Through the Eye of the Master: The Use of Virtual Reality in the Teaching of Surgical Hand Preparation.

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Abstract— **Virtual Reality (VR) demonstrates unique educational benefits over other teaching mediums including enhanced engagement and learner motivation. Such benefits could be exploited to improve teaching of surgical hand preparation (SHP), a practice crucial in preventing post-surgical infection. This study hypothesises that the utilisation of VR technology to demonstrate SHP technique will produce superior skill acquisition and longer skill retention than the standard practice of video demonstration. 40 healthcare students unfamiliar with SHP were recruited from a tertiary university and randomised into two groups. The control group (n=21) viewed a video demonstration of SHP while the VR group (n=19) viewed a VR demonstration of the same technique. Participants were assessed immediately after demonstration (acquisition score), and again one week later (retention score), using a 20-point assessment scale. Scores were compared between the groups. Groups were equal in age, prior education, handedness and gender distribution. Neither skill acquisition (Control mean: 12.29, VR mean: 12.84; p = 0.57) nor retention (Control mean: 12.29, VR mean: 12.74; p = 0.52) differed significantly between groups however a non-significant trend toward better performance in the VR group was observed. Parallel scoring of 35% of participants showed very high inter-rater reliability (intra-class correlation coefficient = 0.92). Utilisation of VR technology did not demonstrate a perceivable acquisition or retention benefit in the teaching of SHP. Future studies could investigate the value of more immersive features including 360-degree point of view or haptic feedback which were not features of the technology used in the present study.**

Keywords— Surgical Hand Preparation, Virtual Reality, Training

I. Introduction

The development of a post-operative infection, termed surgical site infection (SSI), can have devastating consequences. As well as increased pain and suffering, such infections are associated with an increased length of stay and subsequently increased costs, higher readmission rates and increased utilisation of antibiotics [1]. In addition to the aforementioned short term harm, SSIs have the potential to negatively affect patients lives long after they are discharged. Patients that acquire SSIs are more likely to suffer from pain, social isolation and insecurity which often becomes permanent [2]. Depending on procedure, SSI rates can be as high as 10% [2]. The multitude of factors that contribute to the development of postoperative infection has resulted in the development of a varied and extensive list of contemporary preventative strategies that are expected of surgical teams. Such strategies include control of theatre ambient temperature, control of the patient's blood sugar levels and the administration of preoperative intravenous antibiotics [3]. One of the oldest and most universally recognised techniques for the prevention of surgical wound contamination is surgical hand preparation (SHP) that is carried out by all members of the surgical team preoperatively [3].

The objective of SHP is to eliminate transient bacteria and reduce commensal bacteria from the hands of the surgical team. This in turn reduces the likelihood of intraoperative transmission of pathogens to the patient [4]; this being especially important in the event of a breach in the sterile surgical glove [5]. Glove puncture rates are thought to be approximately 30% after 2 hours of surgery and up to 80% of glove punctures go unnoticed by surgeons and peri-operative nursing staff [5].

Despite the well demonstrated effectiveness of infection prevention strategies in surgery, compliance with such strategies in some settings has been shown to be less than optimal. The authors of study assessing both compliance with SHP and the theoretical knowledge underpinning SHP across a variety of surgical specialties concluded that both were low [6]. Gagliardi et al [7] carried out a large study across a network of university hospitals in Canada seeking opportunities to improve compliance with local guidelines for the prevention of infection in surgical patients. They discovered that while awareness of the guidelines was high amongst attending medical and surgical staff, compliance was less than predicted. The authors postulated several reasons for this including organisational factors, lack of clinician accountability, absence of point-of-care implementation tools and the use of passive educational strategies for the teaching of prevention techniques including that of SHP.

While there are many SHP techniques in use around the globe, the preferred technique used in Western Australian hospitals is the Australian College of Operating Room Nurse (ACORN) standard for Scrubbing, Gowning and Gloving. At present all nursing and medical schools in Western Australia use passive video demonstration in the teaching of the ACORN standard. The proficiency with which SHP techniques are performed is critical to their effectiveness in prevention of infection. One can therefore surmise that the delivery of SHP teaching is of vital importance. Kramer et al found that several factors influence the efficacy of SHP but none more so than incorrect performance of the technique [8]. With incorrect SHP technique, there is a significant risk of spreading of disease causing bacteria onto the practitioners clothing or the immediate environment where it may then go on to cause infection [8]. It is therefore critical that SHP is performed correctly to minimize the risk of these contaminations occurring.

Adult learning theory suggests that educational interactions will have a greater impact if they are interactive [9]. One alternative to the current practice of passive video demonstration of SHP is the use of Virtual Reality (VR) technology. VR technology is becoming increasingly prominent in many areas including education. Medical students are coming to rely more and more on VR simulated training environments to practice medical techniques [10]. VR can provide a new paradigm for imparting medical knowledge, and the scope and range of VR applications are increasing in medical education contexts. This is allowing learners to practice detailed procedures without putting the safety of a real patient at risk [11-13]. VR has several educational benefits over video. It has been shown to enhance learner engagement and motivation while producing a richer, more engaging and more supportive learning environment [14, 15]. Functional MRI scanning has provided some clues as to the potential mechanisms for the educational benefits witnessed with the use of VR technology. Adamovich et al [16] found that participants who were instructed to imitate an observed finger sequence performed by a virtual hand avatar seen in first person perspective displayed increased activation in several regions of the brain. These areas included frontoparietal networks typically recruited during observation and execution of real-world actions as well as the left insular cortex, angular gyrus, precuneus and extra striate body which are generally considered to be associated with the sense of agency and control.

The authors hypothesised that the use of VR technology would enhance learning of the SHP standard by medical and nursing students when compared to standard video teaching alone. This study was conducted as a pilot to investigate the potential for improved demonstration of SHP technique through utilisation of VR technology in a small group of medical and nursing students in Western Australia. Despite the increasing interest in educational uses of VR, there are few studies investigating its use in the teaching of procedural medical skills such as SHP.

II. Materials and Methods

Participants for the study were recruited from the Schools of Nursing and Medicine at The University of Notre Dame, Fremantle over a period of five weeks throughout August and September 2016. Recruitment involved placing posters around the university campus as well as presentations to students in lectures and advertisements on student social media sites. Each advertisement stated the name and objective of the study, the time frame for data collection and the authors contact details and as such, would not have influenced the results in any way. Inclusion into the study required each participant to be over the age of 18 and either a nursing student or medical student at the time of recruitment. The only exclusion criteria was previous exposure to any form of SHP prior to the study.

In total 40 participants were recruited and randomised into two separate groups; a Control 'Video Demonstration' Group (n = 21) and a 'Virtual Reality' Group (n = 19). Randomisation was undertaken by alternate assignment to each group in the order of participant application to the study. Following randomisation, each participant viewed a demonstration of the ACORN Surgical Scrub technique. The type of demonstration differed according to the participants assigned group. Participants from the control group were shown a five-minute video demonstration of the technique filmed from the left hand side of the individual performing the technique at a surgical scrub bay. The video featured clear verbal instructions explaining each step in the technique and was played in a quiet room on a 13-inch laptop computer. Participants from the VR Group were shown a five-minute virtual reality immersion of the same ACORN technique performed by the same demonstrator at the same surgical scrub bay with the same voice over explaining each step in the technique. The VR immersion was filmed from a stereoscopic camera mounted on the demonstrator's head. This allowed the participant to view the technique 'through the eye of the master" from a first person perspective. The perspective change allowed the VR group participants to appreciate how performance of the ACORN scrub technique might appear to an expert. Participants viewed the VR immersion through a Samsung Gear VR headset and Bose Quiet Comfort 25 noise cancelling headphones.

Immediately after viewing the designated demonstration, participants of both groups were allowed eight minutes alone at a surgical scrub bay to practice the technique they had observed. This practice session occurred in a closed room without any interaction with the experimenters. Posted above the scrub bay was a simplistic 10-step outline of the procedural order of the ACORN scrub technique. As inclusion in the study required no previous exposure to any form of SHP, all authors agreed that expecting novice participants to remember every step of the technique after only one demonstration was unrealistic. The outline that was made available to the participants listed the order of steps only without any technical information on how each step was to be performed. It was available to all participants during both assessments throughout the study.

Following completion of the eight minutes of practice time the participant repeated the scrub procedure while being assessed by an expert assessor, blinded to the type of demonstration that the participant had observed. There is currently no validated way to assess the performance of the ACORN Surgical Scrub, thus for the purposes of this study, we constructed a 20-point scale that was used to assess participants. The scale consisted of 20 separate items with each item being marked in a binary fashion and worth one point. The assessment focussed on correct preparation of the hands and environment prior to starting the hand scrub (three points), correct technique when performing each of the separate individual steps that comprises the hand scrub (five points), correct order of the individual steps (seven points), adequate time spent on each of the steps (two points) and correct drying technique (three points). Individual points were also deducted for observed contaminations of the hand scrub through accidental contact with a non-sterile surface such as the sink.

The score generated after this first assessment was termed the Skill Acquisition score. Participants were then instructed to return one week later without discussing or researching the ACORN technique in the intervening time. Upon return they were given another period of eight minutes to practice the same scrub technique, again with access to the same brief 10-step outline before being assessed by the same blinded expert assessor using the same 20-point assessment scale. The score generated after the second assessment was termed the Skill Retention score.

To ensure validity of the scoring process, 35% of the data set were videotaped while performing an assessment to enable parallel video scoring by a second blinded expert assessor. Scores were entered into a spread sheet and compared via SPSS software.

III. Results

Both the control and virtual reality groups were similar in terms of demographic parameters measured and are outlined in Table 1 below. There were no significant differences between the two groups in terms of gender (X^2 1(40) = 2.34, p = .104), handedness (X^2 1 (40) = 1.33, p = .249) or current degree i.e. nursing or medicine; (X^2 1(40) = 0.00, p = 1.00).

There was minimal difference in skill acquisition scores attained by control and VR groups however, there was a slight but non-significant trend towards better performance in the VR group (Control mean: 12.29, VR mean: 12.84; t(40) = 0.58, p = 0.57). Skill retention scores were also similar where a slight but non-significant trend towards improved performance in the VR group was again observed (Control mean: 12.29, VR mean: 12.74; t(38) = 0.64, p = 0.52). Two participants, one from the control group and one from the VR group, failed to return for the second assessment. The results of each group are shown in Table 2 and can be compared in Figure 2 below.

As shown in Table 3 below, control variables did not influence the outcomes of the skill acquisition or skill retention scores in any way.

Thirty-five percent of the data set (14 participants) were marked a second time by a second assessor to evaluate the reliability of the measurement scale. The mean rating for these participants for the original assessor was 11.80 (SD: 3.14) while the mean rating for the second assessor was 12.46 (SD: 3.27). Comparison of both assessors scores demonstrated a very high inter-rater reliability with an intra-class correlation coefficient of 0.92. It was proposed by Cicchetti (17) that coefficients less than 0.4

indicate poor correlation, between 0.6 and 0.74 indicate good correlation and between 0.75 and 1 indicate excellent correlation.

A. *Figures and Tables*

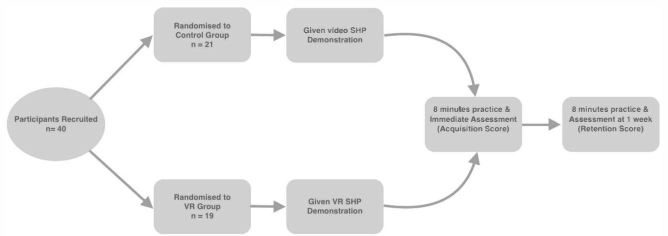

Fig. 1. Flow diagram representing participant movement through the various components of the study.

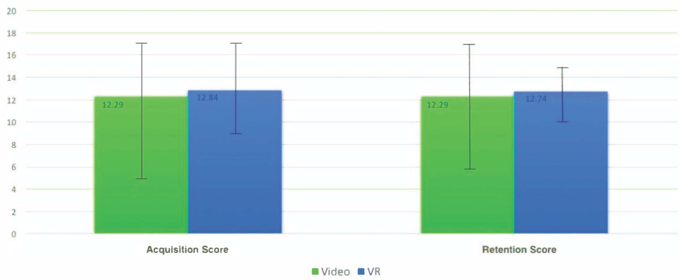

Fig. 2. A comparison of group mean scores with data ranges

TABLE 1. Demographic characteristics of control and virtual reality participant groups.

	Control (n=21)	**Virtual Reality (n=19)**
Mean Age	23.6	25.45
Gender	Male: 3 (7.5%) Female: 18 (45%)	Male: 6 (15%) Female: 13 (33%)
Handedness	Left: 2 (5%) Right: 19 (48%)	Left: 2 (5%) Right: 17 (43%)
Degree	Medical: 11 (28%) Nursing: 10 (25%)	Medical: 9 (23%) Nursing: 10 (25%)

TABLE 2. Comparisons of Assessment Scores by group.

Skill Acquisition Scores					
	Mean Score	Maximum	Minimum	Range	SD
Control (n=21)	12.29	17	5	12	3.23
VR (n=19)	12.84	17	9	8	2.22

Skill Retention Scores					
	Mean Score	Maximum	Minimum	Range	SD
Control (n=20)	12.29	17	6	11	2.65
VR (n=18)	12.74	15	10	5	1.59

TABLE 3. Comparison of assessment scores by gender, handedness and degree.

Gender				
	Number	Mean Score	t-score	SD
Male Skill Acquisition	10	12.40	.258	2.27
Female Skill Acquisition	32	12.66		2.87
Male Skill Retention	9	12.78	.427	2.17
Female Skill Retention	31	12.42		2.23

Handedness				
	Number	Mean Score	t-score	SD
Left Handed Skill Acquisition	4	12.75	.118	2.63
Right Handed Skill Acquisition	38	12.58		2.76
Left Handed Skill Retention	4	12.75	.237	0.50
Right Handed Skill Retention	36	12.47		2.31

Degree				
	Number	Mean Score	t-score	SD
Nursing Skill Acquisition	21	12.90	.735	2.36
Medicine Skill Acquisition	21	12.29		3.05
Nursing Skill Retention	20	12.80	.861	1.61
Medicine Skill Retention	20	12.20		2.67

IV. DISCUSSION

Participants in this study who were taught the ACORN SHP technique through VR demonstration performed at least as well as those who were taught the same technique through the standard means of video demonstration. This study therefore validates VR as a tool for teaching SHP to novice medical and nursing students Performance in this case was judged firstly by the ability of the participant to perform the technique immediately after the demonstration (skill acquisition) as well as the ability of each participant to retain those newly acquired technical skills and be able to perform the same technique under the same test conditions one week later (skill retention). The performance data acquired showed an observable trend towards better performance from the VR group for both skill acquisition and skill retention, however this difference was not statistically significant.

Previous research has indicated that the unique educational benefits inherent to VR technology arise mostly from the ability of the medium to artificially immerse the observer in the virtual learning space. The more immersive the VR technology, the better the learning outcomes have been shown to be [18]. While the technology used in this study featured a stereoscopic point of view and noise cancelling headphones to increase participants sense of presence, the technology did not not fully exploit many of the immersive features available with current VR equipment. One such feature is 360-degree point of view that gives the user the ability to freely and voluntarily explore the learning space by moving their head and shifting their own point of view. Experiencing 360-degree point of view drastically increases one's sense of presence in a displayed environment, something that was not possible in the present study. An argument could be made that because the immersion was developed for the purposes of demonstrating a technique in a confined space, there would be no need for the observer to be able look around the virtual environment. Moreover, this additional ability would add nothing to the demonstration and may possibly function as a distraction to the participant, diverting their attention away from the task being demonstrated. This notion ignores the power of immersion and the effect that increased presence in the artificial learning space has on the learner. Utilisation of 360-degree technology would move the experience of the current VR demonstration one step closer to that of an expert perfectly performing the ACORN Hand Scrubbing Standard. Given the results of other studies [18] into Virtual Reality utilisation in Medical Education, the inclusion of this additional feature is likely to further improve learning outcomes.

Displaying a representation of the users hands within the virtual space throughout the demonstration would also significantly improve the immersive capability. The introduction of Haptic [19] or Leap Motion Technology [20] would allow a participant to see their own hands within the virtual environment and even give them the ability to interact with the environment itself. These additional features would not only contribute to an increased sense of presence but also the ability for the learner to develop their kinaesthetic knowledge or muscle memory throughout the procedure. The development of kinaesthetic memory means that the subject is able to develop a sense of motor patterning and familiarity with the procedure even before they have ever performed it outside of the virtual space [19]. The addition of haptics would also allow for immediate feedback to the learner through continuous assessment as they perform the hand scrub technique. Because the technology would be able to assess the position of the participant's hands in real time, it could be used to grade the learner on several important aspects such as correct order of individual steps, time spent on each individual technique and the surface area of skin covered with the antiseptic agent. These assessment scores could then be made available on a central online leader board to induce a sense of competitiveness amongst learners, further engaging them in the learning process - a concept known as Gamification [21]. The inclusion of 360-degree field of view and haptic technology are features that future studies could incorporate and may further enhance the superiority of VR over standard video demonstration.

Finally, the lack of a validated tool for the assessment of the ACORN SHP standard meant that the authors had to develop an assessment tool prior to the commencement of the present study. Given the extremely high inter-rater reliability achieved using the 20-point scale, the authors feel the tool shows promise and may offer other Australian medical and nursing schools a validated measure for the assessment of the ACORN SHP standard.

V. Conclusions

The current study has shown a simple VR immersion to be as effective at teaching SHP as the current practice of video demonstration in terms of learning outcomes. The technology used in the current study had an approximate cost of $1000 AUD. However, the ability of video to demonstrate any technique to larger numbers of students rather than one student at a time, as is the case with VR technology, means that at present video demonstration is still more applicable to classroom learning. Nevertheless, within the coming months and years the authors predict further advancements in VR technology that will confer additional benefits to learners. It is therefore a distinct possibility that VR technology will one day be able to produce better learning outcomes than video demonstration and will be recognised as a superior educational medium for the demonstration of procedural techniques including SHP. Further research involving currently available technology as well as emerging technologies as they become available is called for.

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