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Looking at sound together: using VR with Dutch Hospitals - a case study

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ABSTRACT

The role of acoustics in healthcare environments is critical for enhancing patient recovery, reducing staff stress, and improving overall operational efficiency. However, the application of effective acoustic design often remains overlooked in the planning and renovation of healthcare spaces.
The Ecophon Immersive Acoustic Experience™ (EIAE™) is a virtual reality (VR)-based tool designed to address these challenges by enabling acoustic simulation and interactive design adjustments in healthcare environments. This paper reviews best practices derived from the implementation of VR in three Dutch hospitals, including a pharmacy, an emergency room and an operating room.
The study demonstrates that VR allows stakeholders, including, occupational hygienists, healthcare professionals, and facility managers, to collaborate effectively by visualizing and optimizing acoustic properties such reverberation time, material absorption, and layout. Findings indicate that this tool can potentially better align design decisions regarding a desired acoustic environment.
Furthermore, the study raises awareness about the importance of acoustics in healthcare. The results emphasize the potential of VR-based instruments to better acoustic practices in healthcare and indicate future development and broader applicability in both the architectural and healthcare sector.

Keywords: *Room Acoustics; Virtual Reality; Soundscape; Collaborative Design*

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1. INTRODUCTION

The acoustic environment within healthcare facilities is of importance in terms of patient recovery, staff well-being, and operational efficiency. Excessive noise levels in hospitals have been associated with increased patient stress, disrupted sleep patterns, and prolonged recovery times, as highlighted by the World Health Organization [1]. Furthermore, substandard acoustics have been demonstrated to impede effective communication among healthcare professionals, which can result in medical errors and increased staff fatigue [2]. Despite these critical implications, acoustic design frequently remains an afterthought in the planning and renovation of healthcare spaces, often overshadowed by visual and functional priorities [3].
However, recent advancements in immersive technologies, particularly VR, have the potential to address these issues. While the efficacy of VR in the domain of education, particularly in the context of acoustics, has been well-documented [4], its application in healthcare design remains under-explored. The Ecophon Immersive Acoustic Experience (herewith referred to as VR) is a VR-based tool designed to address these challenges. By facilitating acoustic simulations and interactive adjustments, VR enables stakeholders to visualize and optimize acoustics, reflecting material absorption, within virtual models of healthcare environments. The objective of this study is twofold: firstly, to enhance collaborative decision-making processes and, secondly, to raise awareness of acoustics as a focal component of healthcare design.
This paper examines the implementation of VR across a range of Dutch healthcare settings, including pharmacies emergency departments (ER) and operating theaters (OR). Through these case studies, this paper explores the potential of immersive tools in advancing acoustic practices within healthcare.

2. CASE STUDY DESIGN

This paper employs a qualitative case study approach to evaluate the efficacy of VR in translating abstract acoustic parameters into actionable insights for healthcare stakeholders. Three distinct cases were examined in Dutch hospitals, each addressing unique acoustic challenges.

2.1 CASE 1: Hospital Pharmacy at Leiden Universitair Medisch Centrum

Context:
The pharmacy at Leiden Universitair Medisch Centrum (LUMC) was the subject of persistent complaints regarding noise levels. These noise levels had a detrimental effect on the ability of staff to concentrate during medication preparation and verification tasks. The acoustic environment was marked by the superimposition of conversations, equipment alarms, and medicine sorting machine.

Stakeholders:
- Housing Department: Responsible for spatial design and material specifications.
- Facility Management: Tasked with operational efficiency and budget allocation.
- Occupational Hygienist: Focused on worker health and ergonomics.
- Medical Staff: Head pharmacist directly impacted by the acoustic environment.

Problem Identification:
Conventional acoustic reports, measured by the occupational hygienist, indicated a reverberation time (RT60) of 0.8 seconds and sound pressure levels (SPL) exceeding 65 dB(A) during peak hours. However, stakeholders experienced difficulties in contextualizing these metrics, with the occupational hygienist stating that "*We knew the numbers were bad, but we couldn't visualize what that meant for daily work.*"

VR Intervention:
VR enabled stakeholders to navigate a simulated representation of the pharmacy environment, encountering two distinct configurations:
1. Baseline: Untreated acoustics with hard surfaces in a generic layout.
2. Treated: Addition of sound-absorbing ceiling panels, and wall panels.

Key interactions included:
- Dynamic Soundscapes: Overlapping voices and alarms replicated real-world conditions.
- Real-Time Adjustments: Toggling between configurations to compare noise reduction efficacy.
- Spatial Analysis: Evaluating how wall panels affected speech intelligibility.

Outcomes:
The VR intervention significantly enhanced stakeholder dialogue by shifting discussions from abstract acoustic metrics to tangible experiential insights. The head pharmacist noted that the wall panels helped reduce "auditory clutter," making it easier to concentrate on a conversation, while facility managers acknowledged the cost-effectiveness of implementing wall panels. Following these discussions, stakeholders reached a consensus on specific design adjustments. It was decided to install wall panels in front of the windows to further improve acoustic conditions.

Furthermore, the VR simulations provided perceptual validation of the proposed interventions. All participants agreed that VR served as a "shared language," allowing stakeholders to better articulate and understand acoustic challenges.

2.2 CASE 2: Emergency Department at Jeroen Bosch Ziekenhuis Den Bosch

Context
The emergency department (ED) at Jeroen Bosch Ziekenhuis encountered issues with perceptual noise and workflow efficiency, despite the presence of technically proficient acoustics. Preliminary assessments by the Technical University of Eindhoven indicated a reverberation time (RT60) of 0.49 seconds and a Speech Transmission Index (STI) of 0.82, both of which exceed the standards for speech clarity in open workspaces. However, staff reported distractions from overlapping conversations, uneven traffic flow, and a lack of acoustic separation between functional zones. VR was implemented not to rectify technical acoustic inadequacies but rather to investigate the potential of spatial interventions through VR simulations, with a focus on optimizing layout, the incorporation of partitions, and the delineation of zones.

Stakeholders
- Head of the Emergency Department: Prioritized workflow efficiency and staff well-being.
- Head Nurse: Sought to reduce cognitive overload during critical tasks.

- Medical Staff: Two nurses highlighted disruptions from uncontrolled movement and mixed-use zones.

VR Intervention: Layout and Zoning Simulations
Using VR, stakeholders virtually experienced three spatial configurations to evaluate perceptual and functional impacts:
1. Existing open layout with centralized workstations and no partitions.
2. Partitioned Zones:
    - Semi-enclosed partitions (1.5m height) around collaborative workstations and individual phone booths.
    - Dedicated zones for social interactions (e.g., breaks) separated from focus-work areas.
3. Traffic Flow Optimization:
    - Redistributed entry/exit usage (north vs. south entrances) to balance movement and reduce congestion.

Key Findings
The addition of partitions helped contain conversations and minimize cross-talk, fostering a quieter and more focused work environment. Social interaction zones, when visually separated from focus areas, encouraged more moderated speech levels, reducing the tendency for staff to unconsciously raise their voices in busy spaces.

One nurse emphasized the psychological impact of these changes, stating, "*The partitions created a mental barrier—I no longer feel interrupted by every passing conversation*."

The head of the emergency department noted, "*This showed us how spatial cues can influence noise levels*," highlighting the role of design in shaping auditory behavior without explicit instruction.

Challenges
Initial resistance stemmed from concerns about visibility and communication. VR simulations helped alleviate these fears by demonstrating how sightlines and teamwork could be maintained.

Adapting to new behavioral norms required training, particularly in managing noise and interaction habits. While this study focused on spatial interventions, a separate paper details the workshop-based approach to behavioral adjustments [5].

2.3 CASE 3: Operating Theater at BovenIJ Ziekenhuis Amsterdam

Introduction
Operating rooms (ORs) present complex acoustic environments where excessive noise can significantly impair verbal communication, increase cognitive load, and contribute to occupational stress [6]. At BovenIJ Ziekenhuis, an evaluation of OT noise conditions was conducted in response to concerns regarding deteriorating speech intelligibility and elevated stress levels among surgical staff. Prior research by Groot M., conducted as part of her dissertation at BovenIJ Ziekenhuis, identified peak noise levels of up to 89.8 dB(A) during procedures such as total knee arthroplasties, surpassing recommended occupational exposure thresholds.

Three primary acoustic challenges were identified:
1. Elevated Ambient Noise: Continuous background noise from HVAC systems and medical equipment maintained levels of 65 dB(A), with intermittent peaks exceeding 100 dB(A) during surgical procedures, impeding clear communication.
2. Reverberation: Measured reverberation time (T20) ranged from 0.9 to 1.1 seconds, exceeding the recommended 0.5–0.7 seconds for spaces necessitating high speech intelligibility.
3. Suboptimal Acoustic Treatment: Reflective surfaces, including hard wall surfaces and hard flooring, exacerbated mid- and high-frequency reflections, further degrading communication effectiveness.

Virtual Reality as an Analytical and Persuasive Tool
This intervention was structured around two fundamental objectives. First, it aimed to enhance stakeholder engagement by leveraging immersive simulations to address skepticism among hospital administrators and technical department personnel. By providing a realistic and interactive experience, the simulation facilitated a more comprehensive understanding of the proposed acoustic modifications. Second, the intervention sought to promote cost-efficient decision-making by reducing the dependency on physical prototypes and international benchmarking visits.

Stakeholder Involvement and Evaluation

- Technical Personnel: Assessed feasibility and compliance with regulatory and budgetary constraints.
- Nurse Researcher: Advocated for interventions based on observed communication deficits and staff fatigue reports.

Challenges and Key Takeaways

Key challenges included skepticism from technical and administrative personnel regarding the necessity of acoustic wall panels in ORs, concerns over hygiene compliance, and budgetary constraints. Resistance stemmed from the fact that such panels are not typically used in ORs in the Netherlands, despite their implementation in hospitals in other countries.

The VR simulation effectively demonstrated the benefits of improved acoustics. The observed impact on communication led the technical department to reconsider its stance, ultimately agreeing to trial hygienic acoustic wall panels.

3. DISCUSSION

These case studies demonstrate that immersive VR has potential to aid traditional acoustic design by harmonizing technical metrics with human perception. Across three healthcare environments, VR's strength lay in simulating the sound environment, also fostering experiential consensus among stakeholders. In the pharmacy, VR shifted focus from RT values to "auditory clutter," demonstrating that even compliant spaces can benefit from perceptual refinements. The emergency department case highlighted how spatial zoning can mitigate behavioral noise (e.g., Lombard effect), emphasizing that design intuition often outweighs numerical thresholds. Conversely, the third case, on the operating theater, illustrated VR's role in validating non-traditional solutions, overcoming institutional skepticism through experience.

These cases collectively underscore that acoustics is as much about human experience as technical compliance. VR's immersive feedback enabled clinicians, occupational hygienists, and facility managers to co-create solutions anchored in shared sensory understanding. However, the reliance on stakeholder buy-in and hardware adaptability suggests VR's efficacy is context-dependent. Future work should explore scalable frameworks for diverse settings.

4. CONCLUSION

VR seems to have potential to aid acoustic design by addressing human experience alongside technical design. In all cases discussed, VR bridged disciplinary divides, contextualizing abstract metrics into experience — validating design, thereby enhancing employee satisfaction.

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