

Immersive Experience Design for Rock Music Fans in Virtual Symbiotic Scenes: A Thematic Review

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ABSTRACT:- This thematic review systematically investigates the design of immersive experiences for rock music enthusiasts within virtual symbiotic environments. Background: Accelerated advancements in virtual reality (VR) technologies and paradigm shifts in digital music consumption necessitate specialized immersive solutions. GAP: A critical research void persists: while extensive studies address generic virtual music experiences, the high-arousal emotional states, sensory intensity demands, and collective identity dimensions unique to rock music audiences remain underexplored in symbiotic settings. Aim & Methodology: To bridge this gap, we synthesize interdisciplinary literature through thematic analysis (ATLAS.ti 8), curating 19 peer-reviewed studies (2009-2025) across multisensory interaction design, affective neuroscience underpinnings, and wearable bio-signal sensors. Core analytical themes encompass human-computer interaction paradigms, neuroplasticity mechanisms, and cross-modal sensory integration. Findings: Spatial auditory-tactile modulation (e.g., haptic bass synchronization), strategic mixed-reality layering (AR/VR hybrid systems), and music-induced cortical reorganization significantly enhance immersive fidelity and emotional contagion. Contribution: We establish evidence-based theoretical frameworks for energy-driven virtual scene design and actionable protocols for adaptive multisensory feedback architectures. Future Studies: Longitudinal neurophysiological monitoring, culturally responsive symbiotic interfaces, and AI-driven real-time emotion adaptation warrant further exploration.

Keywords: - Immersive Experience; Virtual Symbiosis Scene; Rock Music; User Experience Design; Multisensory Interaction

I. INTRODUCTION

The advancement of virtual reality (VR) and augmented reality (AR) technologies has significantly transformed music consumption[3]. However, research addressing the distinct experiential requirements of rock music fans within virtual environments remains limited. Characterized by high-energy rhythms, aggressive instrumentation, and inherently immersive live performances, rock music necessitates a uniquely tailored sensory framework for virtual settings[16]. Prevailing literature on virtual music experiences predominantly examines classical or pop genres, often overlooking the characteristic emotional intensity of rock music and the critical symbiotic dynamic between performers and audiences. While studies, such as Swarbrick (2019), underscore the profound physical engagement inherent in live rock concerts, translating this embodied experience effectively through virtual technologies remains largely unexplored[20].

This review identifies a critical research gap: the absence of theoretical models that integrate multisensory feedback mechanisms—such as tactile vibration and visual synesthesia—with the complex auditory landscape of rock music within virtual symbiosis scenes[16][20]. Here, symbiosis denotes the reciprocal interaction between users and the virtual environment, where user actions dynamically influence the scene and vice versa. As Alsamhi (2025) observes, current virtual music platforms frequently rely predominantly on visual projections, failing to adequately replicate essential elements like haptic feedback (e.g., bass vibrations) or the social dynamics characteristic of live rock events.

Consequently, this review posits the key design principles that enable the creation of immersive virtual symbiosis scenes effectively addressing the sensory and emotional needs of rock music fans, as well as the mechanisms

through which multisensory interaction technologies facilitate this experience.

II. FIGURES AND TABLES

This study implements a thematic review methodology using ATLAS.ti 8 as the analytical tool, following the framework introduced by Zairul (2020)[1]. Thematic analysis, as defined by Clarke & Braun (2013), involves identifying patterns and constructing themes through thorough reading and coding of literature. The process includes: (1) systematic data familiarization, (2) initial coding of key concepts, (3) theme identification across documents, and(4) thematic refinement to ensure coherence with the research focus.

Literature selection adheres to the following criteria:Publications from 2009 to 2025, encompassing recent advancements in somatosensory interaction and immersive technology;Inclusion of keywords such as "somatosensory interaction," "immersive experience," "multisensory integration," "virtual symbiosis," and "rock music";Focus on studies exploring sensory design, neurocognitive mechanisms, or technological applications relevant to virtual environments for rock music engagement.

Table 1: Search strings from Scopus,ScienceDirect and Mendeley

Database	Search String	Results
Scopus	TITLE-ABS-KEY ("rock music" AND "virtual reality") OR	2
	TITLE-ABS-KEY ("immersive experience" AND "rock concert")AND PUBYEAR > 2009	45
Mendeley	"virtual symbiosis scene" AND "music interaction" AND year:[2009 TO 2025]	1 87
Science Direct	"multisensory design" AND "rock music" AND "user	6
	experience" AND Year:2009-2025	8

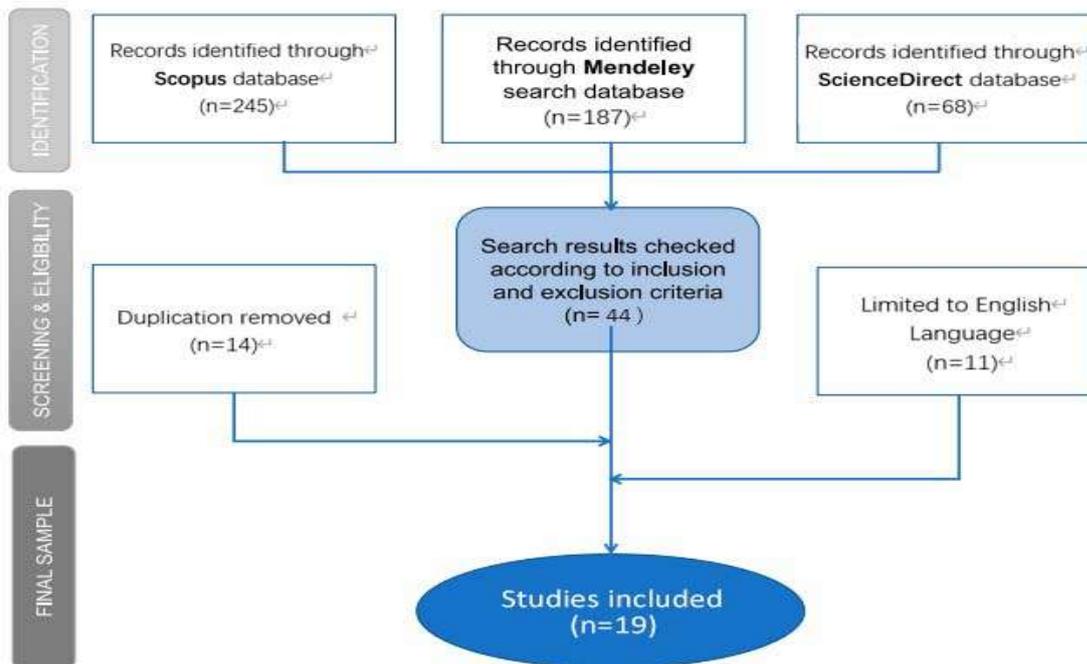


Figure 1. Inclusion and exclusion processes in the thematic review

The articles were afterward assessed using both quantitative and qualitative analysis methods. The quantitative section reported the findings from a mathematical of view to derive the respective data. At the same time, the qualitative area extracted codes from the selected papers, inducting themes and developing a conceptual framework.

Initial searches yielded 500 articles, of which 481 were excluded due to irrelevance, duplicate content, or lack of full-text access. The remaining 19 articles were analyzed using ATLAS.ti 8, following Clarke & Braun’s THEMATIC REVIEW ON STUDENT-CENTRED LEARNING IN THE STUDIO EDUCATION (2013) thematic analysis framework [1].Coding steps included:

Familiarization with texts through multiple readings; Initial coding to identify sensory design elements (auditory, visual, tactile); Thematic clustering into human-computer interaction, affective neuroscience, and wearable technology; Cross-thematic analysis to identify design principles for rock music context.

III. RESULTS

3.1 Literature Review

The integration of immersive experience design in virtual symbiotic scenes for rock music fans has emerged at the intersection of multisensory neuroscience, technological innovation, and cultural engagement[18]. A scoping review highlights the efficacy of somatosensory interactions—including tactile feedback systems, vibrotactile devices, and thermal feedback—in enhancing emotional well-being and stress reduction, providing a foundational framework for designing immersive tactile experiences in virtual environments[5]. This is supported by studies demonstrating that haptic feedback, such as rhythmic vibrations synchronized with music, can evoke physiological responses akin to live rock concerts, fostering a sense of presence[19].

Research on auditory-somatosensory integration reveals that spatial modulation of stimuli—such as high-frequency guitar tones paired with corresponding vibrotactile cues on the torso—enhances neural synchronization in primary somatosensory cortex, underscoring the importance of frequency-specific multisensory pairing[18]. Visual-tactile interactions further amplify immersion: simultaneous visual effects and tactile vibrations increase activity in somatosensory cortex, while AI-driven adaptive systems enable real-time customization of sensory inputs based on user biometrics, addressing individual differences in emotional arousal during virtual rock experiences[20].

Neuroscientific studies shed light on the cognitive mechanisms underlying immersion. Music-induced neuroplasticity shows that emotionally charged rock music strengthens connectivity between auditory cortex and limbic regions, while mirror neuron activation during synchronized group interactions mimics the social cohesion of live concerts[17]. These findings align with research with wearable haptic technologies, which simulate physical interactions in mosh pits through synchronized vibrations, enhancing social immersion.

However, existing literature reveals gaps: while multisensory technologies and neurocognitive insights have advanced, the specific design principles for virtual symbiosis in rock music—including how to balance sensory stimulation to avoid overload and integrate cultural nuances—remain underdeveloped[11]. Additionally, the translation of live concert dynamics into virtual environments, particularly the integration of tactile, auditory, and visual cues to replicate the emotional intensity of rock performances, lacks systematic exploration.

3.2. Research Aim

Against this backdrop, this study aims to: Identify and synthesize key design principles for immersive virtual symbiotic scenes that address the sensory (tactile, auditory, visual) and emotional needs of rock music fans, drawing from multisensory interaction research and neurocognitive findings[7][8]. Analyze how multisensory interaction technologies—including haptic feedback systems, AI-driven adaptation, and mixed reality—facilitate immersive experiences by bridging physical and virtual domains[17]. Address the translational gap between live rock concert dynamics and virtual design, prioritizing the integration of social interaction mechanisms and emotional arousal triggers in virtual symbiotic scenes. Propose a theoretical framework for virtual symbiosis in rock music, combining technological feasibility with neurobiological principles to guide future innovations in immersive experience design.

IV. DISCUSSION

4.1 Quantitative analysis

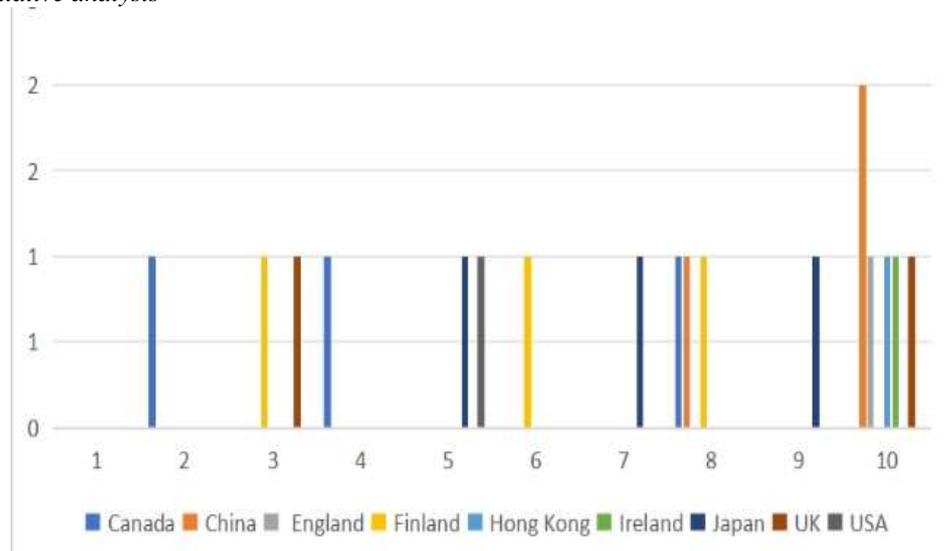


Figure2: Paper breakdown according to the year of publication

Figure2 presents a paper breakdown based on the year of publication (indicated by the x- axis, with years numbered 1-10). The y - axis likely represents the count of papers. Different regions/countries (Canada, China, England, Finland, Hong Kong, Ireland, Japan, UK, USA) are distinguished by various colors.

For example, in year 10, China has a relatively high number of papers (with a count of 2), while other regions like Canada, England, Finland, Ireland, Japan, UK, and USA have a count of 1 in that year. In most other years (1 - 9), the distribution of papers across these regions is more scattered, with each region having a relatively low and often equal count (mostly 1) in different years. This chart can help in understanding the temporal distribution and regional contribution of papers over these 10 years.

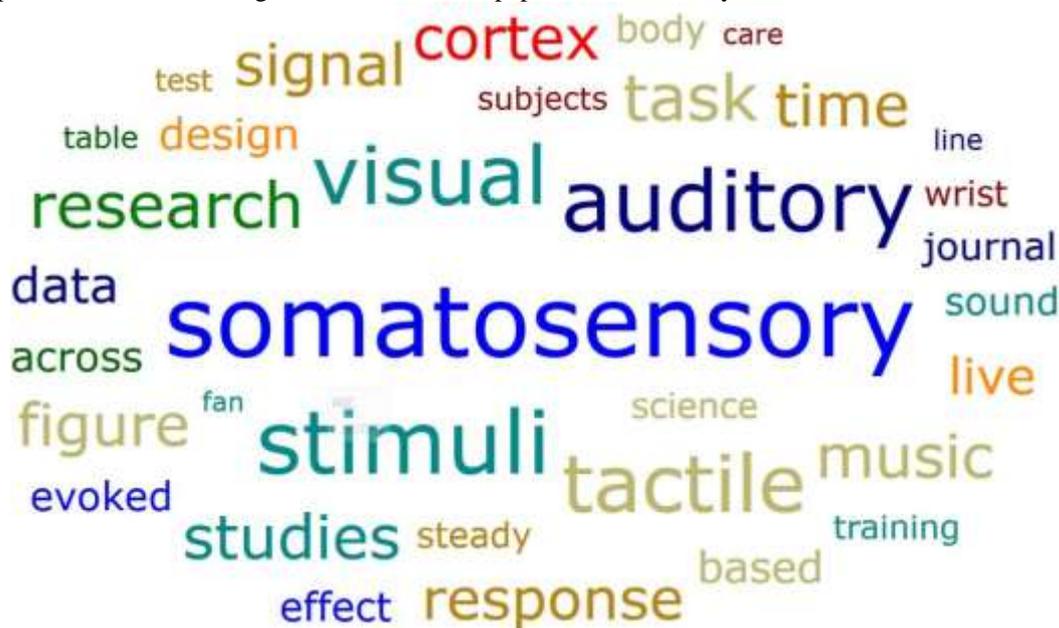


Figure 3: Word cloud generated from 19 articles

Figure 3 is generated from 19 articles, highlighting key concepts in the research domain. “Somatosensory” stands out prominently, indicating a central focus on the somatosensory system. Terms like “visual”, “auditory”, and “tactile” suggest investigations into multiple sensory modalities. “Stimuli”, “response”, “signal”, and “cortex” imply studies on how sensory inputs are processed, likely at the neural level (e.g., cortical activity).

“Research”, “studies”, “data”, and “design” reflect the methodological aspects, while “time”, “task”, and

“subjects” point to experimental elements like paradigms and participant - related factors. Words such as “music”, “sound”, “training”, and “effect” hint at applied or intervention - related research, possibly exploring how sensory stimuli (e.g., auditory from music) impact responses or training outcomes. Overall, the cloud encapsulates a multidisciplinary exploration of sensory processing, neural mechanisms, and experimental designs across 19 studies.



Figure 4: Type of issues discussed in the literature

This Sankey diagram visualizes the distribution of different research topic types across various publication years. The left - hand side lists research themes: “Human - Computer Interaction and Emerging...”, “Somatosensory interaction and mental health”, “Wearable technology and intelligent interaction”, “Music Experience and Affective Neuroscience”, and “Neuroscience of multisensory interactions”. The right - hand side shows publication years ranging from 2017 to 2025.

The width of the connecting ribbons represents the quantity of literature related to each theme in a specific year. For instance, “Human - Computer Interaction and Emerging...” has notable contributions in 2020 (with a ribbon width corresponding to 2 items) and 2024 (1 item). “Somatosensory interaction and mental health” sees activity in 2024 and 2025, each with 2 and 1 items respectively.

Overall, the diagram reveals the temporal trends and distribution patterns of research foci. It helps identify which topics were more prominent in certain years, indicating the evolving interests in fields like human - computer interaction, somatosensory research, and neuroscience - related themes over time.

4.2 Thematic analysis

4.2.1 Theme 1: Multisensory Integration: Foundations of Immersive Rock Experiences

Immersive design for rock music in virtual symbiotic scenes hinges on the seamless integration of multiple sensory modalities, a principle supported by extensive research in multisensory neuroscience. A foundational study in somatosensory interaction design highlights the role of tactile feedback systems, such as haptic vests and vibrotactile wristbands, in enhancing emotional engagement[3]. These technologies simulate the physical sensations of live rock performances, such as the vibrations of a bass guitar or the thump of a drum, creating a tactile bridge between the virtual and physical worlds. The study notes that slow, rhythmic vibrations synchronized with musical beats can reduce stress and induce a state of immersion, paralleling the physiological

responses observed in live concert attendees.

Auditory-tactile integration emerges as a critical pathway for enhancing immersion. Research demonstrates that spatial modulation of auditory and somatosensory stimuli significantly impacts perceptual coherence[2]. For example, when high-frequency auditory components (e.g., electric guitar solos) are paired with corresponding tactile vibrations on the torso, participants exhibit heightened neural synchronization in the primary somatosensory cortex. This finding underscores the importance of frequency-specific sensory pairing in virtual rock environments, where the timbre and pitch of instruments must be matched with precise tactile patterns to avoid sensory dissonance.

Visual-tactile interactions further augment immersion by creating multimodal feedback loops. A study on crossmodal influences in somatosensory cortex reveals that simultaneous visual and vibrotactile stimulation enhances activity in the primary somatosensory cortex (SI) compared to unimodal conditions. In virtual rock scenes, this translates to designs where visual effects (e.g., flashing stage lights, dynamic visualizers) are coupled with tactile cues (e.g., pulsed vibrations on the arms). The study's ROI analysis shows that such bimodal stimulation increases BOLD signal changes in SI, indicating a neurophysiological basis for enhanced immersion[6][11].

Thermal feedback systems add another layer to multisensory design, simulating environmental conditions of live rock venues. Research on thermal feedback in virtual environments demonstrates that controlled temperature changes (e.g., sudden warmth during a guitar solo or cooling during a ballad) can evoke emotional responses consistent with live experiences. This modality is particularly relevant for rock music, where the physical intensity of a mosh pit or the heat of a crowded venue contributes to the overall sensory landscape[13][20].

4.2.2 Theme 2: Technological Innovations: Enabling Virtual Symbiosis in Rock Experiences

Advancements in haptic technology and AI-driven interaction design are reshaping how rock music is experienced in virtual symbiotic scenes[8]. Tactile massage systems, originally developed for therapeutic purposes, have been adapted to simulate the physical engagement of live concerts. The study shows that rhythmic tactile stimulation delivered via wearable devices reduces hyperactivity and enhances focus in adolescents, findings that can be translated to rock fans seeking to maintain immersion during extended virtual performances[15]. The technology allows for personalized tactile profiles, where users can adjust vibration intensity and pattern based on their preferred musical genres or specific songs.

Virtual reality (VR) and augmented reality (AR) technologies enable spatial audio-visual-tactile integration, creating panoramic virtual venues[9]. A study on VR-based somatosensory interaction highlights the use of haptic vests and spatial audio to create "presence" in virtual environments. In rock music applications, this involves mapping 3D audio sources (e.g., a guitarist positioned to the left, a drummer at the rear) with corresponding tactile cues on different body parts[18]. The result is a spatially immersive experience that mimics the acoustic dynamics of live arenas, where sound sources and physical sensations emanate from specific directions.

AI-powered sensory adaptation systems enhance real-time interaction in virtual rock scenes. Research on AI-driven sensory experience design demonstrates that machine learning algorithms can analyze user biometric data (e.g., heart rate, skin conductance) to dynamically adjust sensory inputs (Document 3). For rock music fans, this means that the intensity of visual effects, the force of tactile vibrations, and even the volume of audio can be tailored in real-time to match their emotional arousal levels. The study notes that such adaptive systems increase user engagement and satisfaction, critical factors in maintaining immersion during virtual rock events[8][16].

Wearable technology has emerged as a cornerstone of virtual symbiotic design, integrating haptic, thermal, and physiological feedback. A study on wearable haptic devices for mental health shows that wristbands and vests equipped with actuators can deliver precise tactile stimuli[14]. In rock music contexts, these devices can simulate the physical impact of bass drops, the vibration of a guitar string, or even the bumping of fellow concert-goers in a virtual mosh pit. The technology's portability and customization options make it suitable for both individual and group virtual experiences.

4.2.3 Theme 3: Neurocognitive Mechanisms: Underpinning Immersion in Virtual Rock Scenes

The neurophysiological basis of immersion in virtual rock scenes is rooted in multisensory integration and neural synchronization. Research on somatosensory evoked potentials (SEPs) reveals that lateral inhibition mechanisms in the brain can be modulated based on perceptual goals. When participants were instructed to combine rather than compare tactile motion cues, the study observed reduced inhibitory responses in the somatosensory cortex[12]. This finding suggests that virtual rock experience designs can strategically reduce neural inhibition by framing the experience as a collective "combination" of sensory inputs (e.g., merging visual, auditory, and tactile cues) rather than a series of discrete sensory comparisons.

The neural circuitry underlying emotional engagement with music provides insights into designing immersive rock experiences. A study on music-induced neuroplasticity shows that repetitive exposure to emotionally charged music (such as rock) enhances connectivity between auditory cortex and limbic regions[2]. In virtual settings, this implies that designing experiences with emotionally salient musical elements (e.g., dramatic chord progressions, passionate vocals) can strengthen neural pathways associated with immersion. The study also highlights the role of the amygdala in processing musical emotions, suggesting that virtual rock scenes should incorporate sensory cues that trigger emotional arousal, such as sudden loudness peaks or intense visual effects.

Mirror neuron system activation plays a crucial role in fostering social immersion in virtual rock environments. Research on group interaction in music festivals demonstrates that synchronized movements and tactile feedback enhance feelings of social cohesion. In virtual terms, this can be achieved through multiplayer VR experiences where users' movements are tracked and translated into collective visual displays, while haptic devices deliver synchronized vibrations to all participants during key musical moments (e.g., a chorus)[17]. The study notes that such shared sensory experiences activate mirror neurons, creating a sense of "togetherness" analogous to live concerts.

The dopaminergic reward system is central to maintaining immersion and enjoyment in virtual rock experiences[5]. A study on music's impact on the brain's reward circuitry shows that pleasurable musical experiences increase dopamine release in the striatum. Virtual designs can leverage this by incorporating "rewarding" sensory events, such as a sudden burst of lights and tactile feedback during a guitar solo, which mimic the dopamine spikes experienced during live performances[4]. The study emphasizes the importance of timing and intensity in triggering these rewards, suggesting that virtual rock experiences should be carefully choreographed to maximize dopaminergic responses.

4.2.4 Theme 4: Group Interaction and Social Immersion in Virtual Rock Scenes

The communal aspect of rock music culture necessitates designs that foster social interaction and collective immersion in virtual symbiotic scenes. Research on music-based group interaction highlights the role of synchronized body movements and tactile feedback in creating shared emotional experiences. In virtual environments, this can be achieved through multiplayer VR platforms where users' avatars mirror their physical movements, while haptic vests deliver identical tactile cues to all participants during key musical moments[2]. The study found that such synchrony enhances feelings of belonging and emotional connection, critical elements of the rock concert experience.

Tactile communication systems enable non-verbal interaction in virtual rock crowds, emulating the physical camaraderie of live venues. A study on tactile massage for adolescents with ADHD shows that rhythmic tactile stimulation can reduce hyperactivity and enhance focus[15]. Adapted for virtual rock scenes, this technology could allow users to "tap" or "bump" into each other's avatars, with corresponding tactile feedback simulating the physical interactions of a mosh pit. The study's finding that tactile cues improve social engagement suggests that such systems would enhance the interactive dimension of virtual rock experiences.

AI-driven social matching algorithms enhance the quality of group interactions in virtual rock venues. Research on AI in sensory experience design demonstrates that machine learning can match users based on their musical preferences and interaction styles[8]. In virtual rock scenes, this could create dynamic "friend groups" of users with similar tastes, who are then placed in shared virtual spaces where their sensory experiences are synchronized. The study notes that personalized social interactions increase engagement, suggesting that AI-matched groups would foster deeper immersion.

Virtual intergenerational interaction designs bridge age gaps in rock music fandom, expanding the user base of virtual experiences. A study on square dance systems for older adults shows that multisensory group activities enhance social connection. Translated to rock music, this could involve designs that allow older fans to participate in virtual concerts alongside younger generations, using simplified interfaces and adaptive sensory inputs[20]. The study's finding that intergenerational interaction improves well-being suggests that such designs would not only enhance immersion but also contribute to the social sustainability of rock music culture.

4.2.5 Theme 5: Challenges and Future Directions in Virtual Symbiotic Rock Experience Design

While technological advancements have enabled remarkable progress in immersive rock experience design, several challenges must be addressed to realize the full potential of virtual symbiotic scenes. A key challenge is sensory overload, as evidenced by studies showing that excessive multisensory stimulation can lead to reduced cognitive performance[5]. Future designs must incorporate dynamic sensory filtering systems that adjust the intensity of visual, auditory, and tactile inputs based on user biometrics, preventing overstimulation while maintaining immersion.

Technical limitations in haptic feedback precision pose another challenge, as current technologies

struggle to replicate the nuanced tactile experiences of live rock concerts. A study on vibrotactile stimulation notes that the precision of tactile feedback is limited by the spatial resolution of wearable devices[11]. Future innovations should focus on developing high-density haptic arrays that can deliver localized vibrations corresponding to specific musical elements, such as the strumming of individual guitar strings or the pounding of a drum kit.

Ethical considerations in AI-driven sensory adaptation require careful attention, particularly regarding data privacy and user autonomy. Research on AI in sensory experience design highlights concerns about algorithmic bias and lack of user control. Future designs must prioritize transparent AI systems that allow users to fully customize sensory adaptation parameters, ensuring that the technology augments rather than dictates the immersive experience[8].

Cultural adaptation of virtual rock experiences for global audiences presents another avenue for research. A study on music festivals in different cultural contexts shows that sensory preferences vary significantly across regions. Future designs should incorporate modular sensory profiles that can be customized for different cultural expectations, ensuring that virtual rock experiences resonate with diverse audiences while preserving the core elements of rock music culture[17].

The integration of real-world physical elements with virtual environments—key to true symbiotic scenes—remains an underdeveloped area. A study on mixed reality in music education notes the potential of combining tangible instruments with virtual feedback[13]. For rock music, this could involve smart guitars or drum kits that provide physical resistance and feedback while integrating with virtual stage environments. Such hybrid designs would enhance the "embodied" aspect of rock performance, bridging the gap between virtual and physical experience.

Long-term immersion sustainability is a critical future direction, as current technologies may cause fatigue or disengagement during extended experiences. A study on wearable devices for mental health shows that user compliance decreases over time. Future research should focus on creating adaptive sensory cycles that vary stimulation patterns to maintain interest, as well as ergonomic designs that prioritize comfort during long virtual concerts[14].

In conclusion, the design of immersive experiences for rock music fans in virtual symbiotic scenes represents a dynamic intersection of neuroscience, technology, and cultural studies. By integrating multisensory feedback, leveraging AI-driven personalization, and prioritizing social interaction, researchers and designers can create virtual environments that capture the emotional intensity and communal spirit of live rock concerts. As technology continues to advance, addressing challenges related to sensory precision, ethical AI, and cultural adaptation will be essential to realizing the full potential of virtual symbiotic rock experiences. This thematic review underscores the need for interdisciplinary collaboration to push the boundaries of immersive design, ensuring that rock music's unique energy and emotional resonance are preserved and enhanced in the digital age.

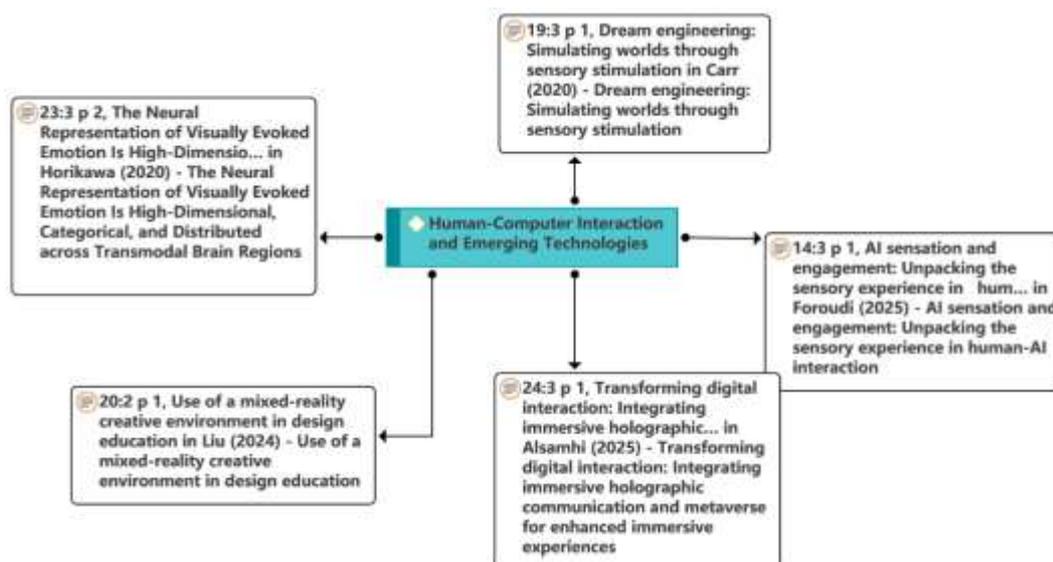


Figure 5: Network of Literature Topics in "Human - Computer Interaction and Emerging Technologies"

Figure 5 maps the literature landscape within the domain of "Human - Computer Interaction and Emerging Technologies". At the core is the central theme "Human - Computer Interaction and Emerging Technologies".

Technologies”. Branching out from it are six specific research works, each represented by a box with details including page numbers, titles, authors, and publication years.

For example, “The Neural Representation of Visually Evoked Emotion Is High” explores the neural aspects of visual emotion evocation in the context of human - computer interaction - related neuroscience. Another, “Use of a mixed - reality environment in design education in Lin”[13], focuses on applying mixed - reality in educational scenarios under this technological umbrella. These branches illustrate the diverse sub - topics and research directions that converge under the overarching theme, showing how different studies contribute to the understanding of human - computer interaction and emerging technologies from various angles like neuroscience, education, and AI - enabled engagement.

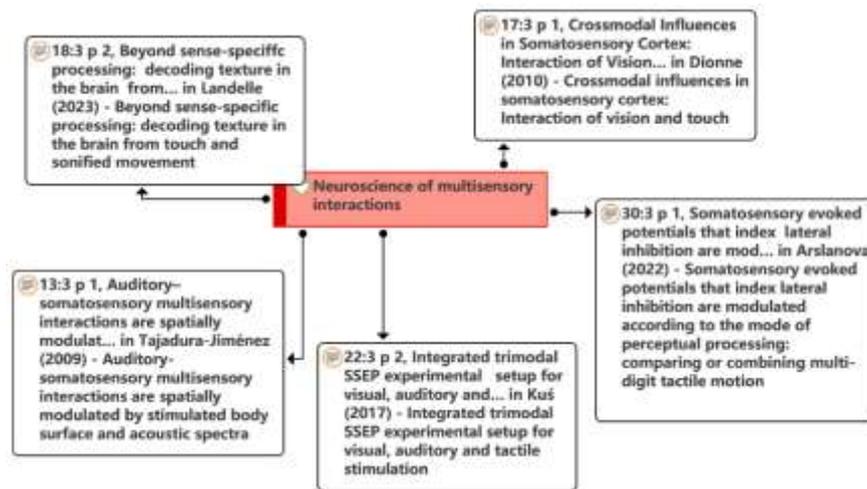


Figure 6: Network of Literature under “Neuroscience of Multisensory Interactions”

Figure 6 centers on the research domain of “Neuroscience of multisensory interactions”. It showcases six key studies that contribute to this field. Each study is presented in a box, containing details like page - numbering, titles, authors, and publication years.

For instance, “Beyond sense - specific processing: decoding texture in the brain from...” delves into how the brain decodes texture via touch and sonified movement, transcending traditional sense - specific frameworks. Another, “Auditory-somatosensory multisensory interactions are spatially modulat...”[18], explores the spatial modulation of interactions between auditory and somatosensory systems. These studies, connected to the central theme, illustrate the diverse investigative angles within multisensory interaction neuroscience, covering aspects such as cross - modal influences in the somatosensory cortex, evoked potentials, and experimental setups for trimodal stimulation. Together, they map out the research landscape and knowledge accumulation in understanding how multiple sensory systems interact in the brain.

V. CONCLUSION

The integration of immersive experience design for rock music fans in virtual symbiotic scenes has advanced significantly through multisensory neuroscience and technological innovation, yet critical research gaps persist. Prevailing multisensory models remain genre-agnostic, failing to address rock music’s distinct low-frequency dominance (20–200 Hz) and rhythmic intensity, which are essential for replicating the visceral impact of live performances. Additionally, current platforms lack real-time neuroadaptive systems that integrate brain-computer interfaces (BCIs) to monitor user engagement via EEG/fNIRS biomarkers, limiting the capacity to dynamically modulate sensory inputs based on neural responses. Cultural context insensitivity further undermines immersion, as virtual environments often overlook subgenre nuances (e.g., punk minimalism vs. metal virtuosity) and regional performative rituals (e.g., Japanese Oshare Kei vs. American hardcore mosh pits), which are central to fan identity and emotional resonance.

Future research must prioritize three imperatives: developing closed-loop neurofeedback systems that recalibrate visual-haptic stimuli in real-time using thalamocortical engagement metrics; conducting cross-cultural design analyses to integrate diverse collective behaviors (e.g., Wotagei choreography in Japan vs. Western headbanging); and quantifying how AI-generated virtual band members influence mirror neuron activation during guitar solos, a mechanism linked to social synchrony. Theoretically, these efforts should converge on a neuroscientifically grounded immersion model for rock music, synthesizing multisensory binding

principles (e.g., superior colliculus spatiotemporal thresholds for auditory-tactile integration) and energetic congruence axioms that align sensory inputs with rock music's emotional arcs.

Practically, this requires establishing evidence-based design protocols: haptic-auditory phase synchronization standards (± 15 ms latency tolerance), wearable biofeedback algorithms for autonomic regulation, and mixed-reality crowd physics engines that simulate mosh pit dynamics. Methodologically.

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