The use of virtual reality simulation to improve technical skill in the undergraduate medical imaging student

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ABSTRACT

In recent years, simulation has increasingly underpinned the acquisition of pre-clinical skills by undergraduate medical imaging (diagnostic radiography) students. This project aimed to evaluate the impact of an innovative virtual reality (VR) learning environment on the development of technical proficiency by students. The study assessed the technical skills of first year medical imaging students. The learning experience by each student was either via traditional laboratory-based simulation or VR simulation, for two specified anatomical protocols. Following the learning experience, the students performed role-plays and were assessed on their technical proficiency. The type of learning environment, laboratory-based or VR simulation, was recorded for each radiographic procedure, as well as demographic data. Data demonstrated an improved total role-play skill score for those students trained using VR software simulation compared with the total role-play skills score traditional laboratory simulation. Demographic multivariable analysis demonstrated no statistically significant association of age, gender, gaming skills/activity with the outcome. The novel medical imaging VR simulation learning tool facilitated technical skill acquisition, equal to, or slightly better than traditional laboratory training. Ongoing data collection will evaluate the impact this VR software has on the undergraduate medical imaging student.

Introduction

The pedagogical approach for the undergraduate medical imaging (diagnostic radiography) student at Queensland University of Technology (QUT) blends theoretical lectures and tutorials with practical simulation experiences. The practical simulation, or "traditional simulation", is facilitated via timetabled access to a functioning laboratory equipped with several x-ray machines. Whilst in the laboratory under supervision, students position each other, prior to irradiating full body and/or partial phantoms. Radiation safety protocols limit student access to this laboratory which is constrained due to timetabling and staffing availability. The use of virtual reality (VR) software to enable independent practice of medical imaging procedures and skills is being assessed for its use as an additional learning tool.

The VR simulation software enables undergraduate medical imaging students to access a VR x-ray room with interactive simulated x-ray equipment and an interactive patient, via a computer screen. This medical imaging VR environment allows students to manipulate a patient and the radiographic equipment into position, in order to produce a VR-generated image. This image can then be compared with a positioning gold standard, for immediate student feedback. The software closely mimics clinical practice and uses 3D visualisation technology to enhance immersion and realism (Bridge, Appleyard, Ward, Philips, & Beavis, 2007; Engum, Jeffries, & Fisher, 2003 and Ost et al., 2001). Initial pilot data, suggested that the use of this VR software improved a student's technical radiographic skill (Bridge et al., 2014). Bridge et al. (2014) also evaluated student satisfaction which highlighted student enjoyment and independent learning as key findings for the implementation of this software. In an extensive review into the use of Simulated Learning Environments (SLE) in Radiation Science Curricula throughout Australia, Thoirs, Giles, and Barber (2011), determined that the benefits of adding simulation to the curriculum were most valuable when preparing students for their initial clinical placement. This study seeks to compare technical skill acquisition of students using the VR simulation learning tool against the traditional laboratory training, prior to their initial clinical experience.

The use of VR simulation to enhance learning in wider health professional education is well documented. Surgical procedures such as laparoscopic procedures, urology cases, bronchoscopy and endoscopy have benefited from training on virtual simulators (de Visser, Watson, Salvado, & Passenger, 2011; Debes, Aggarwal, Balasundaram, & Jacobsen, 2010; Zendejas, Brydges, Hamstra, & Cook, 2013; and Lucas et al., 2008). Health care education has long used physical simulation tools for enhancement of skill acquisition. Examples of these consist of nursing procedures such as intravenous cannulation (Loukas, Nikiteas, Kanakis, & Georgiou, 2011), urethral catheterisation (Johannesson, Silen, Kvist, & Hult, 2013) and midwifery (Brady et al., 2013). Brady et al. (2013) clearly discusses the use of simulation in the education of health care professionals as it provides safe development of "effective clinical skills prior to undertaking clinical practice". The many benefits of using simulation in any health professional education, as outlined by Gaba (2000) include, but are not limited to patient safety and immediate feedback. Despite growing interest in simulation, there is limited documented evidence on the use of VR simulation in the undergraduate medical imaging field. Shanahan (2016), concluded that the use of VR sim software improved the ability of students in radiographic procedures and image evaluation. Unlike the timetabled constraints of utilising the laboratory simulation, the VR software can be accessed on campus at any time, thus making it an independent resource for the students. Students can compare their VR generated image with a "Gold Standard" image, (positioned correctly), thus providing instant feedback to enable students to learn from their mistakes (Seymour et al., 2002).

The purpose of this study is to evaluate the impact that VR software has on the first year medical imaging students' technical skill proficiency, compared with learning via traditional simulation laboratory training. This comparative study will contribute to determining the usefulness of this software in the education of medical imaging students. The results of this study could inform future uses of a VR simulation software on clinical and technical skills development for MRS and other allied health students.

Methods

Ethical approval for this data collection was approved by the QUT ethics committee, 1400000526. The initial pilot project (Bridge et al., 2014) was developed at QUT by academic staff and software developers with funding provided by Health Workforce Australia, as part of the Simulated Learning Environments programme. Convenience sampling of students enrolled in the first year, second semester unit, Radiographic Practice, resulted in two groups, a traditional (control) and the intervention (VR Sim) being formed. A randomised control trial was not possible due to the constraints of practical laboratory timetabling.

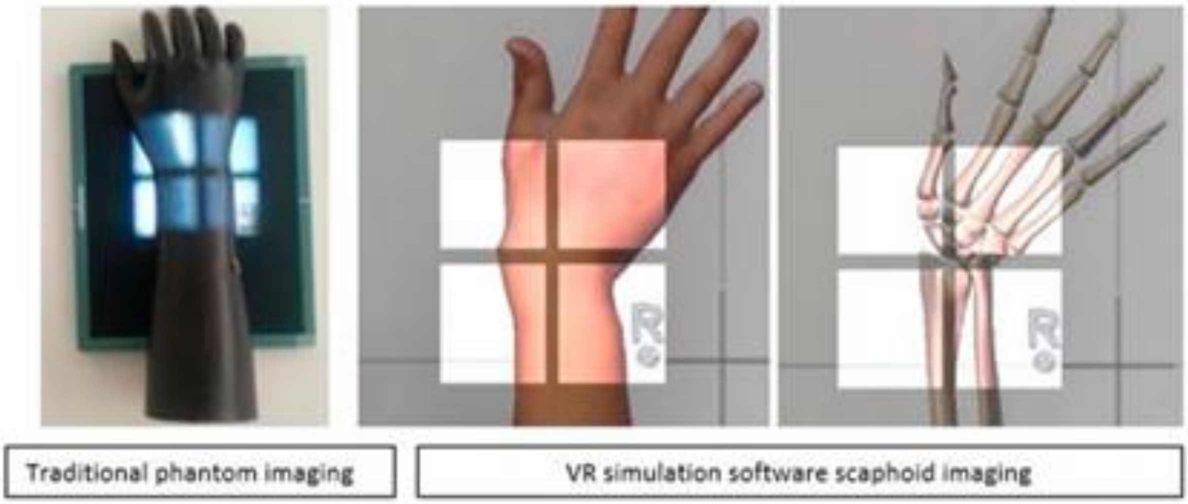
All students were taught the theory of medical imaging positioning protocols for a foot and the scaphoid in a didactic lecture environment. The anatomical areas chosen for this study were deliberately selected as they can be challenging procedures for novices. For example, the (Posterio-anterior) PA scaphoid requires complex fine adjustment of the wrist, see Figure 1, while the (Dorsi-plantar) DP oblique foot is commonly imaged incorrectly by students. An experimental design was implemented to compare the roleplay results of students in each group. Students in Group 1 utilised the VR simulation software as the learning tool to practice the radiographic positioning of the foot and used the traditional practical laboratory experience using a phantom to learn positioning for the scaphoid. Whilst Group 2 students used the VR software for the scaphoid technique and performed x-rays on the foot phantom in the traditional laboratory setting. Therefore, all eligible students were participants in the control/traditional group as well as the VR simulated group. The VR learning group was considered self-directed as the academic was available for software-technical support and not content related support. This was established to evaluate the tool itself and not the teaching.

All students were invited to participate in data collection where their individual participation remained anonymous to the researcher. The assessing supervisor provided critical feedback to assist the student in future summative assessments on completion of both role-plays. Informed consent was sought for the voluntary formative assessment and release of the non-identifiable data. The formative role-play assessment occurred during a timetabled practical class in the laboratory using a single assessor to reduce intra-observer variation. Students were required to perform the Dorsi-Plantar (DP) oblique projection of the foot and the Posterior-Anterior (PA) scaphoid projection. The assessor randomised which anatomical region would be performed first. A detailed rubric was followed to enable objective assessment of the technical skills involved in performing the radiographic procedure. Table 1 demonstrates the specific technical skill breakdown and a marking guide utilised for this formative data collection and also for summative role play exams throughout the duration of the degree programme. On completion of the assessment, the student revealed the teaching method for each anatomical area and provided demographic data to allow correlation analysis. All data was recorded anonymously and coded to enable analysis with outcome measures.

Statistical analysis

A linear mixed method model was used to account for the repeated measures of anatomical projections. The base model included learning style, anatomy and their interactions on mean role-play score, 95% confidence intervals were reported. Order effects, gaming, gender and age were added one at a time and were removed if not significant.

Figure 1. Scaphoid Imaging Traditional vs VR Simulation.



Assumptions of normality and homogeneity of the variance were checked using means, medians, skewness and kurtosis and plotted using histograms and box plots.

Results

Of the 81 students enrolled in the first year general radiography technique unit in 2014, 57 students voluntarily completed a formative role play assessment for this study. However, only 45 students contributed data suitable for direct comparison. Of those excluded, 11 students participated in only one of the role play assessments required and additionally, one student had used both traditional and VR simulation methods for the scaphoid. Therefore, these results were excluded from data analysis. When evaluating data for the individual technical components of the role-play assessment, not all grids in the rubric were included in the assessment of individual students. The details of this extent are shown in Figure 2 along with mean comparisons for each of the criteria factors. Incomplete recording in the rubric for the centring point (CP) was an oversight of the assessor, and resulted in the exclusion of CP marks from the total score. This resulted in the adjusted total maximum points of 40.

Of the 45 students, 27 were in Group 1 and 18 were in Group 2, as shown in Table 2. The order of the role-play assessment alternated between scaphoid and foot. The order of the role-play assessments were randomised with the VR simulator trained procedure being performed first in 23 role plays, compared with 22 trained traditionally. The randomisation was found to be successful with no order effects observed p = 0.981. There was no interaction between learning method and position with VR group scoring slightly higher on both foot and scaphoid (p = 0.678). When results were combined for foot and scaphoid, mean role play score for the intervention group 30.67 (95% CI 29.1, 32.2) was found to be significantly higher than for the control group, 28.8 (95% CI 27.2, 31.3) p < 0.017, as shown in Table 3. The demographics of the 45 students analysed in the direct comparison of results were recorded. The gender distribution in this cohort is indicative of the overall course cohort, being one third male and two thirds female. Student age, gaming skills and experience with gaming activities were collected to evaluate the effect these may have on student results with the VR tool. As students were not allocated randomly to control and intervention arms, demographic variables where added to the base model to assess cofounding effects. However, demographic variables where not found to be either predictive of mean role play scores ($p > 0.05$) or cofounding the intervention. Students indicating their experience at two or more gaming activities; i.e. play station/ Wii/ X Box and PC/Smart phone (n = 13) yielded a total VR mean role-play score of 31.5 (95% CI 29.1, 34.0). This compared to the mean role play score of the students stating "none" (n = 12) to the question of gaming activity as 28.1 (95% CI, 25.6, 30.7) where $p = 0.058$.

Table 1. Rubric for technical skill role-play assessment.

	OUTCOME				
Technical skill breakdown	Ideal	Good	Acceptable	Potential	Not acceptable
Patient positioning	4	3	2	1	0
Part positioning	4	3	2	1	0
Knowledge of x-ray equipment	4	3	2	1	0
Radiographic technique					
Central ray (CR)	4	3	2	1	0
Central point (CP)	4	3	2	1	0
Source Image Distance (SID)	4	3	2	1	0
Exposure factors	4	3	2	1	0
Image Receptor placement	4	3	2	1	0
Side marker placement	4	3	2	1	0
Overall outcome	4	3	2	1	0
Overall efficiency	4	3	2	1	0
Total Outcome Score	**44**				
Total Adjusted Score (without CP)	**40**				

Discussion

The significant improvement of almost 2 (1.9) marks in the role play results by students trained using VR simulation, translates to 4.75% improved skill level. How this relates to clinical outcomes will be assessed in further studies, however, these results highlight that students trained using the virtual reality simulation are not at a disadvantage to those utilising a traditional simulation laboratory, in fact, they are at a slight advantage when considering these results. As with studies by Shanahan (2016), Seymour et al. (2002) and Ahlberg et al. (2007) the use of a virtual simulator can improve outcomes of the novice student and is therefore a valuable pre-clinical learning tool. A study into the impact on student confidence using different learning techniques, including VR simulation, is currently being evaluated.

When evaluating the individual components of the assessment rubric, only three components scored higher in the traditionally trained student compared to the VR simulation training. These were individual results for central ray (mean difference 0.21), SID (mean difference 0.02) and Image receptor placement (mean difference 0.09). These differences are minimal, and if collated together there would be no resultant change to the students' overall score. The overall total score differences demonstrated a greater general technical skill for those students trained by the VR simulation (VR : 30.67 and Traditional : 28.8). Medical imaging professionals, along with other healthcare specialists, require more than these technical skills to perform proficiently in the clinical domain. Therefore, the use of this specific VR technique will facilitate only technical skill acquisition and process as part of the pedagogical strategy for the undergraduate medical imaging student.

It is commonly assumed that VR simulation will benefit the student more experienced in computer game activities, which would likely to be in the younger cohort. In fact, the demographic results challenged this assumption, where 48% of the students described their gaming activities to be nothing or to be limited to that of a PC and/or smart phone and 31% of students describing themselves as having limited or no gaming skills. The results demonstrating a 3.41 difference in VR total roleplay score in those students with experience in two or more gaming activities need to be considered within the limitations of the study. Whilst the p value of these activity results indicates statistically non-significance, the limited number of students needs to be considered in the direct comparison of gaming activity.

Table 2. Allocation of eligible students to training techniques for anatomical regions.

Student $n = 45$	Foot	Scaphoid
Group 1 $n = 27$	**VR Sim**	Control/Traditional Simulation
Group 2 $n = 18$	Control/Traditional Simulation	**VR Sim**

Figure 2. Comparison of individual component scores for VR and Traditional learning.

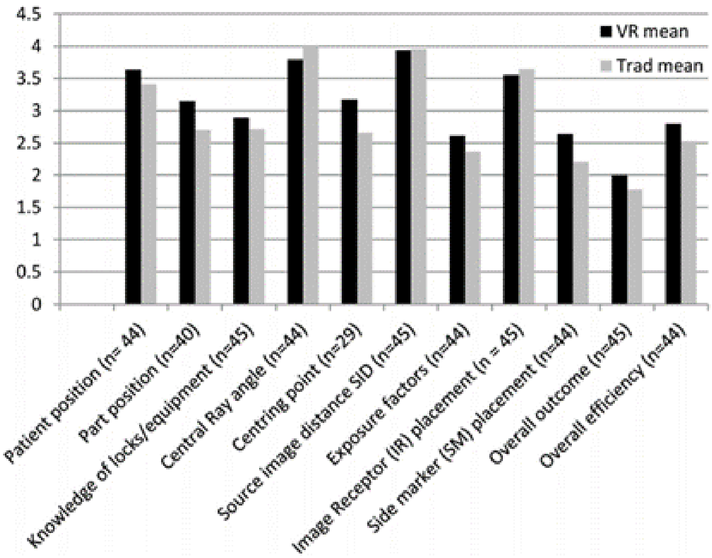


Table 3. Mean scores of learning method and anatomical projection.

Learning method		Mean	95% Confidence Interval	
			Lower Bound	Upper Bound
Traditional/Control	Scaphoid	29.1	27.1	31.1
	Foot	28.3	25.9	30.8
VR Sim/Intervention	Scaphoid	30.4	28.0	32.9
	Foot	30.8	28.8	32.8
Traditional/Control	Combined	28.8*	27.2	30.3
VR Sim/Intervention	Combined	30.7*	29.2	32.2

*$p = 0.017$.

Limitations

As highlighted in the results above, this study excluded some assessment data due to errors at the time of collection. The independent assessor was an academic at the institution where the research was being conducted and this type of role-play examination was standard practice. The researcher is known to the students however did not perform this data collection. The consequent reduction in cohort sizes led to reduced statistical power of the analysis. Further research on future cohorts will enable continued data to be collected and therefore evaluated. These results have only evaluated the performance of student radiographers during assessment of technical skill. No evaluation was performed on the student satisfaction or overall enjoyment of using either training method.

Conclusion

This study has demonstrated that a realistic VR simulation can enhance medical imaging student acquisition of technical skills in two challenging, yet common radiographic techniques. These results have indicated that there is no association of the role-play outcome with previous gaming experience and the association between gaming activities needs further exploration. The technical skill required for formative role-play assessment yielded statistically significant improvements for students trained on the VR simulation software. These results have provided evidence that the use of VR training software in an undergraduate medical imaging degree is at least comparable, if not better than a traditional simulation laboratory utilising phantoms. The importance of training in this physical simulation space is well documented and necessary for these students, however, the effectiveness of the VR simulation provides a viable option if access to the physical x-ray equipment and laboratory set up was limited due to cost and staffing timetables. Future studies into the correlation between student-perceived confidence and measured skills whilst on clinical placements can be further explored. An ongoing study of future cohorts with the VR software tool being embedded in a structured tutorial setting will demonstrate the impact of VR beyond the value of the tool itself and as part of a blended learning strategy. This will have potential benefits to inform various allied health curricula on the addition of VR simulation as an inclusion as part of a complete simulation package.

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