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Under Pressure: A Design to Reduce Blood Pressure Reading Errors by Clinical Staff with Virtual Reality Training

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Abstract. Accurate blood pressure (BP) measurement is an important yet frequently improperly handled clinical skill. Research from the American Heart Association and American Medical Association indicate widespread errors, such as improper cuff selection, insufficient rest time, and poor arm positioning, that can lead to misdiagnosis and inappropriate treatment. As a solution to address these performance gaps, this poster session presents Under Pressure, a virtual reality (VR) training module designed for nurses, physician assistants, medical assistants, and students in healthcare settings. With a foundation in design thinking and adult learning theories, this module provides learners with a process-based, scenario-based practice that focuses on following set guidelines while providing immediate feedback in a risk-free environment. Prototype activities include enforcing a patient rest period with an on-screen timer, selecting appropriate cuffs from a virtual cabinet, and positioning the cuff correctly on a patient avatar. These activities engage cognitive, affective, and psychomotor domains by combining knowledge reinforcement, confidence-building, and hands-on skill practice. Evaluations include standardized reproducible scenarios, automated performance logging, expert validation, and comparative studies with traditional training methods to establish reliability and construct validity. By leveraging VR's affordances for embodied, repeatable, and culturally responsive practice, this work contributes to immersive healthcare education by reducing preventable BP measurement errors and strengthening workforce readiness.

Keywords: Virtual Reality, Medical Education, Blood Pressure Measurement, Psychomotor Training, Healthcare Simulation

1 Introduction

Accurate blood pressure (BP) measurement is one of the most common clinical procedures, yet also one of the most frequently performed incorrectly. As Dr. Michael Rakotz, Vice President of Health Outcomes for the American Medical Association, observes, "for a procedure performed millions of times every day across the country, very few medical professionals—even nurses and doctors—nail the routine correctly" [1]. Common mistakes include but are not limited to failing to rest before a measurement, placing a cuff over the clothing, using the wrong sized cuff, and engaging in conversation during the process [1]. In one study, they found that only one student out of 160 medical students were able to perform all aspects of blood pressure measurement correctly [1]. These errors are not trivial: inaccurate BP readings can lead to misdiagnosis, inappropriate treatment decisions, and overlooked risk factors for serious cardiovascular conditions [2, 3]. The persistence of these mistakes represents a critical performance gap in clinical practice, with direct implications for patient safety and quality of care. This design challenge seeks to address that gap by developing an immersive, evidence-based training intervention that strengthens the competence and confidence of healthcare professionals. Additionally, this simulation is designed to test not only correct BP technique, but also how clinicians manage time pressures and workflow distractions in practice.

2 Context and Learners

This training is designed for adult learners in clinical settings, including hospitals and outpatient clinics using a VR headset. It can be used during onboarding or as a refresher for nurses, physician assistants, medical assistants, allied health students, and clinical technicians. While most participants will have baseline knowledge of blood pressure measurement, many rely on outdated or inconsistent techniques.

To support diverse learners, the simulation incorporates accessibility features such as glasses-compatible headsets, seated or standing modes, and simplified controller options. Scenarios adapt to experience level: novices receive step-by-step cues and immediate feedback, while experts face minimal guidance, time pressures, and delayed feedback. Learners can repeat scenarios, encounter varied patient avatars, and use optional hints as needed. These design choices ensure flexibility, inclusivity, and authentic practice opportunities across skill levels.

3 Design and Theory

The design of *Under Pressure* is grounded in the design thinking process [4], ensuring that learner needs, real-world practice gaps, and evidence-based guidelines directly inform the instructional solution. During the *Empathize* stage, clinical staff were identified as frequently lacking refresher training beyond their formal education, often performing BP measurement in rushed environments that can produce errors such as incorrect cuff size or skipped rest periods. The *Define* stage highlighted the core instructional problem: limited opportunities for hands-on, low-risk practice of BP measurement techniques. In the *Ideate* stage, virtual reality (VR) was identified as an ideal modality because it affords immersive, repeatable, and kinesthetic practice that strengthens psychomotor skills while providing immediate feedback. A series of VR prototypes were developed in the *Prototype* stage, including scenarios for patient rest periods, cuff selection from a virtual cabinet, and cuff placement with real-time visual cues. Finally, in the *Test* stage, pilot users and subject matter experts provided feedback for iterative refinement. To evaluate prototype effectiveness, preliminary testing may incorporate a gap analysis comparing learner performance against guideline-based criteria. Primary endpoints include accuracy of cuff selection and placement, following the recommended patient preparation steps (e.g., rest period and positioning), and correct BP measurement workflow. Secondary endpoints include time to task completion, learner confidence, and perceived usability of the VR environment. These measurable criteria provide a framework for assessing whether the prototype meaningfully increases adherence to evidence-based BP measurement practices.

The theoretical foundations of the design draw from two complementary adult learning frameworks. Experiential learning theory [5] emphasizes learning through active engagement, reflection, and application, which VR uniquely enables through embodied, procedural practice. In parallel, andragogy [6] frames adult learners as self-directed, motivated by relevant and practical applications, and capable of building on prior experience [7, 8]. Furthermore, these VR scenarios include realistic patient profiles (elderly, obese, hypertensive) so learners have immediate workplace application and can appreciate its practicality. The VR module supports these principles by allowing participants to practice and master skills they already possess at a foundational level, apply updated guideline-based techniques, and immediately translate learning into clinical workflows.

By combining design thinking with established adult learning theories, this intervention aligns technological affordances with evidence-based instructional strategies, positioning VR as a powerful solution for reducing BP measurement errors in healthcare practice.

4 Prototype and Learning Outcomes

The *Under Pressure* prototype focuses on three critical steps where healthcare professionals most frequently make errors in blood pressure (BP) measurement: patient rest time, cuff selection, and cuff placement [9, 10]. Each step is represented as an interactive VR activity designed to engage cognitive, affective, and psychomotor domains simultaneously. This prototype was created using Microsoft PowerPoint.

Rest Time Simulation: Learners are presented with patient information and required to enforce a five-minute rest period before taking a reading. An on-screen timer reinforces the American Heart Association's guideline-based protocol and encourages learners to manage perceived time pressures [1]. Additionally, to simulate real-world scenarios, users might be presented with an impatient patient or might have to deal with an interruption.

Cuff Selection Activity: Learners interact with a virtual cabinet containing blood pressure cuffs of varying sizes and must select the appropriate cuff based on patient profile. As users get more comfortable with the simulation, they might be presented with a patient whose arm size could fit two different cuffs, requiring them to think critically. This activity highlights one of the most common sources of error in practice.

Cuff Placement Exercise: Learners position the cuff on a virtual patient avatar with real-time visual cues guiding correct placement one inch above the elbow crease. Error consequences would surface if BP readings are measured incorrectly if the cuff is too loose or too low on the patient. This step provides kinesthetic and visual reinforcement of psychomotor techniques.

Learning Outcomes: By completing the VR simulation, learners will:

- Demonstrate proper BP measurement techniques aligned with AHA guidelines [2].
- Accurately identify and correct at least three common BP measurement errors.
- Report implementing at least one updated practice into their workflow within two weeks of training.

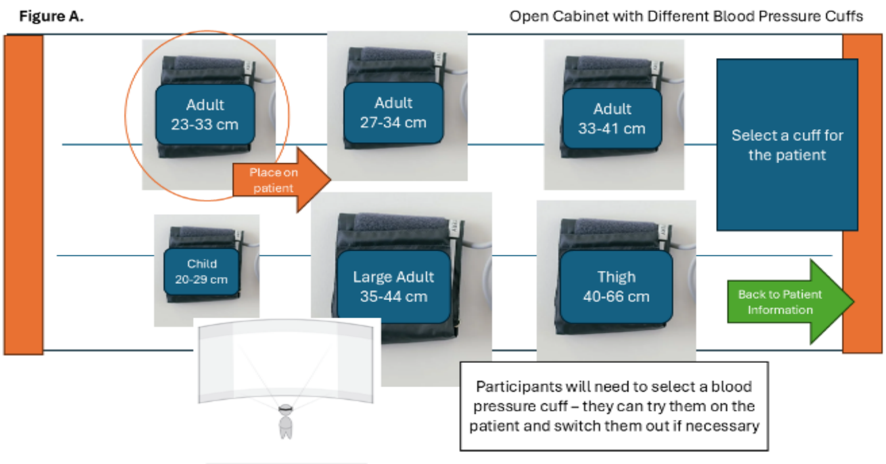

Fig. 1. Prototype activities from the *Under Pressure* VR training module: (A) Cuff selection from a virtual cabinet, where learners choose the appropriate cuff size for the patient.

Fig. 2. (B) Cuff placement on a patient avatar, where learners adjust position with visual cues to ensure guideline-based accuracy.

5 Assessment and Evaluation

Assessment is embedded directly into the simulation to ensure that learners receive meaningful feedback while practicing. Automated logging tracks performance measures such as rest time, cuff selection, placement accuracy, and number of corrections made within the simulation. These data points allow the system to evaluate both accuracy and efficiency, while a debrief screen at the end of each scenario provides formative feedback. Learners see a clear breakdown of what was done correctly, where errors occurred, and how those errors could affect patient care, creating an opportunity for reflection and immediate improvement before repeating the activity.

Because inaccurate blood pressure readings may also result from factors such as improper patient positioning, unsupported arm placement, or measuring over clothing, these additional workflow steps may also be incorporated into the evaluation framework. Improvement can then be quantified as the percentage increase in correctly performed steps following the intervention. Table 1 illustrates an example gap analysis framework that could be used to measure improvements in critical blood pressure measurement steps following the VR training.

Table 1. Example framework for evaluating improvement in blood pressure measurement skills following VR training. Values are illustrative and demonstrate how performance gains could be quantified using pre- and post-simulation assessment.

Critical BP Measurement Step	Before VR Training (% Correct)	After VR Training (% Correct)	Improvement (%)
Rest Time Observed Correctly	48%	86%	+38%
Correct Cuff Size Selection	55%	90%	+35%
Correct Cuff Placement	62%	92%	+30%

The development of assessment features follows a staged design roadmap rather than a research timeline. Phase 1 focuses on building standardized scenarios with clear scoring criteria. Phase 2 integrates expert review to confirm realism and accuracy. Phase 3 pilots the simulation with small learner groups to refine feedback delivery and error logging. Phase 4 prepares the module for wider rollout and comparison with traditional training approaches. Together, these phases ensure that assessment is not an afterthought but a core part of the simulation's design, reinforcing both learning and skill transfer.

6 Discussion and Conclusions

The *Under Pressure* VR training module demonstrates how immersive technology can address persistent gaps in healthcare education [11, 12] by targeting a high-frequency, error-prone clinical skill. By combining design thinking with adult learning theories, the intervention provides a structured yet flexible environment where learners can actively engage in realistic practice, receive immediate feedback, and transfer improved techniques into their workflows. The design specifically engages cognitive, affective, and psychomotor domains, aligning with iLRN's emphasis on multidimensional immersive learning.

A major strength of this project lies in its evidence-based design. Each prototype activity—patient rest time, cuff selection, and cuff placement—was developed in direct response to common errors documented in both literature and clinical observation. The proposed assessment framework further strengthens the intervention by ensuring reliability, validity, and comparability to traditional methods, positioning the module as a credible tool for both training and evaluation.

While the design shows promise, there are also important limitations to address. Hardware access may pose barriers for clinics that lack VR headsets, and some learners may experience motion sickness or usability challenges that limit participation. To increase scalability and inclusivity, future iterations will include alternative delivery formats such as desktop-based simulations or augmented reality modules. These fallback options ensure that training remains accessible across different clinical environments while preserving the core learning objectives.

This work contributes to the Medical & Healthcare Education track by offering a scalable and adaptable model of VR training that can be implemented across higher education, vocational training, and workplace contexts. By emphasizing repeatable practice, culturally responsive patient avatars [8, 13], and low-risk learning environments, *Under Pressure* not only improves technical accuracy but also enhances learner confidence and motivation.

Future research should evaluate the effectiveness of the VR training through controlled studies comparing learner performance before and after the simulation. Randomized studies comparing VR training with traditional instructional approaches, such as lectures, could determine if immersive practice produces more improvements in adherence to guideline-based BP measurement techniques. More research may examine long-term skill retention and transfer to real clinical environments by determining whether learners who complete the VR module show improved measurement accuracy with patients. Finally, future work could explore the integration of learning analytics within the simulation to find common error patterns and provide targeted feedback for individual learners, allowing for targeted interventions and adaptive learning pathways.

In conclusion, VR-based training represents a powerful complement to traditional clinical education [13]. As healthcare systems face increasing demands for accuracy, efficiency, and patient-centered care, immersive learning solutions like *Under Pressure* offer a promising path toward reducing preventable errors and advancing professional competence. Future work will focus on iterative refinement of the prototype, expanded pilot testing, and longitudinal studies to measure knowledge transfer and sustained impact on clinical practice.

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