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Title of Project

Learning in Augmented Reality: Providing Immediate Feedback to Interprofessional Healthcare Students in Performing Healthcare Procedures

Keywords

Interprofessional Education (IPE)
Augmented Reality
Simulation-based Learning
Image-guided Manipulation
Performance Assessment
Patient Safety

Abstract

In learning healthcare procedures with multiple steps, trainees often need to split their attention between performing the task and following instructions. We propose to develop an innovative teaching platform to facilitate student learning with minimal distractions. The platform incorporates the augmented reality (AR) to display instructions to students' peripheral vision while practicing healthcare procedures. A new computing algorithm will be developed to augment instructional messaging in an optimal format and timeframe without interrupting the trainee. We will compare learning outcomes between direct vision and AR guiding conditions, and use evidence extracted from eye-tracking to reveal trainees' learning behaviors. Scientists and educators from Medicine, Nursing and Engineering at the University of Alberta are collaborating to teach skills with innovative approaches. We anticipate that the proposed AR training platform will improve quality of education for healthcare professional students.

PROJECT DESCRIPTION

Introduction

Many healthcare procedures involve multiple steps and need to be learned by a variety of healthcare professional students. Specific procedures, such as wound care after a tracheostomy (a procedure that creates an opening through the neck into the trachea to relieve a breathing obstruction) and urethral catheterization (inserting a catheter into the bladder to relieve urine retention) are required skills for students in these health care professions. A trainee is required to learn the procedure step-by-step and correctly follow instructions [1,2]. Violation of the instructions may lead to unwanted consequences for patient care, including site infection, bleeding, and increased pain [3,4,5]. Inappropriate performance may also elicit patient reactions that may threaten the health of our trainees. For example, secretions from coughing or vomiting may expose the healthcare professional student to a variety of infectious diseases [6]. To prevent the harmful consequences during skill training, these basic procedures are often taught using simulated models [2,7].

A common training scenario begins with the students attending a didactic lecture to learn steps and instructions for each procedure, followed by a hands-on training session in the simulation centre [2,7]. While performing the task, the trainee halts the performance frequently, as he/she needs, to check the instructions outlined in a textbook. In improved circumstances where the instructions are printed out and placed by the side of the simulator, the student still needs to shift his/her attention between the operating site and the instructions on the page. It is not uncommon for the instructions to be printed in small font, which forces the trainee to spend a significant amount of time to find information needed for a specific step. Consequently, the workflow is constantly suspended and learning process is interrupted [1].

Under the current education system, each healthcare professional is educated in a separate program. For the same healthcare procedure, instructions presented in a nursing textbook may not always align with instructions presented in a medical textbook. Conflicts may be introduced due to the discrepancy in instructions and guidelines [8].

We realize the need for creating an innovative teaching technology that allows healthcare trainees to learn basic healthcare procedures in a safer environment with fewer interruptions. It is also important that the designed teaching platform can be shared across different health professions.

Figure 1. Graphic illustrations of an AR scene where 3D images are augmented over the abdominal area of a patient.

Objective

We aim to develop an innovative teaching platform using augmented reality (AR) to teach basic healthcare procedures to our health trainees (Objective 1). In the AR environment, a trainee can see the physical (real) world through a goggle whose elements are augmented (supplemented) by computer-generated sensory input such as sound and images. Figure 1 illustrates an AR scene created by the PIs of this project. A student can see the abdominal area of a patient whose internal anatomy is augmented as a 3D model. This AR technology has been developed for teaching skills in industries outside healthcare [5,9,10,11,12]. It is our goal to implement AR technology into healthcare education and determine its pedagogical value in the context of inter-professional education (Objective 2).

Methods

The project includes two interconnected phases: platform development and validity evaluation.

Phase 1. Platform Development

The goal of this phase is to develop a reliable augmented training environment for teaching two common healthcare procedures: wound care after a tracheostomy (Trach Care) in a 6 year old boy and urethral catheterization (U Cathe) to a 58 year old male adult. Two simulation models will be used to present these cases, i.e., the Trach Care Trainer® (Laerdal Medical Canada Ltd., Toronto, ON) for tracheostomy care, and the Advanced Male Catheterization Trainer® (Limbs & Things USA, Savannah, Georgia) for catheterization. Each of these two procedures involve multiple steps making them excellent candidates for teaching using an AR platform with immediate guidance and feedback [6,13].

In Phase 1, we plan to create the AR training environment by asking subjects to wear a pair of eye-tracking enabled Goggles (the Oculus DK2 headset integrated with Tobii Pro, Figure 2). When viewing through the goggles during the performance, immediate instructions are generated by the computer and displayed in the peripheral vision.

Figure 2. Graphic illustrations on the experiment setting for creating the AR training environment (left); when viewed through the goggles, student can see instructions displayed in the peripheral vision (right).

The augmented instructions are not set to disrupt trainees' visual attention while performing the task. To achieve this goal in Phase 1, investigators will edit the instructions to be concise and to minimize the size of the textbox in the peripheral vision (Objective 1A). We also plan to develop a new computing algorithm that enables a series of instructional messages to be displayed at the appropriate timeframe in a continuous task that includes multiple steps (Objective 1B).

Under the AR training environment, trainees' eye motions will be tracked while practising the task. The eye-tracking signal will be used to control the time for displaying instructions. In particular, *instruction for the next step will only be displayed when the computer detects sufficient evidence that the trainee starts to shift his/her visual attention away from the current step to the next.* The evidence of attention shifting will be extracted from eye-tracking data. Our previous work has shown that a human operator will fix his/her eye gaze when concentrating on task performance involving the hands. When the task is about to end, he/she will perform saccade (rapid eye) motions to the next target a few seconds prior to the hands [14,15,16]. Such a proactive saccade is an indicator of attention shifting [17,18]. The computer can detect the moment when the proactive eye motion occurs, then be programmed to display the instructions for the next step. This is the theoretical foundation for designing the smart AR training platform based on trainee's eye-tracking. TLEF will be used to support a Master's student from the School of Computing Science (CS) for 1 year to work in Phase 1, who will develop necessary computing algorithm to connect the AR training platform with the eye-tracking system.

Phase 2 Validity Evaluation

To validate the pedagogical value of IPE AR training platform for teaching the healthcare procedures, we plan to perform a control study in the simulation research lab. A total of 36 Participants (3rd year Nursing or MD program students) will be required to perform the identical Trach Care and U Cathe procedures twice, once under *direct vision* (seeing through the AR Goggles without augmented instruction) and again under *augmented guiding* conditions. The order of training conditions will be randomized by crossover of different participants. The power calculations for this study are based on findings from previous research. AR guidance improves performance 12-35% [10,12]. We anticipate that we will observe a more modest 15 % improvement. When applied to a one-way ANOVA model with an alpha of 0.05 (two tailed) and a beta of 0.10 (power of 90%), we anticipate we will need 16 trainees in each group as a minimal requirement. We add two extra on each group to protect power for significant test.

In a direct vision setting, step-by-step instructions will be printed out and placed beside the patient. In the AR guiding, instructions will be displayed on the right-lower quadrant of the VR Scenes (Figure 2, right).

Task completion *time* and *errors* made during these two procedures will be compared between direct vision and AR guiding conditions (Objective 2A). We anticipate the AR guiding condition will yield a better training outcome as trainees will undergo uninterrupted learning experience with less amount of attention being used for finding a specific instruction from the printed page.

Besides the above measures on task outcomes, we plan to analysis learning behaviors of the students between two different training conditions using the *hierarchical task analysis* technology on eye-tracking data (Objective 2B). Specifically, each Trach Care and U Cathe procedure will be divided into more specific subtasks. Within each subtask, trajectories of eye motions will be plotted to calculate *frequency* and duration of gaze fixation within the target space and *frequency of saccade* motions among different targets. If the AR guiding truly facilitates skill performance, we anticipate the trainees in these groups will perform longer gaze fixation while they concentrate on current task subtask. Their saccade eye motion will be more directed to the upcoming target instead of to the instruction pages. TLEF will be used to support a Master's student from the Health Science or Education, for one year, to work on Phase 2.

Relationship of Educational Theory to Practice

The proposed study is built on theoretical frameworks regarding skills acquisition under distraction[19]. Skill learning requires an enormous quantity of cognitive resources to process information. Environmental distraction in the early stage of skill learning tends to disturb concentration of trainees on the task performance. Therefore, the learning process is interrupted. Our efforts in designing an optimal training environment with minimal distractions during practice should enhance skill acquisition.

Another theoretical framework underlying healthcare education is the *adult learning theory* [20,21]. As adult learners, our trainees undergo a process of taking external feedback (from others' guidance and comments) into internal control (forming their own sense of values and coordination) on their journey toward self-authorship on practising healthcare procedures. The trainees gradually integrate external feedback into their own coordinated performance and decision making [20,21]. Aligned to the adult learning theory, the proposal AR training platform provides step-by-step instruction (external feedback) at the precise moment when the trainee is seeking guidance, which is expected to facilitate the self-authorship process.

Innovation

The first innovation is the combination of cutting-edge eye-tracking technology with the AR training platform. As mentioned in the Methods section, we use AR to create the training scenario for teaching healthcare procedures in adult and child patients. While practising tasks, trainee's eye motions will be tracked to guide the computer to display needed instructions at the critical moment, which creates a novel learning environment that is not currently being used in the conventional training setting.

The second innovation is the development of a learner-centered evaluation strategy that assesses learning outcomes based on explicit task performance and implicit psychomotor behavior changes. Eye-tracking, in this study, is not only used as a signal for eliciting instruction, but also serves as a behavior indicator for revealing inner psychomotor changes over the learning process. Results from this research will enhance our quality in education assessment.

Sustainability

We expect that AR training platform will be adopted by more healthcare science faculties in the University of Alberta and benefit students in different education programs. We have designed this project to make use of available resources of teaching devices (simulators) and technology (augmented reality, eye-tracking), and plan to make the device and technologies utilized available to all education programs at U of A. External sources of funding will be sought from science and health funding organizations to supporting teaching in U of A, including the NSERC and the Royal College of Physician and Surgeons of Canada.

Collaboration

The proposed research will be conducted at the Surgical Simulation Research Lab (Faculty of Medicine and Dentistry), the Advanced Man-Machine Interface Lab (Faculty of Science), and the Nursing Simulation Centre (Faculty of Nursing) at the University of Alberta. We are planning to share facilities and personnel resources at different labs. The investigators in the proposed project are leading scientists in the fields of artificial intelligent, image-guided performance, and interprofessional education. We are confident that such an interprofessional collaboration will provide a win-win situation for all of us to improve our education and research in this emerging and rapidly growing area.

Evaluation

Two sets of ethical applications will be submitted for phase 1 (platform development) and phase 2 (education evaluation) separately. Feedback from ethical experts to protect human users/ students will be taken seriously before we start the research. An information session will be held in the middle of Year 1 to receive comments and feedback from scientists and educators on the design of the AR training platform. At the end of the first year, we will organize a meeting to summarize our work on the AR platform design and to create an effective protocol for evaluating educational outcome. A mid-term report will be completed at the end of Year 1.

Moving to Year 2, where the education evaluation starts, we will arrange another information session to collect comments and feedback from city-wide experts in the fields of simulation, education, and learning assessment. Comments collected from these experts will be used to improve the design for educational research, particularly on simulation usage, practice time, and psychomotor data analysis. A final report will be completed at the end of the second research year.

Dissemination

We anticipate the AR training platform may be adopted by educators from other healthcare science faculties. We will present the results of this work at local, national and international meetings. Locally, we intend to meet with educators involved in teaching basic healthcare procedures. We also plan to disseminate our results to other Faculties (Science, Education, etc.). We will convey our results to other medical and nursing schools nationally and internationally, through distributive means by posting results to the University Teaching Program website and by presentation at major meetings (CAME, RCPSC, INACSL, IMSH).

Although the AR training platform will be based on a healthcare skill, the teaching content also applies to arts and science education. We will attend conferences in education, human-computer interactions, and publish results in journals of *Academic Medicine*, *Medical Education*, and *Human-Computer Interaction*.

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