Virtual Reality Training for Nosocomial Infections Prevention

Mengjie Fan*
National Institute of Health Data Science, Peking University

Shaoxing Zhang
Peking University Third Hospital

Xintian Zhao
Peking University Third Hospital

Xingyao Yu
Visualization Research Center (VISUS), University of Stuttgart

Liang Zhou†
National Institute of Health Data Science, Peking University

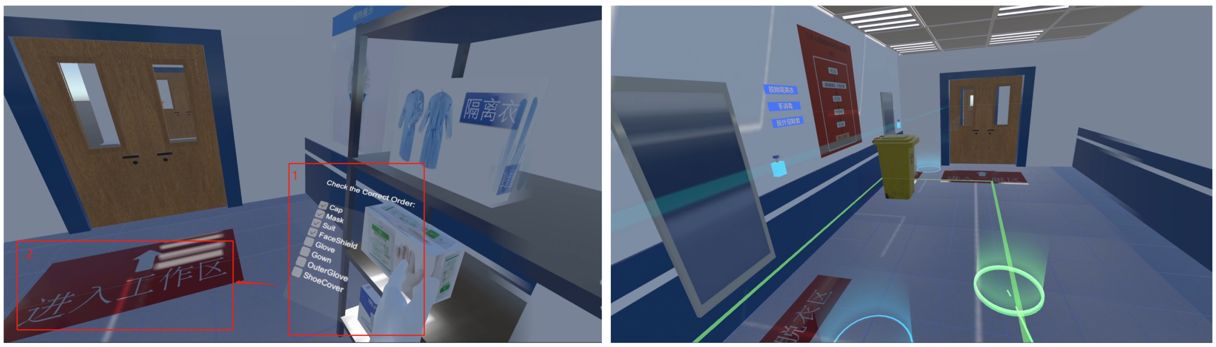


Figure 1: Scenes in our VR prototype for PPE training.

ABSTRACT

Nosocomial infections (or healthcare-associated infections) can greatly affect public health. The prevention and control of nosocomial infections rely on effective training of medical personnel on the correct use of personal prevention equipment (PPE). We introduce a virtual reality (VR) method that simulates the real environment of a hospital and supports repeated immersive practice of PPE donning and doffing. A VR prototype is created and receives positive feedback from a domain expert. The effectiveness of our method will be evaluated in a comparative user study.

Index Terms: Human-centered computing—Visualization—Visualization design and evaluation methods; Computing methodologies—Computer graphics—Graphics systems and interfaces—Virtual reality; Applied computing—Life and medical sciences—Health informatics;

1 INTRODUCTION

Nosocomial infections are infections acquired in healthcare settings. These infections not only prolong the hospital stay and treatment course of a patient but can also lead to serious complications and even death [1,2]. Moreover, medical personnel are also vulnerable to infections, such as during the COVID-19 pandemic, which may increase work pressure and affect the normal operation of hospitals. The risk of nosocomial infections can be significantly reduced by taking proper precautions such as hand hygiene, disinfection measures, proper use of PPE, and maintenance of a clean environment [5,6]. Therefore, training on these precautionary measures is vital for the prevention of nosocomial infections. Among others, PPE donning and doffing training (PPE training, hereafter), is especially important as it requires correct ordering.

*e-mail: mengjiefan@bjmu.edu.cn
†e-mail: zhoulng@pku.edu.cn

Currently, PPE training is based on lecturing and in-person demonstrations, which suffer from the following shortcomings. First, the participants passively acquire the information as the trainer presents lecture slides, lacking interaction and participation. Second, the participants lack practical operation and practice opportunities.

In contrast, VR training provides an immersive learning experience and interactivity, which may enhance learning efficiency in medical education [8]. Moreover, VR training can save training costs and avoid resource consumption in real environments.VR and augmented reality (AR) methods are available for infection controls for various scenarios [3,4]. However, none is available for PPE training for nosocomial infection prevention. Therefore, we propose a VR prototype for PPE training with close collaboration with medical experts. The environment of the prototype is designed based on the “three zones and two channels” regional division of a hospital; the tasks of the prototype are designed for training in the correct donning and doffing ordering of PPE.

2 METHOD

Our study is a close collaboration between visualization experts and medical experts and follows a typical interdisciplinary research paradigm.

A virtual environment is created for PPE training: we start with the requirement analysis, followed by the creation of a VR prototype using iterative prototyping based on frequent discussions between experts of the two disciplines. Basic functionalities are already realized in our current VR prototype.

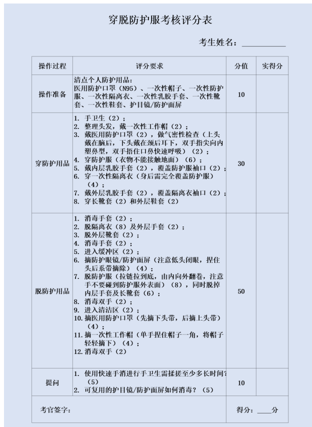
2.1 Requirement Analysis

After extensive discussions with domain experts, we identified three requirements. First, based on the principle of “three areas and two channels” regional division, the training consists of two phases: donning (Phase I) and doffing PPE (Phase II). We further divide Phase II into three zones as each of them is an individual room. Fig. 2 shows one of the zones of Phase II in the real scenario.

Second, the ordering of operations must be strictly followed. In the real-world lecture training, the effectiveness is evaluated using the assessment sheet (in Chinese) as shown in Fig. 3.

Third, during training, a variety of emergency situations such as broken gloves should be simulated to test trainees' ability to deal with occupational exposure.

Figure 2: A real scenario of nosocomial training in a hospital.



穿脱防护服考核评分表

考生姓名：________

操作过程	评分要求	分值	实得分
操作准备	清点个人防护用品： 医用防护口罩（N95）、一次性帽子、一次性防护服、一次性隔离衣、一次性乳胶手套、一次性靴套、一次性鞋套、护目镜/防护面屏	10	
穿防护用品	1. 手卫生（2）； 2. 整理头发，戴一次性工作帽（2）； 3. 戴医用防护口罩（2），做气密性检查（上头戴在脑后，下头戴在颈后耳下，双手指尖向内塑鼻型，双手捂住口鼻快速呼吸）（2）； 4. 穿防护服（衣物不能接触地面）（6）； 5. 戴内层乳胶手套（2），覆盖防护服袖口（2）； 6. 穿一次性隔离衣（身后需完全覆盖防护服）（4）； 7. 戴外层乳胶手套（2），覆盖隔离衣袖口（2）； 8. 穿长靴套（2）和外层鞋套（2）	30	
脱防护用品	1. 消毒手套（2）； 2. 脱隔离衣（8）及外层手套（2）； 3. 脱外层靴套（2）； 4. 消毒手套（2）； 5. 进入缓冲区（2）； 6. 摘防护眼镜/防护面屏（注意低头闭眼，捏住头后系带摘除）（4）； 7. 脱防护服（拉链拉到底，由内向外翻卷，注意手不要碰到防护服外表面）（8），同时脱掉内层手套及长靴套（6）； 8. 消毒双手（2）； 9. 进入清洁区（2）； 10. 摘医用防护口罩（先摘下头带，后摘上头带）（4）； 11. 摘一次性工作帽（单手捏住帽子一角，将帽子轻轻摘下）（4）； 12. 消毒双手（2）	50	
提问	1. 使用快速手消进行手卫生需揉搓至少多长时间？（5） 2. 可复用的护目镜/防护面屏如何消毒？（5）	10	
考官签字：		得分：____分	

Figure 3: The assessment sheet.

2.2 VR Prototype

We create a virtual scene by reconstructing the rooms, items, and their arrangements according to photos of the real hospital scenario (Fig. 2). Notably, we place signs on the floor (the left red box in Fig. 1 (left)), and hand sanitizers, mirrors, and instructions on walls (Fig. 1 (right)) to resemble the real scenario. One zone is created for Phase I for donning and three zones are built for Phase II for doffing.

In the virtual scene of donning PPE in Phase I, the trainee can pick up one item from the shelf at a time and equip it. She/he can enter the Work Area (Phase II) only when specific procedures are strictly followed. The order of donning is shown as an ordered checklist close to the left hand of the player as shown in the right red box of Fig. 1 (left). If the PPE is correctly equipped in order, the corresponding item is checked in the list. Similarly, in each zone (one zone is shown in Fig. 1-(right)) of Phase II, a trainee is only allowed to enter the next zone when operating procedures are performed in the correct order.

Unity was used for the development of the VR prototype. The prototype was tested on an HTC Vive Pro.

2.3 Preliminary Expert Feedback

A medical expert (one of the authors) has experimented with our VR prototype in a pilot study. He provided positive feedback on the method. Compared with traditional lecture-based training, he considered that the immersion of our method may increase the motivation and engagement of trainees, and provide a more in-depth understanding of the process. The convenience of the method (compared to training in a real hospital) allows repeated practice and, therefore, helps the trainees to memorize the procedures more firmly compared to lecture-based training.

3 User Study Design

To study the effectiveness of VR training on nosocomial infection prevention compared to traditional lecture training, we intend to perform a comparative user study.

The study will follow a between-subject design. The main factor is the method of training (VR vs. lecture), and the secondary factor is the visual-spatial ability of participants. We intend to invite 60 medical students who have not received any training in nosocomial infection prevention. Before the experiment, we will use the visual objective and space perception battery (VOSP) [7] to evaluate the level of visual-spatial ability of the participant. In the experiment, participants will be randomly assigned to the VR group (experiment) or the lecture group (control) — each group consists of 30 participants — to take a 15-minute tutorial on PPE training for nosocomial infection prevention, a stratified analysis will also be conducted according to visual-spatial ability in both groups, respectively.

We will collect data using checklists and questionnaires. Objective Structured Clinical Examination (OSCE) will be applied by two assessors before and after the VR Prototype or the lecture to test the participants' short-term knowledge retention ability to evaluate the learning effectiveness. The system usability scale (SUS) will also be applied to evaluate the acceptance of the VR method.

4 Conclusion and Future Work

With an interdisciplinary collaboration, we have created a VR prototype that simulates the environment and procedures of PPE training in a real hospital. Our VR method is expected to improve the effectiveness of nosocomial training and can be a useful supplement to routine training.

For future work, we would like to extend the VR prototype with more visualizations and haptic feedback to support randomly occurring emergency situations, such as broken gloves or a fallen face shield, that are infeasible to simulate in the real world. An idea is to model the risk of infection in the space with probability distributions and visualize it using uncertainty volume rendering, while emergency situations can be simulated and visualized as glyphs on an indicator of equipped PPE items accompanied with haptic feedback.

We would also like to devise visual analysis methods on the trajectories and eye-tracking data collected from user studies to better understand the behavioral patterns of subjects and potentially improve the setup of zones and arrangement of items for nosocomial infection prevention in a real hospital.

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