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Research on Sound Immersion Mechanisms and Psychological Triggering in VR Horror Game Design

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Abstract:

With the proliferation of VR technology and immersive interactive technologies, VR horror games have emerged as a key subgenre in the gaming market, distinguished by their "immersive fear experiences." However, existing studies primarily focus on VR visual design, while systematic research on "sound" as a critical sensory element remains insufficient. In particular, there is a notable gap in in-depth explorations of VR sound's "spatiality," "interactivity," and its role in triggering fear responses. This study centers on "the application of sound in VR horror games," grounded in horror psychology's auditory trigger mechanisms and spatial audio technology principles. Using literature analysis to trace sound design theories, combined with empirical analysis of representative cases (Half-Life: Alyx, Resident Evil 7 VR), it examines in-game sounds' functional roles. The focus is on analyzing ambient sounds' foundational role in building immersion, interactive feedback sounds' immediate impact on guiding player behavior, and enemy creature sounds' direct triggering of fear instincts. It also explores the interaction logic between player-generated sounds (e.g., footsteps, breathing, controller operations) and the game environment. Ultimately, it reveals sound's multi-dimensional role in driving immersion in VR horror games. Findings indicate VR sound's "spatial immersion" (enhancing players' "presence" via spatial sound relationships) and "interactive dynamism" (triggering fear instincts through unexpected sound designs) are core mechanisms amplifying fear experiences.

Keywords: Virtual reality, Horror game, Sound design

1. Introduction

Since VR technology entered the gaming industry horror themes have rapidly emerged as a prominent subgenre in the VR gaming market due to their inherent alignment with „immersive fear“ experiences. These games utilize audio-visual synergy to construct „presence-based fear“ experiences distinct from traditional horror media. However academic research on VR horror has primarily centered on visual design elements such as scene modeling precision and lighting rendering emotional impact while systematic exploration of sound remains notably delayed particularly in addressing key questions like „how sound influences player perception through spatial relationships“ and „how interactive sound effects trigger fear psychology.“

Research on sound in VR horror games can fill gaps in „multisensory storytelling“ within virtual reality by treating sound as an active „fear medium“ and refining the „sensory collaborative storytelling“ theory through analysis of its spatial positioning dynamic variations and interactions with player behaviors. Findings from this research can also provide actionable design guidelines for developers helping them craft more effective emotion-guidance mechanisms by summarizing the patterns through which sound triggers fear psychology.

This study employs a mixed-method approach combining literature analysis and case studies integrating principles from psychology and technical fields to examine how sound's „spatial immersion“ and „interactive dynamics“ specifically affect players' „sense of presence“ and „fear experiences.“ Meanwhile, detailed analysis of specific applications of off-game sounds and in-game sounds in horror games focusing on their collaborative narrative logic integrating sound into gameplay components transforming sound from mere background audio to a core game component enhancing the immersive experience of VR games.

2. Virtual Reality Digital Technology and the Psychology of Fear

Each technological breakthrough pushes the boundaries of „horror,“ while the underlying mechanisms of horror psychology remain the foundational logic of technical design. On one hand, technology provides more precise stimulation tools for horror psychology; on the other, the demands of horror psychology drive technological iteration: players‘ pursuit of „more authentic horror“ compels developers to shift from „visual dominance“ to „multi-sensory integration.“ Therefore when designing horror games game creators must not only focus on the feasibility of existing VR technologies but also consider what constitutes players‘ horror experience. In players‘ sensory network of „terror,“ hearing often serves as an „invisible trigger.“ Compared to vision requiring active brain focus, human sound perception is closer to instinctive reaction: metal friction in darkness, footsteps in open spaces, faint breathing by the ear, unable to be visually confirmed, instead activate the amygdala to trigger physiological fear. Thus, how to precisely simulate real auditory perception via VR audio technology becomes the core proposition for upgrading terror experiences.

2.1 The Spatiality of VR sound

Among the most commonly debated subjects in VR audio research, binaural or spatial audio stands out as a key focus. This audio modality is designed to replicate human auditory perception in authentic 3D settings, thereby endowing each 3D object with a spatially localized audio source [1]. VR sound's „spatiality“ essentially mimics human auditory perception logic in physical spaces through technological means. It relies on algorithms replicating the physiological mechanisms of human ear sound reception—where the pinna's shape, ear canal length, and curvature induce physical reflections and filtering of sound waves—enabling headphone output to precisely simulate spatial positions like „footsteps 3 meters to the left“ or „air conditioning hum 2 meters above the head.“ This technology transforms sound from flat „left-right channel“ output into 3D spatial coordinate attributes. A listener's auditory system, akin to real-world perception, automatically locates sound source directions using clues like interaural time difference and interaural intensity difference. This physically simulated sound field via algorithms essentially taps into the inherent spatial processing mechanism of human perception systems. When headphone-output sound closely mimics real-world environments, perception systems activate mechanisms for identifying potential dangers.

Perception, fundamentally, denotes the mechanism through which living entities interpret and organize sensory stimuli to generate a structured comprehension of their environment. This cognitive process inherently encompasses three interrelated stages: the initial reception of sensory input, subsequent data processing, and the final interpretive synthesis. Specifically in human cognition, perception is manifested as the brain's active engagement in deciphering and contextualizing incoming sensory information to form coherent mental representations of the external world [2]. The unique value of VR spatiality lies in its technological simulation of „physical realism,“ which makes the perceptual system more likely to identify virtual sound sources as real spatial threats. Designers can

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intentionally create scenarios with a discrepancy between sound source position and visual information—for example, footsteps gradually approaching in the visuals but no physical entity visible. This contradiction—where the sound source exists but lacks visual confirmation—prevents the brain from visually verifying the threat source, keeping it in a sustained alert state and inducing a strong sense of being monitored in players.

2.2 Auditory Triggers of Fear Psychology

In VR horror games, sound's "spatiality" and "interactivity" can activate three categories of fear-related psychological mechanisms: anticipatory fear, startling fear, and delayed fear. In survival horror games, the player-controlled protagonist is typically lightly armed and susceptible, frequently encountering terrifying occurrences and existential dangers. These titles leverage players' persistent hypervigilance to impending mortality as a core fear-induction strategy. When paired with additional fear-amplifying mechanisms, such games have been demonstrated to trigger more intense fear responses than other game genres [3]. Anticipatory fear centers on predicting potential threats, triggered by incremental anomalous sound design. VR spatiality's technical features provide physical realism support for this prediction. For instance, in Resident Evil 7 VR's scene, as can be seen in Fig 1, players initially hear only normal ambient sounds; as exploration progresses, these gradually shift to harsh metal friction noises, with sound sources moving from walls toward the player's current position. This "normal-to-abnormal," "far-to-near" sound progression induces anticipatory fear of "imminent attack" via "approaching sounds," prompting players to enter a hypervigilant state even without visual confirmation of threats.

Fig. 1 Gameplay footage from Resident Evil 7[3]

The core of startling fear lies in the instantaneous impact of "unexpected threatening sounds" on players. When sounds suddenly erupt from unanticipated locations or at unexpected timings, the precision of their spatial localization may lead the brain to misjudge them as "genuinely present nearby threats." The abruptness of fear arises partly from the acoustic harshness inherent in the sound itself: auditory stimuli characterized by elevated-frequency components (≥5 kHz) and sudden temporal onsets activate the amygdala's threat-detection pathways, thereby provoking an involuntary neurophysiological fear response [4]. Another root lies in VR spatial construction fostering the perception of auditory sources being proximal.

The core of delayed fear lies in "lingering unease after threat resolution." For example, in Half-Life: Alyx, after destroying an enemy robot, though players visually confirm its destruction, residual "circuit shorting buzz" lingers in headphones. This auditory afterglow keeps players on alert even when safe, leading to overinterpretation of unrelated sounds and elevating horror from "immediate" to "persistent."The table 1 summarizes three psychological mechanisms of fear (anticipatory fear, startling fear, and delayed fear) along with their corresponding sound triggers and effects.

Table 1. Comparison of Three Psychological Mechanisms

The type of mechanism	Core Definitions	Triggering Key
Anticipatory fear	Anticipatory fear of potential threats	Progressive abnormal sound design
Startling fear	Immediate impact fear of unexpected threatening sounds	Sound suddenly erupts at an unanticipated location or timing
Delayed fear	Persistent unease fear following the dissipation of the threat	Residual sound echo after the threat dissipates

3. In-game Sound Functionality

In horror games, ambient audio, character audio, and interactive audio are not merely background fillers but sensory bridges connecting humans to virtual worlds. Taking „functionality“ as its thread, this chapter parses how these sounds—through mechanisms like spatial anchoring, identity immersion, and behavioral feedback—form an auditory narrative grid, enabling players to perceive danger and comprehend the game‘s constructed world through sound. Meanwhile from a cognitive standpoint, auditory input can also facilitate players‘ ability to maintain focus on the game [5].

3.1 Ambient Sounds

Terror games‘ core experiences include „collapse of a sense of security“. The logic of environmental sound design disrupts the natural ecological usual order, plunging players from familiar safe spaces into the unknown horror of these environments.

Outlast, released by Red Barrels in 2013, effectively uses this. The game creates a terrifying environment where surrounding sounds resemble a dilapidated hospital, mixed with screams and pleas of staff and patients [6]. As a functional space, hospital regular soundscapes should follow clear „spatial logic“. Outlast instead disrupts the hospital‘s most typical „safe soundscape“, turning it from a reassuring place into a carrier of horror atmosphere(Fig.2).

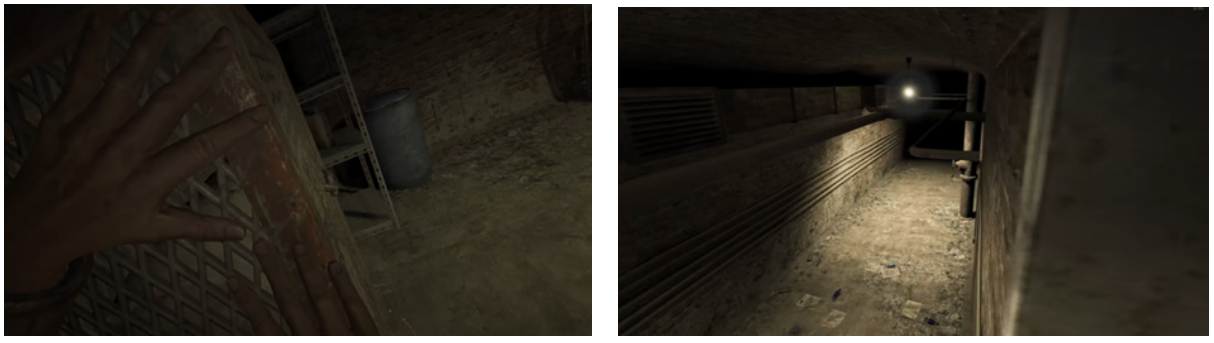

Fig. 2 Gameplay footage from Outlast [6]

Furthermore,among the array of tools utilized in media production, silence stands as one of the most underexploited narrative elements. Functioning as a potent storytelling instrument, its skillful deployment can elevate an unremarkable scene into an indelible one [6]. In the P.T. (a Silent Hill spin-off), players move through a narrow, dimly lit corridor (Fig.3), where ambient sounds are intentionally muted at first—only low-frequency hums, the player’s own footsteps, and the creak of a door opening remain. When Lisa’s footsteps first ring out, the silence breaks; as she draws near a certain point, her footsteps abruptly vanish, replaced by faint sobs in the dead quiet or the twist of a doorknob. This cycle of silence, then sound, then silence again traps players in lingering dread of “where exactly is she?” even fostering the psychological sense that “silence itself is more menacing than sound.” Within the context of narrative design, the strategic use of silence serves a critical function in cultivating suspense and fostering dramatic tension. Notably, genuine silence—though rarely encountered in everyday life—carries a profound psychological weight; when it does manifest, its impact lingers, leaving an unforgettable imprint on the audience [6].

Fig.3 The disturbing circular corridor in P.T [6]

3.2 Character Voice

The core function of antagonist character audio in VR horror games transforms abstract threats into perceptible entities via sound anomaly design, leveraging VR‘s spatial immersion to amplify the oppressive feeling of approaching threat. Much of what unfolds in horror games defies real-world existence or remains uncharted. These elements transcend the boundaries of human understanding, inherently steeped in profound mystery; sound, too, carries an air of unfamiliarity. When players encounter such otherworldly entities on screen and are exposed to these

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atypical auditory cues, their cognitive frameworks are disrupted. This breakdown compels them to reevaluate their surroundings, triggering an instinctive fear response [7]. Pyramid Head, core antagonist in Silent Hill 2, wields a massive pyramid-shaped head blade as its signature weapon. Its footsteps and the drag noise of the blade produce a harsh, muffled composite sound. Paired with its menacing appearance and high threat level to players, it becomes a player's nightmare.

3.3 Interactive Sounds

Interactive audio refers to sounds generated when players interact with game elements (props, environments, NPCs). Its core function is to reinforce the cause-effect relationship between player actions and outcomes via auditory feedback, enhancing interaction authenticity through VR's spatial immersion. In traditional games, interactive feedback primarily relies on visual cues, but VR's head tracking and spatial audio technologies make interactive audio a more efficient confirmation medium. Players can directly verify operation success through hearing, eliminating reliance on visual confirmation and boosting immersion. Meanwhile, auditory feedback typically correlates with quicker response cycles compared to visual cues. It also delivers consistent, all-directional output since auditory perception remains active regardless of attention. Additionally, it avoids cluttering visual interfaces and supports accessibility for users with visual limitations [8]. For example, in Resident Evil 7 VR's combination lock puzzle, players infer password input progress through audio, increasing engagement.

4. Extra-game Audio

Extra-game audio refers to human-generated sounds in games that are neither environmental nor character audio, primarily including player real-time voice, multiplayer communication voice. Its functionality breaks through the boundaries of traditional „character audio" and „environmental audio," becoming a key medium connecting player socialization, collaborative exploration, and immersive storytelling. Beyond enhancing player engagement, extra-game audio elevates sound from an auxiliary element to a narrative subject, revealing its implicitly critical role in game design.

4.1 Player real-time Voice

As technological progress accelerates—marked by growing portability and energy efficiency, exemplified by smartphones—computer-mediated communication (CMC) technologies are increasingly embedded in everyday social exchanges [9]. Similarly, CMC platforms such as VR environments, augmented by peripheral hardware (e.g., VR headsets, webcams, microphones), have emerged as notable components of modern social interaction [9]. In multiplayer online horror games, voice serves not only as an information medium but also as a lethal signal of identity exposure. When players' real-time voice, footsteps, or object collision sounds are captured and converted into tracking cues by monsters, sound transforms from a social tool into a survival threat. This design logic is exemplified to the extreme in Lethal Company's „Eyeless dog" mechanism. As the game's iconic tracking creature, the Eyeless dog locates players based on their vocalizations, leveraging humans' innate wariness of „voice-exposed identity" and forcing players into a dilemma: vocalizing to communicate with teammates or staying silent to stay alive. Its graphic design is equally terrifying (Fig. 4).

Fig. 4 Image design of an eyeless dog [9]

4.2 Online Communication Voice

Multiplayer voice chat in multiplayer horror games acts as a central tool for collaborative survival, its functionality extending beyond mere information exchange to directly shape players' horror experiences.Human social connections are fundamentally vital to survival. In states of solitude, individuals become acutely aware of their heightened susceptibility to environmental influences, rendering daily experiences far less stable or predictable. This awareness triggers an instinctive assessment of the protective capacities of those nearby—a cognitive mechanism that serves to alleviate fear responses when trusting companionship is present [10]. Consequently, when the once noisy team voice environment suddenly falls silent, it easily triggers players' fear and unease. This design logic is equally typical in Lethal Company. As players move farther apart, their voices gradually diminish until inaudible; when submerged in water or attacked by traps, their speech becomes unrecognizable. These audio restric-

tions impose a strong sense of isolation, intensifying both immersive experience and panic. Combined with VR's core audio technology for precise spatial positioning—allowing clear perception of one's own breathing, distant environmental sounds, yet rendering teammates' voices muffled or vanished—it directly amplifies the psychological state of being utterly alone.

5. Conclusion

This study finds VR sound's spatial immersion—via sound's spatial localization/hierarchical distribution—shapes players' environment perception, strengthening presence to intensify realistic threat immersion. Horror psychology reveals interactive dynamism triggers anticipatory /startled/delayed fears through sound effects/volume/plot-sound interaction. In in-game design: ambient sounds use spatialized localization to make threats „close"; interactive sounds enhance fear instincts via action-sound immediate links; enemy sounds break safe rhythms with unique designs. Gameplay mechanisms integrate player-generated sounds/multiplayer elements to strengthen behavior-feedback connections, enhancing immersion authenticity. Superposed player voices/action effects/environmental sounds in multiplayer scenarios trigger group fear's contagiousness via sound unpredictability, deepening social attributes. Ultimately, sound evolves from background to a core driver of gameplay progression/emotional resonance.

This study's practical value lies in providing an actionable theoretical framework for VR horror game sound design: developers need to balance sound's spatial construction and interactive design while integrating horror psychology to maximize sound's horror efficacy. In terms of in-game sound design and out-of-game sound design this study also provides game designers with directions for sound design.

In the future this research will continue to explore multimodal synergy between sound vision and touch expand immersion boundaries and focus on negative emotions potentially triggered by immersion studying safety boundaries and emotional regulation mechanisms. In the field of in-game content sound research it will continue to explore the adaptation of horror psychological mechanisms and sound symbols while focusing on sound interaction design in multiplayer scenarios studying the superposition effect of player voice action sound effects and environmental sounds to strengthen the contagiousness of group fear.

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