ParaVR: Paramedic Virtual Reality Training Simulator

Neil Vaughan
Department of Computer Science
University of Chester
Chester, UK
n.vaughan@chester.ac.uk

Nigel John
Department of Computer Science
University of Chester
Chester, UK
n.john@chester.ac.uk

Nigel Rees
Welsh Ambulance Services NHS Trust
Wales, UK
nigel.rees5@wales.nhs.uk

***Abstract*—This research project developed a Virtual Reality (VR) training simulator for paramedic procedures. Currently needle cricothyroidotomy and chest drain are modelled, which could form part of a larger system for training paramedics with VR in various other procedures. The simulator incorporates a number of advanced VR technologies including Oculus Rift and haptic feedback. We have gained input and feedback from NHS paramedics and several related organisation to design the system and provide feedback and evaluation of the preliminary working prototype.**

Keywords-component; Virtual Reality; Training Simulator; CPR; Paramedic; Ambulance

I. Introduction

This research has developed a prototype VR training simulator for training paramedics. This addresses skills maintenance for paramedics, particularly for life saving procedures that only need to be performed rarely.

Significant potential of the current ParaVR prototype has been recognised by several awards including winning 1st prize at the 2018 Welsh Health Gadget Hack, funding from the Bevan Commission, receiving the Health&Care Research Wales Pathway to Portfolio 2019 and is highlighted in the top 100 lifesaving projects of 2019 (Universities UK, 2019).

Critical procedural skills proficiency and maintenance present concerns for the quality of care in any patient population. Knowledge will inevitably be lost over time if a procedure is rarely carried out, but it must still be performed successfully. ParaVR will provide a cost-effective solution that can easily be deployed in the workplace to help maintain such skills.

The project exploits the latest generation of affordable Virtual Reality (VR) hardware to provide an immersive experience whereby the paramedic can practice a procedure on a virtual patient. The patient will typically be at the accident scene, and the virtual environment constructed accordingly. The initial working prototype has been developed, demonstrating feasibility.

The next stage of the project will be to further develop the simulator, aiming to produce a more advanced version of the prototype that will be ready for formal evaluation, clinical testing and future commercialisation. The target is to port the VR into the new head mounted display: the Oculus Quest – a tetherless device due for release in 2019.

The simulator currently contains a simulated model of needle cricothyroidotomy – a procedure that is used for emergency airway access. It involves passing an over-the-needle catheter through the cricothyroid membrane to provide a temporary secure airway to oxygenate and ventilate a patient in severe respiratory distress.

The developed prototype uses the Oculus Rift HMD that is commercially available. This enables use of a pair of sophisticated hand controllers to interact with the contents of the VR environment.

The prototype has also explored the use of a force feedback device to provide a realistic sensation of needle puncture. The intention is to eventually deploy ParaVR at the work. This will have benefit that paramedics will not be required to attend special training centres.

A requirements phase is being conducted between the Welsh Ambulance Service and the University of Chester to determine the optimal functionality of the first version of ParaVR.

This simulator aims to enhance the skills of expert paramedics, by refreshing their skills for rare procedures that haven't been regularly used. It can also be of use for novice paramedics who are learning the procedures for the first time.

Additionally, a junior module has been included, for simulation with virtual reality the Cardio Pulmonary Resuscitation (CPR) procedure. This module will be used for training school children: ParaVR lifesaver junior.

A. Literature for existing Paramedic VR training

Previous research by Hubble and Richards (2006) has shown that paramedics can be trained at a distance. Also Cone et al. (2011) indicated the efficacy of VR as a platform for paramedic student education. That gives a good indication that a VR training platform could be effectively developed for paramedic training.

Some previous VR training simulators for paramedics have been developed (Conradi et al., 2009). They reported that participants found a virtual environment more authentic and collaborative than using paper-based scenarios. No previous VR simulator is known to have incorporated the needle cricothyroidotomy or chest drain procedures. Some VR paramedic training simulators have been based in virtual environments such as train platforms or by the roadside (Conradi et al., 2009) or in a bus crash (Cone et al., 2011). The MESH360 project presented a work-in-progress VR for paramedic life-and-death pressure situations a critical care (Cochrane et al., 2016).

Research suggests that simulation of rarely performed procedures using mannequins results in an increase in confidence for a clinician to perform the procedure on a real patient when called upon. For example, Sawyer & Strandjord (2014) demonstrated significant improvements in the self-perceived procedural competency of performing pericardiocentesis, electrocardioversion and defibrillation. A recent study by Li & Setlik (2018) also found that a simulation-based curriculum improved physician confidence in performing critical procedures such as cricothyrotomy. Other studies have also shown success in areas of airway management skills (Kovacs et al, 2000) and psychomotor skills for CPR (Niles et al, 2009). Little work has been done to explore clinical procedures skills maintenance using VR, however. This ParaVR project will replicate these studies using a VR solution, particularly for paramedics. Further we hypothesis that immersing the paramedic at the scene of an accident where they have to deal with all of the sights and sounds of the incident will further improve their confidence over and above that obtained by practicing on mannequins alone.

Figure 1. Part-task rescuscitation trainer for needle cricothyroidotomy (Perkins, 2007).

B. The Needle Cricothyroidotomy procedure

There are some basic existing simulation devices for general resuscitation which can support needle cricothyroidotomy among other procedures (Fig. 1). These are simple part-task or procedural trainers which are most commonly used to develop a basic psychomotor skill. No measurements were presented to demonstrate how realistic the feeling is compared to a real procedure on a live human. In the needle cricothyroidotomy procedure, haptic feedback accuracy is important.

C. The Chest Decmpression procedure

The basics of performing a chest decompression involve inserting the needle into the second intercostal space at a 90-degree angle to the chest wall at on the same side as the injury. The optimal insertion point is mid-clavicle line (MAL), 2nd intercostal space (ICS), above the third rib. The mean depth of the pleural cavity when approached from the MAL 2nd ICS is consistently 4-5 cm, however, the range is wide, up to 10cm depth in some cases.

The Russell Pheumofix needle is commonly used. The Verres needle should include visual indicator that moves when the pleural space is first entered. The catheter is 11cm, long enough for majority of individuals. It contains a 12 gauge graduated scale to indicate depth of insertion. The hub is v-shaped allowing two connections to be made. No scalpel is needed.

To begin, the Russell PneumoFix is inserted into the intercostal space at a 90-degree angle to the chest wall and always away from the heart.

On entering the pleural space there will be a sudden movement of the green indicator towards the patient: this suggests that the needle tip is in the intra-pleural space. If aspirating with a syringe, air or fluid might be withdrawn at this point.

The needle should not be inserted any further and, for most adults, this will be approximately 4-5cm.

Fixing the Veress needle at this depth, the catheter is advanced by grasping the plastic hub of the catheter and advancing it 2-3cm into the patient (once inserted and the needle guard has moved into position it is then advocated to advance onto the next number on the catheter).

The Veress needle is withdrawn at this point leaving the catheter in place.

There are possible complications to consider which can be modelled in the simulator. (1) The length of the needle/catheter used can be too short to reach the pleural space to release air/fluid. (2) The needle/catheter does reach the pleural space when pressure is applied allowing some release of gas and fluid but the catheter retracts into the intercostal muscle once the needle is withdrawn. (3) Needles are prone to kinking, or obstruction from blood or tissue. This is much less likely with the Russell Pneumofix, which is designed to be kink resistant. (4) Failure to drain large air leak.

As a general concept, obesity is increasingly prevalent in the population and depth to the pleural space is likely to increase on a population level. This is related to previous research on VR modelling of various BMI patients which affects the depth of needle insertion (Vaughan et al., 2014).

II. METHODS

A. Oculus Rift and Hands Interaction

In our current working prototype VR training simulator, the Oculus Rift head mounted display (HMD) is used. The oculus rift comes with wireless hand controllers (Fig. 1) which can be used by the trainee or trainer to interact with the virtual model, pick up needles and insert the needle into the virtual patient. When the needle is inserted the needle stays in place after the hand controllers let go of the needle.

Figure 2. Wireless Hand Controllers with the Oculus Rift HMD.

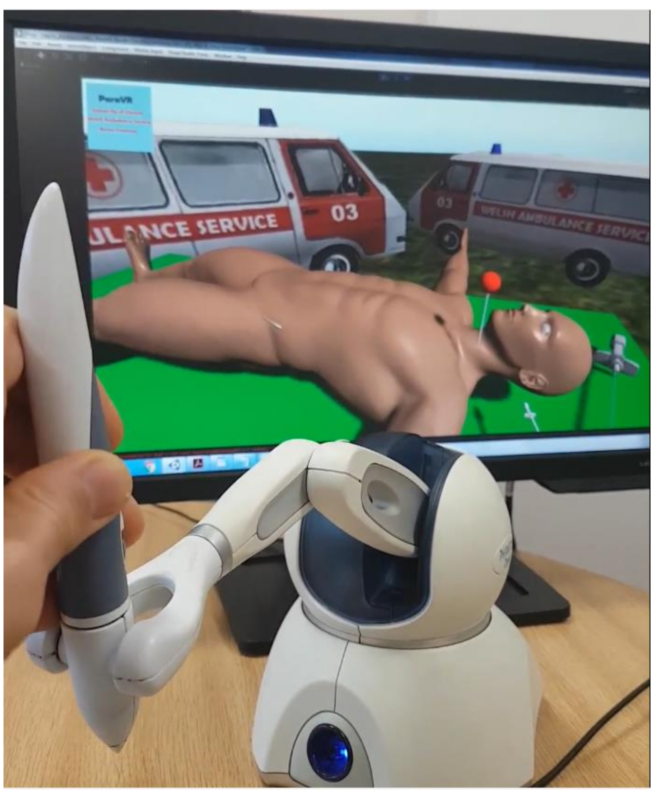

Figure 3. Geomagic Omni 6-DOF Haptic Device with the ParaVR simulator of Needle Cricothyroidotomy.

For haptic feedback, the VR simulator has also been combined with a Geomagic Touch haptic device (Fig. 3). This provides a six degree of freedom haptic interface. The stylus can be move with pitch, roll and yaw and the virtual needle follows. This provides an intuitive interface for needle insertion. When the training simulator begins, the user can then see a virtual model of the needle which moves in relation to the physical haptic stylus. The Omni stylus and the Oculus hand controllers can be used simultaneously (Figs. 3, 4) The Omni stylus is displayed on screen as a moving needle and the Rift controller is displayed as a 3D hand which can pick up needle objects from the scene.

During testing, the simulator has also been connected to the Novint Falcon haptic device. This provides three degrees of freedom. With the Novint falcon, the needle is fixed perpendicular to the torso for a 90 degree entry to the chest. The Novint Falcon device is no longer commercially available and nor are the supporting device drivers for modern versions of Windows. This makes interfacing it with other head mounted displays become increasingly difficult. The Novint Falcon couldn't be used if the simulator is to be commercialized as there would no longer be a supply of the Novint hardware device.

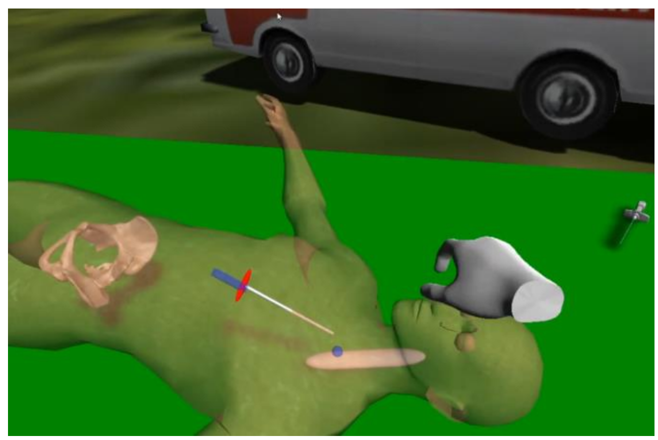

Figure 4. VR model of ParaVR with Omni and Oculus Hand Controller.

B. Virtual environment 3D software development

The virtual environment for the paramedic simulator was designed to reflect the spontaneous nature of emergencies which could occur in unpredictable locations such as at the scene of a car accident at the roadside (Fig. 4). The environment was developed using 3D modelling software.

Additionally, the virtual training simulator was ported onto the Google cardboard VR platform (Fig. 5), to demonstrate the feasibility of paramedic training using a smartphone, without the need for a dedicated PC or HMD. However in the Google cardboard version, the haptic device and Oculus hand controllers cannot be used and so the virtual model of the needle can only be picked up using a vision based interface which has less flexibility.

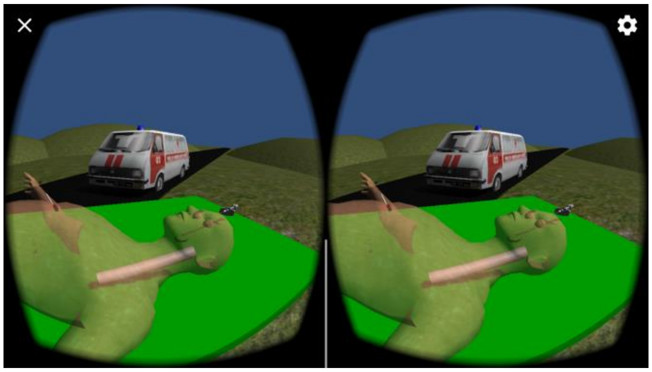

Figure 5. The virtual reality models in stereo Google Cardboard HMD.

When the VR simulator first begins, a ParaVR splash screen is displayed to the user within the VR headset (Fig. 6).

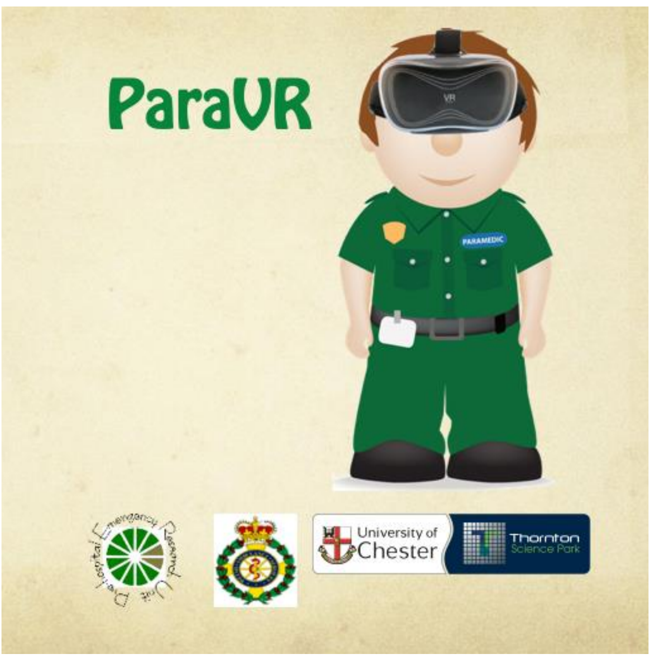

Figure 6. Splash screen displayed to the user within VR simulator.

III. EVALUATION AND TESTING

A. Feedback from Paramedics

Feedback has been provided by input from various paramedics and organization. This has included British Heart Foundation Cymru, Wales Ambulance Service NHS Trust and College of Paramedics (UK).

We are working closely with our supporting team members in the NHS and key stakeholders to demonstrate our developed system and gather feedback. This phase will gather critical evidence and evaluation. This will further demonstrate the commercial potential, applicability and potential of the developed technology in the NHS.

B. Future Work

We are aiming to complete further in-depth clinical evaluation. This could be strengthened by having support from other paramedics, services, trusts or medical companies, supporting clinical evaluation of the developed prototype. Clinical evaluation may recruit two cohorts of trainees, one cohort trained on the simulator and one trained in the conventional manner. Clinical evaluation would demonstrate efficacy and validity of the VR training simulator, reducing risks for future NHS commercialization.

ACKNOWLEDGMENT

Funding was received to support the ParaVR project from Bevan Commission. Funding was provided from Health&Care Research Wales Pathway to Portfolio 2019. The ParaVR was also winner of the 2018 Welsh Health Gadget Hack. The project was highlighted by the Universities UK top 100 lifesaving projects 2019. The Royal Academy of Engineering provided a Research Fellowship funding award to Dr Neil Vaughan.

REFERENCES

[1] Universities UK (2019) Highlighting ParaVR in top 100 lifesaving projects www.madeatuni.org.uk [Accessed 24th July 2019].

[2] Conradi, E., Kavia, S., Burden, D., Rice, A., Woodham, L., Beaumont, C., ... & Poulton, T. (2009). Virtual patients in a virtual world: Training paramedic students for practice. Medical Teacher, 31(8), 713-720.

[3] Cochrane, T., Cook, S., Aiello, S., Harrison, D., & Aguayo, C. (2016). Designing virtual reality environments for paramedic education: MESH360. In Ascilite2016: 33rd International Conference of Innovation, Practice and Research in the Use of Educational Technologies in Tertiary Education (pp. 125-135). Ascilite.

[4] Perkins, G. D. (2007). Simulation in resuscitation training. Resuscitation, 73(2), 202-211.

[5] Vaughan, N., Dubey, V. N., Wee, M. Y., & Isaacs, R. (2014). Parametric model of human body shape and ligaments for patient-specific epidural simulation. Artificial intelligence in medicine 62(2), p129-140.

[6] Li, S., & Setlik, J. (2018). Critical Procedure Skill Maintenance Through Simulation Based Curriculum in Pediatric Intensive Care Unit and Pediatric Emergency Medicine.

[7] Sawyer, T., & Strandjord, T. (2014). Simulation-based procedural skills maintenance training for neonatal-perinatal medicine faculty. Cureus, 6(4).

[8] Niles D, Sutton RM, Donoghue A, et al.: "Rolling Refreshers": A novel approach to maintain CPR psychomotor skill competence. Resuscitation. 2009, 80:909-12.

[9] Kovacs G, Bullock G, Ackroyd-Stolarz S, Cain E, Petrie D: A randomized controlled trial on the effect of educational interventions in promoting airway management skill maintenance. Ann Emerg Med. 2000, 36:301-9