Exploiting Virtual Reality Technology in Support of Collective Training for the British Army

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ABSTRACT

The British Army's Collective Training Transformation Programme (CTTP) is seeking collective training that is conducted in more dynamic and complex environments (physical, virtual and cognitive). It is developing a Future Collective Training System (FCTS) which includes the aim by 2023 to deploy high fidelity simulation across all Army locations. Pilot studies have been initiated, including an investigation of Virtual Reality (VR) technology. Supported by the UK MoD's Defence Innovation Fund, Bohemia Interactive Simulations (BISim) were selected in December 2018 to conduct an FCTS pilot study into the use of Virtual Reality (VR) in Collective Training to explore the strengths, weaknesses, opportunities, and threats of VR technology and its employment. Over a 3-month period, the pilot considered the effectiveness, fidelity, practicality, architecture, scale, interoperability, infrastructure and mobility of VR. The pilot increased in scale and complexity culminating in 37 players in VR conducting training in a combined arms battle. It also investigated Mixed Reality (MR), cloud technology and training measurement and evaluation. The VR technology showed significant potential in support of collective training and conclusions and recommendations from the pilot are presented including those from the spiral development process.

1.0 INTRODUCTION

1.1 UK Land Collective Training

The British Army (Army) is seeking to modernise its collective training to deliver an effective and efficient combat-ready Army, optimised to meet the challenges of the evolving operating environment. This training modernisation will be through the Future Collective Training System (FCTS) being delivered by the Collective Training Transformation Programme (CTTP). The challenge is to produce a collective training environment that emulates the complexity, sophistication and sometimes disorder of the dynamic operating context and is also adaptable to reflect the changing threat and adversary capabilities. FCTS will make greater use of virtual training with a paradigm shift to 'virtual before live', where live training is used to consolidate and confirm skills learned in a virtual environment. All training will be instrumented, recorded, analysed and exploited.

Simulation and instrumentation systems will routinely be held and operated at unit level. The complexity of the contemporary operating environment will be represented by a Synthetic Operating Environment (SOE) which is coherent across the live, virtual and constructive environments.

1.2 The Potential of VR

For the past 20+ years, the training and simulation community has attempted to leverage commercial VR technologies but problems with helmet mounted display devices (HMDs) having insufficient resolution and field of view, excessive weight, and latencies and lag that can lead to simulator sickness. In some use cases the interaction with the virtual environment while "goggled in" is an ongoing challenge. However, the investment, pace of technology development and availability of VR has increased dramatically over the last 10 years and has seen VR migrate from the entertainment sector into many other different industries to be used for training and operational support. VR together with Augmented Reality (AR) and Mixed Reality (MR) have been identified as having the potential to provide better realism and immersion over what exists in desktop training and part-task trainers now, while at the same time reducing live training costs without compromising training experience. There are many examples of the latest VR technology being tested and trialled for training, for example for fast jet pilots, but less so in a collective training (CT) context. Nevertheless, VR technologies have significant potential to enhance land CT as they can increasingly provide high levels of immersion at relatively low cost and with a small physical footprint.

To explore the potential of VR and related technologies in land CT, the Army launched a competition in October 2018 to find a member of industry to lead the Virtual Reality in Land Training (VRLT) pilot study to take place in Q1 2019. In December 2018, Bohemia Interactive Simulations (UK) Limited (BISim) was awarded the contract to lead the VRLT pilot. The delivery of this pilot study commenced in December 2018 and was completed in April 2019 concluding with 37 players in VR.

2.0 AIM AND OBJECTIVES OF THE VRLT

The aim of the VRLT Pilot was "to identify the opportunities that Virtual Reality (VR) technology offers the Future Collective training System (FCTS)". Supporting this aim, the VRLT was to explore the strengths, weaknesses, opportunities and threats (SWOT) of VR technology and its application to Army CT, with a focus on the development of leadership, situation awareness, decision-making, communication and co-operation. Further, the UK Defence Innovation Unit funded the VRLT Pilot with a desire to disrupt the traditional acquisition system, directly work with industry to put technology innovation in the hands of the user.

3.0 DESIGN OF VRLT PILOT AND TECHNICAL INNOVATIONS

3.1 VRLT Pilot Approach

The Army required an agile, spiral development approach to the VRLT Pilot exploring capability through a series of 'Sprints'. Three sprints were agreed, each of which culminated in a technology demonstration within a one-week exercise. This provided an opportunity to integrate and evaluate progressively more complex technical innovations in the hands of the Army user, all within a formal training context. The baseline VR technology was the Oculus Rift with the virtual world generated by the UK's Defence Virtual Simulation (DVS) based on Bohemia Interactive Simulations' (BISim) VBS3 product. The 3 weekly Sprints were:

- Sprint 1 - "Crawl" – Building the foundation for innovation and testing the VR concept for Army CT for up to 18 users. This sprint baselined the use of VR capability, including demonstrating Oculus Rift and HTC Vive HMDs, a targeted high-fidelity grip controller; and automated After Action Review (AAR).

- Sprint 2 - "Walk" – A demonstration at scale with up to 37 users in VR including EXCON. The Sprint included emulation of the Battlespace Management System (BMS), Cloud Technologies, in-VR briefing and AAR and High-Fidelity Virtual Vehicle Interiors.
- Sprint 3 - "Run" – Building on the scale of Sprint 2 with further technological developments, including Mixed Reality, Customized Avatar; Voice and Infra-Red Analysis of User Challenge; and an Instrumented Live 105mm Light Gun.

3.2 VRLT Pilot Training Design

3.2.1 Training Scenario and Vignettes

To ensure that the Pilot technologies were evaluated within a training context, the Sprints were established as formal training events, with six serials (vignettes) that met a set of training objectives and assessed against the Army's Collective Competency Objectives (CCOs). Each of the training serials consisted of a pre-briefing to the training audience, the exercise, data evaluation and after-action review. The training scenario itself was drawn from the US Army's Decisive Action Training Environment (DATE) and included Armoured Infantry with up to 3 Warriors (3 crew and 6 dismounts for each vehicle) and one Challenger 2 (CR2) Armour vehicle (4 crew) together with supporting indirect fire and ISTAR. Common vignettes were used for all Sprints (Figure 3-1) and were scheduled to ensure that the training became progressively more challenging through each weekly Sprint (Table 3-1). The Experimentation period was used to evaluate alternative approaches to the training and test innovations, including: An opportunity for the training audience to "play the enemy"; remove the VR HMDs to rely solely on computer screens; train in the Combined Arms Tactical Trainer (CATT) (networked simulators with high physical fidelity).

Figure 3-1: VRLT Vignettes 1-6

Table 3-1: Typical Weekly VRLT Sprint Plan

	Monday	Tuesday	Wednesday	Thursday	Friday
AM	Intro & Equipment Familiarisation	V1 - Road Move	V3 - Clear Rural	V5 - Defend Urban	V6 - Patrol
PM	EXCON Familiarisation & Practice Game	V2 - Advance to Contact	V4 - Clear Urban	Experimentation	

3.2.2 Health and Safety

Training design and instructions to the training audience on health and safety of the VR equipment was based on guidance provided with the Oculus Rift and the HTC VIVE Pro. Players were advised to 'lock' their eyes at a fixed point while turning in the virtual world, close their eyes when the camera is not controlled by head movements, and minimise head movement. If feeling nauseous, they were required to notify staff and as necessary, remove their HMD. No players had to withdraw from training in VR. Typically, they would be immersed in the VR environment for 30-60 mins for each vignette. However, whilst no one was physically sick during the pilot with over 825 individual person hours in VR, there was the potential to feel queasy with prolonged use, particularly when not in full control of the motion. The high fidelity 3D Warrior interior was found to reduce nausea over the low fidelity 2D for the Warrior Crew used in Sprint 1.

3.2.3 VRLT Architecture

The VRLT architecture evolved as the Sprints were scaled up and new technologies and innovations were introduced. For Sprint 1 there was a single architecture based on DVS running on networked thick client PCs with a games Server. In Sprints 2 and 3 innovations such as the CR2, "Cloud-in-a-Box" and the 105mm Light Gun were linked to the DVS network through the Distributed Interactive Simulation (DIS) protocol. Figure 3-2 illustrates the Sprint 2 architecture.

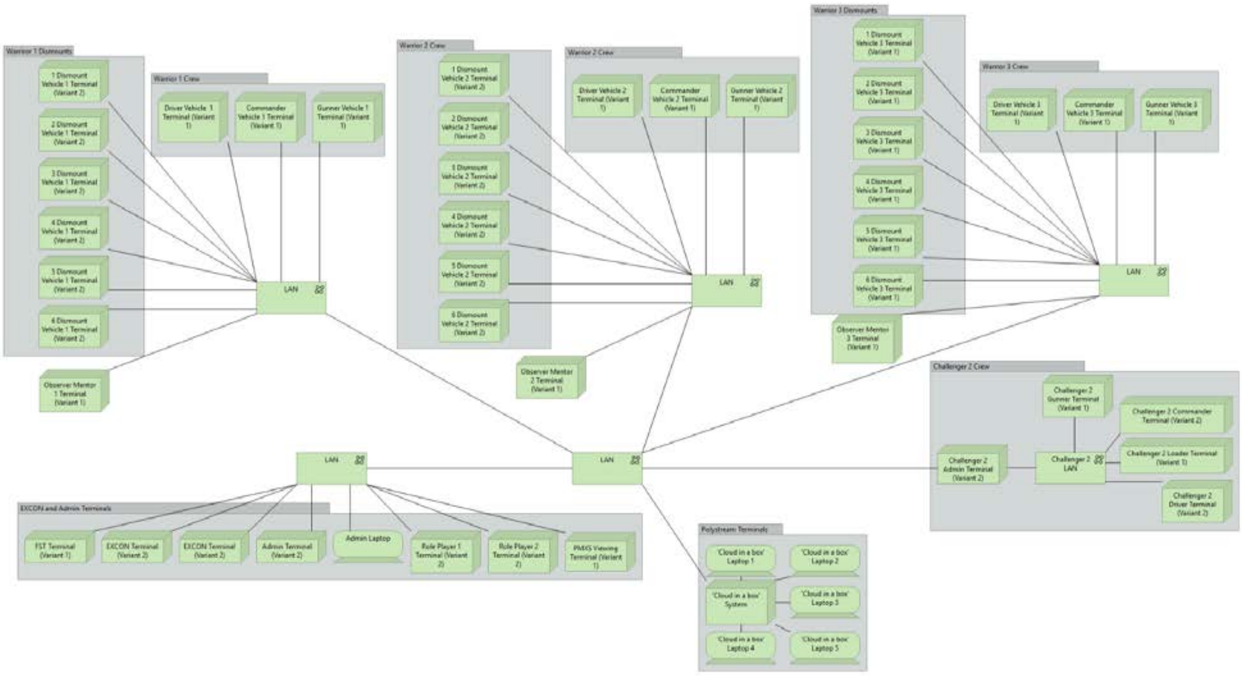

Figure 3-2: VRLT Sprint 2 Architecture

3.2.4 VRLT Infrastructure

The VRLT Pilot took place at Battlesbury Barracks, Warminster in one of the armoured vehicle garages. This provided an opportunity to test the deployability and ease of setting up quickly a training capability. The garage was also easily reconfigured and expanded as the Pilot progressed, including the introduction of a live instrumented 105mm Light Gun. The garage set up and configuration can be seen in Figures 3-2 and 3-3. Although each PC and associated equipment were for domestic use, the scale and characteristics of the total electrical load meant that the power had to be provided by a dedicated mobile power generator. This was considered to be a special case given the nature of power supply to the garage. The other challenge of the garage was temperature control with a condensation risk to equipment in very cold weather.

Figure 3-2: CR2 (Left); EXCON (Centre Left); 3 x Warrior Crew & Dismounts (Right)

Figure 3-3: Warrior Configuration – 3x Crew (Right) – 6x Dismounts (Left/Centre)

3.3 VRLT Pilot Approach to Innovation

To stimulate innovation and pursue the most promising ideas for improving both VR and wider CT, technical innovations were collected and triaged throughout the Pilot. Innovation ideas were drawn from all the technical proposals, the Pilot Steering Group (PSG), the pilot contractors and the training audience and reviewed on their merits and evaluated for its opportunity cost by the PSG. To maximise the number of innovations being demonstrated, the pilot was established as an 'Agile' development with three sprints. This approach targeted the development effort on completing and demonstrating priority innovations, adding more only when these had been achieved. The innovations were delivered through a single customer-industry interface that enabled rapid and timely decision making with the prime contractor managing all the other industry subcontracts through an "innovation as a service" approach. The Agile approach allowed for high-risk / high-reward ideas, ideas to be generated late-on, and continual learning. The VRLT Pilot Technical Innovations and outcomes are described in Section 4.

3.4 Collection of VRLT Evidence and User Perspectives

The collection of evidence and user perspectives was drawn from structured interviews, e-voting and an Observer Mentor (OM) workshop. Structured Interviews were used in Sprint 1, and E-Voting, which was considered more effective, was used in Sprints 2 and 3. This evidence was typically collected immediately after the vignettes. An OM workshop was held to assess the benefit and achievability of the measurement and evaluation innovations. Analysis of the evidence is described in Section 5.

4.0 VRLT PILOT TECHNICAL COLLECTIVE TRAINING INNOVATIONS AND OUTCOMES

4.1 Sprint 1 Innovations

4.1.1 High Resolution VR Headsets

HTC VIVE Pro headsets with higher resolution and framerates were tested, however it was found that the Oculus Rift headsets were sufficient to provide a highly immersive environment for the training audience.

4.1.2 Proximity-Based Voice Communications

The voice communications used in Sprint 1 simulated the loudness of the voice based on the distance between speakers in the virtual world. As this was the cause of some confusion to the training audience it was decided to use SimSpeak in later Sprints.

4.1.3 Data Capture, Storage and Automated Intelligent Analysis Engine

The Cervus HIVE tool provided training data capture, storage and automated intelligent analysis. Taking data from a wide range of sources (eg. quantitative DVS/VBS3 data, qualitative observer/mentor (OM) data) it provided visualisations and infographic charts (Fig. 4.1) to support the AARs shortly after the training event itself (less than 60 minutes). The training audience quickly became familiar with the HIVE layout and when it was explained in context by the OMs, they could more easily interpret the training data being shown.

Figure 4-1: HIVE dashboard showing Metrics from a Warrior crew during a training Vignette

4.1.4 Untethered Headsets

Using wireless technology-based VR headsets (HTC VIVE Pro) eliminated the need for cables and allowed trainees to stand and move freely within a designated area. They were not found however, to improve the training experience of the seated dismounted trainees using tethered Oculus Rift HMDs and the technology was not used in this role again in later Sprints 2/3.

4.1.5 Assessing Development of Collective Knowledge, Skills and Attitudes (KSA)

The HIVE approach captured the training audience's self-assessment of their status before and after the training using tablet-based questionnaires with the aim of judging and reporting competency development. The purpose was to assess the development of collective knowledge, skills and attitudes (KSA) as indicators of leadership, situational awareness, decision making, communication and cooperation competencies. The value of this approach was limited by the errors in the data collected.

4.1.6 Use of Targeted Fidelity Grips

Warrior vehicle gunner station targeted fidelity grips were trialled to provide a realistic interaction for the trainee whilst still wearing the VR HMD (Fig. 4.2).

Figure 4-2: Warrior High Fidelity Gunner Controller with Trainee Using VR HMD (L) and Warrior Driver COTS Steering Wheel and Accelerator and Brake Foot Pedals (R)

When the Warrior gunner controls was not physically stable, calibrated or not as the real vehicle, the grips caused issues that prevented the users from conducting their roles and detracted from the CT. These issues were compounded by the VR which did not give the user feedback as they could not see the position of their hands. In these cases, the generic Xbox / keyboard interfaces were preferred for Sprint 2/3. In the case of the Warrior driver, the Commercial Off the Shelf (COTS) steering wheel, accelerator and brake foot pedals were more acceptable and were used through all Sprints (Figure 4.2).

4.2 Sprint 2 Innovations

4.2.1 2D/3D Battlespace Management System Emulation

Warrior and Challenger 2 Commanders were provided mission planning, situational awareness and blue force tracking through BISim's COTS Chalkboard Pro which is a tablet-based 2D/3D battlespace management application. It did not accurately emulate the actual vehicles' BCIP (Bowman Infrastructure ComBAT and Platform) but it was found to be adequate for training in Sprints 2/3.

4.2.2 "Cloud in a Box" Simulation Hosting

With FCTS driving towards greater employability and access to simulation, Polystream's "Cloud in a Box" was trialled in Sprints 2/3. This solution has no downloads, installs or local data allowing over-the-network distributed or centralised training solutions. The processing servers are stored within a deployable 'box'. During the VRLT demonstrations the technology ran 5 UAV stations with high fidelity graphics on inexpensive commercial business laptops. Due to the compressed timeframes for the pilot, the capability was not integrated with VR. The technology demonstrated the potential of a cloud-based, deployable service, where the footprint of the setup is not determined by the capability of the client machine graphics cards.

4.2.3 Use of VR in Pre-Training Briefing

VR technology was used to brief the plan and issue orders to the whole training audience via an avatar at the start of the training session. This had the potential to support distributed training events. However, the pre-briefing was of only a partial success as the limited behaviour and motion of the avatars and the lack of facial expression resulted in the only effective element of the communication being voice.

4.2.4 Use of VR In-Action by OMs

The VR environment offered the flexibility to enable an invisible observer to conduct inaction learning without disturbing the immersion of the wider training audience. However, the OMs preferred screens to the VR HMDs because the screens provided a wider field of view and could be more easily controlled without the risk of motion sickness. Further, the ability to provide coaching and mentoring during the exercise was limited in the same way as the prebriefing, with the only effective element of the communication being voice. However, with screens, the OMs were able to control their location and observe more than one area at once which meant that they began to change their way of working to focus on task or CCO specialism, such as use of firepower or exploitation of information and intelligence.

4.2.5 Use of VR the After-Action Review

VR HMDs were used to present replays and alternative perspectives to the training audience to illustrate and reinforce the learning points. Overlays and graphics were added to illustrate the After-Action Review, but these did not illustrate adequately the learning points and were hard for the training audience to interpret. The ability to provide after-action review during the exercise was limited in the same way as the pre-briefing, with the most effective element of the communication being voice.

4.2.6 "Play the Enemy"

DVS and the generic stations were rapidly re-configured (5 minutes) to allow Warrior crews to play the role of the enemy infantry fighting vehicle. This provided the training audience an opportunity, which was welcomed, to understand other force capabilities and limitations.

4.2.7 Automated Voice Analysis

Voice data was captured and passed to COTS voice to text software to transcribe the contents of the voice files, which combined meta-data from the audio file provided details of what was said, who said it, and the location that it was transmitted/received. The files were passed through the categorisation algorithm for content analysis and inclusion in the AAR. This allowed OMs to follow-up on cases of miscommunication or misunderstanding and particularly useful for larger exercises (Battlegroup and above).

4.2.8 High Fidelity Warrior Model

After feedback from Sprint 1, a new high fidelity internal and external model of the Warrior was developed and was successful in providing a much higher level of immersion and realism in the VR environment.

4.3 Sprint 3 Innovations

4.3.1 Mixed Reality

Mixed Reality (MR) technology was developed to enable the training audience to view their situational awareness application(s), whilst retaining VR immersion. This was achieved by taking a live webcam feed and rendering this in a set position in the DVS virtual world (Figure 4-3). This feed could be of the Battlespace Management System Emulation (on a tablet) or real maps or any video feed of value to the training audience. This allowed the training audience to interact with equipment and physical aids as they would normally, without the requirement to break their immersion. Without the appropriate situational awareness, the vehicle commander cannot effectively function. This innovation was seen as key to training collective competencies – situational awareness, decision making and cooperation.

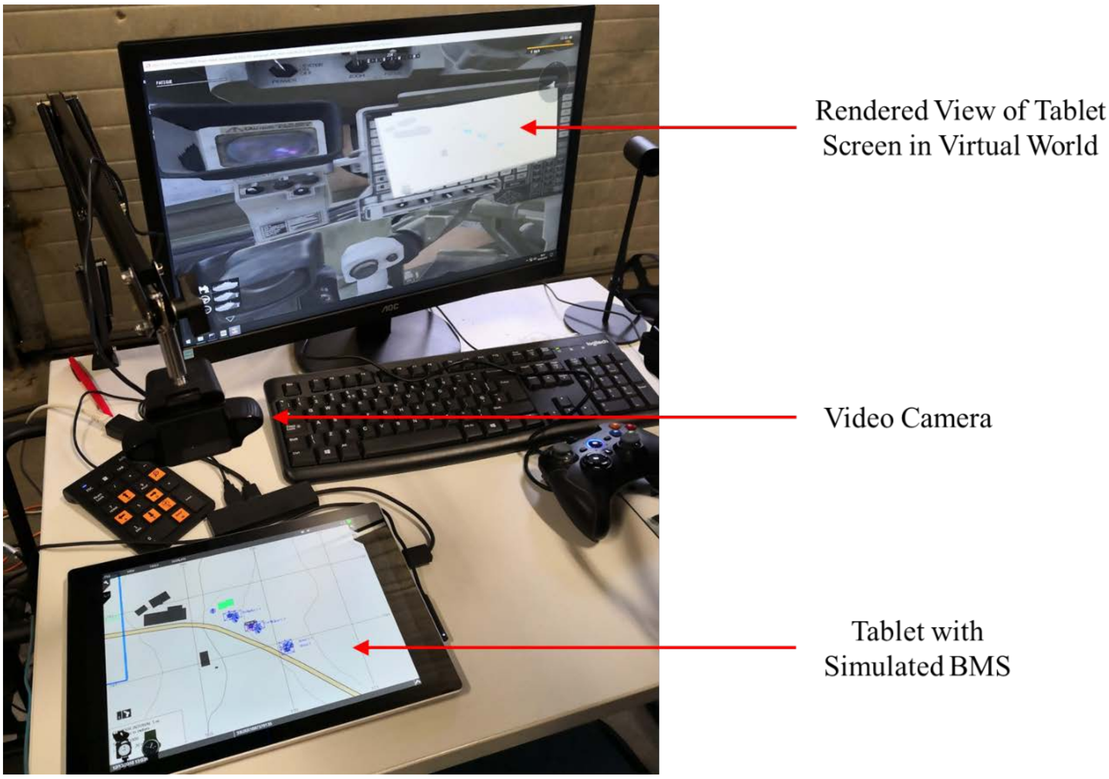

Figure 4-3: Mixed Reality with Real World Video Feed of Tablet Displayed Within the VR Simulation

4.3.2 Avatar Personalisation

Avatars in the simulation where personalised with realistic facial textures and features, height and Body Mass Index (BMI). The purpose was to allow individuals in the virtual world to recognise their colleagues. However, given the resolution of Oculus HMDs and obscuration of the avatar's face (helmet, chinstrap and goggles) the soldiers were not identifiable at ranges greater than about 20m in the virtual world. To enable recognition of individuals, the overhead identifier was preserved throughout. Other characteristics such as gait and BMI were thought to be more beneficial to training.

4.3.3 HIVE/DVS Application Programming Interface (API)

Previously HIVE had taken data from DVS via the DIS protocol. The development of an open API enabled more advanced data analysis, which for VRLT were triggers showing when specific events occurred (eg. BLUE force crossing set lines) and OPFOR suppression detection.

4.3.4 Instrumented 105mm Light Gun

A live 105mm light gun was instrumented such that when fired with dummy rounds in the real world its effects were experienced in the virtual environment. This demonstrated the utility of blending live instrumented equipment and VR, enabling the gun crew to train procedural firing exercises whilst integrated with the broader VR-based training audience and higher command elements.

4.3.5 Communication Analysis and Workload Monitoring

An unobtrusive means of automatically capturing insights into the non-technical skills of communication and teamwork was introduced. The software collected communication data and produced a chart that showing factors contributing towards communication effectiveness providing an objective metric for communication that can be blended with other metrics to support the measurement of competency development within CT (Figure 4-4). Individual physiology measurements (temperature differential across the face) were also unobtrusively collected to assess the workload of an individual over time. This provided real-time feedback to the EXCON on the immediate response of the training audience to the cues and stimulus and challenge within the training scenario (Figure 4-4).

Figure 4-4: Communication Effectiveness Analysis (L) and Workload Monitoring (R)

4.3.6 VR Out of the Hatch

A helmet-mounted VR HMD was introduced that could be worn and easily removed (Figure 3-6). This allowed the participant to engage/disengage the VR headset during training to easily switch between VR, for example looking out of the armoured vehicle hatch, and real-world equipment such as situational awareness tablets and high-fidelity controls. This provided a simple inexpensive way to introduce mixed reality.

Figure 4-6: VR HMD that can be Easily Engaged/Disengaged

4.3.7 Challenger 2 (CR2) Gunner Loader

The CR2 Gunner was able to practice the procedural element of loading the CR2 round and charge from the box into the breech in a Unity-based virtual world within the overall DVS simulation. This innovation was seen to be useful to practice the loader procedure. However, it was not seen as necessary for training collective competencies.

4.3.8 Assessing Execute Against the Plan

The actual training audience's actions were compared with a constructive simulation or previous exercise data. This technique was thought by OMs to have most merit when observing larger exercises.

4.3.9 In-VR ROC Drill

The training audience were immersed in a scaled down virtual environment during the ROC (Rehearsal of Concepts) drill, ensuring a shared understanding of the plan. This showed that VR could be used in the preparatory part of the overall training process.

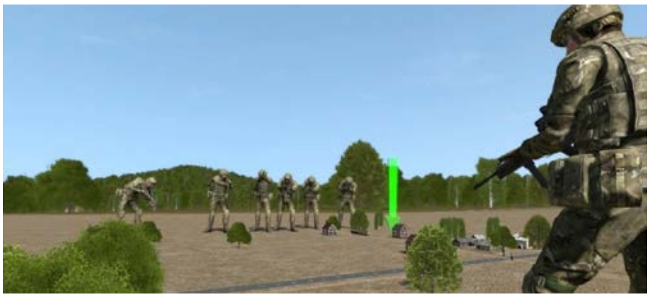

Figure 4-7: In-VR ROC Drill Within a Scaled Down Environment Model

4.4 Ranked Innovations

The innovations were reviewed and ranked by a group of stakeholders put into three tiers:

Table 4-1: VRLT Ranked Innovations

Tier 1	Tier 2	Tier 3
Classed as most beneficial to all arms sub-unit group training	Classed as beneficial but not a priority	Classed as not beneficial but could have wider benefits
* High Fidelity Model * Mixed reality * VR Out of the Hatch * High resolution VR headsets * Physiology/Voice Analysis * HIVE Training Data Analysis * Instrumented 105mm Lt Gun * Play the enemy	* Assessing Execute against Plan * Training from cloud in a * VR in action review * VR in AAR * VR pre-action brief * VR ROC drill * KSA Assessment	* Targetted Fidelity Grips * Untethered HMDs * Avatar Customisation * CR2 Gunner loader

5.0 ANALYSIS

5.1 Strengths, Weaknesses, Opportunities and Threats (SWOT) Analysis

An objective of the VRLT was to explore the Strengths, Weaknesses, Opportunities and Threats of VR in Army CT. The analysis was based on structured interviews, E-voting and workshops and the findings are in Table 5-1.

Table 5-1: VRLT VR SWOT Analysis Findings

Strengths	**Weaknesses**
• Can support significant numbers of trainees conducting CT in a large variety of scenarios • Communication and cooperation skills under pressure created through an immersive environment • High level of immersion reduces distractions from outside the virtual world • Situational awareness through manipulation of a range of aural and 3D visual cues • Easier to judge distance within virtual world than using the non-VR system • Decision making and judgements in a high-risk but ‘safe to fail’ environment • VR + MR supports training with situational awareness and battlespace management tools • Technology is highly versatile, reconfigurable, deployable, and cost effective	• Training skills where there is a need to develop physical psychomotor skills and the lack of haptic feedback and awareness of hand/body position limits the ability to train individual’s physical coordination • Physical fitness as both tethered and untethered headsets offer a limited motion not supporting effective training of individual fitness • VR manufacturers’ recommended time limits may reduce time in CT
Opportunities	**Threats**
• Cognitive procedural competencies can be trained where there is a need educate then	• The need to have a temperate environment to operate the VR headsets which mist up with

rapidly rehearse and repeatedly practice in a variety of scenarios, but physical psychomotor development is not required • Combined arms team working with dismounts operating alongside vehicles and other combined arms capabilities • Wider utility in education as well as training through demonstrating pre-briefing, ROC, briefing the plan, in-action review and AAR • Scale with ~40 users and ~100 deemed achievable • Flexibility to inject complexity and easily switch between configurations and scenarios • Deployability to point of need, with use of a location of opportunity with mobile power supply and network provision	condensation at low temperatures and sweat at high temperatures • The need to be aware of potential for VR sickness with use that does not conform to the manufacturer's guidelines

5.2 Findings Not Directly Related to VR/MR HMDs

The analysis also identified findings not directly related to VR but nevertheless of importance to training systems in general.

5.2.1 Communications

For participants to communicate they had to use training system voice nets. Users highlighted the differences between the way voice communication worked in the simulation and communications in the real-world. The dismounts were not able to tell when they could pass messages by voice (shouting). Participants also commented on the 'unrealism' of communications while using the Warrior vehicle intercom. The Command Net was perceived to be realistic. However, when Commanders were killed there was no way to transfer responsibility of their comms to the 2IC. Future deployments should add this functionality so that longer more complex scenarios can be exercised and be able to represent all forms of communications, i.e. face-to-face, live intercom and voice nets. This should include the ability for OMs to carry out 1-1 with individuals during training to reduce the break in immersion. For VR-based systems a button press for transmit would be preferred over a foot pedal whose position can be lost track of when in VR.

5.2.2 Simulation Artificial Intelligence (AI) Behaviour

In general, the behaviour of the enemy within the DVS simulation was deemed to be realistic. However, the CivPOP behaviour was viewed less favourably as it was sometimes difficult to distinguish between normal and abnormal behaviour, the implication being that it was difficult for the training audience to identify relevant indicators and cues to drive their behaviour. The issue may be more relevant for civilians because of the likely nuance/subtlety of cues (such as observing friendly forces) compared to the more obvious cues generated by the enemy (movement and fire is easier to recognise). For example, civilian-attired threats (so-called 'Dickers') appeared differently to the rest and hence, were easily identified.

5.3 Costs

A single unit of the VR set up was approximately £3000, which suggests for a deployable and configurable system it is a cost-effective approach to support cost effective training. This does not include other costs such as staff, maintenance and infrastructure although these would be applicable for any training system.

6.0 CONCLUSIONS

6.1 VR Technology Related Conclusions

6.1.1 VR can provide greater levels of immersion than using a screen-based virtual simulation because the training audience have a stereoscopic display to infer visual depth, stereo sound and can be less distracted as they cannot see or hear anything external to the simulation. They are not viewing the virtual world, they are in it.

6.1.2 VR has been successfully piloted in accordance with the manufacturers' guidelines on usage. Whilst a minority of the training audience did experience slight nausea on first use of the equipment, no one was physically sick and did not report any lasting side effects from partaking in the pilot.

6.1.3 Operation of up to circa 40 users in VR has been proven and scaling to 100 VR users is considered readily achievable, albeit with performance and stability risk with greater numbers of federated / dispersed users. Integrating simulation capabilities using open APIs directly, rather than DIS/HLA offer the potential to achieve higher system performance.

6.1.4 VR technology together with training system automation tools offer training at the point of need and flexibility to inject complexity, switch between training in alternative scenarios.

6.1.5 There are benefits in training dismounted team skills alongside fighting vehicles, using tethered VR and games console interfaces. The physical space requirements and safety constraints result in VR not being suitable for training untethered en-masse tactical dismounted activity.

6.1.6 VR can be used for conducting pre-briefing, ROC, briefing the plan, in action review and AAR but using screen-based systems also will remain necessary.

6.1.7 MR in concert with VR offers an approach to accessing battlespace management applications and situational awareness tools to train situational awareness competencies.

6.1.8 DVS (VBS3) is a capable of supporting a VR CT environment.

6.2 Other Training and Technology Conclusions

6.2.1 To train team skills (i.e. – cooperation, communication, situational awareness, decision making and leadership) in a task context, it is necessary:

a. To be able to enact the tasks with realistic behaviours and high visual fidelity 3D virtual models. Lack of realism appears to distract the training audience and can lead to false training; and

b. To provide simulated communications and battlespace management applications that behave as they would in operations.

6.2.2 To deliver effective training, it is necessary to complement the VR-based training with observation and analysis package to understand:

a. The workload of the training audience;

b. The ability of the training audience to read the ground, perceive cues, indicators and warnings present in the training scenario; and

c. The ability of the training audience to comprehend the situation and make decisions.

6.2.3 Deployable cloud technologies and virtualisation of the graphics processing are in future expected to:

a. Reduce the acquisition cost of VR client machines by not requiring high end graphics cards;

b. Improve the ergonomics of headsets with compute load transferred to the server; and

c. Reduce the costs of configuring training systems, with the simulation run from the server.

6.2.4 The agile, spiral development approach together with a culture of co-operation and continuous communication successfully put technology innovation in the hands of the Army user in only weeks from contract award. The industry "innovation as a service" approach also ensured an efficient customer/industry interface and the ability to rapidly introduce innovation into the Pilot.

7.0 RECOMMENDATIONS

7.1 VR should be considered for use in CT. It provides a more immersive environment than traditional 2D displays, creating a challenging environment to train teamwork, communication and coordination.

7.2 Further investigations should be undertaken to determine the physiological impact of being in VR for prolonged periods.

7.3 Targeted fidelity grips should be investigating further for use in a VR set up as they were not sufficiently user friendly, especially under the pressure of training.

7.4 Simulation application controls and schemas should be redesigned with a VR specific use-cases in mind to support natural and fluid control of virtual avatars and vehicles in the virtual environment.

7.5 When using VR, a suitable level of fidelity should be identified in terms of how rich the content of the simulation should be in addition to the behaviour of the entities and battlefield effects upon the virtual environment.

7.6 The fidelity of vehicle behaviours, vehicle 3D virtual models, and human behaviours are important to CT and should be researched and invested in to optimise training.

7.7 MR should be considered complementary to VR in a CT VR set up. Being able to use real world objects and natural actions (e.g. using a real world pen) enhances the training and user experience and negates the need to implement features in VR to compensate (e.g. a virtual pen).

7.8 A high priority should be placed on ensuring the emulation of the communications and battlespace management applications in CT is sufficiently representative.

7.9 Simulation interoperability standards should be re-evaluated for suitability in CT VR set ups. With increasing emphasis on VR for greater fidelity, realism, complexity, and how entities react and interact, standards such as DIS and HLA may not be appropriate in future. Alternatively, Open APIs may support improved interoperability, maximise innovation, flexibility and exploitation from the much larger non-defence VR markets.

7.10 More quantitative methods of performance measurement should be introduced into training. Non-intrusive performance measurement tools used in other industries should be brought into CT, eg. voice analysis and stress analysis using IR.

7.11 The agile, spiral development approach as demonstrated in the VRLT Pilot should be used to rapidly evaluate promising technologies in the hands of users.

6.0 REFERENCES

[1] D Orwin, BISim UK; Lessons learned from getting loads of people into VR for Collective Training - an overview and analysis of VR for Land Collective Training for the British Army; ITEC 2019

[2] Roke VRLT Final Report for the UK Ministry of Defence, 72/19/R/133/U, May 2019