Serious Gaming: A New Generation of Virtual Simulation Technologies for Defence Medicine & Surgery

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Abstract

Virtual Reality simulators for part-task surgical training have been in existence since the mid-1990s. Whilst the technology is still in its infancy as far as the surgical community is concerned, recent developments suggest a potential near-term revolution in the capabilities of surgical skills trainers, brought about as a result of significant and positive price-performance trends in computing hardware and software. In terms of the specific requirements demanded by military surgical specialists, it is a fact that opportunities to gain hands-on experience may be limited or lacking entirely until faced with the reality of the battlefield situation. There is therefore a need to engage surgical trainees in military clinical scenarios that require critical decision-making. Although the VR community has, of recent years, failed to exploit fully its own technological developments in the use of interactive 3D (*i3D*) for training, the computer gaming – more correctly *serious gaming* – industry is now taking over and has already found significant opportunities to produce affordable interactive simulators, hosted on standard PCs or laptops. This paper charts the rise and fall of Virtual Reality, particularly in the context of clinical and surgical training and reviews the important contributions being made by serious games developers. A recent case study, to produce a proof-of-concept Interactive Trauma Trainer, will also be described, part-sponsored by the UK's Human Factors Integration Defence Technology Centre, executed and co-sponsored by Blitz Games, and with subject matter expertise provided by the Royal Centre for Defence Medicine.

Keywords: *Trauma Training, Simulation, Serious Games, Human Factors.*

VIRTUAL ENVIRONMENTS: A BRIEF HISTORY

"Virtual Reality (VR) refers to a suite of technologies that support intuitive, real-time interaction with three-dimensional databases..." [(1)]

This definition remains as appropriate now as it did in the heydays of VR during the closing decade of the last Century. The definition is applicable to fields of endeavour that have evolved from the early VR communities, such as *Augmented Reality* (the real-time integration of virtual and real imagery) and *wearable computing*. The definition, which was originally published in a "state-of-the-market" report for the British Government's Department of Trade & Industry [(1)], was a conscious attempt to de-emphasise what many still believe are the two most important characteristics of VR (prerequisites, almost): computer graphics and "immersion" (Figure 1). The term immersion has been used to describe the situation where users allegedly experience a strong sense of presence in a virtual world, typically having donned a head-mounted, stereoscopic display (HMD) and special forms of clothing, such as instrumented gloves, suits, even mechanical exoskeletons delivering force and tactile feedback. Similar immersive effects can, it is claimed, be achieved by placing VR users within sophisticated (and costly) cubic or spherical enclosures, back-projecting visual imagery onto translucent enclosure walls, thereby enveloping their visual fields of view. Today, the quest for immersion continues, although it is unlikely that a credible immersive experience will be forthcoming until well into the second half of the 21st Century (and even this prediction is highly optimistic).

Figure 1: A Typical "Immersive" VR Setup From the 1990s

From an historical perspective, without doubt, the US played a significant and formative rôle in the establishment of a global VR market and community [(2)], although the UK contributed greatly to the accelerated uptake of the technology, especially in Europe [(3)]. Many researchers will acknowledge the 1950s contributions of such US pioneers as the late Morton Heilig with his *Sensorama* entertainment system – the "forerunner" of the single-person virtual arcade system [(4)] – and the 1960s helmet-mounted display efforts of Ivan Sutherland [(5)]. Sutherland's experimental system, called *Sketchpad*, was a computerised design tool that allowed users to design and manipulate graphical objects on a screen using a light pen. *Sketchpad* ran on a TX-2, the most powerful computer available at that time. It was not only a tool for visualisation; it was an operating environment in its own right. Sutherland's later work, described in *The Ultimate Display* [(6)], was based on research for the Advanced Research Projects Agency. Using a ceiling-mounted, cantilevered stereoscopic display headset boasting a 40° field of view - the *Sword of Damocles* - primitive 3D wire frame graphics with hidden line removal could be visually inspected from various directions by the user.

In the 1960s, an alternative form of VR had been the subject of much research by Myron Krueger, who had been investigating the human-computer interaction aspects of what he called "artificial realities" [(7)]. In 1969 Krueger became involved in a project known as Glowflow, creating illusions of perspective and slope by fitting out normal, darkened rooms with tubular lighting at various orientations. Through other, more interactive projects, Krueger's research led to the development of the *Videoplace* or *Videodesk* System. By back-lighting a translucent screen behind the participant (or participants, in the case of a networked system), body form could be distinguished from the background by video digitisers. A special computer processor translated the digitised "behaviour" of the participant into silhouette form which could interact with the graphical world and its constituent objects appropriately (including some early forms of "artificial life"). Today, examples of Krueger's pioneering developments can still be seen in commercially available products, such as the Vivid Group's *Mandala* system [(8)] – a "Video Gesture Control" interface deployed extensively for psychotherapeutic applications.

However, the VR technologies being marketed today have only been under development since the early 1980s, through pioneering ergonomics research into the natural human control of space robots ("telepresence") at NASA Ames, and in the development of the *SuperCockpit* concept at the Wright Patterson Air Force Base in Dayton, Ohio. The goal of the *SuperCockpit* work was to develop advanced, immersive virtual avionics and cockpit management systems to enhance information transfer, situational awareness and to protect pilots' eyes from the dazzle threat posed by laser weapons and nuclear airbursts (for example, the Visually-Coupled Airborne Systems Simulator [(9)]). In stark contrast, NASA's *VIEW* System (Virtual Environment Workstation) combined a low-cost HMD with an interactive glove equipped with magnetic spatial hand tracker and fibre optic finger flexion/extension transducers (the *DataGlove*, one of the products from the late VPL Inc. [(10, 11)]).

In the UK, VR first came to the notice of the British public late in the late 1980s, although commercial research teams who had been involved in developing the technology did not have the opportunity to present their work until the 1990 London Computer Graphics Conference. Even before then, VR projects had been under way, the first notable instance being in the early 1980s. The *Spatial Workstation*, in effect a "mobile television", displaying simple 3D wire frame images to the wearer of shuttered glasses, was developed by Jonathan Waldern, who went on to establish the VR games company W Industries (later the ill-fated Virtuality plc). In 1989, a VR and telepresence research programme was started at the then recently-opened National Advanced Robotics Research Centre (ARRC) in the North of England [(12)]. Following a research period of some 4 years, the Centre launched the first collaborative industrial VR initiative called *VRS* (Virtual Reality & Simulation [(13)]), bringing together organisations from such market sectors as defence, medical, retail, utilities, aerospace and petrochemical.

VR, SIMULATION & SURGICAL TRAINING

A paper such as this cannot cover all historical and contemporary aspects of VR and medicine/surgery under a single cover. Consequently, only a brief overview is presented here. The interested reader can obtain a more in-depth appreciation by selectively reading articles in the excellent IOS Press series of edited papers from the annual *Medicine Meets Virtual Reality* conferences [(14)].

During the late 1980s, many visionaries – notably those at the University of North Carolina and within the Department of Defense in the US – were developing the notion of the *surgeon of the future*. Future medical specialists would, they claimed, be equipped with head-mounted displays and other wearable technologies, rehearsing in Virtual Reality such procedures as detailed inspections of the unborn foetus or gastro-intestinal tract, the accurate targeting of energy in radiation therapy, even socket fit testing in total joint replacement. For many years, the US led the field in medical VR. In 1995, one of the leading practical advocates of VR in the US, Colonel Richard Satava, attempted to categorise achievable applications of VR in medical and surgical domains [15]. He saw developments in the fields of surgical intervention and planning, medical therapy, preventative medicine, medical training and skill enhancement, database visualisation and much more. Satava's original work, sponsored by the Advanced Research Projects Agency, ARPA, focused on large-scale robotic or *telepresence* surgery systems, which included using VR technologies to recreate the sense of presence for a distant surgeon when operating on, say, a battlefield casualty [16]. However, other research efforts began to emerge across the States (and Europe) using VR in a classic simulator mode to rehearse or plan delicate operations (for example, as is evident in certain ophthalmic operations). It was also shown that one could actually use interactive virtual imagery to back up *in situ* surgical performance through the projection of 3D graphics onto the operative site (*Augmented Reality*, as mentioned earlier) when, as early as 1993, a magnetic resonance image (MRI) had been taken of a patient and overlaid onto a real-time video image of his head [17].

During the late 1980s and early 1990s, the application of VR and associated technologies to the field of medicine and surgery steadily increased, with pioneering (if, at that time, somewhat optimistic) companies such as High Techsplanations (HT Medical) and Cinémed becoming responsible for fuelling the obsession with "making surgical simulation real" [18]. By the mid-1990s, advances in computing technology in the mid-1990s had certainly *attempted* to provide the means whereby sophisticated and comprehensive anatomical and physiological simulations of the human body could be constructed. From the digital reconstruction of microtomed bodies of executed convicts (e.g. the Visible Human Project [19]) to speculative deformable models of various organs and vascular systems, the quest to deliver comprehensive "virtual humans" using dynamic visual, tactile, auditory and even olfactory data was relentless. Yet, with one or two exceptions, the uptake of these simulations by surgical research and teaching organisations was (and still is) poor. One cannot attribute this failure to a lack of technological appreciation or foresight on the part of individual specialists or administrators within the target user organisations. The poor uptake actually stemmed from an equally poor understanding – sometimes on the part of simulation developers – of the medical needs and human factors requirements of the surgical users and trainees. Furthermore, it was all too often easy to forget that most medical organisations simply could not justify the excessive initial costs of so-called graphics "supercomputers" - not to mention crippling annual maintenance charges, depreciation and, in today's rapidly changing IT world, rapid technological redundancy.

The prohibitive costs and technological difficulties of implementing a surgical trainer based on comprehensive virtual humans using dynamic visual, tactile, auditory and even olfactory data prompted a number of VR groups to carry out a radical rethink of their methodological approaches. One example of such a rethink, MIST (Minimally Invasive Surgical Trainer, was designed by one of the authors (Stone [20]), and evolved from a comprehensive in-theatre human factors task analysis [21]. MIST (today marketed by Mentice of Sweden) is a PC-based "keyhole" surgical skills trainer that supports and documents trainees' acquisition of minimally invasive surgical skills in laparoscopic cholecystectomy and gynaecology [22, 23]. MIST presents the trainees not with high-fidelity 3D human body models, but with simple geometric tasks (Figure 2) that are designed to represent the surgical procedures evident in theatre (e.g. clamping, diathermy, tissue sectioning, etc.). In doing so, MIST avoids the potentially distracting effects (and negative skills transfer) evident with poorly-implemented virtual anatomy and physiology.

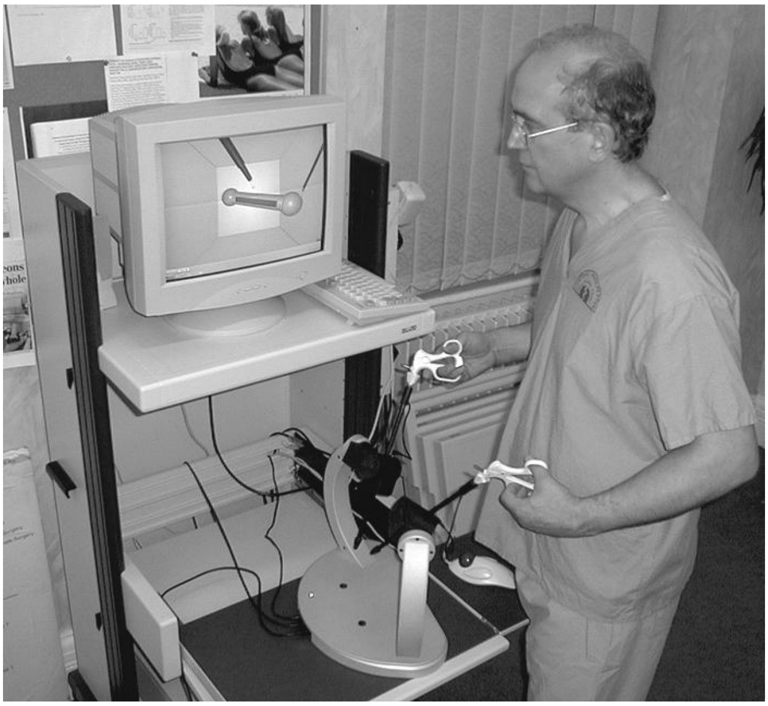

Figure 2: The Minimally Invasive Surgical Trainer

In many respects the MIST trainer set the standard for a range of surgical trainers (including Surgical Science's *LapSim* system). However, the key achievement of MIST was not so much the nature of the final VR product, but the fact that, by adopting a strong human factors approach from the outset, an affordable part-task, surgical simulator could be developed that delivered meaningful and, importantly, measurable interactive training content to medical students.

THE PROBLEMS OF VR IN SURGICAL TRAINING

Unfortunately, the VR community discovered quite quickly that its future could no longer be built on hype and false promises. Many of the early adopters, including those who were convinced they were facing a revolution in surgical and clinical practice, had their hopes dashed as the technology failed time and time again to deliver usable, affordable interactive systems for education, training and in-theatre surgical support. Apart from a small handful of successful products, such as MIST, many of the "high-tech" VR solutions for medicine and surgery were based on highly sophisticated graphics "supercomputers". These systems were not only very expensive; they also suffered from a fundamental problem in terms of training transfer. It soon became apparent that, despite the impressive supercomputer performance (albeit quoted on marketing material), the goal of "making surgical simulation real", as mentioned above [18], was unattainable. Although some of the marketing demonstrations were quite impressive, to the keen eye of the surgical user, the virtual bodies were less than "perfect". The material properties of organs and tissues were not quite right; virtual fluids and gases (e.g. blood, irrigation and diathermy smoke) behaved in ways that would not be evident in the real patient. Indeed, the anatomical and physiological content of many simulators did little to help foster practical skill acquisition. In fact, the distractions caused by irregularities in the virtual imagery probably led to more examples of *negative transfer* of skills from the virtual to the real.

This was but one problem faced by the VR community as the final years of the final decade of the 20^{th} Century progressed. The VR "industry" in the 1990s was dominated by a number of innovative technical personalities who suddenly found themselves thrust into the plc world, dominated by exit-hungry shareholders. The amounts of cash raised were quite phenomenal – not, perhaps on the scale of the "dot coms", but considerable nonetheless. What then happened was that, rather than focus on refining their existing product range to meet the needs of future commercial markets, some companies "lost the plot". Those with promising software toolkits started to concentrate on manufacturing VR hardware (headsets, dedicated computers, hand controllers, etc.) and those involved with entertainment VR hardware tried – too late – to target "serious" industrial users by redesigning their products in the hope of reducing their reliance on an increasingly competitive market. In general, the quality of these companies' principal products began to suffer and, for a while, the relatively strong user base they commanded in the early-to-mid-1990s started to lose faith. The fate of the entertainment VR industry was, to many, predictable in that the early attraction of the head-mounted display -based games in arcades soon wore off and the content could not be revitalised quickly enough to compete with the emerging multi-level "First Person Shooter" (FPS)-style games for PCs and video consoles.

Then, just at the point in the second half of the '90s when the commercial VR sector was experiencing its most fragile period, along came a multitude of academic establishments who, rather than work alongside the smaller, more successful (i.e. just-surviving) VR enterprises, went off at a tangent to compete for the "biggest and best" VR Centre (this was particularly problematic throughout the Europeans Union). At a time when the emerging needs of industry were generating real and sometimes desperately needed requirements for research and development, these universities were spending huge amounts of money on VR facilities, the output of which only a tiny handful of industries would ever be able to exploit. Sadly, this trend continues even to this day [(24)].

THE "EVOLUTION" OF *SERIOUS GAMES*

Long before today's home gaming revolution, and at a time when VR was just about to break out of its NASA and Department of Defense "homes" [(12)], the future potential of computer games to solve the accessibility and affordability problems of modelling and rendering tools for "serious" interactive 3D applications had already been recognised. In the 1980s, for example, basic developments in *modifiable* 3D games technologies for exploitation by communities other than those supporting home entertainment were well under way. For example, *Battlezone* – a successful 3D wire frame tank game published in 1980 for the Atari – was developed a year later into a serious game for the US Army to support training for the *Bradley* military vehicle (*The Bradley Trainer*). Whilst the mid-to-late 1980s was littered by a number of popular 2D and 3D games (e.g. the early *Space Quest* favourites, Rainbird's *Starglider* and *Tracker* and the legendary *Elite* space trading game for DOS), none of these were taken further by their own or third-party developers in the quest for affordable, repeatable training applications or as modifiable 3D simulations.

A major step forward in the history of interactive 3D was provided by *The Colony* – a first-person science fiction game created in 1988 by David Smith (who was also accredited with developing the first VRML Internet toolkit in 1995). *The Colony*, a combat and logical reasoning game, featured a crashed spaceship and a multi-level underground colony infested with aliens. The significance of Smith's game did not just centre on its revolutionary (for 1988) true 3D and "First-Person Shooter" (FPS) qualities. The underlying development software for *The Colony* was eventually commercialised as a 3D toolkit (*Virtus WalkThrough*) and was subsequently modified for use as a virtual scene planning tool for the 1989 20th Century Fox underwater science fiction film *The Abyss*.

However, despite these early activities, it was not until the 1990s that titles started to emerge that were to set the scene for a decade of games engine development. Such revolutionary titles as *Wolfenstein*, *Doom* (the first game to support a user editing function), *Quake*, *Heretic*, *Hexen*, *Unreal* (with its well-exploited "unrealed.exe" editor addition) and *Half Life* provided over 6 years of first-person action. The graphics of some of the early versions of these games may appear crude and simple today. But all of these games had one thing in common – an essential ingredient in their potential exploitation for serious applications. As long as the user's attention is captured and he or she is required to maintain a spatial and temporal awareness of the 3D situation in order to survive within the scenario, and as long as the simulation responds meaningfully in real time, the underlying engine can be used to develop a training simulator capable of delivering valid, reliable and believable content to highly motivated students of all ages and skills. Indeed a version of *Doom II* was used to train US Marines at the Marine Corps Modeling and Simulation Management Office ("McMismo"), Quantico Base, Virginia. Tom Clancy's *Rainbow Six*, mentioned earlier, despite being put on temporary hold following the events of September 11th, 2001, was actually modified using maps and scenarios requested by the US Army to train troops to fight terrorists in urban terrain.

Based on Epic's *Unreal* engine, *America's Army* was originally produced to allow young Americans to investigate military career opportunities (whilst reducing the cost of preparing and distributing printed information). *America's Army*, a distributable 3D game developed by the Moves Institute specifically for the US Army, had, by early 2005, developed into one of the most successful online games ever. Directed and managed by the U.S. Military Academy's Office of Economic & Manpower Analysis at West Point, *America's Army* was, in December 2003, the focus of intense cross-discipline interest at a "Serious Games Day", held at the Wilson International Center in Washington DC, the precursor event to a Serious Games Summit now staged annually.

The UK's effort in the adaptation of games engines for evaluating collective team working, procedures and communications includes *DIVE* (Dismounted Infantry Virtual Environment), developed by QinetiQ and Maverick Developments and based on the original *Half-Life* engine, recently "upgraded" to take account of latest developments offered by the *Half-Life 2* software development kit. More recently, a project sponsored in part by the UK's Human Factors Integration Defence Technology Centre (HFI DTC [(25)]), with subject matter expert support from the Royal Centre for Defence Medicine (RCDM) and significant development effort by Blitz Games (a leading independent UK games developer), resulted in a proof-of-concept *Interactive Trauma Trainer*, the technical case study focus of this paper.

Currently, the worldwide situation for serious gaming is looking very encouraging indeed, not just from a commercial perspective, but for the future of developers of all ages and backgrounds as well. The availability of 3D modelling and rendering tools at very low prices, even free from the Web, is something that those in the VR community could only have dreamed of as it struggled to make inroads into the serious applications markets of the 1990s – and, indeed, continues to struggle today.

SERIOUS GAMES & DEFENCE MEDICINE: THE INTERACTIVE TRAUMA TRAINER

When reading about the application of contemporary simulation techniques in defence training, one is regularly confronted with articles describing technologies supporting combat preparation, weapon familiarisation, flying skills or vehicle driving, command and control, and so on. Yet, one domain that is regularly absent from these international publications seems to be that of defence medicine and battlefield surgery. That this is so is rather hard to understand – after all, defence medical specialists have been in action in all branches of the Armed Forces since time immemorial. It is also hard to appreciate why certain branches of the defence medical community have not exploited the same technological developments evident within the institutions of their civilian counterparts, where, in just over a decade, the role of the surgical practitioner has undergone a significant transformation. A transformation from one characterised by skilful, one-on-one interactions with patients to one where such personal qualities have – allegedly – been "elevated to new heights", courtesy of a new generation of advanced, *empowering* technologies. Frequent references can be found today, in both the general and the medical press, to ground-breaking civilian developments in surgical robotics, in-theatre interactive 3D displays and simulation, speech recognition for critical theatre systems control, electronic skills trainers, telemedicine, *telecare*, *e-learning*, to mention but a few [20, 21]. Of these developments, simulation is one area where the defence surgical community stands to benefit extensively in the near term from parallel developments in related sectors.

So why has simulation not yet made a significant impact in the defence medical arena? Obviously, battlefield medical and surgical environments present a greater challenge to the developers of future interactive technologies than is the case in the civilian domain, including the need for very high reliability, very low maintenance, portability, rapid sterilisation and turn-around and so on. Of course these issues are also important to civilian hospitals, but given the field hospital environments in which battlefield medics are expected to work – often with a continuous stream of military *and* civilian casualties – the demands on equipment are huge. In instances of failed or damaged equipment, for instance, it is rarely possible to replace one item with another, shipped in from the adjacent operating theatre, or a nearby hospital. Another barrier to adoption has been cost – until very recently, medical simulators have demanded sophisticated and highly expensive computing facilities capable of handling detailed virtual human anatomy and physiology. Interactive devices, including haptic (force and touch) feedback controllers capable of approximating surgical skills – suturing, anastomosis, tissue cutting and so on – have also demanded considerable investment, although this situation is now changing for the better.

As a result of these barriers, the UK's Defence Medical service, represented by DMETA (Defence Medical Education & Training Agency) and the Royal Centre for Defence Medicine have, for some time, been viewing developments in synthetic environments/VR with some scepticism. However, recent world-wide events have highlighted an urgent need to develop low-cost, distributable training scenarios to help prepare trainee battlefield surgeons to make timely, life-saving decisions and to provide "refresher" training for specialist surgeons. These surgeons (e.g. urologists, paediatric surgeons, etc) may well end up practising in unfamiliar contexts, such as trauma and emergency medicine, treating military personnel and civilians alike, with the additional stress of the conflict environment. Earlier in 2005, an opportunity presented itself whereby the scepticism of these institutions could be challenged.

The *Interactive Trauma Trainer* (ITT) was the result a 6-month proof-of-concept project, the original aim of which was not so much to develop a surgical training prototype, but rather to demonstrate two key issues in the field of HFI for synthetic environments. Firstly, the importance of applying human factors/human-centred task analytic techniques early in the trainer development process, specifically the *RATaC* (Rapid Assessment of Tasks and Context) technique, developed by one of the authors (Stone [26]). This technique has been demonstrated successfully in the past with such projects as the Minimally Invasive Surgical Trainer, MIST (mentioned earlier [20, 21, 22, 23]) and in VR systems for close-range weapons training for the Royal Navy [27]. The Royal Air Force has also benefited from early task analyses, for example in the development of rear-door crew trainers for helicopter aircrew [28]. The second key issue was to demonstrate the use of games engine technology to deliver useable, affordable, accessible and distributable real-time interactive 3D training content at a level of interactive fidelity appropriate to the needs of the end user.

What is meant by "appropriate"? Given the visual and functional fidelities available with today's serious gaming tools, there is an understandable tendency for developers to stop at nothing to endow their simulations with what *they* believe to be the highest (and, therefore, the most appropriate) fidelity possible. Cursory glances at the effects in such titles as *Far Cry* and *Half-Life 2* demonstrate this. The impressive images of helicopter down-draught effects over water, vehicle explosions, weapon discharge and the use of "rag doll physics" to capture the flailing bodies of the recently deceased certainly focus the attention of the viewer. There is no doubt whatsoever that these effects constitute the best one has ever seen on a PC and far outclass anything the struggling low-end simulation or VR community has to offer. However, will these effects actually contribute positively to the development of relevant military skills and their transfer to real operational settings? Does it actually matter that the underlying particle physics engine is capable of supporting real-time water spray or the dynamic collision effects of barrels rolling down uneven terrain? Just as important is the question of *hyper-realism*. Are these wonderfully impressive visual and behavioural effects actually representative of what happens in the real world, or have they been exaggerated to achieve maximum player satisfaction? Just as the VE/VR community was plagued throughout its early existence by the proponents of "reality or nothing", so will the developers of future games engine-based simulations face exactly the same temptation. These issues are the focus of techniques such as *RATaC*, helping to deliver the following simple message to serious games developers:

"Don't deliver it because you can – deliver it because it's needed".

The Interactive Trauma Trainer project commenced with focused task analysis and storyboarding sessions involving the HFI DTC, the RCDM and Blitz Games. The task selected for study and implementation related to a Zone 1 neck fragmentation wound, causing pulsatile haemorrhage, airway obstruction and rapid patient decline. Interventional endotracheal intubation and cricothyroidotomy procedures using a cadaver were filmed and analysed, concentrating on graphical fidelity requirements, future training content and interactive styles (i.e. hands-on *vs.* animated sequences). Additional patient preparation and handling analyses were conducted during field hospital trials, hosted by 33 Field Hospital, Gosport.

One of the early decisions made on the basis of interaction with, and performance analysis of RCDM subject matter experts was that the ITT was not destined to become a surgical skills trainer (such as MIST). Rather than replicate basic surgical handling skills the user would already possess (e.g. instrument usage), the trainer would enhance the *decision-making* skills on the part of the surgeon – the casualty's life would be lost within 5-6 minutes if appropriate decisions were not taken and relevant procedures applied. Consequently the ITT not only exploits games engine software technology, it also exploits a typically simple gaming interface – mouse control for viewpoint change, option selection and instrument acquisition.

The *RATaC* analysis helped to define the end shape and form of the ITT, applying high fidelity effects only where they would add value to the surgeon's task. The analysis also ensured that highly dextrous tasks (e.g. use of laryngoscope, stethoscope, intubation tubes, Foley's Catheter, etc.; Figure 3) were committed to clear and meaningful *animation* sequences, rather than expect the surgical users to interact via a complex input-output device with limited haptic feedback. The patient's behaviour throughout is designed to help cue appropriate decisions. For example, the casualty can be given a *Glasgow Coma Scale* (GCS) rating on the basis of spontaneous eye opening, verbal utterances and motor capabilities. The end user's performance is scored on the basis of applying the right decisions at the right time – a summary chart is presented at the end of the trial indicating the decision sequence, the timing "window of opportunity" to make the decision and the actual decision time taken (Figure 4).

Figure 4: Interactive Trauma Trainer Screenshot

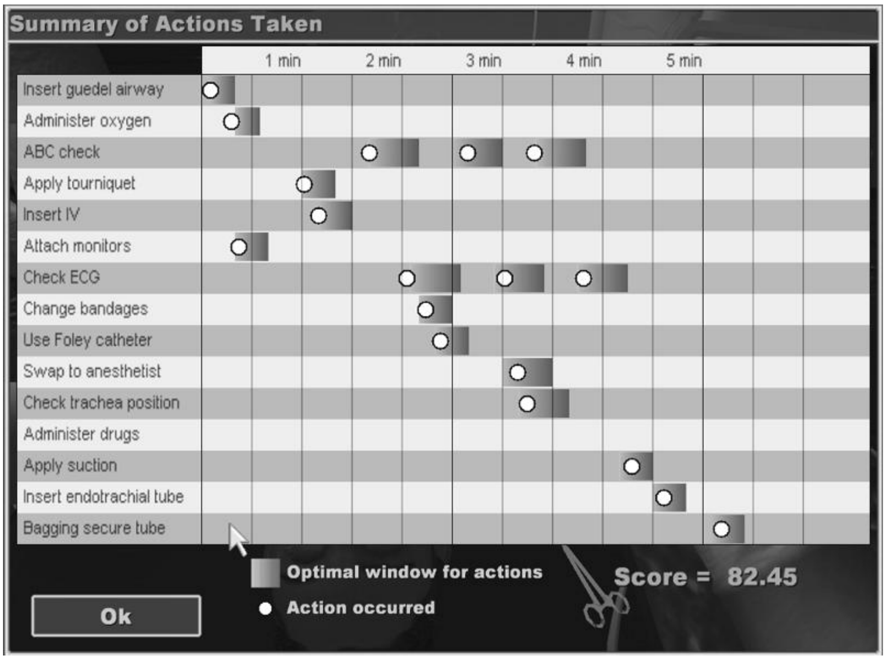

Figure 4: Interactive Trauma Trainer Performance Summary Screen

CONCLUSIONS

The ITT case study has provided some convincing evidence – in a very short space of time – to support the hypothesis that serious games and associated technologies offer enormous potential in the field of early surgical training and in the assessment of decision-making competencies and skills at various stages of the defence surgeon's career. In due course, it is hoped that the single intubation scenario developed in this project will be extended to encompass other operational aspects, from pre-hospital incident management to the ergonomic design and evaluation of new medical equipment and multi-purpose disposable instruments. The technology may even become appropriate for perceptual-motor skills training in surgery, once robust and affordable interactive peripherals become available, as they did in the early days of laparoscopic simulation and VR.

With most new and exciting technologies, there is often an early tendency for the pioneers and "evangelists" to become preoccupied with novel hardware and software and divorced from the requirements of commercial applications and user needs. Typically (witness the historical case for the VR community) the result is a painfully slow and often costly uptake process on the part of industry and commerce. "Technology push" outweighs both "market pull", even "end user pull", and sensible implementations based on sound ergonomics principles become few and far between. The successful adoption of serious gaming technologies, be it for commercial gain, for minimising time-to-market, for training, or even basic education, is not just a case of trying to impress potential users with the capabilities of an exciting technology. Understanding the needs and characteristics of the individual user and his or her organisation is essential to the future development of gaming – indeed any form of real-time interactive media – as a stable form of information technology (21). As has been seen earlier in this paper, it is, on occasions, all-too-easy to fall into the trap of striving for visual excellence or high fidelity at the expense of usability and content, not to mention losing sight of the needs of the end user altogether.

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