerts. Specifically, we investigated the role of vibrotactile feedback conveyed via HMPs and its impact on the audio-only music-listening experience. Specifically, this study assessed empirically whether listening to music with vibrotactile feedback influenced empathy, loyalty, and parasocial bonding with the artist. Participants were randomly assigned to one of two conditions (haptics versus control) in a between-subjects design. Participants in both conditions wore an HMP—a wristband—which was

either turned on to vibrate in time with the music or turned off. The hypothesis was that the haptics condition induces a main effect upon empathy, loyalty, and parasocial bonding, such that people listening to music in the haptics condition reported higher scores on these three measures than people in the control condition. Participants were also asked about social presence to investigate whether the perception of social presence would mediate the main effect of haptics condition on these three dependent variables.

7. Methods

7.1. Participants

Eighty participants (64.1% Female, M_{age} = 23.88, SD_{age} = 5.7) from the city of Oxford were recruited via the Oxford Participant Database and paid £5 for their time. Participants were told that they would be asked to listen to music and answer some questions. They signed consent forms and were told they could withdraw from the study at any point during the study without penalty.

7.2. Procedure

Participants were given a set of headphones and asked to listen to a song on loop for the duration of the study. Audio levels were set at a volume setting of 52 out of 100 on the computer, and participants listened to the music on headphones. While they were listening to the music, participants had an HMP strapped to their left wrist that was either turned on and vibrated (haptics condition) or was left turned off and did not vibrate (control condition).

The HMP used in the study was called The Basslet, a beta-prototype wristband acquired from Lofelt Studio (Lofelt Basslet Review—A Wearable Subwoofer 2017). While musical vibrations are not commonly experienced on the wrist, as we discovered in Study 1, this device was relatively small and cost effective compared to devices such as haptic vests and waist belts. The vibration intensity was set to the 4th (medium) intensity setting for all participants in the experimental condition. All participants were told to wear the wristband and follow the instructions as they appeared on the screen.

The song used was *War of Hearts* by Ruelle, and it was taken from a Spotify playlist titled, "Emotional Songs". This song was listed as "indie" according to Spotify's metadata, the vocalist was female, and the song was about love—an emotive topic. This song was chosen because it is bass-heavy, which is necessary for the haptic device to translate it into vibrations felt on the skin, and because the emotional content of the song was likely to generate empathetic responses in listeners.

Participants were asked to listen to the song for 30 s and then answer some questions about clarity, quality, loudness, quietness, and subjective evaluations of the music. They were also asked a binary-choice question about whether they were familiar with the song used in this experiment.

7.3. Measures

After the 30 s, the study began by asking participants a series of questions presented in a randomized order. To assess cognitive empathy towards the artist, participants were asked to respond to items adapted from the Ad Response Empathy Scale used to assess empathy in response to media (Escalas and Stern 2003). Participants responded to a set of four statements about *Empathy for Artist* (α = .95) on 7-point Likert scales ranging from *strongly disagree* to *strongly agree*: (1) *I understood what the singer was feeling,* (2) *I understood the singer's point of view,* (3) *While listening to the music, I tried to understand the singer's motivations,* and (4) *I was able to recognise the issues that the singer was singing about.*

To assess the *Parasocial Relationship* (α = .90) with the artist, participants were asked to respond to eight statements adapted from the Celebrity Parasocial Interaction Scale (Hartmann et al. 2008; Rubin and Perse 1987; Kim and Song 2016). Participants responded to the following statements on 7-point Likert scales ranging from *strongly disagree* to *strongly agree*: (1) *When this singer sings about how they are feeling, it helps me understand my own feelings,*

(2) *I would feel sorry for this singer if they made a mistake*, (3) *Listening to this singer makes me feel comfortable, as if I am with friends*, (4) *I see this singer as a natural, down-to-earth person*, (5) *I would look forward to hearing news about this singer*, (6) *I find this singer likeable*, (7) *I would like to meet this singer in person*, and (8) *When I listen to this singer, I feel as if I'm a part of their group.*

Artist Loyalty (α = .94) was measured based on a set of items adapted from a study on loyalty towards musicians (Huang et al. 2015). Participants indicated their responses to the following three items on 7-point Likert scales ranging from *strongly disagree* to *strongly agree*: (1) *When I want to listen to music, I would feel safer listening to more music by this singer than trying to listen to a new singer*, (2) *Even though there are many other artists releasing new music, I would feel inclined to listen to music by this singer because I really like them*, and (3) *I plan on listening to new music released by this artist.*

Loneliness (α = .96) was also measured because research on immersive technologies suggests that an increased sense of the social presence of avatars or figures in virtual environments may also decrease feelings of isolation (Liszio et al. 2017). Participants responded to the following three items on 7-point Likert scales ranging from strongly disagree to strongly agree: (1) *I feel a bit lonely*, (2) *I feel quite isolated from others*, and (3) *I feel like I lack companionship* (Hadi and Valenzuela 2014).

Perception of Social Presence (α = .95) of the artist was measured by a set of items adapted from research on immersive reality (Nowak 2001; Nowak and Biocca 2003). Participants indicated their responses to the following five items on 7-point Likert scales ranging from *strongly disagree* to *strongly agree*: (1) *I feel connected to this singer*, (2) *I feel like the singer is here with me*, (3) *I feel like there is a bond between this singer and myself*, (4) *I feel close to this singer*, and (5) *I feel involved with this singer.*

Two attention checks were embedded in the study. Finally, participants were asked some demographic questions (age, gender) and a suspicion probe question.

8. Results

Two participants were excluded for failing the attention checks or failing to answer all questions in the survey, and one participant was excluded due to their familiarity with the song. The following analyses were conducted on the remaining 77 participants. Analysis of Variance (ANOVA) was conducted on all results to establish main effects.

Results indicated a significant effect of listening such that participants in the haptics condition reported a higher Empathy for Artist score than those in the control condition; F (1,75) = 39.53, $p < .001$, $\eta_p^2 = .345$ (see Figure 5a). There was also a significant main effect of the haptics condition on Parasocial Relationship scores such that participants in the haptics condition felt a stronger parasocial relationship with the artist than those in the control condition F (1,75) = 32.88, $p < .001$, $\eta_p^2 = .311$ (see Figure 5b). Furthermore, there was a significant main effect of the haptics condition on Artist Loyalty scores, with participants in the haptics condition reporting higher Artist Loyalty scores than participants in the control condition F (1,75) = 20.43, $p < .001$, $\eta_p^2 = .214$ (see Figure 5c). Finally, there was a significant effect of the haptics condition on loneliness such that participants in the haptics condition reported lower Loneliness scores than participants in the control condition; F (1,75) = 5.95, $p = .017$, $\eta_p^2 = .073$ (see Figure 5d). See Table 1 for means, standard error, and p-values by haptics condition and dependent variable.

Ancillary measures: participants did not perceive any significant differences in clarity (p = .332), quality (p = .146), loudness (p = .558), or quietness (p = .925) of the music between the haptics and control conditions. Furthermore, the six items measuring music evaluation formed a reliable scale (α = .85), and hence they were combined into a single composite measure. An ANOVA determined that there were no significant differences in people's evaluations of the music between the two listening conditions (p = .300).

Based on the immersive-technology psychology literature, social presence was identified as a potential mediator of the effect of the haptics condition on the Empathy for Artist score, Parasocial Relationship score, Artist Loyalty score, and Loneliness score. An ANOVA determined that there was a statistically significant effect of listening condition

such that participants in the haptics condition felt a greater sense of the social presence of the singer (M = 4.56, SE = .24) than participants in the control condition (M = 2.72, SE = .23); F (1, 75) = 30.94, p < .001, η_p^2 = .292 (See Figure 6).

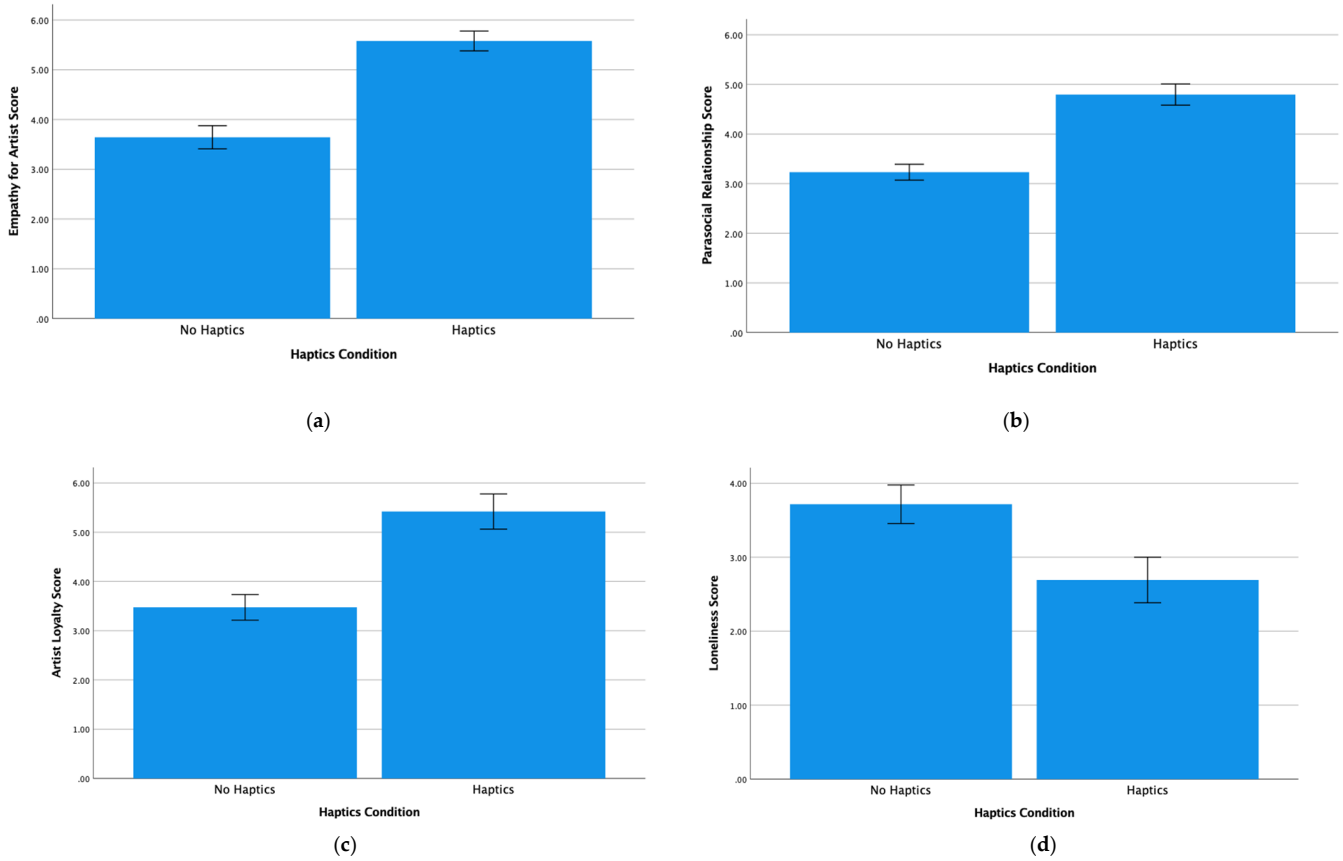

Figure 5. Mean scores by haptics condition for all dependent variables. Error bars show ±1 standard error. (**a**) Empathy for Artist score by haptics condition; (**b**) Parasocial Relationship score by haptics condition; (**c**) Artist Loyalty score by haptics condition; (**d**) Loneliness score by haptics condition.

Table 1. Means, standard error, and p-values by haptics condition and dependent variable.

Score	*Condition*	*M*	*SE*	*p*
Empathy for Artist	Haptics	5.58	.22	<.001
	Control	3.62	.22	
Parasocial Relationship	Haptics	4.80	.19	<.001
	Control	3.23	.19	
Artist Loyalty	Haptics	5.42	.31	<.001
	Control	3.43	.31	
Loneliness	Haptics	2.69	.29	.017
	Control	3.68	.29	

To test for social presence as a mediator of the effects of the haptics condition on the four dependent variables, mediation analyses were conducted using model 4 in the PROCESS SPSS Macro (Hayes 2017). In this study, the confidence interval was set to 95% and the number of bootstraps set to 10,000 (Hayes 2017; Preacher and Hayes 2004). Condition was coded as 1 = haptics, 0 = control.

The bootstrap analysis indicated that social presence was indeed a significant mediator of the haptics condition and on all four dependent variables: Empathy for the Artist score, β = 1.00, SE = .25, 95% CI = [.57–1.53]; Parasocial Relationship score, β = 1.21, SE = .26,

95% CI = [.74–1.77]; Artist Loyalty score, β = 1.91, *SE* = .44, 95% CI = [1.11–2.85]; and Loneliness score, β = −1.25, *SE* = .35, 95% CI = [−2.03–−.66]. Table 2 presents the direct effects of the pathway analyses, and Table 3 presents the indirect effects of the pathway analysis.

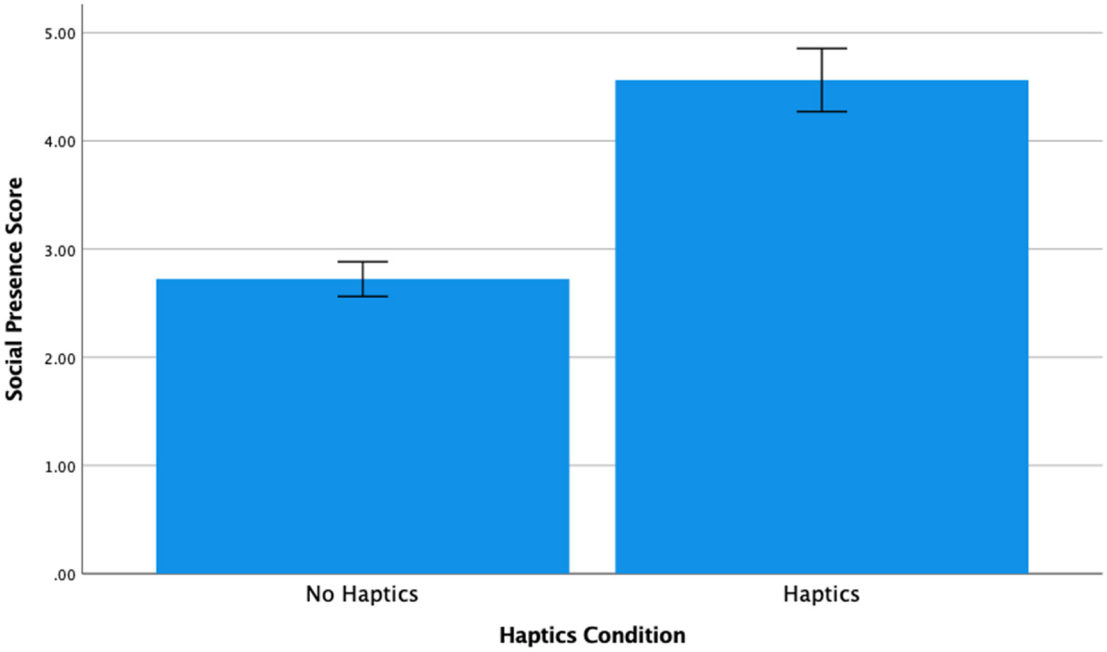

Figure 6. Mean ratings of Social Presence score by haptics condition. Error bars show ±1 standard error.

Table 2. Direct effects of mediation analysis of haptics condition on dependent variables, with Social Presence score as a mediator.

	β	*SE*	95% CI	*p*
Empathy for Artist score	.95	.30	.35–1.56	.002
Parasocial Relationship score	.35	.19	−.02–.72	.07
Artist Loyalty score	.09	.32	−.57–.75	.79
Loneliness score	.26	.41	−.55–1.06	.53

Table 3. Indirect effects of mediation analysis of haptics condition on dependent variables, with Social Presence score as a mediator.

	β	*SE*	95% CI
Empathy for Artist score	1.00	.25	.57–1.53
Parasocial Relationship score	1.21	.26	.74–1.77
Artist Loyalty score	1.91	.44	1.11–2.85
Loneliness score	−1.25	.35	−2.03–−.66

The Social Presence score mediates the effect of the haptics condition on Empathy for Artist score, Parasocial Relationship score, Artist Loyalty score, and Loneliness score. There was only one significant direct effect of the haptics condition on Empathy for Artist score when controlling for Social Presence score (95% CI = .35–1.56), which suggests that social presence at least partially mediates this relationship. There were no other significant direct effects, suggesting that Social Presence score fully mediates the relationship between the haptics condition and Parasocial Relationship score (95% CI = −.02–.72), Artist Loyalty score (95% CI = −.57–.75), and Loneliness score (95% CI = −.55–1.06).

9. Discussion

Study 2 extended the results of Study 1 by investigating the mechanisms that underlie haptic devices to evaluate them as a possible means of recreating feelings of psychological

connection and presence that people lack in VR concerts. Study 2 confirmed the hypothesis that listening to music with haptic feedback increases empathy, loyalty, and parasocial bonding with the artist. Results also indicate that listening to music with haptic feedback decreases loneliness. As predicted, the main effect of the haptics condition on these variables was mediated by feelings of the social presence of the artist. These results suggest that vibrotactile feedback may influence the extent that one feels the presence of the artist and that this, in turn, influences how connected one feels to the artist. The social presence of the artist fully mediates the relationship between the haptics condition and artist loyalty, parasocial bonding, and loneliness, which suggests that it completely explains the effect. Social presence only partially mediates the relationship between the haptics condition and empathy for the artist, suggesting that there might be an additional mechanism by which vibrotactile feedback increases feelings of empathy towards the artist; however, as this was an exploratory study, there were several limitations.

9.1. Potential Confound—Lower Level Explanations

Study 2 did not eliminate all possible confounds, so it is not entirely clear that the synchrony between the vibrotactile feedback and the music is what underlies the relationship between haptics condition and the main effects. An alternative, lower-level explanation is that stimulus intensity might explain the main effects of the haptics condition on empathy, parasocial bonds, and artist loyalty. The mere presence of vibrotactile feedback of any kind might increase positive feelings towards the artist as research shows that vibrational feedback influences expectations and enjoyment of technology-mediated experiences (Maggioni et al. 2017). If the mere presence of vibrotactile feedback explains feelings of social presence, the fact that the HMP provides vibrotactile feedback that is synchronous with the music may not explain the results.

This more parsimonious explanation, however, is unlikely to explain the effect as there is significant research suggesting synchrony in music and dance increases positive affect, generates feelings of social closeness, and facilitates social bonding (Knight et al. 2017; Rabinowitch and Cross 2019; Tarr et al. 2014, 2015, 2016). While this research largely deals with interpersonal synchrony in collective movement or music-making exercises (i.e., kinaesthetic feedback), studies on haptic technologies also show that people are sensitive to auditor–haptic time delays and prefer shorter gaps between auditory and haptic feedback via a haptic device (Montag et al. 2011; Stupacher et al. 2017). It is possible that this preference for haptic–auditory feedback synchrony is due to increased processing fluency (Stanton and Spence 2020). Future research may wish to test whether synchrony impacts empathy, parasocial bonding, artist loyalty, and loneliness.

9.2. HMP Placement

Study 2 required participants to wear an HMP that delivered vibrotactile feedback to the wrist, and Study 1 found that a majority of people experience the strongest vibrations at live concerts in their chest/torso, stomach, and feet. This is corroborated by empirical research suggesting that high-level low-frequency pure tones can cause human body surface vibration which can be felt in the chest and the abdomen (Takahashi et al. 2005). Hence, future studies may wish to use devices that mimic the haptic feedback that one might normally receive in a live event. The Tactstuit X40 (Knoxlab), for example, is a vest that is strapped to the torso and delivers vibrotactile feedback. It is often used in gaming and may provide more natural-feeling vibrotactile feedback when users are listening to music. It thus stands to reason that the most effective HMPs for realistic VR concert experiences would generate vibrations in those regions of the body. Conversely, participants reported feeling the weakest vibrations in regions such as the arms, head, and legs, suggesting that HMPs to augment VR concerts should not stimulate vibrations in those regions of the body.

9.3. Stimulus

In Study 2, participants all heard the same song about sadness with female vocals. This is potentially problematic because it is unclear just how generalizable these findings are. Future research may wish to pre-test songs of a variety of different genres to ensure that the songs were not extremely emotional/unemotional, in order to ensure that there are no ceiling or floor effects due to stimuli choice. Alternatively, future studies may wish to use clips of music that have already been shown to convey sadness in previous research (e.g., Vieillard et al. 2008).

9.4. Haptics and Vocals

While we found that the vibrotactile feedback increased a sense of psychological connection to the singer, it should be noted that the HMP was not actually translating the frequencies sung by the singer into tactile feedback. This is because the HMP works by translating the low-frequency elements in the auditory scene into vibrotactile feedback, and the low-frequency sounds in the music were generated by the instrumentalists accompanying the singer, e.g., the drums and low-frequency piano accompaniment (Turchet et al. 2020). Thus, while it appears that people associated the vibrotactile feedback with the vocals, the HMP itself was not picking up on the frequencies of the singer. It is possible that participants only associated the vibrotactile feedback and sense of connection to the singer because the questions in the study specifically asked about the singer, an example of a possible demand effect. Future research may wish to control for this potential confound by using music excerpts with a single instrument that produces low-frequency noises, such as a bass solo, and then ask questions about sense of connection to the artist.

10. General Discussion

While Studies 1 and 2 are different in terms of methodology and scope, both help paint a picture of the role of HMPs in enhancing the music-listening experience. Study 1 investigated the differences between VR and live concert experiences to better understand what factors would make VR concerts more immersive. One of the key differences identified is that people feel less connected in VR concerts than in live concerts. They specifically mentioned feeling both physically and emotionally less connected to others in VR. In light of the results from Study 2, it is possible that HMPs may be used to generate feelings of psychological connection while watching concerts in VR. Additionally, several participants mentioned that VR concert experiences offered less multisensory stimulation than live concert events due to a lack of touch and olfactory feedback. Interestingly, participants themselves suggested the use of haptic devices to "feel the beat", implying that HMPs might be a viable means to mitigate the lack of multisensory feedback. Participants also indicated, however, that VR concerts have lower-quality graphics and sound, which implies that even with HMPs the experience would feel less immersive. That said, the participant who referred to lower-quality graphics exclusively referred to attending VR concerts within the context of video games which do not attempt to recreate hyper-realistic virtual landscapes (Moritzen 2022). Furthermore, lower-quality sound on VR headsets may be mitigated with higher-quality headphones used in conjunction with VR.

Finally, a smaller group of participants suggested that VR concerts felt less authentic than live concerts. Participants said that VR could partially recreate the feeling of presence but not entirely. Results from Study 2 suggest that HMPs may be used to augment the feeling of presence when watching concerts in VR. Additionally, HMPs may be used to address the lack of novelty of the VR concert experience by creating one-off opportunities for spontaneous movement or interaction. For example, some gaming companies have designed virtual mosh pits for one-off ticketed events so users feel like the experience is special and the movements are spontaneous (Moritzen 2022). Some participants, however, felt that the mere knowledge that the concert is in VR makes the whole experience less authentic. This suggests that even if the affordances of VR and associated technologies such

as haptics generate a greater feeling of presence, the mere knowledge that the experience is not in-person might influence perceptions of the realness and authenticity of the experience.

Study 1 also found that people receive different kinds of touch in live concerts and that people would ideally like to experience them all in VR: touch from the audience, emotional touch, vibrations from the music and audience movements, and thermal feedback. It is possible that haptic devices may be designed to convey these various forms of touch when watching VR concerts. Study 2 provides some initial evidence that HMPs may provide a sense of emotional "touch" in addition to vibrational feedback. Study 2 found that the vibrotactile feedback generated by the HMP leads to feelings of psychological connection, which aligns with Study 1 participants' desire to feel "connected to the music" and the crowd. Future studies may wish to determine how haptic devices may be designed to simulate the feeling of touch from the audience. One can imagine different tactile impulses coordinated with visual stimuli to mimic the sensation of audience members brushing past or the feeling of hands on the back after stage diving.

While there were several limitations given the exploratory nature of these studies, they provide insight into the use of HMPs in VR concert experiences. Study 1 presents some of the first qualitative data validating the use of haptic devices for generating a richer experience in VR concerts. Study 2 presents some of the first experimental data on HMPs generating a sense of social presence and engendering feelings of psychological presence when listening to music. This research builds on previous work suggesting that haptic devices can increase the salience and augment the emotional experience of audio-visual media (Lemmens et al. 2009; Mazzoni and Bryan-Kinns 2015b). Our research suggests that the immersive nature of HMPs allows for the communication of emotions and, thus, generates a sense of social presence: the listener feels like the artist is somehow "there" in the same space as them. These findings suggest that social presence mediates the effect of haptics on several measures of psychological connection to the artist. Additionally, because the vibrotactile feedback generated by the HMP increased a sense of social presence, it also decreased feelings of loneliness in the listener.

The findings from these studies present a promising route of inquiry for future research on HMPs, social presence, connection, and immersive musical experiences. VR-concert and haptic-device designers may find this research of interest to understand the impact of their technologies on user psychology. Artists may also find this research of interest when considering novel ways of connecting with fans.

Author Contributions: Conceptualization and methodology T.V. and Q.J.W. Investigation, analysis, data curation, and original draft preparation T.V. Review, editing, and supervision under Q.J.W. All authors have read and agreed to the published version of the manuscript.

Funding: Study 1 was conducted with support from the Carlsberg Foundation for a Young Researcher Fellowship, grant number CF19-0587. Study 2 was conducted with financial support from Dr. Rhonda Hadi at the Oxford Saïd Business School.

Data Availability Statement: Data is available upon request.

Acknowledgments: We would like to thank Signe Lund Mathiesen for her inputs on qualitative coding in Study 1. We would like to acknowledge Rhonda Hadi for her contributions to the study design, analysis, and funding for Study 2. We would like to thank Lucy Bowes for reviewing the methods, analysis, and discussion section in Study 2.

Conflicts of Interest: The authors declare no conflict of interest.

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