Development and implementation of VR-simulated experiences to train communication skills

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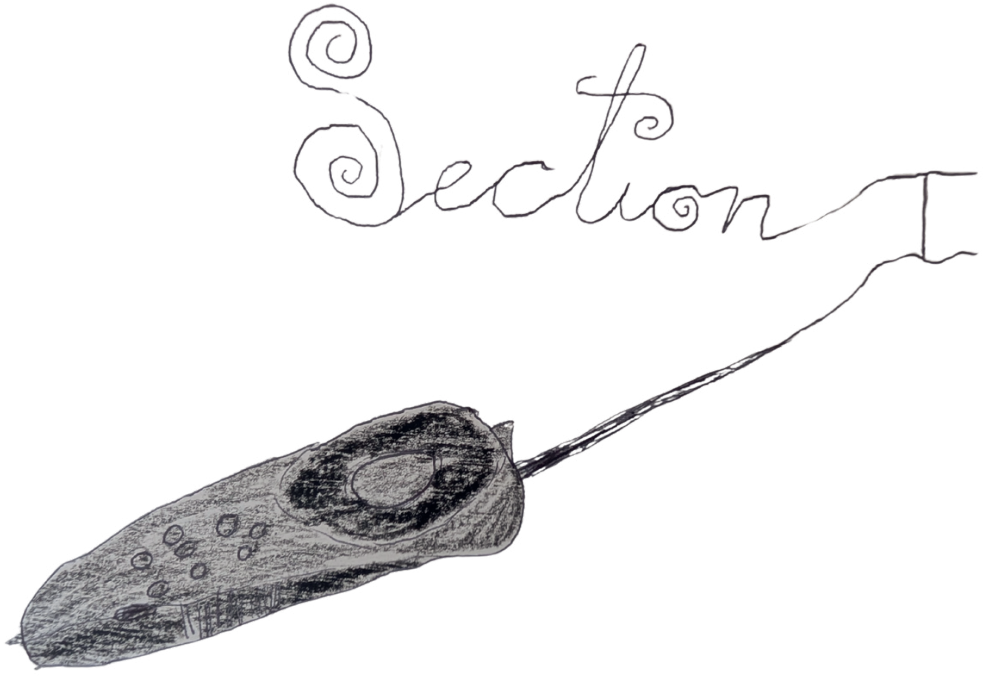

Introduction

General Introduction

Medical education evolves as traditional training methods are being reimagined through innovative technologies and pedagogical approaches. This thesis investigates the use of Virtual Reality (VR) simulations and embodied experiences as tools in medical education, specifically focusing on their application in communication training.

In recent decades, communication has increasingly been recognised as a core component of patient safety, driven by insights from human factors research and major patient-safety reports that revealed how breakdowns in communication rather than technical incompetence often lie at the heart of adverse events. This shift has reframed communication as a system property shaped by context, cognitive load, and team dynamics, rather than a simple interpersonal skill.

This introduction outlines the research questions, contributions, and structure of this thesis.

LITERATURE REVIEW AND RESEARCH GAP

Communication in High-Stress Situations

Simulation-based training has become an essential part of medical education, particularly in anaesthesiology, where healthcare providers (HCP) are frequently required to manage high-stakes, low-frequency events. These include acute airway problems, haemodynamic instability, and unexpected complications during surgery. Simulation offers a structured, risk-free environment in which both technical and non-technical skills can be practised and refined without putting patients at risk (1, 2).

The ability to communicate effectively, make decisions under pressure, and work as a team is increasingly recognised as critical. To address these interpersonal and cognitive demands, Crew Resource Management (CRM) training, originally developed in aviation, has been adapted for healthcare. The importance of CRM in healthcare was widely acknowledged after the Institute of Medicine's *To Err is Human* report highlighted the central role of communication errors in adverse events (3, 4). Indeed, adverse outcomes in acute care settings often stem not from technical failures, but from disruptions in communication, lapses in situational awareness, and cognitive overload during time-critical events. Its principles, including shared mental models, closed-loop communication, mutual performance monitoring, and debriefing provide a theoretical backbone for understanding why high-stress clinical communication so often breaks down.

Traditionally, CRM has been taught using manikin-based simulations. While effective, this method requires significant resources, scheduled group sessions, and access to simulation centers. These requirements cannot always be fullfilled, limiting execution. These

limitations were amplified during the COVID-19 pandemic, which forced many training programs to cancel or severely restrict in-person simulation (5).

VR has emerged as a viable and scalable alternative, offering immersive environments where learners can engage with scenarios on demand. In theory, VR simulation allows for dynamic scenario control: for instance, trainers can modify a patient's physiological responses in real time, supporting adaptive challenge levels that match the learner's pace (6, 9, 10). These affordances may reduce cognitive overload and enhance engagement, aligning with principles from Cognitive Load Theory (7). Cognitive Load Theory (CLT), developed by John Sweller, explains that our working memory has a limited capacity for processing new information. It distinguishes between **intrinsic load** (task complexity), **extraneous load** (inefficient presentation), and **germane load** (effort to build understanding). Effective teaching reduces extraneous load and balances difficulty—enough to stimulate learning, but not so much that the learner becomes overwhelmed or shuts down (8). During high-stress events, poorly designed information flow can overwhelm working memory, increasing the likelihood of communication errors.

Effective simulation should therefore be built through an iterative, user-informed process. User-centered design (UCD) is particularly valuable when combined with risk assessment tools like Failure Modes and Effects Analysis (FMEA), which systematically identifies potential points of system failure during early development (11, 12).

Incorporating human-factors principles at the design stage ensures that simulations do not merely represent clinical tasks but resemble real-world team behaviour.

In summary, CRM training through VR holds substantial potential. However, further evidence is needed to demonstrate its feasibility in communication skill acquisition and clinical performance. This thesis addresses these challenges through developing, validating, and early evaluation of a multiplayer, scenario-adaptive VR training system for anaesthesiology, built through a user-centered process and tested using both qualitative and quantitative methods.

Communication for Patient Comfort and Anxiety Reduction

Hospitalisation and medical procedures can provoke significant anxiety in patients, particularly in the preoperative setting. This anxiety amplifies physiological stress responses, increases pain sensitivity, and is associated with poorer postoperative outcomes and prolonged recovery (13-16). Routine interactions and procedures, as 'simple' as the placement of an IV cannula or drawing blood, can leave a lasting emotional imprint on patients reinforcing or relieving their distress (17-19).

Therapeutic communication refers to the use of suggestive and positive language, careful non-verbal cues, and rapid rapport techniques to create a sense of safety, trust, and comfort in the clinical encounter. It is both an attitude and a technique—requiring the healthcare professional to be aware of how words, gestures, and tone may implicitly influence a patient's physical and emotional experience through the creation of a connection with the patient, also referred to as rapport.

Findings from neuroscience and cognitive psychology increasingly support the clinical importance of this skill in increasing patient comfort. Language does not merely describe but actively shapes perception, including the experience of pain. Negative phrasing, such as "this might hurt" or "don't worry", can draw attention to threat, reinforcing anxiety and discomfort via nocebo effects. In contrast, positive suggestions have been shown to reduce pain and even modulate neurophysiological pathways associated with stress and comfort (18, 20, 21)."

Despite this growing body of evidence, therapeutic communication is still underrepresented in medical education. While most curricula cover the basics of patient interaction, these are often confined to structured checklists or theoretical instruction. In reality, communication behaviours are shaped implicitly—through the clinical environment, observation of senior colleagues, and organisational culture. This *hidden curriculum* can perpetuate habits that prioritise efficacy, inadvertently modelling communication styles that undermine patient trust (22, 23).

Addressing this gap requires training methods that move beyond technical skill acquisition. Experiential and immersive approaches are particularly promising, as they engage not only the cognitive but also the affective and reflective dimensions of learning (24). Patient-embodied VR simulations, where the user experiences a clinical interaction from the patient's perspective, allow clinicians to *feel* the impact of tone, phrasing, and non-verbal communication. These experiences draw on the *Proteus effect*, where embodiment influences perception and behaviour, and they are aligned with experiential learning theories such as Kolb's cycle, which emphasises reflection on lived experience as a pathway to lasting behavioural change (10, 25, 26).

In summary, therapeutic communication is a powerful yet underused skill in patient-centered care. Integrating immersive training with patient-embodied VR into education may help create deeper awareness, empathy, and behavioural adjustment. This thesis explores how these interventions can enrich clinician training.

Communication and Team Culture in the Operating Room

The operating room (OR) is a high-stakes environment where communication is both critical and complex. It brings together diverse professional roles—surgeons, anaesthesiologists, nurses, and trainees—who must coordinate their actions under time pressure and in close physical proximity. In this setting, communication extends far beyond spoken words. It includes routines, tacit norms, glances, hand gestures, and even silence. The subtle cues exchanged among team members often determine whether a procedure runs smoothly or breaks down (26, 27).

Within the OR, nonverbal communication plays a particularly important role in shaping team rapport and ensuring patient safety. Elements such as sustained eye contact, open postures, and supportive touch—though often overlooked—can signal attentiveness, solidarity, or readiness to act (28, 29). In dynamic clinical settings like endoscopy or emergency surgery, nonverbal synchrony among healthcare professionals has been associated with more fluid teamwork and higher perceived trust. These cues are not always consciously recognised but contribute significantly to how team members interpret one another's intentions and emotions.

Yet many of these communicative behaviours are not formally taught. Instead, they are absorbed informally—through observation, imitation, and trial-and-error. This process forms part of what is often referred to as the *hidden curriculum* in medical education: the set of implicit values, behavioural norms, and unspoken rules that shape professional identity and conduct (30, 31). In the OR, this hidden curriculum is particularly potent, as trainees are acutely aware of power hierarchies and often hesitant to ask questions or disrupt expectations. Over time, these silent lessons may reinforce not only communication habits but also assumptions about status, authority, and belonging.

Together, these observations highlight a central educational challenge. If nonverbal communication and team norms in the OR are largely implicit, and context-dependent, how can they be studied, made visible, and addressed in training? Traditional educational approaches tend to focus on explicit knowledge and verbal skills, leaving these aspects of teamwork underexplored. As a result, critical elements of rapport and team culture often remain invisible, despite their influence on collaboration, learning, and psychological safety.

In this thesis, a video-ethnographic approach is used to examine nonverbal elements of rapport.

Research Aims and Objectives

The central aim of this thesis is to explore how VR simulations and embodied experiences can be used to enhance communication skills among HCPs in different clinical contexts. The research is structured around three key sections:

Section II: Communication in High-Stress Situations

- Investigating if and how VR simulations can help HCPs train CRM skills for handling stressful clinical scenarios.

Section III: Communication for Patient Comfort

- Examining if and how HCPs can be trained in therapeutic communication with the use of patient-embodied VR experiences.

Section IV: Communication and Team Culture in clinical practice

- Analyzing team rapport and non-verbal communication among HCPs in clinical practice.
- Developing and validating a VR experience designed to help new medical interns navigate communication challenges and adapt to the OR environment.

To achieve these objectives, this thesis follows a structured approach: first, establishing the theoretical foundation for using VR in communication training; second, developing novel VR simulations tailored to each domain; third, validating their usability in a clinical setting; and finally, implementing these VR experiences in real-world medical training programs.

By addressing these three domains, this research provides a comprehensive analysis of how VR-enhanced training can equip HCPs with essential communication skills, ultimately improving patient care and team dynamics in clinical practice.

Methodology

The research methodology employed in this thesis are quantitative and qualitative, with a strong emphasis on user-centered design (UCD) and phenomenological approaches. For the development of the VR simulation prototype (section II), iterative design cycles were informed by feedback from multidisciplinary expert teams, employing qualitative techniques such as interviews, focus groups, and prototype testing. The embodied VR experiences (section III) were assessed and validated through semi-structured interviews with healthcare providers, analyzed using thematic analysis to capture the lived experiences and impact on therapeutic communication.

Structure of the Thesis

This thesis is organised into three main sections, each addressing a specific domain of clinical communication and how it can be enhanced through simulation-based education and immersive VR. Across eight chapters, it explores how VR tools and embodied experiences can be validated and used to train healthcare professionals in complex communication tasks.

Section II: Communication in High-Stress Situations

This section investigates how VR simulations can help HCPs develop communication skills for managing stressful clinical scenarios, with a focus on improving situational awareness, decision-making, and teamwork during crises.

- **Chapter 1** gives an overview of how simulation in anaesthesiology is applied in practice, illustrating how active learning experiences support the acquisition of both technical and non-technical skills.
- **Chapters 2A, 2B, and 2C** present the development and validation of the first prototypes of a VR simulation for anaesthesia training.

Section III: Communication for Patient Comfort and Anxiety Reduction

This section examines how VR-based embodied experiences can be used to train HCPs in therapeutic communication, with the aim of fostering patient-centered care and reducing preoperative anxiety.

- **Chapter 3** introduces the core message that *a good intention does not suffice*, illustrating the subtle yet powerful effects of language and suggestion in healthcare settings.
- **Chapters 4A, 4B, and 4C** investigate the development, validation and use of patient-embodied VR to increase awareness of therapeutic communication strategies.
- **Chapters 5A and 5B** outline the study protocol and results of integrating the VR experience into a communication training in the acute admission ward.
- **Chapter 6** describes the use of this training format, combined with other non-pharmacological interventions, to decrease patient anxiety in the preoperative holding area.

Section IV: Communication and Team Culture in the Operating Room (OR)

This section explores communication skills and team dynamics in the OR, focusing on non-verbal rapport and the hidden curriculum that shapes team culture and intern enculturation.

- **Chapter 7** investigates the non-verbal elements of rapport in the OR, and how these influence team cohesion and trust.
- **Chapter 8** focuses on the adaptation of new medical interns to OR team dynamics, describing the development of VR-embodied experiences designed to expose and reflect on the hidden curriculum in the surgical setting.

REFERENTIES

1. Yunoki K, Sakai T. The role of simulation training in anesthesiology resident education. J Anesth. 2018;32(3):425-33.
2. Anthony G. Active Learning in a Constructivist Framework. Educational Studies in Mathematics. 1996;31(4):349-69.
3. Helmreich RL, Merritt AC, Wilhelm JA. The evolution of Crew Resource Management training in commercial aviation. Int J Aviat Psychol. 1999;9(1):19-32.
4. Institute of Medicine Committee on Quality of Health Care in A. In: Kohn LT, Corrigan JM, Donaldson MS, editors. To Err is Human: Building a Safer Health System. Washington (DC): National Academies Press (US) Copyright 2000 by the National Academy of Sciences. All rights reserved.; 2000.
5. Pottle J. Virtual reality and the transformation of medical education. Future Healthc J. 2019;6(3):181-5.
6. Bracq MS, Michinov E, Jannin P. Virtual Reality Simulation in Nontechnical Skills Training for Healthcare Professionals: A Systematic Review. Simul Healthc. 2019;14(3):188-94.
7. Reedy GB. Using Cognitive Load Theory to Inform Simulation Design and Practice. Clinical Simulation in Nursing. 2015;11(8):355-60.
8. Sweller J. Cognitive Load During Problem Solving: Effects on Learning. Cognitive Science. 1988;12(2):257-85.
9. Macnamara AF, Bird K, Rigby A, Sathyapalan T, Hepburn D. High-fidelity simulation and virtual reality: an evaluation of medical students' experiences. BMJ Simul Technol Enhanc Learn. 2021;7(6):528-35.
10. Navarro J, Peña J, Cebolla A, Baños R. Can Avatar Appearance Influence Physical Activity? User-Avatar Similarity and Proteus Effects on Cardiac Frequency and Step Counts. Health Commun. 2022;37(2):222-9.
11. Davis S, Riley W, Gurses AP, Miller K, Hansen H. Failure Modes and Effects Analysis Based on In Situ Simulations: A Methodology to Improve Understanding of Risks and Failures. In: Henriksen K, Battles JB, Keyes MA, Grady ML, editors. Advances in Patient Safety: New Directions and Alternative Approaches (Vol 3: Performance and Tools). Advances in Patient Safety. Rockville (MD)2008.
12. Göttgens I, Oertelt-Prigione S. The Application of Human-Centered Design Approaches in Health Research and Innovation: A Narrative Review of Current Practices. JMIR Mhealth Uhealth. 2021;9(12):e28102.
13. Kain ZN, Caldwell-Andrews AA, Maranets I, McClain B, Gaal D, Mayes LC, et al. Preoperative anxiety and emergence delirium and postoperative maladaptive behaviors. Anesth Analg. 2004;99(6):1648-54.
14. Kain ZN, Mayes LC, Caldwell-Andrews AA, Karas DE, McClain BC. Preoperative anxiety, postoperative pain, and behavioral recovery in young children undergoing surgery. Pediatrics. 2006;118(2):651-8.
15. Maranets I, Kain ZN. Preoperative anxiety and intraoperative anesthetic requirements. Anesth Analg. 1999;89(6):1346-51.
16. John M. Managing anxiety in the elective surgical patient. British Journal of Nursing. 2009;18(7):416-9.
17. Lang E. Comfort Talk®: From the Waiting Room to the Treatment Suite. Dtsch Z Zahnarztl Hypn. 2019;25(1):22-4.
18. Lang EV, Hatsiopoulou O, Koch T, Berbaum K, Lutgendorf S, Kettenmann E, et al. Can words hurt? Patient-provider interactions during invasive procedures. Pain. 2005;114(1-2):303-9.

19. Dutt-Gupta J, Bown T, Cyna AM. Effect of communication on pain during intravenous cannulation: a randomized controlled trial. Br J Anaesth. 2007;99(6):871-5.
20. Benedetti F. Placebo and the new physiology of the doctor-patient relationship. Physiol Rev. 2013;93(3):1207-46.
21. Finniss DG, Benedetti F. Mechanisms of the placebo response and their impact on clinical trials and clinical practice. PAIN. 2005;114(1).
22. Klitzman R. Improving education on doctor-patient relationships and communication: lessons from doctors who become patients. Acad Med. 2006;81(5):447-53.
23. Vaidyanathan B. Professional socialization in medicine. AMA J Ethics. 2015;17(2):164-70.
24. Kolbe M, Grande B, Spahn DR. Briefing and debriefing during simulation-based training and beyond: Content, structure, attitude and setting. Best Pract Res Clin Anaesthesiol. 2015;29(1):87-96.
25. Kolb D. Experiential learning: experience as the source of learning and development: Eaglewood Cliffs; 1984.
26. Bian Y, Zhou C, Tian Y, Wang P, Gao F, editors. The Proteus Effect: Influence of Avatar Appearance on Social Interaction in Virtual Environments. HCI; 2015.
27. Lingard L, Espin S, Whyte S, Regehr G, Baker GR, Reznick R, et al. Communication failures in the operating room: an observational classification of recurrent types and effects. Qual Saf Health Care. 2004;13(5):330-4.
28. Edmondson A. Psychological Safety and Learning Behavior in Work Teams. Administrative Science Quarterly. 1999;44(2):350-83.
29. Hall JA, Roter DL, Blanch DC, Frankel RM. Observer-rated rapport in interactions between medical students and standardized patients. Patient Education and Counseling. 2009;76(3):323-7.
30. Ambady N, Koo J, Rosenthal R, Winograd CH. Physical therapists' nonverbal communication predicts geriatric patients' health outcomes. Psychol Aging. 2002;17(3):443-52.
31. Hafferty FW, Franks R. The hidden curriculum, ethics teaching, and the structure of medical education. Acad Med. 1994;69(11):861-71.
32. Lempp H, Seale C. The hidden curriculum in undergraduate medical education: qualitative study of medical students' perceptions of teaching. Bmj. 2004;329(7469):770-3.