Project Deep Dive: Investigating Audio-Visual Cue Design for Stress-Response Training in Underwater VR Environments

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Figure 1: Perspective view of the Project Deep Dive virtual environment demonstrating the atmospheric fog, limited lighting, and sense of vastness that contribute to the psychological tension (enhanced for visibility). The dark, murky water restricts visibility and enhances feelings of isolation and vulnerability.

Abstract

Project *Deep Dive* is a virtual reality (VR) training prototype designed to investigate how audio-visual stimuli evoke stress responses in underwater environments. As a pre-exposure training tool for occupations requiring underwater operations, the system delivers auditory and visual cues within a deep-sea wreck scenario to help trainees identify personal fear thresholds and practice emotional regulation. The experience tasks users with investigating a sunken military cargo plane while being exposed to fear-relevant audio-visual stimuli. A pilot study with 12 participants explored how different auditory and visual cues affected self-reported fear and physiological measures. Preliminary findings suggest that spatial audio—particularly sounds implying unseen threats—may be more effective than post-processing visual effects in inducing immersion and discomfort, with 75% of users rating audio cues as more impactful. We discuss implications for designing VR training environments where auditory realism may enhance stress-management skill development for real-world contexts.

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Index Terms: Virtual reality, training transfer, audio-visual design, spatial audio, stress response, ecological validity, thalassophobia.

1 Introduction

Underwater operations—whether in commercial diving, marine biology, search-and-rescue, or military contexts—require personnel to manage psychological stressors including low visibility, spatial disorientation, and perceived environmental threats [22, 3, 20]. Thalassophobia, defined as intense fear or anxiety related to deep water, represents an extreme manifestation of such stress responses, characterized by racing heart, rapid breathing, nausea, anxiety, sense of doom, and detachment from situations [7, 8]. While not all underwater workers develop clinical phobias, understanding how sensory cues trigger fear responses may inform the design of pre-exposure training that builds psychological resilience before real-world deployment [16, 15].

This project explores the relative contributions of auditory and visual modalities to perceived fear and presence within an underwater Virtual Reality (VR) training environment. Unlike entertainment-focused applications such as *Ocean Rift* [1], which prioritize passive atmospheric immersion, or *Subnautica* [23], which utilizes aggressive creature AI to trigger acute startle responses (emergent "jump scares"), Project *Deep Dive* focuses on the systematic elicitation of sustained anticipatory anxiety. By avoiding reflexive shocks in favor of scripted, ambient atmospheric tension—leveraging the "fear of the unknown"—the system creates a controlled environment for testing emotional regulation during search-and-recovery tasks. Our goal is to develop an VR-based stress-inoculation tool that exposes trainees to environmental stressors, enabling them to identify personal fear thresholds and practice emotional awareness.

This work contributes to VR training research in two primary ways. First, we provide preliminary observations on how specific sensory modalities induce stress, utilizing scripted sequences to ensure stimulus consistency across participants to allow an initial comparison of how different cues trigger anticipatory anxiety in a repeatable manner. Second, our findings suggest that spatial audio and visual scarcity may warrant design priority over explicit visual effects for eliciting authentic stress responses in underwater training applications.

VR has proven effective for both exposure therapy and stress-inoculation training in high-risk professions [2, 26, 6, 10]. Within underwater contexts specifically, research indicates that thalassophobia significantly impacts cognitive load; Pan et al. [17] found that fear of the sea can enhance simple task performance but severely degrades performance on complex tasks. This suggests that immersive pre-exposure can serve as a vital tool for trainees to calibrate their stress thresholds before entering high-stakes operational environments. However, current underwater VR research is only distributed across three main domains: entertainment-driven experiences [25, 14, 13], clinical and therapeutic applications [11, 12, 21], and cultural heritage-related or educational systems [9, 4, 19, 18]. While desktop-based applications such as *Thalassophobia* [24] demonstrate that scale and restricted visibility can induce dread on traditional displays, these commercial titles are not designed to isolate the specific sensory modalities that drive such responses. Consequently, it remains difficult to extract formal design principles for professional training. Project *Deep Dive* addresses this gap by empirically investigating the relative effectiveness of auditory versus visual cues in a high-presence VR environment, providing preliminary insights into how sensory design can be optimized for stress-management training.

2 System Design and Implementation

The simulation places users in the role of a deep-sea investigator tasked with examining a sunken military cargo plane on the ocean floor. The plane wreckage rests partially over an abyss edge, with components including cockpit, cargo bay, and engine sections scattered across the environment. Users follow a series of illuminated waypoints to investigate four points of interest, simulating a search-and-recovery operation. Figure 3 shows the layout of the crash site, indicating the locations of key investigation points, including the cockpit, engine, passenger area, and the black box.

This task-driven structure serves two purposes: providing cognitive demands such as navigation, spatial memory, and decision-making, and preventing users from passively waiting, requiring them to manage stress while maintaining task focus.

The environment is designed around psychological triggers associated with thalassophobia and underwater stress. Volumetric fog and limited ambient lighting restrict sightlines to create uncertainty and low visibility. Oversized wreck geometry and proximity to a deep abyss emphasize human smallness and vulnerability. Sparse lighting, distant spatial audio sources, and absence of surface reference provide isolation cues. Stimuli often imply threats before they become visible, engaging imagination through anticipation rather than reflexive startle responses [5]. This approach differs from entertainment-focused horror, as real underwater hazards rarely announce themselves with sudden shocks.

The prototype was developed using Unreal Engine 5 and deployed on a Meta Quest 3 standalone VR headset. All locomotion, event triggers, and post-processing effects were implemented using Blueprint visual scripting to enable rapid iteration during pilot testing. The prototype uses a seated water-scooter locomotion scheme where users control forward movement via controller grip buttons, with direction determined by controller orientation. This design was selected for safety, accessibility, and future scalability.

Spatial audio cues were implemented using 3D sound attenuation and positioned in world space to create directional threat perception. These include low-frequency rumbles and distant calls suggesting large unseen creatures, wreck structural sounds such as metal stress and creaking, and creature movement cues, including eel vocalizations positioned behind or below the user. Visual post-processing effects simulate physiological stress responses, including vignette effects that intensify as users approach high-stress zones, chromatic aberration creating visual disorientation, and brief darkening simulating momentary dissociative responses. These effects are triggered by invisible trigger volumes placed along the waypoint route, ensuring consistent delivery across participants. Audio feedback simulating physiological stress responses (accelerated heartbeat, rapid breathing) was implemented using pre-recorded spatial audio rather than real-time biofeedback from participant sensors. This design choice ensured consistent stimulus timing across all participants during the pilot study. All audio was delivered through the Meta Quest 3's built-in spatial audio system, which provides adequate directional cues for our initial investigation. While true biofeedback could potentially create self-reinforcing anxiety responses, our approach prioritized experimental control and reproducibility for this exploratory phase.

A large eel-like creature serves as an explicit threat stimulus (Figure 2). The encounter is implemented as a scripted level sequence, ensuring consistent event timing across participants. Initially, the creature was implemented as an autonomous agent utilizing the Unreal Engine 5 Behavior Tree (BT) component. The BT is a native UE5 hierarchical framework that organizes AI decision-making into a structured tree of tasks—such as selectors and sequences—which are evaluated in real-time based on environmental conditions.

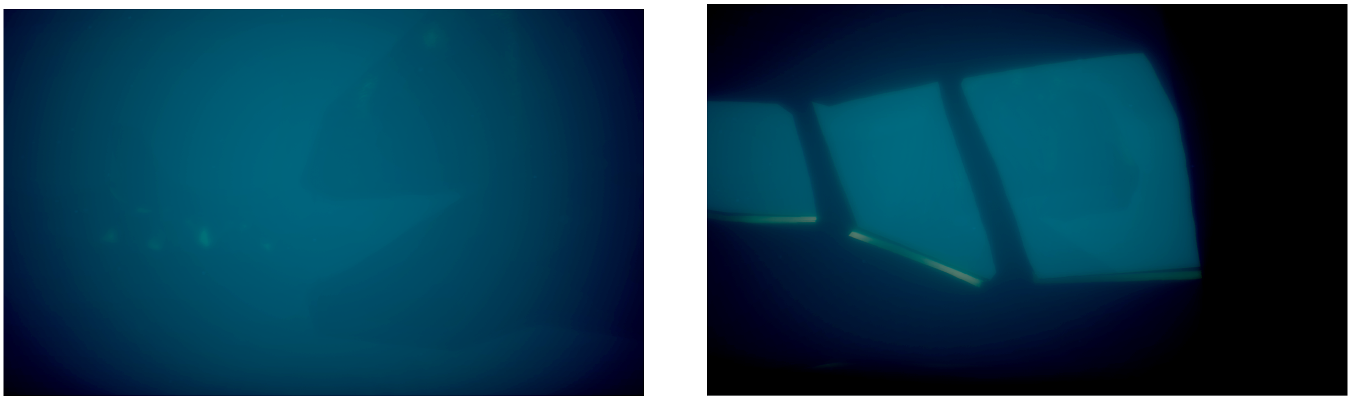
This system was intended to manage the eel's state logic as it traversed a spline-based path toward the player. However, the agent encountered orientation and synchronization errors between the spline's local coordinate system and the global 3D navigation space, leading to erratic positioning and unrealistic movement. To ensure stimulus consistency and experimental repeatability for the pilot study, we pivoted from dynamic AI to scripted Level Sequences. This transition allowed for precisely controlled event timing and identical stimulus delivery for all 12 participants, which was necessary to isolate the effects of auditory versus visual cues.

Feedback from development critiques and informal studies with colleagues led to key refinements. Initial realistic lighting created "awe rather than fear," so jarring red emergency lights were added during high-stress moments. The underwater scooter was initially bright yellow for visibility but was changed to worn gray to improve environmental integration. These iterations suggest that authenticity may require balancing realistic operational elements with targeted psychological impact.

From a pilot study with 12 participants, nine participants reported that audio cues—muffled sound effects, heart rate, nervous breathing, and spatial, suspenseful audio around the player—were more effective than visual effects in eliciting fear responses. Among all audio and visual effects, six participants identified unseen eel sounds as the most fear-inducing element, while the other six noted the vignette effect as the most significant stressor.

3 Discussion

Our preliminary observations suggest that the "fear of the unknown" principle [5] plays a central role in the underwater VR



(a) (b)

Figure 2: Hallucinatory eel encounters (enhanced for visibility) demonstrating how thalassophobia distorts perception of marine life, circling (a) the crash site, and (b) near the wreckage with exaggerated scale as a psychological manifestation.

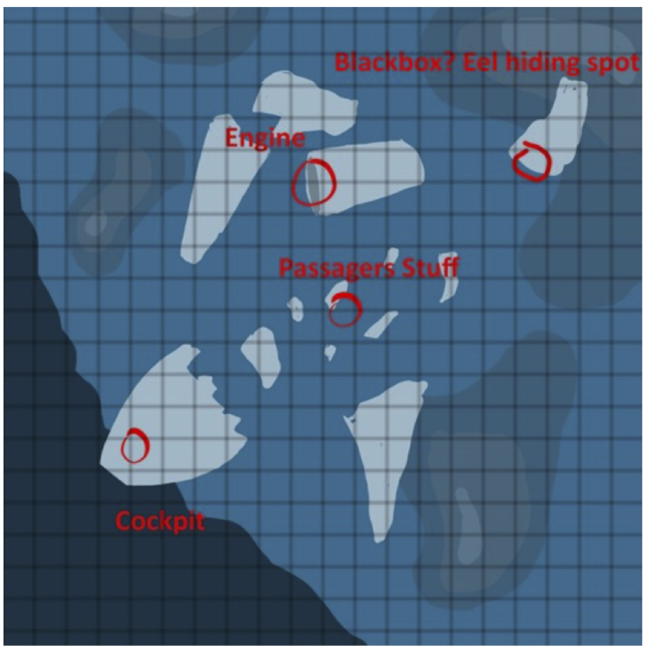


Figure 3: Top-down map of the underwater crash site showing the scattered plane components and four investigation waypoints. The cockpit rests near the abyss edge, with the engine, passenger belongings, and black box locations marked throughout the environment.

training experience. Rather than relying on explicit visual confrontations, the environment appears to induce stress through information scarcity and environmental ambiguity. This trend is reflected in our pilot data, where 75% of participants identified auditory cues—specifically sounds implying unseen threats—as more impactful than visual post-processing effects.

These findings suggest that strategically limiting visual information may be a more effective design choice for stress-response training than the introduction of explicit threats. By omitting clear visual confirmation of a hazard, the simulation may better force trainees to manage the psychological burden of uncertainty. This "threat of presence" mirrors real-world underwater operations where visibility is often severely compromised. Consequently, a design focus on spatial audio over visual post-processing could potentially create a more authentic context for practicing emotional regulation, as it requires the trainee to maintain task focus despite persistent, non-visible stressors.

Furthermore, audio and visual cues may serve distinct, complementary functions in training contexts. Spatial audio appears to be a primary driver of persistent ambient tension and directional threat awareness, whereas visual effects provided contextual information but risked feeling artificial if overused. Based on these observations, we propose a design hierarchy: spatial audio should be prioritized to establish the environmental atmosphere, while visual effects should be used selectively to simulate specific physiological responses (e.g., tunnel vision).

The use of scripted sequences rather than dynamic AI enabled consistent event timing for initial exploratory studies, though dynamic events may better mirror operational uncertainty in future versions. For this approach to support real-world skill transfer, future work should incorporate performance metrics measuring task completion accuracy and decision latency under stress, alongside coping strategy training informed by existing research [8].

4 Conclusion

Project *Deep Dive* demonstrates that an underwater VR scenario can elicit stress responses relevant for pre-exposure training. Our pilot work indicates that spatial audio cues and visual scarcity are more potent tools for inducing tension than explicit visual shocks. This finding suggests that development resources might be allocated toward sophisticated audio design when the goal is stress-response training. By combining entertainment VR techniques with training principles, this project contributes initial insights into how audio-visual design choices may affect stress-management skill development in virtual-to-real-world contexts. Future work will pursue three key directions. First, we plan to consult with professionals in ocean engineering and marine biology to validate the ecological validity of our stressor design against real-world underwater operations. Second, we will explore incorporating real-time physiological sensing to create personalized biofeedback loops, which may enhance training effectiveness through embodied stress awareness. Third, we will investigate whether upgrading from built-in Quest 3 audio to professional-grade headphones further enhances the spatial audio effects that emerged as most impactful in our pilot study.

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