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Babak Akhgar *Editor*

Serious Games for Enhancing Law Enforcement Agencies

From Virtual Reality to Augmented Reality

Springer

Security Informatics and Law Enforcement

Series editor
Babak Akhgar
CENTRIC (Centre of Excellence in Terrorism, Resilience,
Intelligence and Organised Crime Research),
Sheffield Hallam University
Sheffield, UK

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Dedicated to Aryan H. Akhgar You are always in our hearts.

Preface

It is my privilege to present readers with this book on *Serious Games for Enhancing Law Enforcement Agencies*. This volume explores the lesson learned from a number of applied research projects in the context of serious games conducted by the Centre of Excellence in Terrorism, Resilience, Intelligence and Organised Crime Research (CENTRIC, Sheffield Hallam University, UK) in close collaboration with law enforcement agencies (LEAs) and colleagues across Europe. CENTRIC's mandate has always been to bridge the gap between the operational reality of policing and security and the original research and expertise brought by academia. This book bears witness to the potential of such collaborations to bring research excellence into reality and operational practice.

Recent years have seen a rise in the popularity of serious games for organisations tasked with the security and safety of our societies, be it police forces, military or first responders. The growing interest in serious games is driven by the twin challenges of increasingly complex security challenges and limited resources for LEAs. Serious games can support police organisations in addressing and preparing for many of the new complexities and insecurities. Their special value lays in offering realistic scenarios to understand, learn, comprehend and gain new insights into how to manage complex situations in the context of police operations.

For instance, many of the most harrowing events police forces and other first responders encounter are singular and rare incidents. Terrorist attacks by groups or lone actors such as the 2017 London Bridge attack and the 2019 Christchurch attacks in New Zealand or man-made disasters such as the 2017 Grenfell Tower fire in London spring to mind. How can we prepare law enforcement officers to deal with such situations, physically, mentally and practically?

Serious games enable LEAs to prepare and experience decision-making in complex and fast-changing situations within a safe and secure environment. Serious games can thus serve as an important knowledge management tool – enhanced by the fact that trainings can be conducted collaboratively across geographical and professional boundaries. Virtual and augmented settings make it possible for LEAs from multiple countries or personnel from different organisations to train together in a realistic scenario. This book presents a wide variety of serious games examples that demonstrate their potential for areas as diverse as handling the aftermath of terrorist attacks and preparing field personnel for life-threatening situations to enhancing cyber-resilience in local businesses to community engagement in the context of community policing.

Examples do not all stem from the law enforcement area – authors in this book strategically showcase serious games also from other areas such as healthcare, military, marketing, sports and arts. These areas can provide fascinating lessons for law enforcement applications.

Given that the resources of law enforcement agencies to keep citizens safe and secure have never been more keenly tested, police, governments and other security services require innovative, and often technological, solutions to face current and emerging security challenges. Serious games – and with them virtual and augmented reality applications – are one of the technological advances that enable police forces to better address the ever-changing threat landscape of today's and tomorrow's security domain.

Sheffield, UK Babak Akhgar

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Editor Biography

Babak Akhgar is Professor of Informatics and Director of CENTRIC (Centre of Excellence in Terrorism, Resilience, Intelligence and Organised Crime Research) at Sheffield Hallam University, UK, and Fellow of the British Computer Society. He has more than 130 refereed publications in international journals and conferences on strategic information systems with specific focus on knowledge management (KM) and intelligence management. He is a Member of editorial boards of several international journals and has acted as Chair and Programme Committee Member for numerous international conferences. He has extensive and hands-on experience in the development, management and execution of KM projects and large international security initiatives (e.g. the application of social media in crisis management, intelligence-based combating of terrorism and organised crime, gun crime, cybercrime and cyberterrorism and cross-cultural ideology polarisation). In addition to this, he acts as Technical Lead in EU security projects (e.g. the EU H2020 project TENSOR on dark web). He has co-edited numerous books on intelligence management, for instance, *Emerging Trends in ICT Security*, *Application of Big Data for National Security*, *Open Source Intelligence Investigation* and *Combatting Cybercrime and Cyberterrorism*. Prof. Akhgar is Board Member of the European Organisation for Security (EOS) and Member of the academic advisory board of SAS UK.

CHAPTER 1

Introduction: Serious Games for Law Enforcement Agencies

Babak Akhgar, Andrea Redhead, Steffi Davey, and Jonathan Saunders

1.1 Why Serious Games for Law Enforcement?

The term *serious games* refer to games designed with a specific function in mind such as professional training, education or awareness raising. This purpose sets them apart from games developed primarily for the entertainment of players (Djaouti, Alvarez, Jessel, & Rampnoux, 2011). Serious games can be used in a variety of settings that meet law enforcement agencies' particular needs and requirements. Whether it be the practical skills of a traffic accident investigator, training for forensic examination skills, to prepare for terrorism-related incidents, criminal investigations or leadership challenges – there is almost certainly a serious game that can be (or has been) created to complement the current training or educational curriculum. The main benefit of serious games is their extreme flexibility: They can be utilised within a classroom setting, in which the participants undertake the scenario individually, or trainees can share the same virtual world to learn

B. Akhgar · A. Redhead (✉) · S. Davey · J. Saunders
CENTRIC, Sheffield Hallam University, Sheffield, UK
e-mail: a.redhead@shu.ac.uk

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together. Serious games can also be used outside of a classroom environment and in distributed settings. Especially the latter can be beneficial, as it allows users to cooperate and train without having to be in the same location.

Perhaps the most important value of serious games for law enforcement agencies (LEAs), however, is to create a realistic scenario and situational awareness to understand, learn, comprehend and gain new insights on how to manage a problem-solving process in the context of police operations. Knowledge is an abstraction of a learning process (Akhgar, 2007). With their focus on realism and experiential learning, serious games are powerful tools for knowledge management (KM) processes within LEAs, whereby knowledge gained during the game can be applied in an actual operational environment. In this way, they can facilitate the transition between classroom learning and on-the-job training: By simulating a real-world situation, serious games train knowledge and skill sets that police officers require before they have to experience real-life situations first-hand, hopefully minimising the number of mistakes that occur in the field. Serious games also benefit more experienced personnel (Binsubaih, Maddock, & Romano, 2009). As most experienced officers are used to working in the field under time constraints, there is a chance that they develop 'bad habits' or shortcuts that may lead to mistakes. A serious game gives officers the chance to reassess their current knowledge and methodologies and to develop alternative ways to cope with the constraints of their job and, most importantly, learn from their mistakes in a safe and secure environment.

As these examples illustrate, serious games have a broad application and usefulness for the area of law enforcement. This book provides practitioners and designers alike with an overview of the possibilities of serious games as well as practical guidance on the process of serious games development – following the process from user requirements elicitation to evaluation. The knowledge and case studies presented can be used by law enforcement agencies intending to commission their own serious games and by game developers interested in collaborative pedagogy.

To make the application of serious games more concrete, in the following we present four areas with relevance for law enforcement in which serious games can be and already have been successfully employed.

1.2 Serious Game Examples for Crime Scene Investigations

A challenge for new crime scene investigators is the knowledge transfer between skills acquired in the classroom and their practical application in the field. Typically, this challenge is solved by on-the-job training in which a new investigator is paired with a more experienced officer. The expectation is that, as the new investigator works on live cases, any mistakes will be identified by the more experienced colleague who will either prevent or rectify the mistakes. Whilst on-the-job training is effective, it is also time-consuming and limited by the availability of sufficiently experienced officers.

Serious games offer an addition or even an alternative to the traditional approach of on-the-job training to prepare new recruits. They have further been explored for the re-training of experienced investigators to ensure continuation of best crime scene practices.

An example in this area addresses traffic investigations using a virtual reality (VR) environment (Binsubaih, Maddock, & Romano, 2006). The scene presented to the trainees involves a two-vehicle collision. The investigator is given 30 minutes to complete the investigation, including the drawing of the scene. The scenario and task are independent of the experience level of the trainee in the field. Engaging with the scenario, the participant should be able to park their patrol vehicle in an appropriate location at the scene, search for and identify clues, mark the position of the clues in order to secure them, use traffic cones to secure the scene, photograph the incident, take measurements that could be used to provide a reconstruction of the accident and draw the accident scene. After completing the session, the trainee fills in a self-assessment form on which they are asked to check which of the expected actions they think they have taken. This self-assessment can be compared with the actions logged by the serious game system. In the game, records are kept of the user's navigation choices, interactions and questions along with a few additional metrics. The analysis of the game metrics is based on a marking scheme approved by two traffic investigation trainers. If a participant does not score at least 70%, they are asked to replay the scenario.

An evaluation of the training (Binsubaih et al., 2009) showed that the first time the scenario was played the experienced investigators scored generally higher than the novice investigators. However, neither group achieved the 70% requirement; the average score of experienced investigators reached only 36% of correct actions. After a second play-through, the novices scored an average of 76% correct actions, whilst the experienced users scored 67%. This difference may be an indication that experienced officers used shortcuts developed during their work, which resulted in lower scores compared to the optimal solution. Another interesting observation was the initial low score for both groups after the first run through the game. A possible reason for low starting scores can be the lacking familiarity with the game system. To ensure that lacking VR experience was not the main factor, trainees had to fill in a written test before and after the experiment. Both groups improved their scores by over 20% in the second written test, i.e. after engaging with the serious game. Overall, both groups showed a significant increase in their scores after their second session with the serious game. This suggests that serious games can benefit both novice and experienced investigators, although in different ways (i.e. first time learning of new skills versus unlearning of potentially faulty behaviours).

Another serious game for crime scene investigators – entitled *Unravel the Mysterious Murder* – focuses on preparing a police cadet for forensic examinations (Drakou & Lanitis, 2016). In this particular scenario, an elderly lady is found murdered in her home with eight potential suspects. Eight potential murder weapons are hidden around the house (see Fig. 1.1), and each possible suspect had equal opportunity and access to the weapons. Once the trainee has found the potential weapons, they are expected to take them to the in-game forensic laboratory where they must follow the correct procedures to analyse them. This game trains four forensic investigation steps: (1) registering the evidence, (2) the collection of fingerprints from the suspects and murder weapons, (3) matching the fingerprints and (4) analysing and matching the blood.

Fig. 1.1 Scenes showing the eight murder weapons in *Unravel the Mysterious Murder* (Drakou & Lanitis, 2016)

The process users have to go through in order to perform these forensic investigations replicates the processes used by forensic departments in police authorities.

As in the traffic investigation study, the effectiveness of the game was evaluated using a questionnaire before and after trainees experienced the software (Drakou & Lanitis, 2016). The results of the forensic examination game closely matched that of the traffic setting, in that participants showed improvements after the game. The positive results across such different contents and scenarios suggest that serious games can be a valuable approach for crime scene investigation trainings.

1.3 Serious Game Examples for Training Investigative Interviews

An important element in the education of police cadets is the training in interview techniques. Investigative interviews are held for the purpose of collecting additional information about a case, questioning potential witnesses or victims as well as trying to obtain potentially incriminating information from a suspect. If the physical evidence within a case is weak, interrogations can provide vital additional information.

Trainings for investigative interviews are usually based on the PEACE framework (College of Policing, 2016), which consists of five phases: (1) plan and prepare, (2) engage and explain, (3) account clarification and challenge, (4) closure and (5) evaluation. The ability to manage these five phases well can 'make or break' an investigation. It is thus important that police officers receive effective training to ensure they perform these interview techniques to the highest standards.

Traditionally, training sessions for interviewing are performed with actors that take on the role of suspects, witnesses or victims. Depending on the scenario at hand, these actors can portray different personalities, so that trainees can experience the range of emotions and reactions they may have to contend with in a real interview. A downside of this approach is that it depends heavily on the quality of the actors, i.e. the availability of highly skilled actors who understand the nuances of the interviewing process and situation. An inexperienced actor may not be aware all of the nuances that cadets need to learn. The costs and time investments for actor-based trainings can thus spiral dramatically, not least because officers can only train one at a time.

Serious games can offer cost- and time-efficient alternatives, allowing multiple students to train simultaneously whilst an instructor oversees the training. Automated reports created from trainee's in-game behaviour can provide additional input for reflection and add a further possibility for feedback. *Virtual-Suspect* is an example for a serious game for investigative interviewing developed with the help of criminology researchers, psychologists and police departments to provide multiple scenarios based on real cases, which also offers a range of personalities as interview partners (Dias, Aylett, Paiva, & Reis, 2013).

A criticism sometimes voiced against using serious games to train investigative interviewing is that the simulation of responses may not always be realistic for the personality in question. In order to assess the effectiveness of serious games against human responses, Bitan, Nahari, Nisin, Roth, and Kraus (2016) compared the behaviour of three people in an interrogation situation. One worked with a human actor, another experienced the *Virtual-Suspect* simulation with a specialised response selection model and the third used the same serious game but with random responses. In each situation the participant had 30 minutes to attempt to get the suspect to confess. The three interviews were recorded, and their transcripts provided to a further 24 participants. The participants in the second phase of the experiment received all three transcripts and were asked to read through them carefully. Whilst the simulation with random responses was picked out easily as being from a computer, the participants were unable to differentiate between the interview based on the specialised game-based selection and the interview conducted with the human actor. This suggests that serious games using appropriate response models can be similarly effective as hiring a trained actor.

1.4 Serious Games for Communication and Collaboration Skills

Law enforcement personnel often operate under high pressure in stressful situations, which can impact negatively on their communication, teamworking and decision-making. These 'soft skills' are another area of focus for serious games. An example for 'soft skill' training is a serious game from the *DREAD-ED* project developed to teach communication and team building skills using a collaborative board game (Linehan, Lawson, & Doughty, 2009). The game has three timed rounds during which the players must assemble a team with the task to control an emergency situation. In this game, each player has a unique role that allows them to alter the game in subtle ways. Also, each player has six cards, each of which represents personnel they can use or exchange with other players. The key lies in communicating and collaborating during the allotted time to ensure the right people receive the correct cards (i.e. personnel), whilst still adhering to the game mechanics. Throughout the game, new pieces of information can be given to the players to simulate a developing situation and add an element of uncertainty. The *DREAD-ED* game was also transferred into a computer game to allow for multi-location training (Haferkamp, Kraemer, Linehan, & Schembri, 2011). The basic mechanics in the computer-based version remained the same, although the use of an instructor became optional. Haferkamp et al. (2011) tested the computer version on students and managers under controlled conditions and found that both groups experienced improvements in social skills.

1.5 Training for Terrorism Response

Increasingly, law enforcement agencies have to consider the likelihood of a terrorist incident. In consequence, the need to prepare officers for this eventuality has grown. One way to provide such training is the use of terrorism-based scenarios in which one team plays the role of the insurgents and the second plays the law enforcement side aiming to stop the first group.

Running realistic scenarios is, however, often associated with considerable efforts and costs. Not only do they require access to an adequate location (e.g. a hotel, train station or sports stadium), but another limiting factor is that only one specific scenario can be trained and tested at any one time. Further, in order to conduct a comprehensive debrief at the end of the training, multiple trainers must be present to follow the chain of events and take note of any areas for improvement.

Serious games can offer a realistic training experience, whilst again reducing some of the costs and resource requirements associated with scenario trainings in real-world locations. The largest investment is the specialised technology (e.g. Virtual Reality or Augmented/Mixed Reality headsets and computers) and the efforts involved in developing the scenarios. Yet, once both are available the costs to re-train and re-do exercises remain comparatively low. Also, multiple teams can train either separately or together at the same time, and often one instructor (instead of an instructor group) will be sufficient to oversee the training. This is possible as a computerised system can store data about participants' behaviours throughout the training, which can serve as foundation for detailed reports about actions officers took either individually or as a team. Whilst not necessary for most learning goals, the possibility for continuous data collection thus presents instructors with the chance to accumulate records with highly detailed information for the assessment of individuals as well as group interactions. Depending on the training requirements, a serious game can also use artificial intelligence (AI) to simulate the insurgents and different tactical locations.

Different designs are available: Some games expect officers to train in the role that they will have in a real-life incident; other games allow for two teams to play against each other, which gives officers the chance to experience terrorist incidents and their logic 'from the other side'. Both versions have merits, depending on the training purpose.

A serious game that allows for two teams to play against each other is the game *PROACTIVE* (Sormani et al., 2016), a turn-based game between law enforcement agencies and insurgents. The aim of the game is for the insurgents to successfully complete an attack against a specific location, whilst the law enforcement agency team tries to prevent the attack. To accomplish the attack, the insurgent team has to complete a number of preparatory phases before they can carry out the assault. First, the specific location must be observed four times either by vehicle or on foot to acquire sufficient information. After the information is gathered, the security of the location must be tested; only then can the attack be carried out. If the insurgent team manages to complete the attack, they reached their goal, and the game ends. Whilst the insurgent team performs these steps, the law enforcement team has to identify information or events generated by the activities of the insurgent team in order to correctly identify which location will be struck.

Although this sort of serious game can prepare officers for well-planned terrorism attacks, it does not necessarily help with unpredictable and seemingly random terrorist incidents. In this regard games such as *PROACTIVE* are limited, especially as they assume a turn-based logic (i.e. one side always has to wait until the other finishes their turn before being able to make the next decision). Transferring the game into a (virtual) environment, in which decisions of both teams can be put into motion simultaneously, would allow for more realistic encounters.

PROACTIVE focuses on the surveillance side of counter-terrorism. Another serious game, *Sibilla*, addresses the sheer amount of data received and the decision-making challenges that come with it. *Sibilla* was developed with the goal of training individuals involved in preventing terrorist attacks (Bruzzone, Tremori, & Massei, 2009). The game encouraged the sharing of information with a focus on improving the analysis skills to assess the gathered information and thus the quality of available information overall. By taking the role of a higher-level operator in a counter-terrorism organisation, the player attempts to understand what the insurgents are planning to do with the information they are collecting. *Sibilla* can be played either by individuals or groups with differing learning aims for both. For an individual, the game is primarily focused on training the individual's analysis capacity, whilst for a group the main focus is on team building, relationships and negotiation skills. The latter can be beneficial especially for players who do not know each other before the game and will have to learn to trust each other quickly.

The players both gather and connect various fragments of data, whilst also contending with limited resources in order to achieve their goal. In the multi-player version, each player controls a different agency with disparate budgets and resources ensuring the cooperation of all players. The players do not have all the necessary information; hence, a lack of cooperation could spell failure for the entire team. As the game progresses, more and more information is released and spread out amongst the agencies including dummy information. The players must decide which information to share and which to invest money and resources into to find additional useful information. A time limitation for the game means that players must act faster than the insurgents to stop the attack.

In the real world, terrorist attacks are usually not broadcast in advance, as is the case in *PROACTIVE*. Hence, *Sibilla* is probably a better example of how to use serious games to train for the specific skills that counter-terrorism efforts require. *Sibilla* has the further benefit in that it can be used by multiple people at the same time, even when the aim is to train people individually. The multi-player option allows collaboration between officers that are not stationed at the same location. Not only can this improve teamwork within the station, but it can also support building connections across the police forces as a whole. Both games, however, have equal merit as a learning tool and work to highlight the importance of knowing what the learning aims are in order to effectively develop a serious game for training.

1.6 Conclusions

As the above examples illustrate, serious games have a wide range of application areas and features that law enforcement agencies can benefit from. At the same time, serious games do not have to replace real-life scenarios or on-the-job training. Instead, they should be seen as enriching and complementing other training approaches, especially in the sense that they provide a link between the classroom, scenario-based trainings and real-life operations.

Serious games can expose trainees to more variety in terms of situations and scenarios and provide additional opportunities for training. If the same training is provided on a regular basis, they are further comparatively frugal in terms of costs and resource requirements. As long as the technologies are available, trainings can be conducted at any time independent from the availability of actors and potentially even instructors. Reports generated from in-game responses can serve for individualised feedback from instructors or for self-evaluations. Most attractively, serious games can both be used for training teams locally as well as collaboratively, i.e. in conjunction with other police forces or first responders worldwide.

At the organisational level, serious games can provide police forces with a baseline tool for their knowledge management strategy (KMS) capabilities. Akhgar (2007) defines KM as:

> a term that reflects an evaluatable framework for a complex matrix of thoughts, visions, ideas, insights, learning processes, experiences, goals, expertise, values, perceptions, and expectations or collective mental constructs of individuals that provides specific guidance for specific actions in pursuit of particular ends by utilising knowledge within organisational extended value systems.

Thus in an LEA context a serious game KM strategy can also be defined as a pragmatic, action-oriented and goal-driven process of transforming organisational knowledge from a current status ('AS IS') to the desired status ('TO BE') based on KM lifecycle processes which include knowledge collection at particular stages of the game, creation (new insights gained from the game), transformation (e.g. improving tactical decision-making) and collaboration (through collaborative gaming environments), visualisation using game-based scenarios, evaluation and operational and tactical model refinement and assessment. Lessons learned from training and decision-making processes during serious game-based scenario exercises can be analysed and evaluated in order to improve police forces' knowledge and insights about particular areas of interest and capabilities.

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PART I

Foundations

CHAPTER 2

Fundamentals of Serious Games

Nathanaël Maugard

2.1 What Makes a Game a Serious Game?

Games are an ancient form of expression, competition and learning, which have been embedded within cultures throughout the world for millennia. Whilst computer games are a modern form of game facilitated by technological advances, many of the core concepts and benefits of traditional games exist within them. Traditionally, cultures used games to understand concepts, reinforce knowledge or learn new skills; computer games are designed to capitalise on this behaviour using modern computer game technology.

With the emergence of mobile devices, the market for gaming has widened dramatically. Audiences, who in the past had little engagement with this industry, are now some of the largest target markets (an example are gamers over 50). This rise in popularity has also led to an increase in the demand for serious games. But what makes a game a serious game? The difference between games and serious games resides in their core purpose. A *serious game* is designed to respond to a functional need, to train, educate or raise awareness, whereas *standard games* are built purely for entertainment purposes (Djaouti, Alvarez, Jessel, & Rampnoux, 2011).

N. Maugard (✉)
CENTRIC, Sheffield Hallam University, Sheffield, UK
e-mail: nm9112@exchange.shu.ac.uk

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Whilst most games have elements of learning (e.g. strategies for gameplay or knowledge about the context of the game, for example, if the game is based on a historical event), unless the core purpose of the game is to educate, it would not be classified as a serious game (Breuer & Bente, 2010).

The concept of serious games predates the digital games industry. Tactical board game such as *chaturanga*, the predecessor to chess, has been argued to be one of the first serious games as it involved militaristic elements (Wilkinson, 2016). However, the contemporary view of serious games often revolves around digital games (Breuer & Bente, 2010). Connolly, Boyle, MacArthur, Hainey, and Boyle (2012) suggest that one reason serious games have gained so much traction is that modern society associates positive feelings with gaming.

For instance, research has demonstrated that regular gamers show significant improvements in attentional and visual perceptual skills (Boyle, Connolly, & Hainey, 2011). Serious games can facilitate knowledge acquisition as well as support perceptual, cognitive, behavioural, affective, motivational, physiological and social outcomes (Connolly et al., 2012). These effects are attributed to the fact that serious games discourage passive learning, in contrast to other forms of e-learning in which users are often simply presented with static information and then assessed almost immediately after. Dynamic game mechanics help to encourage and motivate users to engage with the learning and to actively apply their knowledge to succeed in the game (Arnab et al., 2015). Serious games can further provide a cost-effective alternative to complex and/or large-scale real-life training events.

There frequently is confusion between serious games and gamification. Gamification involves adding game mechanics to a training environment and is often used in e-learning. This technique can be applied to any form of training, for example, by adding leader boards, awards and a scoring system (see Chap. 5 for more details on simulation and gamification). Serious games follow a typical game structure but incorporate training and learning outcomes into the gameplay. Serious games tend to adopt one of two approaches: open environments in which players learn through problem-solving or a more guided/instructed-based approach (Wilson et al., 2009; cp. examples in Figs. 2.1 and 2.2).

Serious games find application for a multitude of purposes and in various sectors including law enforcement, education, health and persuasion. The following are examples of serious games that illustrate the variety of purposes and designs across sectors.

Fig. 2.1 Open environment in the AUGGMED serious game platform (cp. Chap. 6)

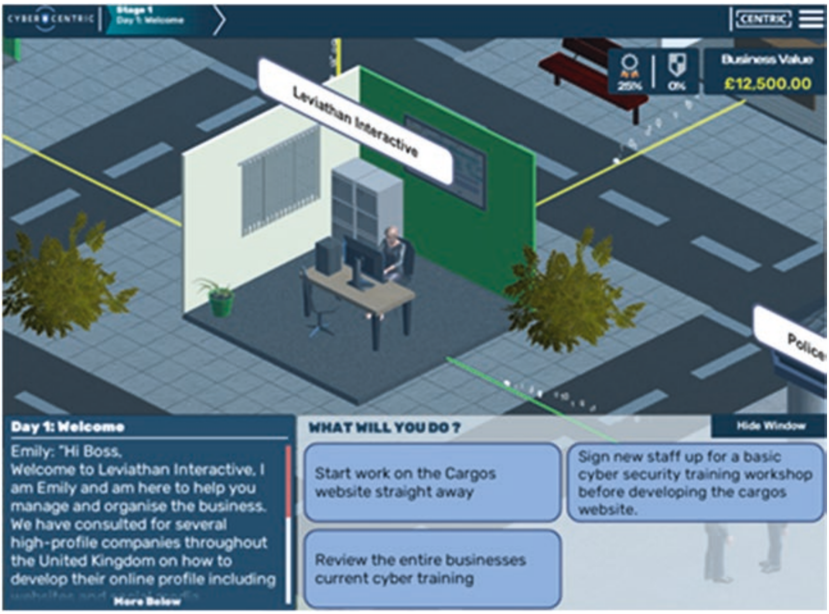

Fig. 2.2 Guided learning in *CyberCentric* (cp. Chap. 12)

2.1.1 Serious Games for Education

Educational games include edutainment, game-based learning and organisational-dynamic games:

- *Edutainment* – These games aim for an even balance between entertainment and education. Examples of games that could be assigned to this category are *Dr. Kawashima's Brain Training*, *Democracy*, *Food Force* and *Big Brain Academy*.
- *Game-based learning* – These are games that focus more heavily on specific learning outcomes and are often created for a specific training purpose.
- *Organisational-dynamic games* – These games are often similar to simulations. They encourage critical thinking and support transfer of knowledge from the game to real life as users gain experience in a training environment that is similar to their working situation.[1]

2.1.2 Serious Games for Persuasion

Persuasive games include advergames, art games and news games. This game genre aims to influence a player's behaviours, thoughts or perceptions. For this reason, persuasion games are often controversial; for example, military games such as *Call of Duty* and *Battlefield* have been criticised as recruitment techniques for the army. Whilst this was not their primary intention, the American Army did release a game for this purpose called *America's Army*. Another controversial type of advergames are car racing games, which are argued to encourage reckless driving. Examples of racing advergames include *Need for Speed Porsche Unleashed* and *Turbo Esprit*. Both companies named in the game titles used the games to advertise their cars.

Persuasion games have also been criticised for being counterproductive, as whilst some gamer types may find them motivating, others may feel demotivated and experience negative impacts. Orji, Vassileva, and Mandryk (2014) tested this assumption evaluating the efficacy of persuasive games on different gamer types in order to determine the best strategies to please the majority of gamers. Results showed that 'competition and compari-

[1] Serious game types and their importance. Retrieved from http://game-accessibility.com/documentation/serious-game-types/

son' and 'self-monitoring and suggestion' were on average the most effective strategies. However, these strategies still had a negative impact on individuals who identified as 'daredevil' and 'socialiser' gamer types. 'Simulation and personalisation' strategies did not have a negative impact on any gamer type, suggesting that these strategies and associated game mechanics can be employed to appeal to a broad audience.

Serious games for art are primarily produced for artistic value; game elements are mostly an addition. Art games have been exhibited in museums and are commonly used to educate about history and culture. The communicative nature of art games and the interaction within a game can make serious games a highly impactful medium, and as such they are frequently used to evoke empathy. An example that combines art and education is *Unpacked VR*, an application designed to experience art in a first-person view by individuals unable to see the physical exhibition (cp. Saunders & Gibson, 2018; see Chap. 3 for more details).

2.1.3 Serious Games for Health

This category of serious games overlaps somewhat with persuasion games. Games for health include exergames as well as games for healthcare. *Exergames* include the *Just Dance* series, *Lets Yoga*, *Wii Fit* and *Kinect Adventures.* These games often either involve motion tracking or additional accessories such as a dance mat or a balance board. Serious games are also used in healthcare. Here, they can act as a distractor to help with pain and can also be used for their therapeutic abilities (Wilson et al., 2009; see Chap. 3).[2]

2.2 Theories Behind Serious Games

In the production of a serious game it is important to consider how they work and affect players, including any psychological impacts. Design choices should thus be underpinned by learning theories to understand how to design an effective game. There is no theory that can be applied to every serious game; yet, it is important to be aware of existing theories and how they may affect decisions in the development of a serious game. Design choices start with the consideration of intended learning outcomes.

[2] UK-first research into use of virtual reality to help burns victim with their rehabilitation. Retrieved from http://sth.nhs.uk

2.2.1 Learning Outcomes

Learning outcomes are essentially the goals of any teaching activity. Predefined learning outcomes should drive how a game is developed; therefore, it is important to identify desired learning outcomes before the actual development of the game begins. Bloom's taxonomy of learning domains (Bloom, Engelhart, Furst, Hill, & Krathwohl, 1984; Krathwohl, 2002) differentiates between three outcome levels:

1. *Cognitive learning outcomes* – This learning outcome refers to knowledge gains. It is suggested that there are six cognitive processes to achieve cognitive learning outcomes: remembering, understanding, applying, analysing, evaluating and creating.
2. *Psychomotor learning outcomes* – This aspect refers to the learning of skills. Learning success is measured by assessing speed, precision, distance, procedures or techniques.
3. *Affective learning outcomes* – This aspect assesses changes in a user's attitudes, emotions and perceptions of the subject area. The five affective processes to achieve affective learning outcomes are receiving, responding, valuing, organisation and characterisation by value.

Serious games for skill-based learning have received especially avid attention. Skill-based learning outcomes can be categorised into the following groups (Simpson, 1972):

- *Perception* – The player is attending to a stimulus.
- *Readiness to act* – The player is preparing for action.
- *Imitation* – The player is responding with assistance.
- *Mechanism* – The player is responding through habit.
- *Complex overt response* – The player is responding with a coordinated series of actions.
- *Adaptation* – The player is changing responses to fit new situations.
- *Origination* – The player is creating new pattern needed to fit unique situations creatively.

2.2.2 Relevant Theories

The list below adapted from Wu, Hsiao, Wu, Lin, and Huang (2012; also Protopsaltis, n.d.) provides a brief overview of relevant learning theories underpinning the logic of serious games. These theories thus aim to explain why serious games may enhance learning. The first three theories are key psychological theories, which are foundational perspectives on human behaviours. The final three theories draw on these foundational theories extending upon ideas and concept these theories present.

Psychological Theories

- *Behaviourism* – The basis for this theory stems from Skinner's theory of operant conditioning (Skinner, 1990) and assumes that a learner is largely passive. That is, learners respond to stimuli in the game and learn due to rewards for the correct behaviour throughout the game.
- *Cognitivism* – In contrast to behaviourist views, cognitivist theory advocates that learning is a process of extending existing knowledge and is formed based on existing understandings of a subject. This understanding is facilitated by an expert or a teacher of the subject. Learners are encouraged to actively participate and interact with the game in order to learn. This theory suggests that older learners may find it harder to learn as they will already have an extensive understanding of certain subject areas, which will be more challenging to alter or extend (Mayer, 2003).
- *Constructivism* – This theory assumes that knowledge is actively constructed from past experiences and context (Geary, 1995). This theory can be applied to serious games that involve elements from reality, whereby the learner will be able to apply the lessons learned to various real-life scenarios. Constructionism extends the constructivism theory, adding that learners must reinforce learning by relaying the knowledge that they obtain (Ackermann, Gauntlett, & Weckstrom, 2009).

Learning Theories

- *Experiential learning theory (ELM)* – Lessons are learned entirely through direct experience. Based on this assumption, Kolb created a learning cycle (Kolb, 1984), which consists of the four elements: (1) concrete experience, (2) observation and reflection, (3) formation of abstract concepts and generalisation and (4) testing in a new situation.
- *Sociocultural theory* – Working together as a team often involves elements of imitating more experienced members. In this perspective, learning takes place largely through social interactions with group members including discussion, encouragement, support, reflection and analysis. The facilitator of the learning process will focus discussions on the key learning outcomes (Vygotsky, 1978).

- *Problem-based learning theory* – This theory assumes that collaborative learning through open-ended problem-solving helps knowledge transfer (Savery & Duffy, 1995).
- *Situated learning theory* – Learners must be presented with authentic contexts with respect to the learning objectives with relatable settings and situations (Lave & Wenger, 1991).
- *Full cycle learning* – This theory suggests that learning is a progressive cycle. The learning starts with an initial understanding. Practice or tests of this knowledge will enhance the understanding of the subject (Aldrich, 2002).

In addition to these learning theories, there are also cognitive psychology theories worth noting when designing learning platform.

Relevant Cognitive Theories

- *Cognitive load theory* – suggests that any learning needs to be concise. Any unnecessary information given to the learner could add to their cognitive load and may thus have a detrimental effect on their learning (Sweller, 1988).
- *Social cognitive theory* – Learning is influenced by three interrelated factors: behavioural, environmental and personal. Observation, reproduction, self-efficacy, emotional coping and self-regulatory capabilities underpin the learning process (Bandura, 2002).
- *Cognitive behaviour theory* – suggests that the cognitive triad can affect a person's learning. The theory is related to the positivity or negativity of individuals' perception of themselves, their environment and their future (Meichenbaum, 1977).

A comparison of the theories above shows that several elements overlap. In particular learning through experience, reflection and testing of knowledge appear in many of the cited approaches. Learning theories have been developed to aid the design of any educational content and to help create more effective learning materials. A meta-analysis found that serious game research often failed to make use of learning theories as foundations in development (Wu et al., 2012). The authors suggest that learning theories have been pushed aside in preference of focusing on technical functionality. However, with technologies maturing there is (and should be) an increase in the use of learning theories to guide the development of effective serious games.

2.3 Development of a Serious Game from Concept to Creation

To create an effective serious game can be challenging, as it requires developers to get the correct balance of components. For example, the game should have a balance of motivation and learning and should challenge learners without overwhelming them (cp. Chaps. 6, 7, and 8).

Finding this balance can be hard, as the way educational games are designed must adapt to the targeted population. In contrast to entertainment games, which tend to appeal to fairly similar audiences ('gamers'), serious games often need to appeal to a more extensive audience, especially as many are obligatory (e.g. in companies or professional education). At the same time, now that computer games have become so prevalent in households, it is important that games are engaging and challenging for a more advanced audience as well as generations with less exposure to computer games.

Bellotti et al. (2011) aimed to combine pedagogical principles and game mechanics to create a list of factors that should be considered when designing a serious game. The following list provides a short overview of important design considerations collated from earlier research conducted by Ketamo and Kiili (2010):

- Learning outcomes and game elements must integrate seamlessly.
- Learners must be triggered to reflect on and process relevant content throughout the gameplay.
- Make sure the player extracts relevant content. Developers need to be wary of displaying unnecessary information, as irrelevant information can add unnecessary cognitive processing. This can result in high cognitive load as information needs to be stored in working memory and thus impair learning.
- Social input should come either from teachers observing and providing a feedback summary or from game-based assessments.
- The game must be engaging and motivate players.
- The interface design should support engagement and appeal to audiences that may otherwise not be interested.
- Appropriate levels of interaction should be applied.
- Feedback should be clear and act as a motivator to encourage players to continue to play/learn with respect to the relevant learning outcomes.

- Ensure that the users are aware of their successes and failures within the game. This is vital so as to not confuse learning outcomes.

2.3.1 Game Attributes Supporting Learning in Serious Games

Below is a list of game attributes, which have been identified to aid learning in serious games (Wilson et al., 2009):

- *Fantasy* – Allows the user to interact without fear of real-life consequences, with the additional benefit of making users feel immersed in the game (Driskell & Dwyer, 1984; Garris, Ahlers, & Driskell, 2002). Research on fantasy has suggested that users are more interested in 'fantastical' serious games than in traditional classroom techniques or non-immersive games and are therefore able to learn material more readily (Cordova & Lepper, 1996; Habgood, Ainsworth, & Benford, 2005; Parker & Lepper, 1992).
- *Representation* – Involves the accurate physical reproduction of the real-world environment as well the reproduction of accurate cognitive processes in order to act and respond as they would in the real world. This allows players to relate easily to the game.
- *Challenge* – Without challenge there is a risk that learners will become bored with the game. The game should aspire to create 'motivational tension', that is uncertainty in the player's ability to successfully complete a task.
- *Sensory stimuli* – This relates to audio, visual and tactile effects used to provide feedback to the user. Introducing sensory stimuli can help to immerse the user better in the game.
- *Mystery* – Creating mystery will encourage learners to continue playing the game in order to 'fill the gap' in information.
- *Assessment* – It is vital in serious game developments to track the learner's activities, so an assessment of their learning can be given. Without assessment learners will not be aware of their progress, as the evaluation of acquired skills is an important aspect of learning.
- *Control* – This aspect refers to the ability of the learner to interact with the game and to influence how the game progresses. This will help the learner gain ownership of their learning.

A list of the game mechanics supporting skill-based learning can be found in Fig. 2.3 (based on Arnab et al., 2015).

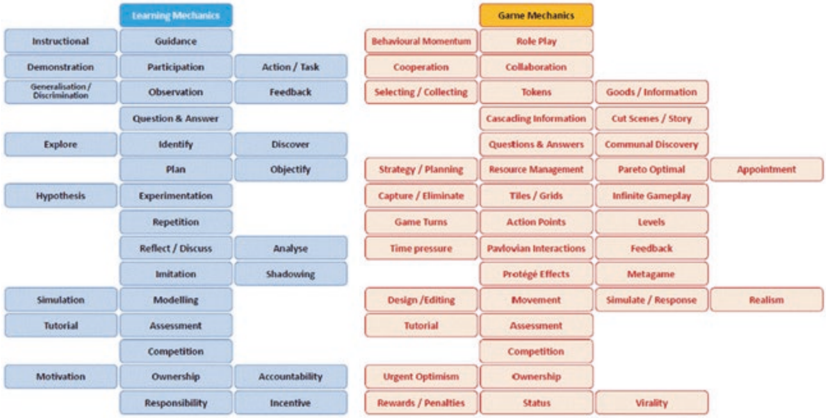

Fig. 2.3 Learning and game mechanics used as the basis to construct the LM-GM map for a game. (Based on Arnab et al., 2015)

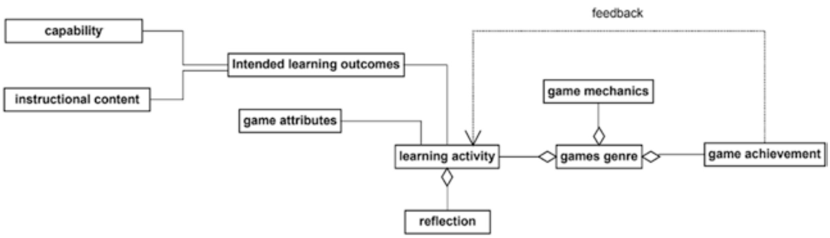

Fig. 2.4 Conceptual framework for serious games (Yusoff et al., 2009)

2.3.2 Serious Game Design Frameworks

Yusoff, Crowder, Gilbert, and Wills (2009) proposed a design framework for serious games. This framework suggests a number of elements that contribute to the development of serious games, including capabilities, instructional content, intended learning outcomes, game attributes and learning activity (see Fig. 2.4).

An alternative view is Winn's (2009) expanded design, play and experience (DPE) framework based on the mechanic, dynamic and aesthetics framework – a framework designed for the creation of entertainment games. The expanded DPE framework is an extension to support the for-

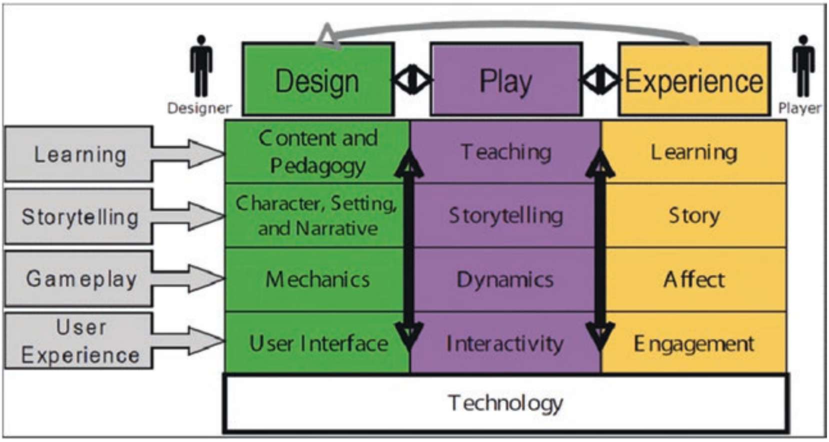

Fig. 2.5 Expanded DPE framework. (Based on Winn, 2009)

mal and iterative development of serious games for learning. It depicts games as a system implying a relationship between a designer (or a multidisciplinary team behind the creation of the game) and the players. The framework is divided into modules and submodules (see Fig. 2.5). The designer influences the design of the game only by planning out learning material, storytelling, gameplay and user experience. As a result of the playing process, users will have their own personal experience.

These two – and related – conceptual frameworks help serious game design teams to streamline their approach and make sure that the end product of their work will respond to the end users' learning objectives and needs as well as offer an engaging experience.

2.4 Key Criticisms and Benefits of Serious Games

2.4.1 Criticisms

The main criticism of serious games is that educational games are often only engaged in because it is an involuntary requirement (e.g. on the behest of one's organisation or for professional training). This may negatively affect a learner's motivation, which is one of the key drivers for the effectiveness of serious games (Michael & Chen, 2005). Ensuring that games are engaging for a wide audience can alleviate some of this challenge.

Another criticism is focused on technological limitations (Sanford, Starr, Merkel, & Bonsor Kurki, 2015) in that interactions with virtual characters and objects often lack realism. For instance, in real-life situations people rely on a number of social cues that are impossible to recreate in a virtual world at this point in time. Whilst the technology is continuously improving, and there are possible solutions, the serious game industry often has a much lower budget than the entertainment game industry and simply cannot afford the technology to invest into the development of highly realistic environments. Techniques such as motion capture can be used to create realistic body language, but there is still an element of predictability to an avatar's actions in a virtual environment, and the number of interactions possible to a player will have its own limitations. This is an issue, however, that can be expected to improve as technologies advance.

Also, serious games often fail to be accessible for people with disabilities such as blindness, deafness or mobility limitations (Game Accessibility, 2019). Making games accessible can be costly and dramatically increase production time. Still, especially in a professional setting, equal opportunities are an important factor. It is therefore vital to consider access for players with disabilities during the concept and design. Guidelines for producing accessible serious games will hopefully improve in the future.

2.4.2 Benefits

It has long been recognised by developmental psychologists such as Piaget that play is a fundamental aspect to learning and development. Some key features that help to understand why serious games may be effective for learning and training are that they provide a number of features that facilitate learning (Aldrich, 2009; Federation of American Scientists, 2006), amongst them:

- *Time on task* – Games have the ability to hold the attention of players. Some players will spend up to hundreds of hours to master a game. Good serious games will be designed to keep players' attention whilst delivering critical information to complete tasks.

- *Infinite patience* – Teachers can lose their temper and may leave some challenging students behind. A game can offer learners innumerable opportunities to retry.
- *Motivation and strong goal orientation* – Games are often highly rewarding even despite failures (e.g. ex die and retry games in which difficulty and failure are core to the game appeal; Bushner, 2015). This is a major advantage in teaching complex and difficult material.
- *Scaffolding* – Games provide the learner with cues, prompts and partial solutions offering players learning material until they are able to independently acquire knowledge.
- *Skill-based/experiential/active learning* – Game simulations offer a safe and low-consequence environment to experiment, practice and exercise practical skills such as surgery, operate an aircraft or handle the aftermath of a terrorist incident.
- *Immediate feedback* – Digital games are constantly monitoring a player's progress and are able to provide clear and immediate (or nearly immediate) feedback. A good game will provide increasing difficulty and challenges following a player's learning curve, keeping them at the edge of their capabilities.
- *Situational awareness* – refers to seeing the world through the filter of domain expertise by being able to omit unimportant details and highlight others that are relevant to solve a problem in a specific context.

2.5 Serious Games: Notable Case Studies

This section presents a number of case studies in which serious games have been utilised to deliver training and learning content in various industries and sectors. The choice of games is meant to illustrate the breadth and variety of serious game designs.

2.5.1 Matari 69200

Politics has started to utilise the power of video games to change people's hearts and minds. The highly interactive nature of this medium makes it possible for individuals to be placed 'in the shoes of other people' and to be faced with tough decisions that we would otherwise never need to process. Video games can thus be powerful tools of empathy. For this reason, governmental agencies like UNESCO have expressed interest in them:

> When you watch the news or a documentary, you might not feel connected to the issue. But video games immerse you in the action. Your actions have consequences within the game and therefore there's a greater emotional and cognitive investment. (Darvasi, 2016)

Moreover, games are an effective storytelling medium offering new and immersive ways to access news and history and get a political message across. Games have emerged as a medium of popular culture with a wide global reach and power to question political matters (Bernstein, Klein, & Malone, 2012; Pederson, 2010a). Games featuring cultural artefacts are therefore increasingly used as interactive additions to museums (Kidd, 2015) but can also be works of art in their own right (Smithsonian American Art Museum, 2012[3]; Pederson, 2010b). *Matari 69200* shows that games can transcend their purpose for entertainment and address social injustice (Pederson, 2010a).

Matari 69200 is a play on words combing the Spanish verb 'matar', meaning 'to kill', and 'Atari', a popular gaming system in the eighties. The number 69200 represent the casualties and fatalities due to the conflict depicted by the art installation. In the eighties there had been a 20-year conflict between the Shining Path Maoist paramilitary force and the Peruvian military. The game constitutes a commentary on these events and how they were depicted by the media. The art installation is comprised of a cathodic TV, an Atari gaming console, a joystick, five cartridges and a few chairs. The purpose of this setup is to immerse players in a 1980s family room. Four of the cartridges illustrate four violent televised events and the last one offers a commentary on the media depiction of the conflict at the time. The game content is based on a report by an independent organisation, the 'Truth and Reconciliation Commission'. The installation setup can be seen in Fig. 2.6.

The four events depicted by the cartridges are:

- *Cartridge one 'Penalties'* – Players embody a prison guard that conducted a state-enacted execution/massacre of 224 alleged terrorist prisoners in 1986.
- *Cartridge two 'Acomarca'* – Users play as one of the soldiers that killed 69 villagers or campesinos (i.e. peasant woman, elders and children) during an army patrol in 1985.

[3] https://www.youtube.com/watch?v=7gXrCEzuAis

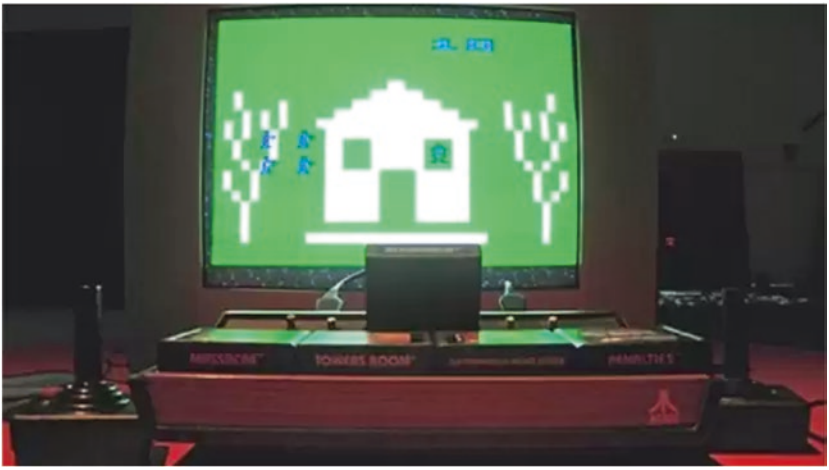

Fig. 2.6 Matari 69200 (Sánchez, 2005)

- *Cartridge three 'Lucanamarca Revolution'* – Users play as a Shining Path soldier in a village massacre in 1983.
- *Cartridge four 'Tower Boom'* – Users play as part of the terrorist group and re-enact the bombing of several high-voltage communication towers.

By letting the gamer play as the guerrilla and the state, the game creators aim to show that there was no right or wrong in this war and that both sides perpetrated atrocities affecting civilians. Also, the game's creator, Sánchez explains that, "w*hile parts of Peru suffered the inclemency's of war, for others war was only an experience they partook through watching TV; their position in relation to the war was similar to one of a child playing video games*" (cited in Pederson, 2010a, p. 9). The installation serves as a metaphor, a reflection on the passive spectator role of television audiences viewing a mediated war. But the actions necessary to interact with the video game create a tension between passive and active roles and open a reflection about the complicity of the spectator. *Matari 69200* is an interesting edge case demonstrating how a digital game can serve as an artistic statement about a political case and identifies uses of the technology, which can inform participants of a specific point or story.

2.5.2 *Spent, Game for Change (Urban Ministry of Durham; McKinney, 2011) (Freudmann & Bakamitsos, 2014)*[4,5]

Spent is a web-based game built by Urban Ministries of Durham and the McKinney Communication Agency to raise awareness about the issues of poverty and homelessness. In the United States, North Carolina has had one of the highest unemployment rates in the nation during an economic downturn, making it difficult for families to manage their household budget whilst having to work. Through a turn-based decision-making process, this game immerses the player in the day-to-day life of a poor worker and requires the player to make decisions on how to manage their budget on a daily basis to survive until the end of the month. The player is faced with different hurdles of life such as a job loss, death of a loved one, divorce, natural disaster or a serious illness. Users are able to see directly how their own decisions and unforeseen events can influence their budget and by extension they are obliged to make compromises. This can help players to understand that in some cases there is no 'good' solution. Also, the gameplay can create frustration in the player, as would similar real-life situations.

Some situations give the option to reach out to a friend through social media (Facebook, Twitter) to get help. This serves two purposes: firstly, to let the player understand how it would feel if they had to ask for financial help from friends or relatives, and secondly, to communicate about the game and entice more people to play it. Also, for each decision, players get information about the possible impacts of the decision. The game ends either when the player runs out of money or when they reach the end of the month with money left over. The player is invited to donate money to a non-profit organisation to help fight against poverty.

Spent showcases a game which is designed to enable users to experience and understand poverty from the perspective of people in this situation. It is an example of a persuasive serious game, which tells a narrative designed to help users identify with a specific community.

[4] http://playspent.org/html/

[5] http://www.umdurham.org/spent.html

2.5.3 Foldit[6,7]

With new technologies and worldwide networks, we are now able to harness and combine the power of calculation and communication of computers with the cognitive ability and creativity of people. Some applications and services take advantage of this collective intelligence and build truly transformative products that use the power of crowds.

Examples of this can be found in a domain called ‘citizen science’ (Bernstein et al., 2012). For instance, the puzzle game *Foldit* used the general public to help solve protein folding problematics to speed up discovery in this area of scientific research. *Foldit* was developed by the UW Center for Game Science, UW Institute for Protein Design, Northeastern University and Vanderbilt University Meiler Lab, UC Davis (2008; cp. Cooper et al., 2010).

For this game, scientists put a monkey virus (similar to AIDS) puzzle into *Foldit* to see if players would be able to develop solutions to crack the crystal structure of M-PMV retroviral protease by molecular replacement. A protein is a chemical key that has to have a specific shape to unlock their specific functionality, created from a chain of molecules that fold in a specific way. A group of *Foldit* players called ‘Foldit Contenders Group’ discovered an incredibly elegant, low-energy model for the monkey enzyme virus. They managed to resolve a challenge that had puzzled scientists for a decade in less than 10 days. Within a few days, researchers were able to test out and confirm the validity of the model (Khatib et al., 2011).

Foldit players were able to come up with a solution using the community feature of the game along with the team chat feature that enabled the exchange of information amongst players from across the world. The knowledge built over the years by the community on the game’s wiki meant that players were able to quickly come up with an efficient solution. As Zoran Popovic, director of the University of Washington’s Center for Game Science, comments: *“Fold-it shows that a game can turn novices into domain experts, capable of producing first-class scientific discoveries”* (cited in Boyle, 2011).

Building serious games to encourage the collective handling of challenges, whether for gameplay elements or to find real-world solutions, is an effective method of using game technologies to outsource tasks to a

[6] https://fold.it/portal/info/about

[7] http://www.washington.edu/news/2008/05/08/computer-games-high-score-could-earn-the-nobel-prize-in-medicine/

wider community. *Foldit* is a good example of how a serious game, which can facilitate an active community, can become a major contributor to scientific research.

2.5.4 Start Thinking Soldier (British Army, 2009)

In the United States, the military and police departments have been involved in the video game industry since its infancy for training and recruitment purposes (Rayner, 2018). In 2002, the US army released *America's Army*. This was a pioneering entry in this genre and a great success. The military discovered that it was a great tool to engage and communicate with the youth. They even organised LAN parties (i.e. gatherings where players play together on a local network) employing the game as part of their 'Future Soldier Sustainment Program' (Thompson, 2008).

This approach of using a game as a marketing tool to attract young adults to join the army caused some controversy. For example, art professor Joseph DeLappe spammed players with names of soldiers killed in Iraq as a protest against the game. Another major group of protesters were Iraq Veterans, who worried that the game glamorises and glorifies war by highlighting certain parts and glossing over the bitter reality of fighting and killing people (Thompson, 2008).

The UK army has implemented their version of a recruitment game in 2009. It was called *Start Thinking Soldier* and was available online on their website during their recruitment campaign. The game was a mixture of interactive 'real-life' documentary and mini games immersing potential recruits in the daily life and missions of soldiers (Hall, 2009). The goal of the platform was to encourage potential recruits to sign-up and get their contact information to stay in touch, track their progress and encourage them to go to army events. The campaign was paired with traditional TV advertising, which raised awareness of the game online. Today, the military working environment is increasingly complex, and many citizens tend to be unfamiliar and sceptical about the political aim behind military missions or the armed forces more generally (Strand & Berndtsson, 2015). The objective of these adverts was to support the engagement with the online platform and to improve military recruitment numbers. The result of utilising the *Start Thinking Soldier* game for recruitment seems to have been positive. In 2009, army recruitment figures rose by over 25%, the highest level of recruitment since 2005 (Taylor, 2009), although it cannot be ruled out that these statistics are influenced also by the effects of the recession in 2008 and the subsequent austerity measures as well as the increased awareness of the military as a career opportunity. Still, one of the criticisms against army recruitment practices through games remains that they provide insufficient information about the risks involved in a military career (Gee, 2007, 2013).

2.5.5 BiLAT (Bilateral Negotiation Trainer; USC, Institute of Creative Technologies, 2004–2008)

The military is not only about combat; it is also about human contact, negotiation and diplomacy. *BiLat* is a game developed in 2005 by the Institute of Creative Technologies in the University of Southern California, USA, to train soldiers in negotiating with people from other cultures during overseas deployment. In *BiLat*, the player's mission is to conduct a series of bilateral engagements or meetings with local leaders. To do so, the player has to gather information about the social relationships between characters they encounter in each scenario. For instance, the objective of one of the scenarios is to understand why a marketplace built by the United States is not used by the locals. In the game the player has to be wary of local cultural conventions, and they are encouraged to build and establish their own relationships with the characters in the game. A mistake in a conversation could cause a setback or stop a negotiation. As a result, the player has to employ carefully planned negotiation strategies for which they get complimentary training before playing the game. The aim is to get to a win-win situation for both parties. *BiLat* used several technologies to achieve an accurate representation of social and cultural models: a dialogue manager, *SmartBody* animation technologies and the *Psychsim* social simulation (Bilateral Negotiation Trainer (BiLAT), 2012). The game includes an authoring tool, enabling trainers to change existing scenarios or to implement new scenarios easily without support from the original developers.

Utilising a serious game to train communication and negotiation skills between diverging cultures and ethnicities enables users to experience situations and interactions, which are hard to stage in real life without significant investment. The US military's use of serious games and their integration with existing technologies showcases the benefits of combining existing capabilities with newer training capabilities. *BiLat's* utilisation of the *SmartBody* and *Psychism* simulations helps identify the further benefits of serious game technologies, when they are enhanced by existing capabilities and research.

2.5.6 Sea Hero Quest (2014)

Aging populations make it imperative to tackle the issue of geriatric-related pathology. In 2017, the number of people living with dementia was estimated at 47 million (Livingston et al., 2017; World Health Organization, 2019), and the prevalence of this disease will supposedly double by 2030 and triple by 2050. However, due to a lack of effective treatment methods, pharmaceutical companies are not eager to fund research in this field. Game platforms can serve as a tool to gather relevant data in a fun and enjoyable way for the patient. Such data can be used to simplify the diagnosis of the disease, whilst the game itself can be a tool to detect signs of the pathology.

A collaborative research project by the University of East Anglia, Deutsche Telekom, University College of London, Alzheimer's Research UK and Glitchers created *Sea Hero Quest* to reach this goal. *Sea Hero Quest* was built based on the *Morris Water Maze*, a neuropsychological test usually used on rodents in labs to assess navigational abilities. The game aimed to help in better understanding our human navigational skills, knowing that losing them is one of the first symptoms of dementia. It is a simple maze game, in which the player will play the role of a character whose father has been afflicted with dementia. The game is set at sea, and the quest is to get back the father's lost memories. The gameplay is simple. The player is required to navigate through a maze to chase whimsical creatures and photograph them. To get an orientation cue, players are also able to shoot a flare. At the time of writing, the game has been downloaded more than 4.3 million times, reaching out to more people than originally intended by the game developers (Alzheimer's Research UK, 2019).

Whilst *Sea Hero Quest* is mainly utilised to collect data from players, integrating this method with the analysis of the gameplay enables researchers to get representative data, which directly correlates to user actions as opposed to written or verbal accounts. The reach of *Sea Hero Quests* is also a significant benefit, demonstrating the effectiveness of utilising a serious game. Being able to distribute the platform globally over the Internet enables millions of users to provide data or interact simultaneously, increasing the yield and number of potential results exponentially.

2.6 Summary

The proliferation of games throughout modern culture has resulted in an exponential increase in the number of identifiable uses and potential benefits from serious games. This is especially true when considering areas such as education, learning and training; areas are also relevant for law enforcement, security and military, as illustrated by the examples above.

Whilst serious games can provide a multitude of benefits, it is important to maintain a balance between entertainment and education, whilst at the same time ensuring that key learning principles are not forgotten. Although games are becoming increasingly prevalent, there is still a generational divide. As a result, not all learners may respond positively to serious games, and in some instances utilising serious games could harm learning if adoption of new technologies is not handled properly. It is also argued that for learners to achieve the best results, there should still be social interactions with a teacher or trainer for feedback (Ketamo & Kiili, 2010).

The case studies presented in this chapter helped identify numerous benefits of serious games such as exposure, learning, community engagement and resource pooling. These benefits from across industries and sectors help showcase the widespread benefits of the technology, but do not necessarily help us understand why serious games are successful. It is important to have an understanding of key learning theories in order to create effective serious game, the most important of which have been outlined in this chapter. However, no specific theory or method can be applied to all games. Much like learning within a real-world environment, active learning will change depending on a number of variables depending on the learner, their environment and the context of learning.

When creating a serious game, it is the creators' responsibility to ensure the content, interaction medium and targeted learning outcomes are in alignment. An effective serious game is built on a core foundation of how learners engage with content, interact with it and retain the knowledge or understanding imparted by interacting with the game. These elements need to work together seamlessly, for the learner to be enabled and supported by the game.

It should also be noted that not all learners are the same; some may benefit more from learning through serious games than others. Thus, in our view, serious games should not replace traditional methods for learning. They often work best as a supplement to established training approaches or as an assessment platform for lessons already learned.

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CHAPTER 3

Virtual Reality Technologies

Steffi Davey and Paul Hancock

3.1 Introduction

The concept of virtual reality (VR) has been around for longer than most would expect, dating back to the 1950s. However, this initial introduction to VR is quite removed from what we would refer to as VR today. Also, there is a wide spectrum of what people envisage when asked about VR. Therefore, it is important to start with a definition of the concept. Although there have been many conceptualisations, most involve interaction within an 'immersive' computer-generated environment, including platforms such as semi-immersive caves.

For the purposes of this chapter, VR will be referred to by the following definition:

> VR is an interactive, participatory environment that could sustain many remote users sharing a virtual place. VR is characterized by the illusion of participation in a synthetic environment rather than the external observation of such an environment. It relies on three-dimensional, stereoscopic, head-tracked displays, hand/body tracking, and binaural sound. VR is an immersive, multisensory experience. (Earnshaw, 2014)

S. Davey (✉) · P. Hancock
CENTRIC, Sheffield Hallam University, Sheffield, UK
e-mail: steffi.davey@shu.ac.uk

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The 1960s saw the introduction of the first head-mounted displays (HMDs). Probably the most famous of these was the *Sword of Damocles* invented by Ivan Sunderland. Yet, it took until the twentieth century for VR technologies to experience a real surge in popularity, even if VR was used to a certain extent in research and the military. An increase in interest arose with the introduction of the Oculus Rift (often misconstrued to be the first VR headset). Since then the excitement around VR has remained relatively consistent (Blach, 2008).

There are two key benefits of using VR: Firstly, VR offers a cost-effective option to experience something that would otherwise be very costly and/or time intensive to execute in reality (e.g. traveling to the International Space Station); secondly, it enables users to experience things that would otherwise be impossible (e.g. traveling in a capsule through a human body).

This chapter discusses some of the popular technologies available for VR development in the context of serious games. It will then go on to explore current applications of virtual reality in both research and industry and considerations for serious game-based virtual reality developments. It will further discuss pertinent challenges around VR including ethical implications.

3.2 An Overview of VR Technologies

There are a number of VR technologies available in the market, although they fall into two main categories. The first are solutions in which users sit or stand whilst they are wearing the device, which means they are only able to move their head whilst using the headset. The second group are devices with which users can move around and have their movements tracked via cameras, so that these movements can be translated into the virtual environment. The following section will discuss features of the different types of products, including a range of VR headsets along with accessories that may enhance users' experiences in VR.

3.2.1 Seated or Standing VR Headsets

Seated or standing headsets are devices that contain a small screen, displaying an image for each eye and often include headphones. The headsets are typically tethered to a PC either by cables or via a wireless connection. Some of the more high-end headsets will use infrared cameras to track the position of the headset, these are usually positioned in front of the user (commonly mounted on a monitor). This setup largely limits tracking to head movements as opposed to whole body movements. As a result, the

Fig. 3.1 Example of a seated or standing VR headset. (Picture credits: https://commons.wikimedia.org/wiki/File:Oculus-Rift-CV1-Headset-Front.jpg)

user will typically stand still or sit whilst wearing the headset – hence, the term seated or standing VR. One of the first headsets of this type to have a significant impact on the advancement of VR technology was the Oculus Rift (see Fig. 3.1). Seated or standing VR headsets are ideal for use in locations where there is insufficient space to allow for the user to move around.

3.2.2 Room-Scale VR Headsets

In contrast to seated or standing headsets, room-scale headsets allow for a user's movements to be mapped to movements within the virtual environment. This setup enables the user to move more naturally in VR leading to a more realistic experience. Often two or more infrared cameras are used to track the player's position. This positional tracking enables users to have complete control over what they see in VR. They are further able to crouch down, lean around corners and get as close as they like to the objects in the virtual environment. The use of two cameras instead of one ensures that the tracking remains reliable. Tracking of body movements requires a larger, dedicated area compared to the seated or standing setup.

Room-scale systems are ideal for the development of serious games platforms in which learning outcomes are better served if users can move around, even if movement is limited to the allocated playing area (e.g. skill development and environmentally based learning; see, for instance, Chaps. 6 and 10). Limitations to the physical space can be overcome by including functionalities such as teleportation to move within the game. This is an area of extensive research[1,2] investigating ways to make the most of

[1] https://ieeexplore.ieee.org/document/7460053

[2] http://shura.shu.ac.uk/18594/

restricted playing areas (e.g. how to design games in a way that will encourage users to turn naturally before reaching the edge of the physical playing area).

Whilst range of movement adds to immersion, room-scale VR headsets are typically tethered to a PC by a wire. This wire can be a trip hazard and can detract from the sense of immersion with negative impact on the user's game play. As an alternative, wireless adapters are available for some headsets such as the HTC Vive. The downside of headsets without cables is that the headsets have to use battery power, which will need recharging during long sessions.

Room-scale headsets generally come with handheld controllers, which allows the users' hand movements to be tracked accurately. Further, buttons on the handset allow the user to interact with the game applications. For instance, pressing a button may be linked to firing a gun or the teleportation to another location, which can lead to confusion and detract from the user experience. In the future we can expect to see the advent of VR gloves and hand tracking which will open up the window for much more intuitive interactions within VR. Some headsets also include front cameras, so that the user can see the outside world opening the possibility for augmented reality (see Chap. 4). The HTC Vive Pro, for example, includes two cameras on the front enabling stereoscopic 3D views (see Fig. 3.2).

Fig. 3.2 Example of a room-scale VR system. (Picture credits: https://www.flickr.com/photos/bagogames/25845851080)

3.2.3 Mobile VR

Mobile VR platforms offer an inexpensive VR solution, as they make use of the hardware already built into mobile devices. In mobile VR setups, a mobile phone can be clipped into the front of the headset, so that the phone screen sits in front of the user's eyes (cp. Fig. 3.3). The screen on the phone is split to create a stereoscopic display. These headsets typically have a single button the user presses to interact with the application. Some devices come with a handheld controller, which can be used to navigate the virtual world and offer increased user interaction.

An example for an even cheaper mobile VR solution is Google Cardboard (see Fig. 3.4). This setup is perfect for trying out VR applications without the need to acquire sophisticated and expensive equipment. As the name suggests, the device is largely constructed from cardboard and contains lenses for each eye. Head movements are tracked using the gyroscope of the smartphone. The low cost of such devices and their easy assembly makes them ideal for applications that are intended for a large number of users for short periods of time and where users are not expected to move whilst using the application. As there are no cameras for the tracking of users' movements, they do not work well if the user tries to walk around. These devices also provide an efficient solution during the

Fig. 3.3 Example of a mobile VR. (Picture credits: https://www.samsung.com/global/galaxy/gear-vr/)

Fig. 3.4 Google Cardboard. (Picture credits: https://vr.google.com/intl/en_uk/cardboard/)

prototype phase before a final headset has been chosen for deployment. Conversely, the low quality of the lenses and the lack of features to provide comfort make it unsuitable for applications that require the user to wear the device for long sessions.

3.2.4 VR Accessories

To enhance the sense of immersion, numerous hardware devices can be added to the basic setups described above. This includes items such as haptic vests and full body rigs, which introduce somatic senses (i.e. body sensations of touch and pressure) into the virtual world (cp. right side of Fig. 3.5). Another innovation in this field is the omnidirectional treadmill (see left side of Fig. 3.5 for an example), which detects the user's steps and will move the user in VR in accordance with their movement on the treadmill. Treadmills can help with locomotion issues that can induce sickness during VR-based games (see discussion below).

Fig. 3.5 Examples of VR accessories. (Picture credits: https://commons.wikimedia.org/wiki/File:Virtuix_Omni_product_view,_profile.jpg, https://commons.wikimedia.org/wiki/File:NullSpace_VR_Mk_2.jpg)

3.2.5 Considerations for Choosing VR Technologies

Finding the balance of value for money is an important consideration when deciding which VR hardware should be used for the intended serious game product. This often means considering financial budgets next to the question of how comprehensive and interactive the serious game needs to be; that is, how important is it for the user to feel a sense of immersion and how much interaction (with virtual objects, people or an environment) is required to achieve the desired learning outcomes?

Generally, for maximum impact or to evoke emotions or a sense of awe, the higher-end hardware offered by camera-tracked headsets is preferable. Additional hardware, such as a treadmills or haptic vests, can be used to increase the sense of immersion. Further, it is important to consider whether the user should be able to walk around or can also stand still or sit whilst using the application. If movement is not required, a headset with a single camera for tracking as opposed to a multi-camera tracked headset is sufficient. For lower budgets, minimal interaction and lower-fidelity projects, hardware that uses mobile VR devices, such as Google cardboard, may be adequate.

Whilst VR systems have dramatically dropped in price since their initial release, they also require an appropriate system to run VR (i.e. PCs or laptops). Here it is important to ensure that the system is 'VR ready'.

3.3 VR Innovations

For a better understanding of the possibilities of VR for serious games, the subsequent sections explore innovative ways in which VR has been used in the past. Areas with extensive experience in VR-based serious games are healthcare, therapy and education.VR has also been explored for its use as a unique, artistic experience, which can help to create greater impact than traditional methods may otherwise achieve. These case studies can offer lessons and ideas for applications in the law enforcement area.

3.3.1 Pain Therapy

To date, the healthcare industry has been one of the predominant areas for the adoption of VR technologies, to aid both medical practitioners and patients. Examples of VR applications in the healthcare industry include improving impaired balance,[3] eating disorders (Perpiñá, Botella, & Baños, 2003), autism (Kandalaft, Didehbani, Krawczyk, Allen, & Chapman, 2013), pain management (Li, Montaño, Chen, & Gold, 2011), medical training procedures (Grantcharov et al., 2004), limb rehabilitation (Henderson, Korner-Bitensky, & Levin, 2007) and improving memory in the elderly (Optale et al., 2010).

For instance, hospitalised patients can profit from VR applications in experiencing less anxiety during illnesses and better coping mechanisms within an often daunting medical environment (Mosadeghi, Reid, Martinez, Rosen, & Spiegel, 2016), an effect that employs VR as a distractor. VR distractions can also be useful in the treatment of pain, potentially reducing the use of opioids and other pharmacological pain management methods (Morris, Louw, & Grimmer-Somers, 2009). For example, it has been shown that, by engaging multiple senses and providing a platform for interaction, serious games have helped children to become less receptive to pain (Le May, Paquin, Fortin, & Khadra, 2016). Functional magnetic resonance imaging (FMRI) confirmed this link, as the brain interprets pain differently in patients using VR (Hoffman, 2004). Results on the reduction of anxiety in patients were less conclusive.

[3] https://journals.sagepub.com/doi/full/10.1177/0269215513509389

3.3.2 Traumatic Experiences and Illnesses

VR games are being trialled extensively in a military context. Jobs in the defence sector can be highly physical and involve exposure to high-risk tasks and environments, confronting personnel with challenges to their mental health and well-being. Physical and mental stressors are especially prevalent during deployments overseas but may also occur in non-operational environments. Potentially traumatic events are related to exposure to threatened or actual violence (death, sexual violence or injury); non-traumatic stressors may be related to life in the military such as distance from family and friends during a deployment or adjustments after returning from deployment.

Serious games have been trialled as tools to protect well-being and in the rehabilitation of injured soldiers assisting in their treatment and care. For instance, *BraveMinds* is an immersive VR exposure therapy tool for returning veterans with post-traumatic stress disorder (PTSD). It simulates exposure to an improvised explosive device (IED) with a 360-degree headset and a haptic plate to give the feeling of an IED explosion. In addition, a smell kit is used to replicate the smell of fuel, burning plastic and body odour (Ungerleider, 2014). *BraveMinds* creates an environment with a high degree of reality; the simulated world is real but not too real. This leaves some room for the imagination of players. By populating the scene and allowing the veterans to add details from their own experiences, it is possible to identify areas where assistance may be needed (Ungerleider, 2014).

Another aspect of VR technologies has been trialled is in the treatment of anorexia, a disease linked to a disturbed body image in which patients wrongly believe they are overweight, even if they are below a healthy weight limit. To reduce body image disturbances in patients suffering from anorexia, a full body illusion (FBI) was created by stroking the user's actual body at the same time as the user watched their virtual body being stroked. The body contact was intended to create a sense of embodiment, that is ownership over a virtual avatar (although it can be argued that this was an unnecessary measure, as the first-person perspective obtained through VR itself may be sufficient to induce a sense of embodiment) (Keizer, van Elburg, Helms, & Dijkerman, 2016). Evaluation demonstrated that the experience resulted in a more accurate estimate of body size for more than two hours after the experiment.

Another interesting area for VR is the treatment of drug addiction. One of the hardest challenges for people suffering from addiction is accepting that the addiction is a problem. VR has been used to support recovering drug addicts[4] by measuring physiological responses to potential triggers placed in a VR scene. This approach is similar to exposure therapy, in which users learn to endure uncomfortable situations and identify what might trigger their cravings. Health professionals can then offer advice on how to deal with these feelings (Kuntze et al., 2001).

3.3.3 Skill Learning

The education and training of medical professionals is another common field for VR applications. In particular, surgical simulators have been adopted, for instance, for the training of laparoscopic surgeries. Laparoscopic surgery has become a relatively common surgical practice, because it is less invasive and therefore promises quicker recovery compared to traditional open surgery. Unfortunately, laparoscopic training involves a steep learning curve and can often lead to complications in surgery with newly qualified or trainee surgeons (Larsen et al., 2009).[5] In 2006, a study investigated whether trainee laparoscopic surgeons could achieve a basic proficiency in technical skills by training in VR prior to training in the operating theatre in order to reduce errors on patients (Aggarwal et al., 2006). The study assessed the performance of 20 trainee laparoscopic surgeons compared to the performance of 20 trained surgeons. Results indicated that the VR simulation could reduce the learning curve prior to training on real patients.

Another promising facet of VR-based training is addressed in professional sports, such as climbing. Climbing marries together both technical and puzzle-solving skills as well as pure physical strength. Often climbers will be faced with problems that seem impossible, until shown the correct technique by a peer or coach. A company called Uniform created a prototype for a VR training aid called *GRIP*, which is used in combination with electronic wristbands (Shorter & Amico, 2016). If a climber finds a particular route challenging, they can scan the bottom hold with their wrist band. They can then put the VR headset on to receive virtual coaching.

[4] https://news.vanderbilt.edu/2018/03/19/virtual-reality-world-offers-drug-addicts-low-risk-place-to-just-say-no/

[5] https://www.bmj.com/content/338/bmj.b1802.long

The virtual coaching is given by both Shauna Coxey (British Bouldering champion) and her coach Mark Glennie, who many climbers will look up to as inspirations. The coaches will talk them through the route and give them suggestions on how to achieve the climb. To add more motivation to this platform, Uniform has added an element of gamification: Once the user reaches the end of the route, they can swipe their wristband on the top hold and receive a reward.[6] This project presents an interesting combination of practical skills mixed with virtual reality learning.

A more serious note strikes with a VR training platform for people who were convicted as juveniles and served up to 20 years in prison (Taylor & Emma, 2017). The prospect of release can cause anxiety, as the world outside will be a very different place compared to the one at the time of their conviction. The training starts by showing inmates a series of VR experiences from the outside world using 360-degree videos, helping them to familiarise themselves with the technology and at the same time adjust to new experiences. Once familiar with the VR headset, they were asked to carry out mundane tasks expected of them after release that they never had to do in prison (e.g. doing laundry or grocery shopping when living alone). By completing this training, the aim was to leave inmates better prepared for everyday situations. In addition, participation also offered the chance for early release.

3.3.4 Artistic Experiences

As mentioned previously, VR can be a great platform for offering experiences that are otherwise costly or in some cases impossible. This can also be used to tell stories or enable users to achieve a sense of empathy. With the use of VR, users have been teleported to popular tourist destinations to relive historic events at a museum,[7] watch a film in a virtual cinema, visit a live music festival or even travel to Mars.[8]

Such experiences can also allow us to step into the world of people with unfamiliar or exceptional life stories. In 2017, *Unpacked VR*[9] was created. This was a supplement to an art exhibition that took place on international migrants' day. The aim of the exhibition was to humanise refugees by showing the destruction that war brought to the refugees' homes. To do

[6] http://tv.thebmc.co.uk/videos/grip-a-virtual-reality-training-aid-for-climbing/
[7] https://www.museumnext.com/2019/01/how-museums-are-using-virtual-reality/
[8] https://www.framestore.com/fieldtriptomars
[9] https://research.shu.ac.uk/centric/project/unpacked-vr/

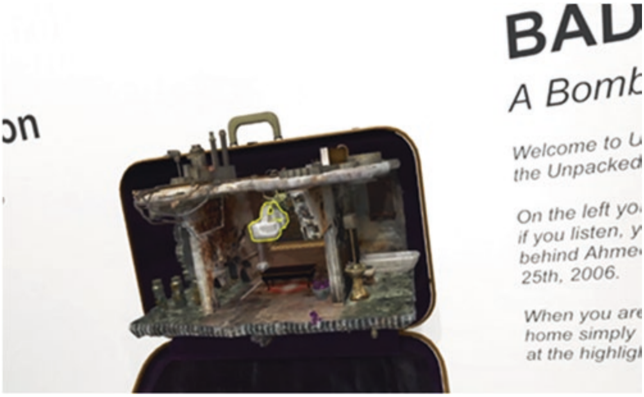

Fig. 3.6 Impression of Unpacked VR. (Picture credit: CENTRIC)

this, artist Mohamad Hafez and writer Ahmed Badr worked together to capture real stories of migrants' experiences. These stories were reconstructed in suitcases showcasing the homes that the refugees had left behind. One of these suitcases was turned into a VR environment to allow members of the public to be immersed in the exhibition (see Fig. 3.6). VR users were placed in the virtual exhibition, being teleported inside one of the artefacts. Recorded interviews with the migrants were played through the headphones, making the immersive environment even more impactful.

3.4 VR Development

3.4.1 General Principles

The development considerations and processes of VR applications are similar to the development of other game platforms such as detailed in Chap. 8. However, there are a few areas specific to VR which are worth drawing attention to (Tanriverdi & Jacob, 2001). These can be summarised in the following advice:

1. 3D models should be efficient. Whilst technology is advancing, high-resolution 3D models can still cause the system to slow down, which can increase the chance of cybersickness. Texture maps (normal, height, specular, etc.) can be used to give the illusion of a highly detailed model without increasing processing time.

2. How will users navigate in the environment? If using room-scale VR, the user will often only have a small area to move around, which will be a limiting factor in the development. If a controller is used to navigate through environments, precautions must be taken to limit possible effects of motion sickness; for example by slowing down the speed of movement.
3. What is the purpose of using VR instead of a standard desktop application? How can virtual reality enhance a user's experience and in which way? These are important questions before embarking on VR developments. For example, if the purpose is to produce a sense of awe, then the development should largely focus on the artistic outcomes more so than if the purpose is to educate.
4. Who is the target audience? If the audience has past experience with computer games or VR, then more advanced game mechanics can be included.
5. 3D sound is important and can add to the impression of immersion and presence which is crucial to VR.
6. Testing should be done with a wide variety of people from different backgrounds with different physical capabilities and differing levels of experience in terms of relevant technologies and computer games.
7. Always ensure that the product being developed is ethical and will not cause harm, especially to vulnerable people.

3.4.2 Basics VR Development Processes and Methodologies

Polcar, Gregor, Horejsi, and Kopecek (2016) developed a methodology for creating VR applications, which splits the development into six phases: assignment, analysis, creation, testing and implementation. This methodology is a useful general framework to guide VR design considerations.

1. The *assignment phase* involves collecting the requirements, aims and objectives for the VR application in addition to defining the target audience.
2. The *analysis phase* involves using the information gathered from phase one to formulate a plan of all objects involved in the creation of the VR game. If any objects are to perform actions, these actions will be defined in this phase. The objects can have varying states, which can be mapped out using a state diagram.

3. During the *creation phase* all assets will be created including the scripts, 3D assets and 3D animations.
4. The *testing phase* should run throughout the process, including the test of scripts, environments and interfaces to ensure that all elements work together and the desired look and feel is achieved.
5. In the *implementation phase* the product is tested with end users in the setting that the final application will use.
6. In the *operation phase* data is gathered from users to check for any necessary modifications.

3.4.3 Interactions Within Virtual Environments

The nature of VR lends itself to natural interaction methods, which reduces the risk of any ambiguity for the user. The replicating of real-world interactions makes interactions in VR simple and intuitive and helps users to adapt quickly to the interface. On the other hand, there are also risks involved in using natural interactions. For instance, user may miss feedback to show that they are interacting with the interface successfully. This means that users can be interacting with objects without being aware that they are doing so.

At times unusual gestures are needed for interactions, which are unfamiliar from real-world settings, for example to make physical alterations to a character or an object such as changing its colour or shape. There will be objects that in the real world a user would be able to interact with, whilst this functionality is unavailable in the game. In these cases, visual guidance is necessary to inform users which objects can be manipulated and which not. Otherwise users can easily become irritated. Also, most users will be accustomed to information displayed on screens in front of them. In the case of VR, it can take some time to adjust to the 360-degree field of view. Therefore, it can be important to encourage users through visual prompts, such as arrows, to guide their gaze to relevant content in other areas of the environment (Affordances, 2019).

One of the key advantages of VR is that there are few limitations to what can be simulated. This enables users to interact in new ways that are not feasible in the real world. Such experiences are referred to as 'magic interactions' (Jerald, 2015), as they can extend beyond the powers of real-world interactions. For example, in order to interact with an object in VR, the object does not necessarily have to be close to the user. Users can interact with the interface simply by looking at objects. However, if this is used too frequently or in a way that lacks context, it can distract and confuse the user and ruin the sense of immersion.

'Active interaction' denotes situations in which a user is aware of interacting with an object (e.g. during clicking or scrolling to interact with an interface). The opposite to this is 'passive interaction', which occurs when a user is less or un-conscious that they are interacting with an interface in VR (e.g. tracking head rotations and motions for movement through a virtual environment or crowds of people that move out of the way when the user approaches). If executed correctly, both type of interactions can add to the plausibility illusion and a sense of presence. For this reason, interactions should be subtle. If used incorrectly, especially passive interactions can frustrate the user and cause feelings of lacking control over the environment.

When designing an interaction interface, it is important to take affordances into consideration. *Affordance* is a term introduced by the psychologist James Gibson (Gibson, 1979) and refers to features of an object or element that enable users to determine possible interactions simply by looking at it. With regard to virtual environments, affordances determine whether interactions with objects work the way a user expects and, if not, whether these interactions could be improved. False affordances occur when users cannot determine the correct interaction from looking at the object.

In VR, it is sometimes difficult to avoid false affordances. This is partly because objects are available in the same way as in the physical world. For instance, when users see a surface in a virtual reality game, they would expect to be able to place objects on the surface. It causes confusion, if this is not the case. The proper design of visual elements in VR can help to avoid these false affordances (e.g. by removing handles from doors that cannot be interacted with). If interactions with objects are not intuitive, it is important to provide clear instructions in addition to either audio, haptic or visual feedback.

3.5 Challenges of Virtual Reality-Based Serious Games

3.5.1 Cybersickness

A common symptom of using VR is cybersickness, that is a feeling similar to motion sickness when using a VR environment. There are a number of theories as to why people may experience cybersickness. The three most important ones are shortly summarised below (cp. LaViola Jr, 2000):

1. *Sensory conflict theory* is the most widely accepted theory to explain cybersickness.[10] It occurs when the body is stationary, but a sense of self-motion remains. Normally, when subjected to motion, the brain receives vestibular information (i.e. information relating to balance and orientation). In VR, balance and orientation information is often missing. This lack of vestibular information can create conflicting messages in the brain, which can cause cybersickness.
2. *Poison theory* is an evolution-based theory that posits that physiological effects will occur when the body is trying to reject poison. In the case of cybersickness, the body misinterprets visual-vestibular information, which can trigger an emetic response.
3. *Postural instability theory* suggests that humans seek postural stability and that a significant change in the environment will lead to a loss of postural control. The theory states that the degree of motion sickness is proportional to the amount of postural instability (Warwick-Evans, Symons, Fitch, & Burrows, 1998). This is in reference to a lack of control over acceleration, meaning that postural control cannot be used to gain postural stability.

Artificially stimulating the vestibular system has been suggested as a way to combat cybersickness. This has been trialled using a motion platform (see Sect. 3.2.4) and by direct vestibular stimulation sending electrical signals to cranial nerves (LaViola Jr, 2000). Alternatively, certain design techniques can be used, for example, a tunnelling effect around the user's vision by dynamically reducing the field of view (Fernandes & Feiner, 2016). This is barely noticeable to the user but seems to reduce the effects of cybersickness. Another method is to create a static frame of reference that is constantly in the user's field of view, that is does not move with the user's head movements. Such a frame is sometimes referred to as an anchor.[11] Another option is to simply remove all locomotion movement in the environment and to replace it with teleportation. Cybersickness can further occur if there is a lag between the user's movements and the display. In order to avoid lag, the 3D environment should be as efficient as possible by using lower-fidelity models and adding more detail to the textures through the use of normal maps and specular maps.

[10] https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8446269&tag=1

[11] https://vr.arvilab.com/blog/combating-vr-sickness-debunking-myths-and-learning-what-really-works

3.5.2 Ethics

Whilst virtual reality continues to gain momentum, the ethics around the use of VR are sometimes contested. There are several areas discussed in terms of ethical implications. Spiegel (2017) lists the following concerns developers should be aware of (Spiegel, 2017):

1. Cybersickness (see above)
2. Dissociation disorders
3. Self-neglect
4. Lost sense of reality ('blurred line')
5. Real-world object collisions
6. Manipulation/marketing

Earlier in this chapter we mentioned the benefits of VR for mental health. Yet, it is also possible that VR can pose a risk for mentally vulnerable users. A study published in 2014[12] reports that nearly half of UK adults interviewed believed they had symptoms of a diagnosable mental health condition at some point in their life. With this in mind it is vital to consider the implications of VR on users suffering from mental health conditions whilst developing virtual reality applications.

This is relevant as VR applications can have side effects. Some of them are related to issues of embodiment after exposure to VR. Embodiment is a sense of having ownership over a virtual body presented to the user in the virtual reality. Whilst this can be used to help mental health disorders such as body dysmorphia (see Sect. 3.3.2), there is a possible link between embodiment and dissociation disorders such as depersonalisation and derealisation (Aardema, O'Connor, Coˆte´, & Taillon, 2010). Derealisation refers to losing the sense of belonging to the real world and living in a dream world instead; in contrast, a user experiencing depersonalisation will feel detached from their own body and thoughts. They feel as if they are watching the world unfold around them like a movie and are simply observing their emotions but not feeling them first-hand.

Another negative consequence discussed is post-VR sadness (Searles, 2016). This term refers to a state in which users report feelings of sadness after removing the VR headset including a lack of motivation for real-

[12] https://digital.nhs.uk/data-and-information/publications/statistical/adult-psychiatric-morbidity-survey/adult-psychiatric-morbidity-survey-survey-of-mental-health-and-wellbeing-england-2014

world activities after being exposed to powers and experiences in the VR environment that are not possible in the real world. Whilst this is often a short-lived feeling immediately after removing a VR headset, the feeling can strengthen into a dissociation episode, which can continue for a longer period of time.

Whilst there has long been a concern about video games influencing users to engage in acts of violence and other criminal activities in reality, the higher sense of immersion in VR seems to bring this argument to the forefront once again, as here the line between the two realities becomes increasingly blurred. Also, the World Health Organization (WHO) recently classified gaming disorder as a registered illness (WHO, 2018), the illness occurs when users become addicted to playing video games and lose control over their gaming behaviour. This in turn can result in self-neglect, when players become so deeply distracted by the virtual environment that they forget to care for their physical self. This can cause issues with cardiovascular health, personal hygiene, over-exhaustion, starvation and dehydration.[13] Severe cases have resulted in deaths, often caused by over-exhaustion leading to cardiovascular issues.[14] The risk of addiction to VR gaming could increase due to the added sense of immersion and heightened feelings of escapism.

VR can further disorient users affecting players' balance. VR platforms can also cause trip hazards, for example due to objects in the play area or headset wires (although the increasing use of wireless technologies should reduce the latter risk). In the meantime, users should be made aware of such risks before participating in any VR activity. Whilst precautionary measures can prevent collisions with objects in the real world – such as a warning grids alerting the user when they are approaching the perimeter of the playing area – users must remain mindful of their surroundings including observers entering the playing area. Pregnant users may be advised not to enter VR environments due to the risk of falling.

There are further considerable concerns about the potential of (mis) using VR environments for targeted advertising and misinformation. Personal data used in targeted political and commercial advertising campaigns is often gathered without the users' knowledge. For instance, it has been claimed that infrared cameras with virtual reality could be used to

[13] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5700714/

[14] https://www.theguardian.com/technology/2015/aug/09/who-killed-the-video-gamers-simon-parkin-taiwan

gather personal data about people's lives or working environments alongside information about how they interact (e.g. exploiting capabilities to gather information on how long a gaze fixates on one specific area). This information could be used to target vulnerable people (Redmiles, 2018) or to impact decision-making.

3.6 Conclusion

Virtual reality has considerable potential to enhance serious games. Numerous applications exist that demonstrate how VR – either on its own or in combination with other approaches – can support areas from professional learning to support and recovery of personnel. VR is not without challenges, notably in terms of physical and psychological reactions as well as ethical considerations, but they can be managed by careful design and deployment. Overall, VR offers an effective and efficient approach to broaden the appeal and application of serious games.

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CHAPTER 4

Augmented Reality and Mixed Reality Technologies

Paul Hancock

4.1 Introduction

There is some debate as to the exact meaning of *augmented reality* (AR). The Oxford dictionary provides the following definition: "A technology that superimposes a computer-generated image on a user's view of the real world, thus providing a composite view".[1] This differs from virtual reality, which completely replaces the user's view of the real world with computer-generated images (see Chap. 3).

AR gained initial success in smartphone applications due to the fact that smartphones typically have rear-facing cameras. By utilising this feature, AR is available without the need to make an additional hardware purchase. Well-known smartphone applications that utilise AR are Snapchat, a social media application that can add computer-generated effects to human faces, and the computer game *Pokémon Go*, which renders computer-generated characters that appear to be standing in front of the player's

[1] https://en.oxforddictionaries.com/definition/augmented_reality

P. Hancock (✉)
CENTRIC, Sheffield Hallam University, Sheffield, UK
e-mail: ph5218@exchange.shu.ac.uk

B. Akhgar (ed.), *Serious Games for Enhancing Law Enforcement Agencies*, Security Informatics and Law Enforcement,
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Fig. 4.1 Impression of augmented reality game RoboRaid. (Picture credits: https://docs.microsoft.com/en-us/windows/mixed-reality/case-study-using-spatial-sound-in-roboraid)

phone. There is a wide spectrum of additional AR devices from wearable devices like headsets and watches to tablets. In the future, these technologies could be expanded with contact lenses or potentially even implants (Buhr, 2017). The term *mixed reality* (MR) is often used to describe a form of augmented reality in which the real world and digital objects interact (Franklin Institute, 2017). The Microsoft HoloLens family of devices offers MR experiences, for example, a game called *RoboRaid* (see Fig. 4.1) in which computer-generated robots break through the walls of the player's room creating a unique video game experience. This is possible because HoloLens devices are able to scan the environment and determine where the walls and furniture are whilst the game is played.[2]

Whilst *RoboRaid* is a game intended for entertainment purposes, it provides an excellent example of what can be achieved from a serious game perspective. The way in which the computer-generated images interact with the real world can be used to create powerful training simulations to train practical skills, tactical thinking and decision making, whilst fixed position overlays can be used to provide additional information and guidance to increase subject knowledge and enable more informed decision making.

By allowing users to see the outside world alongside computer generated images, AR creates an effective platform to provide instructions, guidance and training. VR can provide a similar service (see Chap. 3), yet

[2] https://docs.microsoft.com/en-us/windows/mixed-reality/spatial-mapping

considerable work is required to create an accurate 3D representation of an object or scene, and there can be ambiguity and errors in 3D models. AR removes these problems, since activities such as training sessions can take place within the actual environment, which remains visible to the user whilst they wear the headset. AR has the added advantage that the user can observe their own body and hand movements, which makes it easier to interact with real-world objects. Using AR, it is also possible to attend meetings or participate in a collaborative exercise, in which participants are in separate locations using a technique called holoportation. (Microsoft, n.d.) uses a type of 3D capture technology that allows high-quality 3D models of people to be reconstructed, compressed and transmitted in real time. When combined with mixed reality displays, this technology allows users to see, hear and interact with remote participants in 3D as if they were present in the same physical space. It is claimed that communicating and interacting with remote users in AR becomes as natural as face-to-face communication (Orts-Escolano et al., 2016).

This chapter will discuss some of the most popular technologies available for AR-based serious game developments. It will then go on to explore current applications of AR in both research and industry and offer considerations for AR-based serious game design. Finally, it will discuss some of the current issues around AR including ethical implications.

4.2 Current AR Technologies

The most popular platforms currently available for AR are mobile devices such as smartphones and tablets. However, this chapter will focus primarily on wearable AR technologies as these are better suited to most serious game applications. The following section will discuss the features of a selection of wearable AR devices as well as possible software solutions and plug-ins that can be used to develop AR applications.

4.2.1 Hardware for AR Technologies

Wearable AR headsets come in a wide range of designs. Whilst the technology itself is still very much in its infancy, each headset has its own shortcomings as well as areas where it may excel over other products. For this reason, it is important to consider carefully which elements are most important for the purpose of the AR application that will be developed. Two main types of wearable devices can be differentiated: *AR overlay*

Fig. 4.2 Example of an AR overlay headset. (Picture credits: http://www.x.company/glass/)

devices, which effectively project a mobile phone screen onto the lens of a pair of glasses (as, for example, in Fig. 4.2), and *holographic headsets,* which can support MR applications where computer-generated images interact with the real world.

AR Overlay Technologies

Overlay devices are a popular style of AR device. These are normally available in the form of a pair of glasses (which can even include prescription lenses). They include a small screen close to one of the lenses, so that the user sees a small translucent screen in their vision. A well-known example of this type of device is the Google Glass headset, first demonstrated by Google in 2012. Google Glass is a lightweight wearable computer with a small prism-based translucent screen mounted above the right eye that brings information into the wearer's line of sight. The screen floats in the top right-hand side of the wearer's vision, appearing as a small display projected in front of the user. This device essentially provides a hands-free smartphone-like display with content similar to what would be seen on a smartphone. The device can be used for sending and receiving calls, messages and photos. It can also be used for navigation, for which a map is displayed on the screen with information that updates with the user's movements. In addition, a camera is mounted on the device, which can be used for taking photos or capturing video. Audio is provided by a microphone situated just behind the user's right ear using bone conduction. This means that sound is generated by vibrating bones near the ear (Warr, 2013). One benefit of this conduction system is that environmental noise is not blocked out in the way it would be if headphones or earphones were used, this makes having conversations easier and also improves safety whilst walking around outside, in particular whilst crossing roads.

Whilst Google Glass was initially launched as a consumer device, it failed in this regard. This was mainly due to three reasons: the high price, the lack of any functionality not already provided by smartphones and privacy. Especially significant were privacy concerns, as people could not be sure whether someone wearing the headset was filming them. As a result, the wearing of the device in movie theatres, banks, schools, bars and some other public spaces was banned (Gray, 2013).

Whilst this type of headset has so far failed as a consumer device, it still has considerable potential as a professional device, either for training or enhancing communication: In 2014, Google announced that Google Glass would be relaunched as a business only device (Kastrenakes, 2014). At the time of writing, Google restricts sales of the device to developers, who are referred to as 'Glass Partners'. If a business requires a Glass solution, they have to contact a 'Glass Partner' who will sell the device with whatever software the business requires pre installed. One business who has made use of this possibility is Hewlett Packard Enterprise (HPE), which uses Glass to provide technical support to their business customers via a service called 'HPE Visual Remote Guidance'. This service enables staff to collaborate virtually with a support engineer. The engineer is able to observe what the camera on the headset of the staff member records. They can then send images to the staff member's headset, which shows what they should do to resolve their issue (HPE, 2015).

One major advantage of a headset that provides smartphone functionality is that workers in wide-ranging fields such as manufacturing, logistics, field services and healthcare may find it useful to consult a wearable device for information and other resources leaving their hands free. The way in which the user is able to communicate remotely with other people makes this type of device suitable also for instructional training or support.

Holographic Technologies

Holographic headsets project 3D computer-generated holograms onto a visor in front of user's eyes. The user interacts with these objects by moving their hand to the position in the real world where the holograms appear to be. These holograms can be set to remain locked in their position in the real world or be made to track the user's movements. For instance, an engineer may wish to review the design of an engine. Wearing a holographic headset, they could load a 3D model of the engine and then place it in front of themselves. By locking the position of the model, they would then be able to walk around the engine so they can investigate it from all angles. Alternatively, a user may want to have a head-up display (HUD) with relevant information about the application they are using. This HUD could track the user's movements, so that information is always displayed in a convenient position in front of the user so as not to obscure their vision. These devices can be either AR or MR. Holograms generated on AR headsets will still appear to exist in the real work but will not interact with their environment. By contrast, sensors mounted on MR headsets allow the device to map and understand physical spaces. This enables the computer-generated holograms to interact with their environment.

4.3 Software for Developing AR Applications

There are multiple software platforms to develop AR applications. Apple and Google, who are currently the main players in the smartphone industry, each have their own software development kit (SDK), which can be used to create software for devices running their own operating systems (primarily phones and tablets). Another popular solution is Vuforia, which is a cross-platform SDK meaning that applications developed this way can be deployed to a wider range of devices (including wearable devices like HoloLens).

4.3.1 Apple ARKit

Apple's approach to AR is to view the screen on a mobile device as a lens that allows the user to see a computer-generated world which augments the real world. This approach is not as immersive as a headset approach but means that there is no requirement for additional hardware beyond a phone or tablet. ARKit works by tracking 'feature points' which are visually distinct features in the real world that can be tracked by the camera on a device. By triangulating the relative positions of these feature points, it is possible to calculate the position of objects in the real world. The real-world position is calculated relative to the position of the device when the application starts. This together with the accelerometer and gyroscope that are available on most modern devices can track a user's motion (Goode, 2018).

In order to understand the world around the devices, the application will initially scan for horizontal and vertical surfaces (e.g. floors, tabletops and walls). These surfaces can then be used to position computer-generated images, so that they appear to be placed on a surface. There is also functionality to provide an estimation of light levels and the positioning of light sources using camera exposure information to determine relative brightness. This can be used to correctly light the computer-generated images, so that they blend in with the real-world and cast shadows appropriately.

Positional tracking works best in well-textured environments, as visual complexity is required to find features which the camera can track. If facing a white wall or in a room with insufficient lighting, it becomes challenging to track feature points, in consequence reducing tracking accuracy. Static scenes work best, since if too much of what the device's camera can see is in motion, visual data will not correspond to motion data, which can cause projected objects to drift. ARKit can detect when these problems occur. This makes it possible to give users feedback and make them aware of why tracking has become unreliable and to allow them to make improvements. ARKit can also recognise images and objects. An example of this could be a museum app that adds interactive 3D visualisations when the user points their device at a displayed sculpture or artefact. At present, applications developed using ARKit are only compatible with devices running the iOS operating system, which includes iPhones and iPads.

4.3.2 Google ARCore

Google have their own SDK called ARCore. As a user experience, it is almost identical to ARKit. ARCore has some advantages due to Apple having more control over hardware and software with their devices. ARCore has some advantages with respect to how real-world environments are mapped but these differences are trivial for the average user (Miesnieks, 2017). Applications developed using ARCore are compatible with devices running the Android and iOS operating systems, which means they are compatible with more devices than applications developed with ARKit.

4.3.3 Vuforia

Vuforia is a cross-platform AR and MR application development platform. Due to its cross-platform nature, it is possible to deploy a Vuforia application to devices running iOS, Android and Windows (including HoloLens) operating systems. Vuforia has been integrated into Unity, which at the time of writing is the world's most popular game engine. The cross-platform nature of Vuforia eliminates the need to create separate applications for use on different AR/MR platforms, in contrast to specialised applications such as ARKit and ARCore. A useful feature of Vuforia applications is that 3D virtual content appears when a device's camera recognises either a 3D object in the real world (e.g. a specific industrial equipment or a home appliance) or a 2D image (e.g. a magazine page or trading card). Vuforia has been used in a variety of applications, aimed at both entertainment and serious games.

4.3.4 Considerations for Selecting Software Platforms

When deciding which software platform to use to develop an AR application, it is important to consider which device it needs to be compatible with. If the application has to be compatible with iOS, Android and Windows (or Windows plus either iOS or Android) devices, then a multi-platform software solution is a good choice, as this reduces the work required to make an application compatible with every device. If an application only needs to support a single operating system, then a software platform designed specifically for this operating system will provide a slightly better experience in terms of motion tracking, light detection and object anchoring.[3]

4.4 AR Innovation Examples

The following section explores a range of innovative ways AR has been used for education, marketing and enhanced situational awareness.

4.4.1 AR in Education

AR has great potential for educational purposes, as it is ideal for delivering instructional information: AR applications can be designed to recognise objects or images and then display computer-generated images to a user. For instance, an application could teach users how to replace a machinery component whereby the application can detect the correct component, highlight it to the user and also indicate the fixing points holding it in place. Whilst such an application could also be developed in VR, users may

[3] https://skywell.software/blog/vuforia-vs-arkit-vs-arcore-choosing-an-augmented-reality-sdk/

find it easier to engage with the platform if they can physically touch and explore the objects they are learning about. Concrete examples of this approach already exist.

AVATAR Partners

A company called AVATAR Partners develops AR training systems based on Vuforia, which are being used by the US Department of Defence as well as the commercial sector. One such application is aimed at training maintenance personnel. Military combat aircraft present unique challenges for maintenance personnel given that space within the aircraft is optimised to allow a large number of hardware systems in a very tight, crowded space. Traditionally, if a trainee wished to see the wiring within an aircraft, it would be necessary to bring in equipment specialists to remove, reinstall and test systems which are in the way of the respective wiring. This takes time and can cause additional wear and tear on sensitive equipment. An AR system allows the trainee to see the positions of the wiring (and other internal components) without having to touch an actual aircraft. Another benefit of such a system is that it works on scale models as well as actual aircrafts (AVATAR Partners, 2017).

Japan Airlines

Japan Airlines (JAL) employs an AR application to train engine mechanics. This training is delivered to trainee engineers using the Microsoft HoloLens device. Traditionally, hands-on training for mechanics required the trainee to wait for an appointment when a plane is in the hangar for maintenance. This creates challenges in coordinating training schedules with maintenance schedules and locations. Additional challenges are factoring in time to deal with tasks such as removing the engine's cover, known as a cowling, to get to the engine itself. Koji Hayamizu, senior director of the planning group for JAL's Products and Service Administration Department, explains the benefits of AR for training:

> The engine looks real, in front of you ... Mechanics can learn an engine structure by extracting important parts with the simulation, learning names of parts and studying the structure of engines and surrounding systems, regardless of location or time of day. (Choney, 2016)

Whilst it is an important training tool, this application differs little from what could be achieved in a VR application. The advantage of using AR/MR in this instance is that, because the experience is not fully immersive, collaboration between trainer and trainee becomes simpler. In this example, a trainer would be able to walk around an engine (or an extracted component of an engine) and point parts out to the trainee.

Daimler Mercedes-Benz 'Ask Mercedes'
The car manufacturer Daimler Mercedes-Benz has created a smartphone AR application aimed at helping its customers to learn how to take advantage of the features of their car. The application called *Ask Mercedes* is marketed as a 'virtual assistant for immediate help'.[4] It makes use of artificial intelligence (AI) and combines a chatbot with AR functionality. The user can ask questions by typing on a virtual keyboard or by using the voice recognition feature supported by the app. The AR aspect of this app allows the user to use a smartphone camera to scan the car's controls and displays. The user holds their smartphone in front of the car's steering wheel or dash board. The application then identifies various controls and displays by scanning the image captured by the smartphone's camera. Once the objects have been visually identified, an explanation of the corresponding functionality is provided.

Military Usage: AITT
Military applications are another area that are making increasing use of augmented and mixed reality technologies, both in terms of training and in active warfare. One example of a military training application using AR/MR is the *Augmented Immersive Team Trainer* (AITT) system developed by the US-based Office of Naval Research (ONR). *AITT* is delivered via a helmet-mounted display and supports a wide range of live, virtual and cutting-edge training scenarios. There have been live demonstrations of this system in which US Marines using the AITT display could see realistic battlefield effects such as aircraft, ground vehicles, opposing forces and explosions from mortar shells and similar munitions. Dr. John Pazik, head of ONR's Expeditionary Manoeuvre Warfare and Combating Terrorism Department, expects that:

> the AITT system will be an enormous assist to our Marines, giving them the ability to train more often, and in more places, than ever before … New technologies like this increase war fighter preparation for different scenarios, and reduce training costs at the same time. (cited in Duffle, 2015)

[4] https://media.daimler.com/marsMediaSite/en/instance/ko/Intelligent-dialogue-technology-combined-with-augmented-reality-Ask-Mercedes-the-virtual-assistant-for-immediate-help.xhtml?oid=30345702

Prior to *AITT*, Marine Corps combat training was costly and time-consuming to set up. Additionally, there were often long waiting times for a test range to become available and poor weather could lead to the training being cancelled. The *AITT* training is considerably easier to coordinate, also removing the logistical problems of having to manoeuvre land vehicles, aircraft and munitions. Training using *AITT* also allows for realistic visual effects from explosions, which would not be as easy to accomplish using traditional training methods.

4.4.2 AR for Marketing

The promises of AR technology and the rapid development of AR platforms have led to its uptake as an effective marketing strategy in many industries, as it is believed that AR can be very persuasive. Below are examples of the effective implementation of AR in this area.

Pepsi Max
Pepsi Max demonstrated an innovative example of how AR can be used for marketing purposes. Pepsi Max used augmented reality on a bus shelter advertisement space to gain the attention of passers-by. A camera hidden in a static Pepsi Max advert on the exterior of the bus shelter recorded footage from the street. This footage was displayed on the reverse of the static advert to give the appearance of a transparent window. An AR overlay was then used to illustrate abstract scenarios such as an alien abduction, a robot invasion or a tiger walking through the street. This demonstration worked by grabbing the attention of passers-by causing them to question what was happening. By forcing the passers-by to investigate, they are more likely to remember the advert. Moreover, the novelty value of this ad should encourage audiences to tell others about their experience, leading to a secondary, extended form of advertisement (Abramovich, 2017).

Disney Colouring Book
Disney released a colouring book for children that utilises augmented reality to bring the characters to life as soon as the children colour them in. The underlying system creates a textured 3D model of the characters in real time. The aim is to extend children's engagement with the Disney franchise whilst also raising parents' interest and attention (Cox, 2015).

Pizza Hut
Pizza Hut created an augmented reality menu, bringing a 3D representation of the prospective meals directly to the table in front of the user. The user can select their meal and place an order to their table, all through the app. It also includes an augmented reality treasure hunt style game to encourage customers to engage with the app on a longer basis (Engine Creative, n.d.).

4.4.3 AR for Improved Situational Awareness

Situational awareness is the knowledge of what is happening in surrounding areas. Inherent in this definition is a notion of what is important (Endsley & Garland, 2000). By not obstructing the view of the real world, AR has the capability to improve situational awareness by supplying the user with a constant stream of important information that otherwise may have required interaction with other forms of technology.

Military TAR
Military field officers have to maintain continuous awareness of their environment, which makes fully immersive VR applications unsuitable. In this situation, AR/MR headsets are better suited. The US Army has created an eyepiece to improve soldiers' situational awareness, called *TAR* (Tactical Augmented Reality). *TAR* enables soldiers to see the position of team members and enemies on a map, which is overlaid on their field of view. When a weapon is drawn, additional information will be supplied such as the target's distance. The eyepiece combines functionalities of night vision goggles and GPS into one piece of hardware. In addition, the eyepiece enables rear view vision. This allows soldiers to have a holistic view of their surroundings (Haridy, 2017). There are also potential applications for AR in command and control centres (CCC) and militaristic planning. For instance, AR devices can allow generals to see a tabletop representation of live battle scenes.

Vehicles
Another area in which AR aims to improve situational awareness is driving vehicles. Byoung-Jun Park and colleagues (2015) developed a system that uses colour coding to illustrate the threat level other vehicles pose on the road. This information is overlaid onto the windscreen. BMW created their own wearable AR headset, which also presents information from the

dashboard to keep the driver's attention on the road. Another function is to draw attention to any low objects under the car that may otherwise be obscured making use of external cameras; that is, the driver can see through the car, as the glasses essentially offer drivers 'X-ray vision' (Baldwin, 2015). Baldwin (2017) cautions, however, that such applications could rather act as a distraction by blocking the user's field of vision with information that is not overly important, at the same time blocking the view on potential hazards.

4.5 Current Issues and Limitations of AR

AR has been referred to as a persuasive technology. For this reason, augmented reality can be subjected to numerous ethical concerns. For instance, computers can be more effective persuaders, as they are not susceptible to social cues or emotions and are more persistent than any human could ever be. Giving them the ability to trial different persuasion techniques in a methodical manner, computers can collect data on their audience and therefore are able to target their arguments very specifically. A frequent reason for discussion is thus whether using technology to persuade is an ethical concern[5],[6]. Persuasion can be used to affect the way people behave or what they believe in. This is a form of manipulation, which causes concern (Pase, 2012). Whilst audiences may believe that they are strong and able to resist manipulation, there is a high risk to vulnerable groups who may also be more susceptible to misinformation or misdirection. Surveillance is another persuasive technique available to an AR application that creates concerns, depending on the context and purpose for its use. If used in order to covertly observe, collect private information or to punish, then its use should be avoided (Pase, 2012; Sabelman & Lam, 2015).

Related to the above, there has been a rise in concerns about privacy. The public is growing increasingly concerned about the use of their data and are more aware of their online presence. Due to this, the EU's General Data Protection Regulation (GDPR) was introduced, which provides stronger rules on data protection giving people more control over their personal data. Most AR applications require the use of a camera to overlay

[5] https://becominghuman.ai/six-ethical-problems-for-augmented-reality-6a8dad27122

[6] https://medium.com/inborn-experience/what-are-the-ethical-considerations-of-augmented-reality-243de50a3f9

the computer-generated elements on top of the view of the real world. The majority of these systems utilise outward-facing cameras. This could raise concerns about the public not being aware of being filmed, which can cause anxieties about not knowing if one is on camera or not. With wearable AR, there is also a concern about what data may be collected and stored about the user. If the data is not securely stored, it would be possible for rogue actors to obtain highly personal and/or sensitive information (Pase, 2012).

Allowing users to still see their surroundings, yet partially obscuring their vision with information, can cause distractions. In an uncontrolled environment this could be a safety risk, for example, if the user is crossing a road and they do not see a car, because the augmented reality content has created a blind spot in their vision. Such scenarios outline potentially life-threatening consequences of faulty AR designs.

4.6 AR Development Processes and Methodologies

A basic AR development process can be relatively fast. Camba and Contero (2015) created a methodology for the rapid development of marker-based AR tools, which illustrates the main milestones for creating an AR application. The stages are split into two main components: 3D content creation and AR content creation (see Fig. 4.3). The first stage of this methodology uses image-based modelling, which is convenient for recreating real-world objects, although in some circumstances, this will not be possible (e.g. if an object is transparent or overly reflective, the image processing software may struggle to recreate the object in 3D). In addition, the object

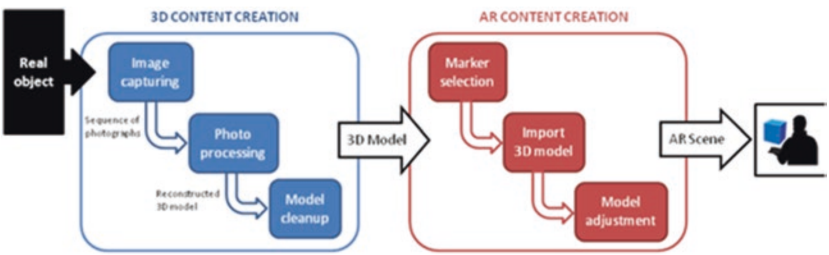

Fig. 4.3 Methodology for the rapid development of marker-based AR tools (Camba & Contero, 2015)

may not be readily available. In this case, the object will need to be modelled from scratch, which may slow down the development speed. Once the object has been captured in 3D, there will probably be clean-up work required by an artist to ensure that the model is efficient and will not require too much processing power to render.

Once the 3D content has been created, the second stage of AR content creation begins. The methods used to create content may vary depending on the software, although the general principles will remain the same. Firstly, a marker must be chosen and printed if necessary; then a camera needs to be set up and pointed towards the marker. Once the marker has been recognised, the area will be highlighted. The 3D content can then be dragged and dropped into the scene.

As AR is a relatively new field of research, the current methodologies are rather basic. With the maturing of the field, more comprehensive methodologies for developing AR applications should be available in the future. These will likely address aspects such as design, interaction and the evaluation of the product.

4.7 Interacting with Wearable Augmented Reality

Interactions with augmented reality should feel natural. Whilst current efforts are still in their infancy, given progress in gesture tracking, speech recognition, motion tracking and eye tracking, it can be expected that improved interaction methods will become available in the not too distant future.

According to Engine Creative (2017) there are three ways to add augmented reality elements to a scene:

1. *Fixed screen* – This form of interaction works exactly as current standard interaction interfaces such as mobile or desktop app. No matter what happens in the scene, the augmented elements will remain in the same location.
2. *Real world related* – In this method the app analyses the real-world scene and places the augmented elements inside. This means that as the camera moves, the augmented reality aspects will remain in the same relative position.
3. *Object related* – Here the augmented reality elements are attached to a real-world object. If the object is moved, the augmented element will move with the object.

In any standard design, interactions should be intuitive to avoid users becoming frustrated. This is possibly even more important in the context of augmented reality, as the user is interacting with the real world and therefore will expect to interact with the augmented objects in a way that is familiar with the real world. In comparison with traditional human-computer interactions, augmented reality thus attempts to replicate naturalistic interactions. This comes with a higher chance of error due to how gestures, speech or eye movements are interpreted by the system (Curran, 2016).

An issue for interactions with wearable AR is that the augmented elements are often overlays of videos. Therefore, the user's hands often obstruct the augmented reality aspects. Another aspect to take into consideration is background lighting (e.g. will the elements still be visible in both poorly lit and overly bright environments?).

4.8 Choosing Between AR and VR

Augmented reality is a powerful platform for educational purposes. It allows trainings to be conducted at real locations in which people interact with computer-generated characters (either as a 3D representation of another human at a different location or as an AI-controlled character). Because AR is not fully immersive, the problems with simulator/cybersickness some people experience in VR are less prevalent.

That is not to say, however, that AR is always a better choice than VR. VR can be a better choice for training in hazardous environments, for instance. Also, AR is an up and coming technology, and there are still numerous hurdles to overcome before the true power of its capabilities can be realised. For example, AR headsets are still largely in development and have not yet reached their full potential. Also, considerably more research is needed to achieve naturalistic interactions with AR. In addition, ethical questions could cause issues for augmented reality in the future.

Despite these concerns, AR undoubtedly carries potential as an approach for training. Future iterations of AR headsets such as HoloLens will be more comfortable to wear and offer more immersive experiences. Interactions between human users and holograms will also improve with advancements in eye tracking technology and by incorporating haptic feedback.[7]

[7] https://www.cnet.com/news/the-future-of-ar-according-to-microsoft/

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CHAPTER 5

Gamification and Simulation

Andrea Redhead and Jonathan Saunders

5.1 Introduction

There are two core elements to any serious game: gamification and simulation. This chapter will discuss why these two parts play such an important role in serious games. It will also aim to help readers understand how both gamification and simulation can be used to enhance a serious game without undermining the learning objectives that are a fundamental part of their purpose. As both gamification and simulation can be overused, and in doing so overshadow the main objectives of a serious game, it is also important to consider the impact that one has on the other. With correct game design, the gamification techniques that will be discussed can build upon the simulation to provide the user with more incentive and drive to learn.

5.2 Gamification

Gamification uses elements commonly found in games to enhance other applications, with the central idea that the motivational potential of games can be transferred to non-game environments (Groening & Binnewies, 2019). The concept has a myriad of definitions, but most can be simplified

A. Redhead (✉) · J. Saunders
CENTRIC, Sheffield Hallam University, Sheffield, UK
e-mail: a.redhead@shu.ac.uk

B. Akhgar (ed.), *Serious Games for Enhancing Law Enforcement Agencies*, Security Informatics and Law Enforcement,
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to "the use of game design elements in non-game contexts", a definition provided by Groh (2012) to allow a broad application of the concept. Gamification is used in a variety of applications from encouraging people to work through their to-do lists (Habitica, 2019) to learning languages (Duolingo, 2019).

Considerable research has been conducted into how gamification can be used to enhance education. Dicheva, Dichev, Agre, and Angelova (2015) systematically reviewed papers that looked at introducing different types of gamification to this context. They concluded that gamification has the potential to improve education, provided that it is designed and used in the correct way. Although there are no hard and fast rules as to this 'correct' implementation of gamification, there are specific guidelines that can be put forward in order to help achieve concise and appropriate integration. For instance, Deterding, Khaled, Nacke, and Dixon (2011) split gamification into five different levels:

1. *Interface design* – integrating badges, levels, leader boards or similar goal-oriented systems.
2. *Game mechanics* – implementing systems that are common to games.
3. *Design principles* – solving issues through game design approaches.
4. *Conceptual models* – using particular game models whilst creating an application.
5. *Game design methods* – applying specific practices and processes common to game design.

These five levels will form the basis for the first part of the chapter on gamification, which will specifically consider how they can be introduced into serious games. Not every serious game requires all five aspects, and it may not suit the game for all of them to be introduced either. Instead, it is best to consider the subsequent sections as a guide on how to help provide interactivity and motivation. As seen in Fig. 5.1, serious games can be independent from gamification entirely. It is thus important to judge whether gamification enhances or hinders the aims of the serious game to be developed.

5.2.1 Interface Design

The introduction of goal-oriented systems into games appeared with the earliest arcades in the form of a leader board and three initials to indicate the player. This simple form of interface design had players vying for the

Fig. 5.1 The differentiation of gamification. (Deterding et al., 2011)

top spot long before home console systems were commonplace. A publisher for the Atari 2600 games console, Activision, took the concept of leader board scores a step further. Until about 1983 they sent players patches for reaching certain score requirements (Hilliard, 2013) (see Fig. 5.2). These patches were the motivation for players to take part in the goal-oriented system that Activision had developed.

The release of Microsoft's Xbox 360 console system in 2005 (Dybwad, 2005) digitalised this form of achievements and thus sparked the extension of this aspect of gamification into the new environment. It also prompted Sony to introduce a version of this feature to their console, the PlayStation 3, 3 years after the original release (McMahon, 2017).

Today, games are primarily focused around achievement systems, though racing games and other competitive styles also use leader boards as a way of showcasing high scores. Gamification in today's applications and serious games also use a strong mix of leader boards and achievement systems.

5.2.2 Achievement Systems

Microsoft and Sony may have popularised digital achievements, but it is one of the main gamification elements across a myriad of non-gaming applications today. A wide range of studies aimed to determine the effectiveness

Fig. 5.2 Some of the badges that Activision sent to players. (Hilliard, 2013)

of an achievement system in gamification. Groening and Binnewies (2019) concluded that a low number of difficult achievements can be used as a gamification system to improve performance. Although very similar, they concluded that achievements outperform conventional goal-setting systems, which is relevant for serious games with their learning objective.

Intrinsic motivation (i.e. motivation driven from within a person and not based on the surrounding world such as monetary rewards) is considered to be a highly productive force that encourages individual's behaviours (Deci & Ryan, 2000). Xi and Hamari (2019) investigated whether achievement systems can satisfy those intrinsic needs. They discovered that achievement-related features were the most positively associated with satisfying those intrinsic needs over social-related and immersion-related features.

Achievement-based systems can thus be useful in encouraging specific behaviours, provided the achievements are suitable within the context of the game. Not every serious game will benefit from having an achievement system in place, but it may be appropriate – and indeed productive – for serious games that are intended for shorter play sessions. Still, intrinsic motivation alone may not be enough to get players to seriously interact with the game. It may need the combination of an extrinsic reward to achieve intensive engagement.

5.2.3 Leader Board Systems

Leader boards are frequently seen in games with a competitive nature and can be used in the same manner for serious games. They provide an extrinsic motivation to do better through competition: Whenever there is a way to score points, either from achieving in-game targets or meeting some other form of criteria, leader boards can be used as a way to distinguish players from each other and encourage self-improvement.

Since leader boards are so prominent, it is highly unlikely that anyone will require an explanation as to what leader boards are. Users intuitively understand the concept when presented with a list of names and corresponding scores. Leader boards do, however, present an issue with respect to data protection as they put people's names on prominent display. As such it is common practice to allow users to decide on an alias. This allows the player to decide what information they wish to share with other users of the system whilst still encouraging the competition that leader boards are well known for.

5.2.4 Game Mechanics

One of the fundamental principles of gamification is the use of game mechanics in non-game systems. One of the principle game mechanics is the core game loop. A core game loop is a set of actions that a player has to repeat in order to progress through the game. The details vary from game to game, but every game has some form of core loop at its heart, usually following a structure close to the following: *acquire resources* → *train* → *battle* (co. Fig. 5.3).

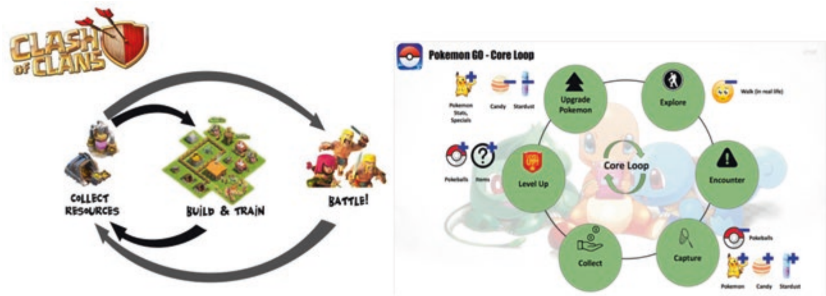

Fig. 5.3 The core game loop of the popular mobile games. "Clash of Clans" (left; Lara, 2017) and "Pokémon Go" (right; Das Gupta, 2016)

With serious games, a similar core loop can be achieved. Although instead of the cycle being about resources, training and battles, a serious game cycle is more akin to the e-learning cycle of *learn* → *practice* → *test*. This cycle can be displayed to the user in a more gamified manner. A good example is *Duolingo* (Duolingo, 2019), which is an app for learning languages. This serious game introduced the concept of experience points, levels and virtual rewards to provide a richer core loop to its users.

5.2.5 Design Principles

One of the common game design principles is to start with a core game mechanic. This allows for the game to be focused around the primary element and helps to ensure that the final product feels like a complete package. The same holds true for serious games. Focusing on one core learning goal will provide a better experience for users than a game that tries to do too much.

Another game design principle is to ensure that the game's initial entry point is low, but still takes time to master. This 'easy to learn, difficult to master' principle is one that was adapted by Blizzard Entertainment, the creators of *Hearthstone* and *World of Warcraft,* with great effect (Cifaldi, 2010). A reason for this design choice was the multiplayer element, which can also transfer to serious games that wish to encourage collaborative (or competitive) elements. Having a multiplayer element introduces the complication of not being able to assume a player's skill level. Not every user will perform the same actions, unlike within a single-player game that can be quite linear and often possesses blocking points that require a player to gain a specific skill before moving onwards.

Still, when the objective of the game is to teach, it is important not to let the multiplayer aspects overpower what a player is trying to learn. Thus, keeping the idea of one core game mechanic (e.g. learning) at the heart of the game design can help ensure that the message remains consistent and strong throughout. Keeping the entry point low (i.e. allowing players to learn how to use the game quickly whilst ensuring it takes time to master the game) can have the added benefit of ensuring that players will return rather than play it just once.

5.2.6 Conceptual Models

The phrase *conceptual model* is one that often prompts some confusion and bewilderment. It links in with the previous section about game mechanics, in particular the core loops. The conceptual model provides a visual way to showcase what the core loop, and other activities, will allow users to do and can also prompt a discussion on how best to gamify the application or serious game.

Figure 5.4 shows a conceptual model for a role-playing game that highlights all the different interactions that can be performed. Melero and Hernández-Leo (2014) created a very similar conceptual model to identify the different ways that puzzles interact, showing that this idea can be performed for a variety of different game types.

In serious games, the same form of conceptual model can be used to help ensure that the product is on the planned track before development begins. It is not expected that the models produced during this phase will be the final models, as it is important to ensure that the development can change and adapt. However, these models provide real value in ensuring the interactions that are desired are feasible and that the gamification does not push the serious game past its learning objectives.

Relationships are just one example that can be shown through conceptual models. Depending on the style of the game, other elements may become important. In language learning apps, for instance, the focus is around the vocabulary and the grammar. In this instance, a conceptual model showcasing when different levels of vocabulary are introduced may be useful. Another useful conceptual model may be at what point grammar can be presented to the user without overwhelming them with too many new words.

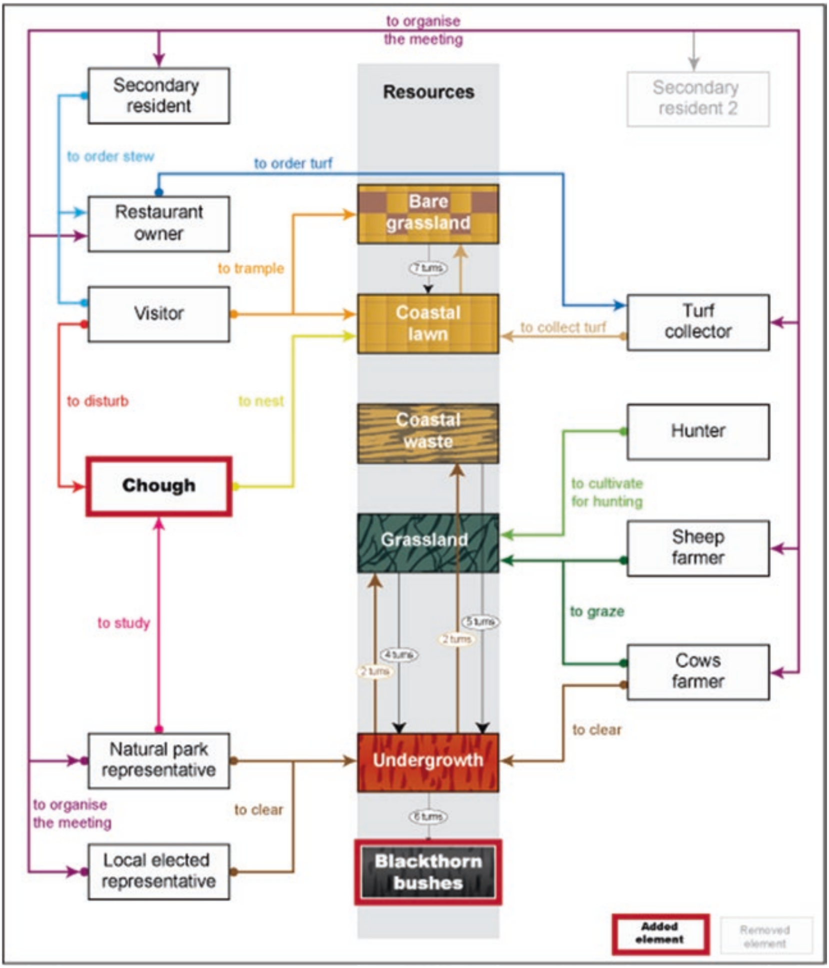

Fig. 5.4 A conceptual model for a role-playing game. (Gourmelon, Rouan, Lefevre, & Rognant, 2011)

5.2.7 Game Design Methods

The most well-known methodology used in both game development and software development is the agile methodology (Shama & Shivamanth, 2015). This is the principle of not designing everything outright and instead taking an iterative approach. This system is not unique to games but is used frequently throughout the software development world. The agile methodology allows for the software developers and game designers to ensure that they are meeting their client's brief whilst allowing them to respond to any changes and new requirements that may emerge along the process.

This is not to say that the game should not have some forethought of design. Indeed, the majority of the game should be discussed and planned well before any development starts. Instead, the methodology encourages the client and developer to meet at regular intervals for updates on the progress. If any changes are required, the developers can begin to plan for how to implement those changes, whether this is because an idea has not worked as planned or because the basic requirements have changed in the lifecycle of the product.

The same principles apply in serious games, no matter whether the game is on a 2D platform or a virtual reality platform. Maintaining a close relationship between developers and clients is always valuable, as is having regular update meetings on the status of the game. The flexibility that the agile development methodology provides cannot be overstated.

5.2.8 Gamification Implementation

After looking at the different areas of gamification, the question remains how to best implement it. The short answer is: Every adaption of gamification will need to be unique to the product being made. The best recommendation is to work in close collaboration between developers and end users of the product to ensure that the gamification elements are right for the end goal.

In the context of serious games, it is important to make sure that the learning goals are placed at the forefront of the development. Gamification should be primarily used to enhance and enrich the user's experience. If this is not the case, then the serious game runs the risk of being closer to a recreational game or that its learning objectives are hidden entirely. Both will undermine the purpose and effectiveness of the serious game.

5.3 Simulation

Simulation is a core concept of serious games, which encompasses the ability to automatically process a set of variables over time based on external stimuli. Often these simulations replicate real-world processes to help identify patterns and/or anomalies in behaviour.

Historically simulations have been used to provide insights and feedback for new ideas or concepts and are commonly employed to prove mathematical theories or engineering principles. As an example, fluid dynamics is the process of calculating the flow of liquids and gases, which is applied extensively in aerospace engineering. Often fluid algorithms require extensive and continuous simulations to achieve a goal, whether it is validating engineering designs (Baysal & Eleshaky, 1992) or conducting fuel combustion simulations (Gosman & Loannides, 1983). In addition, simulations have been used within the manufacturing industry, the automobile industry, military and healthcare (Banks, 1998).

Modern systems within the twenty-first century have expanded this portfolio to increasingly complex challenges including educational clinical simulations (Cioffi, 2001) or applications in the law enforcement area such as crowd behaviour (Wijermans, Jorna, Jager, van Vliet, & Adang, 2013) or interviews and interrogations (Luciew, Mulkern, & Punako, 2011; see also Chap. 1). These newer forms of simulation show a movement from traditional mathematical simulations for engineering and design purposes to higher-level conceptual simulations with a focus on enhancing education and understanding. This shift towards more general concepts for simulation has enabled serious games to utilise these new simulation applications to help reinforce current knowledge and learning. Many of these simulations follow one or a combination of mainstream simulation models, for instance, stochastic or deterministic simulation.

5.3.1 Deterministic Simulations

Deterministic simulation models are fully realised by the initial conditions and values of the system. If the simulation is re-run with the same conditions and parameters, the simulation will behave in the same way every time. Such predictable behaviour can be preferable depending on the requirements of the simulation (Hunecker, 2009).

Deterministic simulations are often used when all the variables required to influence a simulation are known and fully understood. This type of simulations can be found in applications for military training or wargaming, as these systems are expected to behave in a specific way in response to external stimuli (Chapman, Mills, Kardos, Stothard, & Williams, 2002). In serious games, many required behaviours are only comprised of known variables. For instance, the basic laws of physics are well documented and understood, and the makeup of a physics simulation within a virtual world often comprises known, quantifiable factors including weight, gravity, force and resistance. Also, serious games often simplify real-world behaviours into approximated representations, which can be simulated efficiently turning something, which could be represented by a stochastic model, into a simpler deterministic algorithm. This enables multiple simulations to be run concurrently without affecting the performance of the entire application.

Figure 5.5 gives an example of how a deterministic simulation model could work when simulating a dice roll within a serious game. If a user throws a pair of dice with the same force, in the same direction and from the same point in space, the result should be the same every time – in this case a roll of 6. Whilst the representation of forces, which could influence a dice roll, are dramatically simplified compared to a real-world simulation, this approximated method would enable a computer to calculate these variables with minimal effort and a high degree of accuracy.

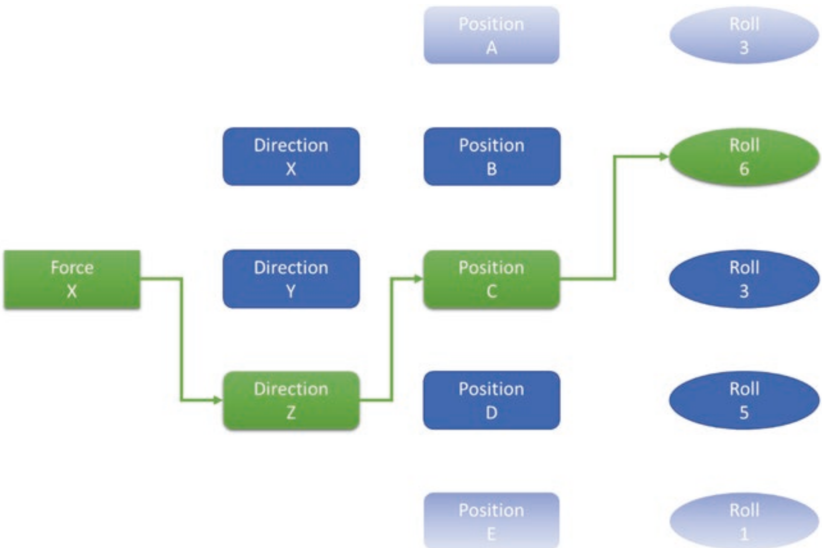

Fig. 5.5 Deterministic dice example

5.3.2 Stochastic Simulations

Stochastic simulations are random in nature, combining known conditions with random variables to model a behaviour. These simulations can be run continuously to build a distribution graph of outcomes including probabilities and predictions. This capability makes stochastic simulations a perfect method for approximating an outcome, which cannot be determined in advance (Rubinstein & Kroese, 2016). For this reason, stochastic simulations have been used extensively within the financial industry to model market trends and potential investments.

Alongside models for artificial behaviour throughout the business sector, stochastic simulations are particularly suited for simulating the behaviour of natural phenomena across all aspects of science and technology. The ability to model variables with an unknown magnitude can help provide insights into complex behaviours and has been used extensively when simulating chemical systems (Gibson & Bruck, 2000), particle physics (Ceperley & Alder, 1980) and ballistic simulations (Tahenti, Coghe, Nasri, & Pirlot, 2017).

Building on our example earlier in Fig. 5.5, a stochastic representation of this simulated dice throw would include some inherent variance or randomised behaviour, which would influence the result of the roll. Whilst this is more representative of the real-world behaviour of a dice throw, it can be counterproductive if a serious game required a certain level of control for a developer.

5.3.3 Simulations Within Serious Games

Serious games often comprise of multiple simulations running concurrently, building a network of algorithms that are both influenced by and interact with each other. This dynamic structure of information can make designing and understanding the underpinning forces of serious games a significant challenge. However, understanding the responsibility of each simulation and its influence on the surrounding environment helps developers compartmentalise each function into its own discrete package.

Many serious games contain some form of physics simulation, which could be modelling the physical movement of a character or interactions with environmental objects. Artificial intelligence simulations are also commonly included in serious games, controlling virtual avatars in order to replicate real-world behaviour. When these systems exist simultaneously within a virtual environment, they continuously interact with each other. The AI could be moving agents, opening doors, picking up objects and updating its behaviour based on the state and location of these interactable items. This continuous interconnectivity between simulations is inherent within a virtual environment. Simplifying these systems into discrete packages helps expose the variables that can be influenced, ensuring the simulation behaves as expected.

As an example, a core concept of any physics simulation is gravity, which influences almost every aspect of a virtual world from how fast objects fall to how high a user can jump. Gravity is often measured in meters per second m/s^2, with Earth's gravity being roughly 9.8 m/s^2. Simulating any virtual environment on earth should use these values to influence physics behaviours, as almost all users have an intimate understanding of the effects of gravity. However, if a scenario is taking place on the moon, simply changing the value of gravity to 1.62 m/s^2 would have a drastic effect on gameplay. Users who could previously kick a ball only 5 meters would now be able to kick it 30 meters or more, increasing the impact of certain forces by a factor of 6 (see Fig. 5.6).

Whilst Fig. 5.6 gives a basic example of how changing a variable in a physics simulation can affect the wider environment, it only showcases a very basic deterministic model of simulation. Additional factors, which could influence the behaviour of a ball including air resistance and its weight, size, shape and material, and simulating these in an Earth-like or moon environment would show significant differences. A stochastic simulation model could better represent the impact of these additional features and expected behaviours, as no two kicks would ever be the same.

Physics simulations within serious games are almost always stochastic in nature, as this better represents the real world. However, this can be

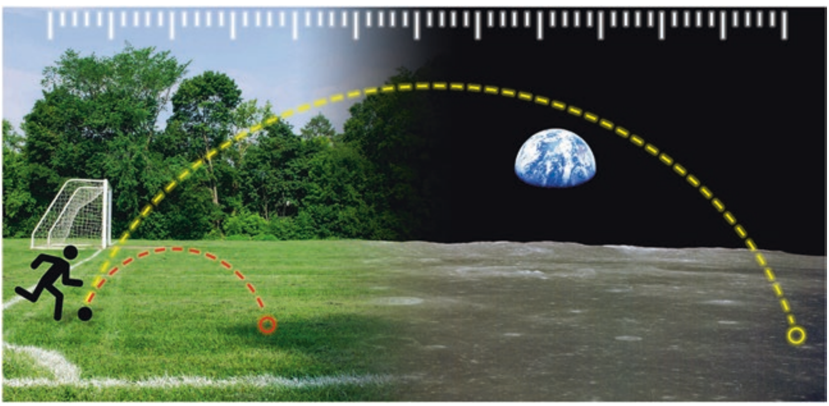

Fig. 5.6 Simulating Gravity

counterproductive as serious games need some form of predictability to meet educational requirements (Hunecker, 2009). Therefore, the educational requirements of a serious game have a significant impact upon the simulation methods utilised when realising a virtual world.

When considering what form of simulated behaviour is required for a serious game, an understanding of the relative complexity of a system helps to define whether a capability is within the scope of a serious game. Some behaviour is standard and included in game development engines. However, others are more bespoke and can take months or even years to develop. As an example, physics, lighting, rendering and pathfinding are standard simulations which come pre-packaged. However, artificial intelligence and advanced physics behaviours require additional development and specialised expertise. This can result in a significant increase to the costs and development time of a serious game and should be evaluated to justify which simulated features to include within a game.

Deciding what simulations are appropriate to meet the needs of a serious game is one of the fundamental challenges faced by developers and practitioners. Due to the complexity of some simulations and the availability of pre-existing implementations of others, there can be large discrepancies between the resource costs of two similar simulations. This can lead to misunderstandings between developers and practitioners and can result in unexpected delays and additional costs. These risks involved in utilising complex simulations mean it is extremely important to follow a clear and open development methodology, such as the one discussed in Chap. 8.

5.4 Conclusion

Gamification and simulation are two core components of any serious game. Without gamification methods, a serious game loses the unique capability to improve learning and motivation through intrinsic reinforcement, whereas simulations provide the underpinning behaviour required in order to realise a virtual world. Combined these components can build upon their strengths, interweaving the risk/reward models of gamification with the stochastic nature of simulations. This results in a platform, which remains engaging whilst educating users effectively and efficiently.

When designing and building a serious game, these are two of the most important factors in how effective it will be at training users. If the gamification methods and simulations are developed in line with the learning requirements of end users, they synergise to create an effective training platform (see Chaps. 7 and 8). However, they must be reinforced by evidence about their effectiveness for a specific learning objective to ensure they help instead of hinder the learning process.

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PART II

Process

CHAPTER 6

The AUGGMED Serious Game Platform: A Case Study of a Serious Game Development for Law Enforcement

Jonathan Saunders, Babak Akhgar, and Steffi Davey

6.1 The AUGGMED Concept

AUGGMED

Funded by the European Commission's Horizon 2020 Research and Innovation program, the AUGGMED project was established in May 2015 running for 3 years until May 2018. Throughout the project a serious gaming platform was developed alongside multiple end user agencies and was validated against unique sets of requirements established through end user/developer collaboration workshops (see Chap. 9 for details).

The multiplayer serious game training platform AUGGMED was created in a collaboration of 14 organisations and agencies distributed throughout Europe representing industry, academia, first responders and the public

J. Saunders (✉) · B. Akhgar · S. Davey
CENTRIC, Sheffield Hallam University, Sheffield, UK
e-mail: Jonathan.Saunders@shu.ac.uk

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Fig. 6.1 Organisations involved in the AUGGMED project

sector (see Fig. 6.1). Designed for law enforcement agencies (LEAs) and first responders, AUGGMED provides a multimodal training facility which enables trainees to connect remotely and train simultaneously in a single virtual environment. AUGGMED thus addresses the challenges of multi-agency training, a vital activity in the preparation for serious incidents in which different first responders will be required to work together. However, logistical issues (time, cost of travel, etc.) make it difficult to organise such training events and train different first responders at one physical location.

The multimodal system utilised by AUGGMED enables a host of interaction methods including virtual reality (VR), augmented reality (AR), touchscreen mobile devices and mouse and keyboard. The AUGGMED platform thus provides users with the capability to train collaboratively using the appropriate input method for their specific learning objectives. Each of the interaction methods possesses its own benefits for training purpose and identifying the correct method for a learning objective has been found to ensure enhanced results (Ragan et al., 2015). The touchscreen capability enables trainees to train remotely whilst on the move, whereas desktop computers are generally the most familiar option for a wider audience. The latter is especially well suited for users who have played computer games in the past, as this allows users to adapt to the game controls more quickly. Both VR and AR offer a more immersive experience creating more natural interactions than using a standard desktop mouse and keyboard. Especially augmented reality, which makes use of the real-world location, can be more relatable for trainees (see Chap. 4).

The AUGGMED platform consists of three core systems: trainer tools, the automated game scenario engine and the augmented and virtual reality environments. These three components work together seamlessly to provide users with the ability to set up and run their own simulations, to customise specific parameters required to meet their specific training needs and to get a more holistic overview when observing live exercises. Trainees, trainers and observers can access the system each with their own control systems and capabilities adjusted to their role.

AUGGMED was designed from the ground up with pedagogical principles, effective learning methods and the appropriate use of technology in mind (see Chap. 2). The simulations provide a platform to enhance a first responder's technical knowledge and decision-making skills whilst developing their emotional resilience within a psychologically stressful situation. The learning is further reinforced by choosing an appropriate interaction system, whether it be virtual reality to build emotional and psychological resilience (Wiederhold & Wiederhold, 2008) or keyboard and mouse to focus on decision-making capabilities.

The aim of the AUGGMED platform was to provide a single large-scale training solution, which could be accessed remotely allowing for multiple trainees and organisations to collaborate in large-scale training exercises. This in turn should enable the trainee organisations to significantly reduce their training costs by replacing prohibitively expensive live training exercises with virtual simulations (Allen, 1992).

Training first responders is not a new process and has been developed and iterated upon consistently throughout history. This has led to a training process, which is both refined and extremely effective for professions from firefighters to medical experts and law enforcement agencies. However, this historic training practice has always been underpinned by the capabilities of technology. As technology develops, the best practices for training strive to utilise these advancements, and AUGGMED is another step in this evolution. As technology has enabled multiple users to exist within a single virtual environment and interact using new mediums such as augmented and virtual reality, these capabilities have been identified as critical factors, which enhance existing training approaches and provide avenues for previously unachievable practices (see Chap. 10).

Recognising these factors helped identify potential solutions to this evolution in a training's potential and eventually led to the design of the AUGGMED project itself. Developing a project through the European Commission's (EC) Horizon 2020 funding program provided the perfect environment to research and develop on these factors as international collaboration, training and research is at the core of both the AUGGMED project and the EC's priorities. The remainder of the chapter outlines the development process of the AUGGMED platform as a case study of a highly successful serious game development for law enforcement agencies and first responders based on tight end user integration and collaboration.

6.2 The AUGGMED Development Process

Large projects such as AUGGMED require regular interactions between remote teams to ensure project milestones are met reliably. The scope of the project required excellent communication between all partners, but most importantly constant contact with technical and end user partners. Without regular updates, discussions and demonstrations, the project would have risked falling into the trap, which claims many modern software development projects – creating the wrong product.

When creating software products for end users, gathering their requirements is the most important part of any project (see Chap. 7). Gathering the wrong information, misinterpreting requirements or missing changes of requirements along the course of development can stop any project in its tracks or amplify development costs exponentially.

For the AUGGMED project, initial end user requirements were gathered through numerous interviews and open discussion with participating law enforcement agencies. These requirements drove the development of the first pilot of the platform. Existing LEA training methods were reviewed to identify areas that could potentially be improved by the use of serious games as well as areas of training that worked well to ensure these aspects were retained or at least not hindered in the serious game platform. Following each pilot, feedback was gathered from the participating end users based on surveys and interviews (i.e. quantitative and qualitative data) to collect suggestions about how to further improve the platform to ensure increasing fit for purpose. The feedback gathered information on the usability of the system and features or capabilities that the end users desired to be added to the platform. After the feedback and updated requirements had been collected, the results were analysed and assessed by the project consortium to decide which suggestions would be the most beneficial for the platform as well as feasible for development. The overall approach and timeline for the development is presented in Fig. 6.2.

6.2.1 Piloting the AUGGMED Platform

Over the course of the project, regular workshops, demonstrations and pilots took place across Europe including in the UK, Spain and Greece. The pilots stress tested and validated the outputs of the project whilst

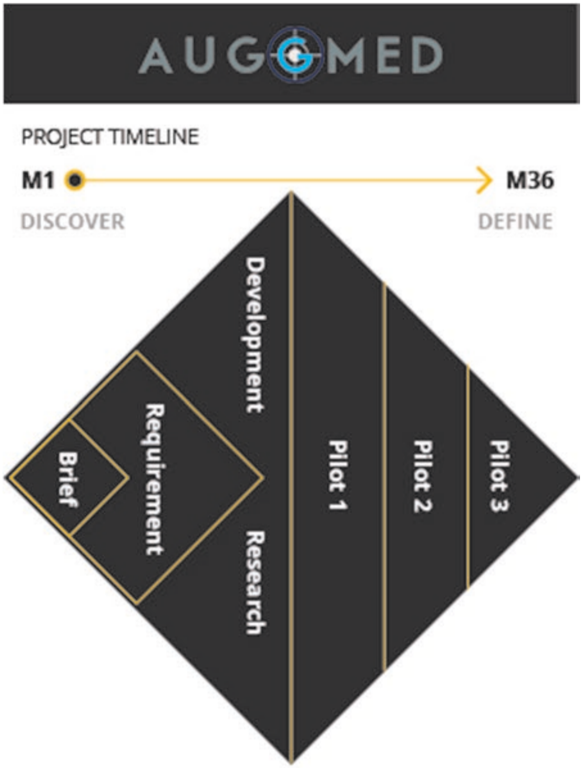

Fig. 6.2 General timeline for the development of the AUGGMENT platform

providing opportunities for end users to give direct feedback and input to the platform itself. The AUGGMED piloting system thus enabled the system to be routinely tested by multiple end user agencies. The live testing and analysis provided the consortium with an immediate list of requirements, which could be implemented for the next iteration and validated at a following pilot run.

The first AUGGMED pilot in the UK validated the AUGGMED platform's capability to be used by police officers on touchscreen and desktop devices. The platform was utilised by two Firearm Training Police Constables (PCs), an Authorised Firearms Officer, a Firearms Training Sergeant and a Police Constable. This variety of users helped ensure every stakeholder who would utilise this platform validated the system against their individual requirements and the requirements of their organisation.

The training scenario requested officers to evacuate civilians from an airport whilst identifying and neutralising multiple terrorist threats. In the scenario, the red team members (terrorists) started a large fire in the main lobby of the airport, initiating an evacuation and forcing civilians into small bottlenecks at emergency exits. Throughout the training simulation the trainees were observed and evaluated on their critical decision-making skills, threat response methods and communication skills during a high threat situation.

The results from the pilot were extremely valuable, with updated requirements gathered from end users and a number of technical problems delivering important lessons for future pilots. The importance of the mantra 'test early and test often' was highlighted during this first pilot, which experienced a number of technical difficulties including network problems, hardware malfunctions and software bugs. Whilst these issues did not stop the pilot from being a success, they did interfere with the reliability of the system and reduced its viability as a working training system. Evaluating these problems, the AUGGMED consortium identified a number of important lessons, which could be integrated into the second pilot. These lessons combined with the updated end user requirements and feedback gained from post pilot interviews and performance measurements fed into a new requirements document, which ensured that the technical development remained in line with the end users' expectations.

The second AUGGMED pilot was held in Barcelona, Spain, and validated the first implementation of the virtual reality technology within the AUGGMED platform. Multiple trainees from both Ferrocarrils de la Generalitat (FGC) and Sistema d'Emergències Mèdiques (SEM) trained using post explosion and suspect package scenarios. The suspect package scenario was tailored to the learning objectives of FGC's existing doctrine ensuring trainees experienced and responded to the simulation as they would be expected to in real life. Within this scenario, users trained in pairs utilising virtual reality to interact with civilians, find any suspect packages and respond accordingly. The trainer and observers monitored the trainees' behaviours, communications and decisions, grading them based upon their performance and knowledge. The post explosion scenario was tailored to the needs of SEM.

The main objective of this training was to prepare trainees emotionally for what they may witness in a similar event. For this purpose, trainees were exposed to some fairly graphic sights and sounds and required to carry out triage on casualties in an effective and timely manner. The use of virtual reality helped to immerse the trainees into the scenario to increase its impact on the trainee.

Over the course of this second pilot the AUGGMED consortium streamlined the VR training processes, facilitating communications between users, building user confidence in the platform and helping new users acclimatise to the new technologies, which many of the users had not seen before. This process was documented and utilised consistently following the pilot, enabling the AUGGMED platform to be used across Europe at conferences, workshops and industrial expositions including the Security and Counter Terror Expo 2017 and the 2017 Security Research, Innovation and Education Event.

The third AUGGMED pilot was hosted in Athens, Greece, showcasing the platform's multimodal augmented and virtual reality control systems. Trainees wearing augmented reality glasses participated in simulations on-site with digital agents, non-AR trainees and red team members rendered over the real world. Remote VR trainees participated and collaborated in the same simulation as the AR users, working together to identify and neutralise threats effectively.

The third pilot validated and demonstrated the final version of the AUGGMED platform providing end users with an extensive demonstration of the platform and its capabilities to meet their training needs. Security officers from a Greek police force trained in a multi-agency simulation containing hundreds of simulated civilians. Trainees were responsible for ensuring the safety of civilians by responding to incidents involving red team members wielding firearms and explosives. In total six scenarios were played in this final pilot, including some involving tactical planned attacks from the red team players.

The results from the final pilot helped identify further benefits of using AR/VR for training including the importance of immersion compared to classroom training exercises. Trainees also highlighted motion sickness as a large barrier to the ubiquitous deployment of such a training platform and the importance of improving user comfort when using such a system for longer periods of time (cp. Chaps. 3 and 4).

6.3 AUGGMED Core Components

This section introduces each of the components within the AUGGMED system, discussing the motivations for their inclusion whilst presenting their roles and functionalities in the context of what the AUGGMED platform was aiming to achieve.

6.3.1 Core System

The AUGGMED platform is comprised of a set of core systems. The platform itself utilises the Unity® Games Engine[1] to handle the base game algorithms responsible for rendering, physics simulation, sound, networking, etc. Through the utilisation of a pre-existing game engine, the development could focus on the simulation-specific requirements of the platform, rather than the base algorithmic functionalities that exist within most game platforms. The trainer tools are built on top of this, which enables trainers and trainees to customise, observe, record, analyse and assess any training scenario as well as trainees on an individual basis. Civilian intelligence and fire and explosive simulations are processed and handled by the Exodus[2] platform, a civilian population simulation program designed for large-scale evacuation models.

The architecture of AUGGMED consists of several individual components, each responsible for a specific aspect of the platform. By dividing the platform into individual instances – each with a specific responsibility – the project can also break down the overall development challenges into manageable tasks (see Table 6.1). This method of dividing the development into succinct modules enabled the AUGGMED consortium to distribute responsibilities to partners across Europe, helping to overcome common development challenges including communication, time zones and remote development operations.

6.3.2 Trainer Tools

The trainer tools are responsible for providing the trainers, trainees and observers with an interactive interface, which provides control over all integrated AUGGMED systems. This single point of interaction enables the system to be user-friendly and approachable whilst avoiding the

[1] https://unity3d.com/
[2] https://fseg.gre.ac.uk/exodus/

Table 6.1 Module challenge matrix

AUGGMED module	*Development challenge*
Trainer tools – configuration	To enable users to configure a scenario by controlling parameters within Exodus, the Automated Game Scenario Engine and VR and MR environments
Trainer tools – real-time Observation and Intervention	To enable trainers and observers to monitor trainee activity during live training exercises; to provide trainers with methods of altering live training simulations to ensure learning objectives are met
Trainer tools – assessment and evaluation	To provide trainers and trainees with the capability to review exercise data during debrief sessions
Exodus	To provide realistic civilian behaviour simulations for large crowds during hazardous situations
Automated game scenario engine	To simulate realistic environmental behaviours including physics, voice commands and interactions through communication with Exodus, the VR and MR environments and multimodal interaction interfaces
VR and MR Environments	To simulate 3D environments in a realistic manner to enhance training effectiveness
Multimodal Interaction Interfaces	To provide an effective medium of interaction and feedback with the virtual system including head-mounted displays and haptic feedback

chances of user error. The trainer tools consist of three modules: configuration interface, real-time observation and intervention interface and assessment and evaluation module.

Configuration Interface

The configuration interface allows the trainer to create custom scenarios. A number of parameters can be adjusted to affect the scenario. These parameters include location (airport, station, port), threat type (gun attack, explosive, car bomb, etc.), crowd population, avatars for trainees and weapons available to each trainee type. The trainer is also able to select how many trainees can join in each role. This helps to avoid errors when trainees enter the game and choose a role.

The interface is constructed through an amalgamation of iconography and text, ensuring the system is immediately accessible to users and easy to understand (see Fig. 6.3). Each interface was also optimised to ensure mouse and keyboard user as well as touchscreen users can utilise the tool effectively.

Fig. 6.3 Configuration options in the configuration interface

Real-Time Observation and Intervention Interface

The real-time observation and intervention interface provides controls for trainers and observers to interact with the system whilst a simulation is taking place. The observation controls are available for both trainers and observers throughout the duration of a live simulation. They enable users to navigate the virtual environment from a top-down perspective and to monitor teams or individuals by setting the camera to follow their movements.

In top-down view, trainers and observers can quickly identify trainees using markers, which are easily identifiable and distinct. When the trainer wishes to observe a specific trainee, the trainee can be selected, and the camera will automatically follow this trainee. These functionalities are useful to help the trainer identify and assess an individual trainee's performance. Users can also access a 'trainee view' which allows them to observe a trainee's actions through their own camera giving them immediate access to the trainee's experience for assessment and feedback.

The intervention controls are specifically tailored to the needs of trainers enabling them to pause/play the simulation, deploy and redeploy trainees who have been injured or trigger alarms. Specific trainer intervention controls also allow deploy red team members and suspect packages to any location within the geometry. Once the game started the trainer is able to intervene in a number of ways. The trainer can set off an explosion or start a fire at predetermined locations. This will cause close-by crowds to run to the nearest exit, and the building will start to fill with smoke. The trainer will have the option at this point to turn off the visibility of the smoke in their view, so that they are still able to see trainees even though they are caught in the smoke. Trainers are also able to start an alarm, which will cause the whole building to evacuate. At any point the trainer can pause, resume or end the simulation.

Assessment and Evaluation Module

The assessment and evaluation module enables trainers to evaluate trainees' performance following the completion of one or more training scenarios. Information regarding individual trainee performance is collated and summarised, enabling trainers to quickly assess trainee performance using data including weapon fire statistics, trainee movement heatmaps and environmental reviews. Information recorded and displayed within the assessment and evaluation module can be used by trainers during debriefing sessions or by trainees who wish to evaluate their own performance following a successful simulation.

6.3.3 Exodus

Exodus[3] is a crowd simulation environment which predicts in real time the movement and behaviour of large crowds of people within urban environments. Running in parallel with the AUGGMED platform, Exodus creates simulations of crowd movements by receiving environmental and interaction information directly from the game engine using a bespoke API. Developed by the University of Greenwich, UK, Exodus uses data collected from real-life environments to predict the movements of crowds in several scenarios, creating a scientifically accurate simulation which reinforces training with realistic civilian behaviours.

Exodus incorporates realistic fire and explosion simulations by communicating directly with the game environment, calculating injuries, civilian smoke inhalation and hazardous material propagation throughout the environment. This enables trainees to experience realistic complex and life-threatening situations, which are impossible or challenging to replicate in real life. The fire and explosion simulations are grounded in real-world ballistic and thermal data, incorporating environmental and situational data to provide a realistic solution. Exodus also simulates intelligent crowd agents within the platform, which react to trainees, the environment and the situation. Trainees and red team members can directly interact with agents using voice commands, weapons fire and/or explosives. This crowd simulation provides a realistic representation of a crowd's behaviour in the event of an incident and enables trainers to assess a trainee's ability to interact with civilians within the simulation.

[3] http://fseg.gre.ac.uk/exodus/

The bi-directional communication between the AUGGMED and Exodus platforms ensures real-time simulations can be dynamic and adaptive. This enables trainers to provide unique training experiences, which do not become repetitive or predictable, testing any trainee's ability to react to unexpected challenges.

6.3.4 Automated Game Scenario Engine

The game scenario engine is responsible for simulating and managing the virtual objects and behaviours, providing a realistic digital structure which replicates real-world expectations during training. The functionality of the engine exists within the Unity Games Engine, building on the existing simulation capabilities which the engine provides.

Alongside the basic physics behaviours (e.g. gravity or collisions) and AI behaviours (such as pathfinding), the AUGGMED platform built new simulation features. A bespoke functionality, which is built upon these existing aspects, was the fire-based smoke distribution system. Designed with efficiency in mind, it enabled the distribution of smoke to be rendered dynamically across large environments. This provided an effective method for displaying the effects of realistic smoke distribution within an environment whilst creating a medium which could inform a trainee's situational awareness. In the simulation, trainees which enter a smoke cloud begin to inhale smoke and are detrimentally affected, losing speed over time and eventually falling unconscious. The smoke rendering system is only one of the simulation requirements which were necessary to provide an effective training platform, some of which were achieved within other modules of AUGGMED.

6.3.5 Environments

The environments in which the trainees operate in the context of the AUGGMED platform were based upon real-world environments. This ensures that the training remains grounded, reinforcing the gravity of the simulation the trainees are participating in whilst preparing them for real events.

Three environments were created for AUGGMED: a fictitious airport based in the UK, an existing metro station in Spain and an existing port in Greece. For the airport environment, the geometry required was both complex and large scale. The entire environment needed to facilitate hundreds of agents behaving realistically, including checking in bags, queueing at security, embarking and arriving on flights and collecting baggage.

Due to security considerations it was decided that a fictitious airport would be constructed from pre-existing CAD DXF files utilised by the University of Greenwich for the Exodus platform.

In order to create a high sense of realism, extensive high-resolution reference images were taken and used for texture creation. The 3D models of the locations were either created by hand or by using CAD files and blueprints as a starting point. For the mixed reality (MR) mode, it was especially important to have an accurate model, as any inconsistencies in scale or positioning of objects would cause misalignments with the real world, which would result in errors when obscuring virtual objects. This would dramatically reduce the sense of immersion that the player experiences when training in MR. Another reason that the environment had to be scaled was that the 3D environment had to map precisely to the Exodus environment, which is responsible for the intelligent agents. Any inconsistencies within the environmental scale data could cause avatars to collide with environment models, causing unrealistic behaviours such as agents walking through solid objects within the virtual environment.

6.3.6 Multimodal Interaction Interfaces

The multimodal interaction interfaces consisted of a combination of commercially available hardware and bespoke interaction systems. Touchscreen, desktop and VR interfacing was achieved using standard commercial hardware, ensuring the system remains accessible and affordable. The requirements of the AUGGMED system meant the augmented reality and haptic vest systems were bespoke creations, which were designed to the specifications provided by end users in order to ensure they could integrate with every aspect of the system.

The touchscreen and desktop versions of the platform are designed to work with little to no technical expertise. Because of this the system requirements were specially tailored to work with most game-ready desktops and high-end touchscreen devices. However, due to technical limitations inherent in touchscreen devices, the decision was made to stop their support as the platform became more graphics intensive, requiring more than just a CPU to render the environment.

The virtual reality capabilities were achieved through the utilisation of the HTC Vive,[4] a head-mounted display which provides users with full freedom of movement within a space of up to $5m^2$. This enables trainees to fully

[4] https://www.vive.com/

explore their virtual environment, utilise cover in the event of live fire events in the simulation and search effectively when looking for suspicious packages. The controllers give VR users full control over their environment, including weapon selection and discharge, voice commands and locomotion.

The augmented reality interface required specific technical capabilities which were not readily available on the commercial market. Due to this a bespoke system was designed which modified the HTC Vive by integrating a square HD camera to the headset that streams visual data to the engine. Using a positional triangulation of the HMD user alongside positional/rotation matrices relating to agents/objects within the environment, the AUGGMED platform can overlay these digital visualisations onto the real world in a realistic manner. However, at the time of testing the system, this method was slow to update and render due to hardware limitations.

To facilitate vibrotactile and thermal feedback, the AUGGMED consortium designed and created an integrated haptic vest which can communicate directly with the AUGGMED platform. Building upon AUGGMED's iterative development process, the haptic vest was developed through a number of iterations, each one fed by end user feedback and testing. The vest consists of three different types of feedback mediums utilising vibrotactile actuators (vibration motors) to provide tactile feedback, thermal actuators to provide heat-based feedback and impact actuators which replicate bullet impacts. Each type of feedback is responsible for conveying specific information to the wearer. The vibrotactile actuators provide physical feedback for contact with solid objects within the virtual world, be it a wall or a person. In contrast, the thermal actuators can help replicate the temperature of an environment or inform a trainee of their proximity to a heat source. Lastly, the impact of actuators can provide immediate feedback for injuries during a live fire scenario, informing the wearer of a potential injury immediately in line with the simulation.

6.4 AUGGMED's Impact – Now and in the Future

The outputs of the AUGGMED project have an impact that goes beyond the platform itself. From new design considerations to validation studies and scientific papers, AUGGMED is having a continuing influence on research into serious game development, virtual reality and training.

The AUGGMED project has provided several significant lessons learned, which have influenced further serious game projects and helped shaped the content throughout this book. Subsequent chapters will discuss the developmental processes in more detail (see Chaps. 7, 8, and 9) as well as subsequent projects, which have all been influenced by the research and development carried out within AUGGMED (see Chaps. 10, 11, 12, and 13).

Alongside the lessons learned, platform demonstrations, conferences and expos have helped proliferate the idea that serious games can be used to train a wide range of skills. This has been especially evident for first responders and law enforcement agencies. The project's use of VR and AR technologies has demonstrated their key niche in enabling trainees to experience simulations in an immersive environment without the risks involved in dangerous real-world trainings. It has also showcased the affordability of serious games as training medium, which have capabilities that go beyond live training or classroom exercises.

6.5 Conclusion

Over the course of 3 years, AUGGMED proved to be a highly successful research and innovation project, which had a significant impact upon both the perceptions of serious game technologies and the virtual training industry specifically in the area of security, law enforcement and first responders. The success of the platform depended on a conclusive development that ensured the software aligned with end user needs whilst being adaptable for use by multiple agencies. The iterative method of end user engagement and development ensured that platform was able to adapt and evolve throughout the project to respond to ever-changing threats, such as of terror attacks, and that each iteration could be demonstrated and validated as part of a pilot.

Following the completion of the project, the successes and failures were analysed and used to help guide future serious game projects. These lessons learned are one of the most significant intangible results of AUGGMED.

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CHAPTER 7

User Requirements Elicitation

Steffi Davey and Jonathan Saunders

7.1 Introduction

There are many names that can be given to the process of collecting end user requirements, for example, requirements gathering, requirements elicitation and requirements engineering. For the purpose of this chapter, we will use the term requirements elicitation. When developing (entertainment-focused) computer games, requirements elicitation is often disregarded, or if requirements are collected, this is often done quite late in the development process (Kasurinen, Maglyas, & Smolander, 2014). Serious games differ in this regard due to their primary focus on learning (or pedagogy). Here, an in-depth understanding of the end user characteristics and needs is vital early on to ensure the game can fulfil its intended purpose.

Abugabah and Alfarraj (2015) found that a large portion of projects did not meet their end users' needs. Furthermore, an even larger number were seen to exceed their budget. A well-known example is the BBC Digital Media Initiative which cost over £98 million and was abandoned after 5 years because it failed to "keep pace with new developments and requirements within both the BBC and wider broadcasting industry". Ultimately, if a product does not comply with end user requirements, the project is not

S. Davey (✉) · J. Saunders
CENTRIC, Sheffield Hallam University, Sheffield, UK
e-mail: steffi.davey@shu.ac.uk

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a success (Hickey & Davis, 2003; Kasurinen et al., 2014). Thus, the collection of user requirements has the power to determine the success or failure of a project (Davis, Hickey, & Moreno, 2006; Kumar & Sharma, 2015; Lane, O'Raghallaigh, & Sammon, 2016; Nuseibeh & Easterbrook, 2000). If incorrect information is gathered, requirements are misinterpreted or change through the course of development, projects may have to be abandoned or rescued with considerable additional developmental costs.

There are many factors which can impact the efficacy of the requirements elicitation process. Successful gathering of user requirements is not simply a question of choosing the correct technique. The process hinges on many factors, for example, how the technique is carried out or even the mood of users, which can impact on the quality of the requirements gathered (Lane et al., 2016).

This chapter will discuss why end user requirements elicitation is so important. It will then progress to discuss different methods and techniques of collecting requirements, before looking at how to overcome possible challenges in the process. Finally, this chapter will discuss the processes used to collect end user requirements using the AUGGMED project (see Chap. 6 for project details) as a positive example.

7.2 The Importance of User Requirements Elicitation for Serious Game Development

Unlike computer games for entertainment where the game is frequently designed by the development team with few early interventions from end users (Kasurinen et al., 2014), serious games are more utilitarian and centred around end user needs. It is therefore imperative that end users are involved in the design of the game to ensure that their pedagogical needs are met (Hauge, Duin, Oliveira, & Thoben, 2006). Conversely, whilst the game is being developed, it is also important to have input from developers in the requirements gathering process, as this will ensure that the created is of sufficient quality and that expectations for a game system are not set unreasonably high for the given budget.

The main purpose of requirements gathering is thus to capture the expectations and needs of intended end users. It ensures that the game is developed from multiple perspectives (i.e. designers and intended users) and that designers obtain specific information and details to create a holistic vision of what the final product will and should encompass.

There often are tensions about what is required of the system after the initial game proposal, as end users likely have little experience of developing games and may struggle to envisage the end product (Hauge et al., 2006). Leffingwell (1997), for instance, found that 40–60% of errors in a system were attributable to errors in requirements elicitation or in the analysis phase of a project (also Hauge et al., 2006). Requirements gathering can act as a bridge between developers and end users that helps to ensure that both sides are on the same page and share the same perspective about the final product (Lane et al., 2016).

7.3 User Requirements Elicitation Techniques

User requirements elicitation for serious games can be (and often is) an iterative process of refining low-level concepts into a highly detailed prioritised list of requirements. According to Kumar and Sharma (2015), end user requirements gathering includes four stages:

1. *Elicitation* – identification of the relevant stakeholders, reason(s) to develop the system, user roles and characteristics, external interfaces, non-functional requirements and specific quality and reliability targets and to establish a clear vision of the project
2. *Analysis and specification* – development of a conceptual model of the game, prioritising the requirements and analysing the risks
3. *Validation* – verification that requirements correspond to users' needs using iterative feedback from stakeholders
4. *Management* – monitoring that the process adheres to user requirements, including the measurement of defects and controlling modification in requirements

Others have separated these four phases into six stages, separating analysis and specification into their own disparate stages and adding a verification stage (e.g. Courage & Baxter, 2005).

7.3.1 Participant Recruitment

End users for serious games are often trainees or trainers in a specific professional field, for example police officers training interviewing techniques (see Chap. 1) or first responders preparing for the handling of major crisis events (see Chap. 10). The type of end users should be established at an early stage of the game/concept design process to ensure that their expectations and needs inform the design process from the very start.

Depending on the nature of the project, end users may be stakeholders in the development project, reducing barriers to the recruitment. If end user stakeholders are not directly involved in the development project, then relevant end users will need to be recruited externally. In both cases, care needs to be taken to achieve a sufficient number and diversity of relevant individuals.

Once the end users are enrolled in the process, an important part of the requirements elicitation process involves getting to know the end users, obtaining an understanding of their roles, attitudes, values, skills, knowledge and behaviours in relevant situations. This in-depth knowledge is captured in a persona (or multiple personas) to guide the game design and development process.

7.3.2 Choosing Methodologies

A wide variety of methodologies exist for user requirements elicitation, ranging from interviewing to field studies (see Table 7.1). Several studies have aimed to determine the most effective method of requirements elicitation, often suggesting interviewing as the most appropriate approach (Davis et al., 2006). However, as Lane et al. (2016) suggest, it is difficult to assess the effectiveness of requirements gathering techniques quantitatively, as the fit of the method depends on the context of the project. Relatedly, Hickey and Davis (2003) found that design experts often tend to favour one specific data collection technique instead of evaluating the best techniques for the specific project and users in question. To avoid this bias, this section will discuss a range of common techniques and discuss where they may be most useful. This will help to make an informed decision about requirements gathering techniques driven by the context of the project.

Whichever method is chosen, it is vital to plan every method meticulously before starting the collection of requirements. An important consideration is the type of information designers wish to acquire from their end users. Another is the time and effort required to gather the relevant information. In Table 7.1, we list common methods to obtain end user requirements as well as their advantages and disadvantages. Beyond the techniques in Table 7.1, also newer and more elaborate approaches exist (e.g. gamification techniques; Kelly, de Boer, Uhlenbruck, & Webb, 2015).[1]

[1] https://ieeexplore.ieee.org/document/7129512

Table 7.1 Strengths and weaknesses of typical requirement elicitation techniques. (Based on Courage & Baxter, 2005)

RG Technique	*Details*	*Strengths*	*Weaknesses*
Interviews	Interviews collect subjective information about individuals such as their attitudes, emotions, perceptions or personal stories. They should be planned well in advance with a set of pretested questions. Standardised interviews only ask identical questions from each participant. In semi-structured interviews, additional questions can be asked for follow-up and elaboration.	Allows developers to understand subjective positions of individuals in their own words Support in-depth exploration of unfamiliar subjects and domains with a focus on end users' perspectives.	Information is personal and subjective and thus does not lend itself easily to quantification. Can be time consuming to conduct and analyse, which precludes very large sample sizes. Requires experienced and well-trained interviewers to obtain high-quality information.
Surveys	Surveys can be used to collect both qualitative and quantitative data in a standardised format.	Allows standardised data collection from large groups. Allows direct comparison of groups and investigation of influencing factors Collection and analysis tend to be considerably faster and more economical than interviews. Well suited to prioritise and/or validate an existing list of requirements (e.g. collected from interviews).	The fixed format precludes discovery of new themes or perspectives Subject to social desirability bias, low-quality answers and selective missing (e.g. due to specific user groups refusing to participate). Tendency to reduce often complex reasonings and motivations to simple quantitative scores.

(*continued*)

Table 7.1 (continued)

RG Technique	*Details*	*Strengths*	*Weaknesses*
Want and needs analysis	In want and needs analyses, users list their expectations and requirements for a system.	Can be conducted relatively quickly using a brainstorming session with relevant end users, where ideas about what is expected and required from a system are collected systematically. Can be used to create a prioritised list of requested features and functionalities.	Users must be well-informed about the purpose of the serious game and able to formulate their expectations and requirements very clearly. If the focus is too closely on the system itself, this method can miss out important elements such as usage contexts or adoption barriers within the environment. This technique is best used in conjunction with other end user requirements gathering techniques
Focus groups	Focus groups are guided discussions in a group of relevant end users.	Given detailed recording (written or audio/video), focus groups provide rich information on requirements and often unearth important disparities in requirements amongst users. Encourages discussions amongst end users to explore possibilities for the system, which supports innovative ideas.	Requires experienced moderators and well-prepared questions to ensure discussions stay focused and on topic and all participants are heard. Focus groups should not (or only very carefully) be used for highly sensitive topics, as presence of others can induce discomfort and social desirability pressures.

(*continued*)

Table 7.1 (continued)

RG Technique	*Details*	*Strengths*	*Weaknesses*
Field studies	Field studies use data collection in the environment of end users themselves; usually multiple methods for data collection are used to capture a broad range of information.	Allows the game development team to experience and observe the settings in which the systems will be used first-hand providing a second perspective to end users' own reports of their environment and work. Facilitates the combination of multiple data collection methods (interviews, observations, collection of documents, etc.) in one setting Facilitated encounters with a wider array of people beyond the original end users allowing the system to be developed with the wider organisational/ user environment in mind.	Obtaining sufficient access to organisations can be challenging as some organisations may not want to have staff from other organisations on site. Field studies are often time consuming and resource intense. Due to the diversity of information gathered (quantitative and qualitative), interpretation of information is often more challenging and less straightforward than single method studies.

7.3.3 Planning

Before the requirements gathering activities take place, it is important for end users to be made aware of the aims of the project and the benefits of the use of serious games to train and educate. It may also be beneficial to brief end users about the history of serious games and to provide examples of the game mechanics that can be employed in gamification and simulations (see Chap. 5) to provide end users with a clear understanding of what the project aims to achieve. It should be noted that by introducing demonstrations of serious games, users may be influenced in their requirements and expectations for game mechanics. For this reason, careful consideration is needed about when to demonstrate current serious game capabilities.

Whatever the chosen elicitation method, there are numerous aspects that will need to be planned. Often end users will have very busy schedules, especially when dealing with LEAs and first responders, so it can be a challenge to find a time convenient for all end users involved. In this case, methods that do not need to be moderated, such as surveys, may be preferable.

Requirements are often separated into functional and non-functional requirements. *Functional requirements* relate to front-end behaviours, whereas *non-functional requirements* refer to system capabilities such as performance and maintainability (Hauge et al., 2006). When planning requirements elicitation activities, both of these areas should be investigated.

Frequent questions guiding requirements elicitations are:

- What are the current training capabilities and their strengths and weaknesses?
- How could these be improved through the use of serious games and/or virtual reality?
- What are the learning outcomes, and how will they be evaluated?
- What game mechanics should be included in the game (e.g. score system, leader boards, etc.)?
- What are the desired functionalities to be included in the game?
- How adaptable should the game or simulation be?
- What is the budget?
- What is the timescale?
- What are the system requirements (e.g. should it be run over a network)?
- What will the style of the game be (e.g. will the game follow a story, or should it be more of a simulated scenario)?
- What are the general technical abilities of the users?

These are just a few examples of questions that often appear in requirement elicitations. The aim should be to obtain as much initial information from end users as possible and then to refine ideas along the process.

Creating a relaxed atmosphere that avoids time pressure, a setup that is sensitive to potential conflicts between participants from disparate organisations (e.g. police officers and NGOs) and expert moderation facilitates the collection of meaningful and detailed requirements. An agenda for the day should be prepared and communicated early to participants. In the planning, it is important to allow sufficient time to explain the project and its purpose thoroughly, including the current state of the art, to ensure end users are aware of the aims, expectations towards them and their investments for the project.

Throughout the requirements gathering process, it can help to repeat the outcomes that have been recorded to ensure that participants agree with the information and none of the information has been misinterpreted or missed. To prevent loss of information the event should be recorded, either through careful minute taking or through video or voice recording. In case of the latter, consent must be explicitly given by all participants before recording any data.

7.3.4 Analysis

Analysis of the recorded information should begin immediately after the event, this will again prevent loss of data and misinterpretations. The following are common methods used to analyse results of end user requirements gathering:

- *Coding* – Coding is a common analysis approach for qualitative data. It refers to the process of assigning summative words or short phrases to part of transcriptions or documents. These initial codes can then be combined into higher-order categories to identify common themes or unique and conflicting perspectives (Langdon, 1984).
- *Categorising* – Can be used with both qualitative and quantitative data. It aims to identify common themes within the data and thus aids the summarisation and interpretation of data. Categorisation helps to prioritise the development of features within the system.
- *Affinity diagrams* – The creation of an affinity diagram is generally a team activity between stakeholders involved in the end user requirements gathering. The data collected through brainstorming sessions is segmented into small pieces, which are then grouped according to relationships. It is important to approach this activity without preconceptions or predefined categories in mind to allow themes to evolve naturally throughout the process.

Results should always be validated. This can be done by presenting results or summaries of the results to stakeholders who were present at the event, or a new set of end users with the same characteristics. If multiple elicitation sessions are planned, a choice can be made whether to conduct an analysis between each session or once all the data has been collected.

Whilst the second approach saves time, the first approach allows to adapt data collection (e.g. type of people invited to the sessions, type and content of questions or collection methods) to delve deeper into specific sub-themes.

7.3.5 Management

The conscious management of end user requirements ensures that the project continuously complies with end users' needs, even if they shift. Both developers and end users should be able to add unplanned features they believe will be beneficial. At the same time, repeated discussions should not lead to feature creep and overcomplicate the system, meaning that some requirements may have to be purposely left off the documentation (Courage & Baxter, 2005).

7.3.6 Verification

Throughout the development, a continuous engagement process should ensure that the chosen end users are still relevant and that their needs have not changed. This can be done by piloting the system in different iterations along the development process (cp. Chap. 6).

7.3.7 Negotiating Requirements

The requirements elicitation process focuses on discovering end user's needs. This process also has an element of negotiation, as end users may wish to incorporate features into the game which may be out of scope or impossible to realise given the budget. Ahmad (2008) created a requirements negotiation spiral to illustrate common phases in the negotiation (see Fig. 7.1).

The spiral starts with the identification of potential conflicts, which are common if users want functionalities that would exceed the given budget or timescales for the project. In this case, alternative solutions should be suggested. Once the alternative solutions have been agreed, they should be elaborated so that end users are aware of where the compromise has been made. This will help to forestall disagreements in the future and allow end users to make an informed decision about which solution they would like to pursue. If any parties involved are still unhappy at this point, renegotiations can be reopened.

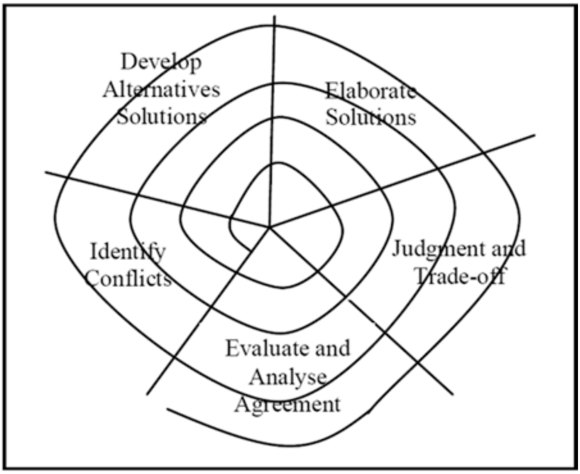

Fig. 7.1 Requirements negotiation spiral. (Ahmad, 2008)

7.4 Common Barriers in Requirements Elicitation and Possible Solutions

Even with meticulous planning prior to the requirements gathering activities, it is still possible to encounter unforeseen issues. Listed below are a number of common issues and suggestions on how to avoid or overcome them.

- *Language barriers* – Questions should be formatted in simple language, avoiding the use of technical terminology (if this terminology is necessary, a clear and concise explanation should be provided). Questions should be asked in the mother language of participants where possible to allow participants to express themselves in their mother language. If this is not possible, questions should be presented in both written and spoken forms as participants may feel more comfortable reading in foreign languages.
- *Lack of common understanding* – By frequently summarising the information that has been captured from participants, it allows the opportunity to correct misunderstandings and gaps early on and ensures that all of the information has been interpreted as intended.

- *Scope of information* – Methods of requirements gathering such as interviews and focus groups often unearth a plethora of information. This can make it difficult to analyse and draw conclusions, especially in terms of prioritising needs and requirements. When dealing with large amounts of data, collating the data into smaller common themes can help to summarise and interpret the data. At this stage it also good practice to go back to end users for validation of summaries.
- *Volatility* – It is not uncommon that requirements change over time. A series of end user requirement studies will retain the contact with the end user and ensure that they are informed about developments and content with the work that is being produced.
- *Bias* – Unconscious bias is sometimes hard to avoid. Special attention should be given to the wording of questions and instructions, as it is easy to ask leading questions or provide examples which may inflict opinions and views on participants. Good practice is to pilot questions, surveys, prompts and examples with a different group from the intended end users to make sure they are easy to understand. Further, interpretations should be checked by participants and against additional sources to avoid narrow or selective representations of results. Below are suggestions for the formulation of questions, especially in the context of interviews:

  – Avoid putting words into peoples' mouth
  – Be aware of putting emphasis on specific words
  – Avoid using loaded words or words with positive or negative connotations in the study setting
  – Ensure the questions are formulated clearly and unambiguously
  – Keep questions short, as participants may struggle to remember complex questions and feel overwhelmed
  – Avoid or limit the use of closed questions, especially questions that can be answered with yes/no

- *Participants feel uneasy* – Participants should feel comfortable enough to express their views and opinions free from judgements of other participants or moderators. Interviews and focus groups can be an uncomfortable experience for participants if they feel they are being judged for giving an 'incorrect' or 'embarrassing' answer. To make the participants feel comfortable, the following strategies can be implemented:

- Sessions should be conducted in five stages: introductions, warm-up questions, main questions, summary and wrap-up.
- Participants should be interrupted as little as possible.
- All focus should be on the subject to ensure that they feel their views are valued and important. Summarising in a non-judgemental way what the participants said can show that their views are being heard and noted.

• *Losing focus* – The moderator should ensure that the focus is kept on appropriate subjects and discussions do not veer off into irrelevant topics.

7.5 Conclusion

Requirements elicitation is a crucial milestone of the serious game development process. Without successfully collecting end user needs, it is impossible to create a product that is fit for purpose. As outlined above, the process of requirements gathering can be separated into five stages: elicitation, analysis, specification, validation/verification and management. The actual process of elicitation is flexible in the sense that data collection techniques need to be adopted to the specific situation and end users in a game development project. All requirements gathering activities should be thoroughly planned and any foreseeable barriers should be addressed prior to the event. Interviews are often argued to be the most effective method of eliciting requirements. However, more innovative techniques (e.g. playing games) can inspire additional insights. Although the initial session has probably the biggest impact in terms of starting the game development, further engagements should be of help throughout the process to ensure the development keeps on track with (changing) user requirements.

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CHAPTER 8

Design Processes and Decisions

Jonathan Saunders

8.1 Introduction

How serious games are designed and created has been a significant area of research, which is informed by both technical and psychological knowledge. Over time, this research has coalesced into numerous serious games design methodologies, each with their own approach for creating an effective training medium. These design methodologies themselves are underpinned by findings regarding principles of serious games including pedagogy, immersion and presence.

Serious games utilise a method of understanding called 'experiential learning'. *Experiential learning* is the process of learning from experience, in contrast to classroom-based learning. Learners build knowledge through interaction or by undertaking an action – as opposed to simply reading or writing about it (Kolb, 2014; see also Chap. 2). This form of learning requires the training to be comparable to the real-world actions a trainee is trying to acquire or improve. Without sufficient similarity between a real-world activity and its virtual representation, the experiential knowledge transfer will be inefficient as users identify discrepancies between the two environments.

J. Saunders (✉)
CENTRIC, Sheffield Hallam University, Sheffield, UK
e-mail: Jonathan.Saunders@shu.ac.uk

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Presence and immersion are important tools, unique to serious games, unavailable in classroom-based learning. Their ability to engage learners is a key capability that serious games developers use to enhance practical learning and knowledge transfer. *Presence* is defined as the experience of inhabiting a specific environment, whether it is real or virtual. *Immersion* can be defined as the feeling of being engrossed or absorbed in a specific experience (Witmer & Singer, 1998). This capability to achieve absolute focus on an educational activity is one of the greatest strengths of serious games, with users building upon their existing knowledge without realising they are currently learning intrinsically. However, this requires a careful balance of real-world behaviours within the virtual environment.

In this chapter, we will explore a serious games development methodology utilised to create many of the serious games detailed within this book (e.g. Chaps. 10, 11, 12, and 13) discussing factors that can influence presence and immersion when creating a serious game.

8.2 Fidelity

It is generally agreed that several components of fidelity need to come together to produce an effective serious game (Shepherd, 2010). Research has shown that adequately designed virtual environments (VEs), with levels of realism that induce presence and immersion, lead users to behave realistically and in a context-appropriate manner (Slater, Pankaj, Jesper, & Insu, 2009). However, relevant empirical evidence is not readily available to quantify and help designers balance the trade-offs between high-fidelity simulations, financial costs (Shepherd, 2010) and the requirements of various pedagogical objectives.

Furthermore, with the current commercially available technology, when visual or interaction fidelity is increased, system performance usually suffers resulting in reduced frame rates and system stability. The challenge is to identify the appropriate level of fidelity to meet pedagogical objectives whilst addressing computational power and cost-related issues. It is therefore essential that serious game designers understand the relationship between pedagogical objectives and fidelity to make the best possible decisions regarding system design and implementation.

Research has shown that higher fidelity does not always result in more effective training (Toups, Kerne, Hamilton, & Shahzad, 2011). For the purposes of understanding the effects of VE fidelity on training and user performance, it is essential to separate fidelity into its relevant components

(Shepherd, 2010). The following sections will consider visual, auditory and interaction fidelity, their components as well as their effects upon knowledge acquisition and skill transfer within serious games and specifically VR-based trainings. Olfactory and taste fidelity could also be considered. However, given the current lack of commercial technologies to support these channels, they are beyond the scope of most serious games.

8.2.1 Visual Fidelity

When considering visual fidelity, the type of serious game being designed has a significant effect on the impact it will have on a user's learning. In three-dimensional virtual environments, especially with virtual reality control systems, visual fidelity plays a significant role within the platform. However, a two-dimensional serious game can have significantly lower requirements when it comes to the necessary level of visual fidelity.

Visual fidelity refers to the degree of exactness with which a virtual environment mimics real-world visual stimuli. This is influenced by several hardware- and software-related factors, including frame rate, virtual asset quality and rendering. Due to the complexity of three-dimensional virtual environments and virtual reality, significant research has been conducted to understand and apply these technologies. This research has identified the impact of two-dimensional versus three-dimensional virtual worlds as well as effects of virtual reality compared to desktop interfaces.

In recent years, most research has focussed on the effects of visual fidelity on user performance and the sense of presence within virtual environments (Dinh, Walker, Hodges, Song, & Kobayashi, 1999). The parameters that have been more widely investigated include stereoscopic versus bioptic displays for virtual reality serious games, level of visual detail (e.g. textures, shadows, reflections) and field of view. Generally, research has found that higher levels of visual realism result in users reporting higher levels of presence. Presence is the term adopted to describe users' sense of inhabiting a world different from the one where their real body is located (Rooney, 2012). However, it is still unclear how presence and visual fidelity relate to skill acquisition and skill transferability from virtual environments to the real world.

In virtual reality, higher-fidelity 3D stereoscopic displays such as those found in existing commercial head-mounted displays (HMDs) seem to significantly reduce user errors and time needed for completing path-tracing tasks and to improve performance in spatial understanding tasks

(McMahan, Bowman, Zielinski, & Brady, 2012), when compared to standard 2D displays.

Similarly, Slater, Linakis, Usoh, and Kooper (1996) found that subjects' performance on a memory and spatial awareness task was better when using a stereoscopic HMD instead of a standard screen and that the environment's level of visual realism also positively influenced subjects' performance. Ware and Mitchell (2005)'s results seem to demonstrate that for complex path-tracing tasks, the depth of cues offered by stereoscopic displays have a significant impact on reducing subjects' error rates, while Yeh and Silverstein (1992) found that they also improve subjects' performance for spatial understanding tasks.

With respect to visual detail, shadows and reflections have equally been found to contribute significantly to users' sense of presence in a virtual environment and to positively affect their behavioural responses (Shepherd, 2010; Slater et al., 2009). There is also evidence that learning is enhanced when the visual complexity of a scene matches reality for tasks involving visual scanning of an environment (Ragan et al., 2015).

Similarly, evidence suggests that a wider field of view (FOV) has a positive effect on performance in tasks such as aiming and shooting (Ragan et al., 2015), visual search tasks, comparison tasks and walking tasks (McMahan et al., 2012). McMahan et al. (2012) further found that users performed best in a first-person shooter (FPS) game under a high visual and high interaction fidelity condition or under a low visual and low interaction fidelity condition, as opposed to conditions that provided mixed levels of visual and interaction fidelity. The authors attributed this to subject familiarity, where the low-fidelity condition mimics existing FPSs and the high-fidelity condition mimics real life. Arthur and Brooks Jr (2000) found that FOV predicted subjects' task completion times for visual search tasks and for a walking task, with the wider FOV having a positive effect on performance.

Furthermore, fidelity is generally associated with higher end user acceptance, where judgements are made on whether the look and feel of a simulation appears reasonable to those knowledgeable about the real-life scenario being recreated (Alexander, Brunyé, Sidman, & Weil, 2005). Nonetheless, previous work suggests that low visual fidelity VEs may be sufficient to effectively support object-based memory recognition tasks (Mania, Wooldridge, Coxon, & Robinson, 2006) and route knowledge tasks (Waller, Hunt, & Knapp, 1998). Further evidence suggests that when a certain threshold of visual realism is achieved, especially considering human-like avatars, subjects' levels of believability, comfort and empathy towards these avatars drop. This phenomenon is known as the 'uncanny valley' and is a consequence of the high expectations, in terms of behaviour and physical attributes, that humans place on photorealistic virtual representations of human characters (Rooney, 2012).

In conclusion, research to date shows that, depending on the nature of the skills being trained, different minimal levels of visual fidelity are acceptable (Rojas et al., 2012).

8.2.2 Auditory Fidelity

Auditory fidelity is understood as the extent to which audio in VEs mimics real-life audio experiences. The concept is tightly linked to spatialised audio, which is audio processed to give the listener the impression of experiencing a sound source within a 3D environment. It is different from stereo audio, in that stereo only varies along one axis (generally the x-axis). In existing HMDs, head tracking can be used to deliver spatialised auditory information based on a user's location and factors such as direction, distance and elevation of the sound source in relation to the user.

In VR, higher-fidelity audio has been found to aid users with object recognition, object placement, identification and localisation of disparate sounds as well as understanding the scale and shape of the overall environment (Hulusic et al., 2012). Rojas et al. (2012) revealed that background sound had an influence on subjects' perception of the quality of graphics, where white noise had a negative impact and music had a positive effect. Similarly, Bonneel, Suied, Viaud-Delmon, and Drettakis (2010) found that higher-fidelity audio directly influenced participants' perception of the visual materials being represented. They suggest that using higher-fidelity audio could compensate for constraints in visual fidelity that may be imposed by a system's technical capabilities.

In comparing subject performance, a study conducted by Jones, Stanney, and Foaud (2005) revealed that participants performed better under the spatialised audio condition with head tracking for search and detection tasks than under the non-spatialised audio condition. Similarly, in a target acquisition task, where subjects were asked to search the visual environment, the spatialised audio conditions significantly decreased subjects' search times (Bolia, D'Angelo, & McKinley, 1999). Perrott, Saberi, Brown, and Strybel (1990) also found that spatialised audio has a significant role in regulating visual gaze. Further studies with positive effects of spatialised audio on target acquisition tasks are Begault (1993) and McKinley and Ericson (1997).

In addition, and of particular relevance to VR, is the concept of self-motion, where users are given the illusion that they are moving in the virtual environment while remaining in place in the real world. Riecke, Väljamäe, and Schulte-Pelkum (2009) found that high-fidelity auditory feedback has a significant positive influence on subjects' perception of self-motion and sense of presence in a VE.

Unsurprisingly, given humans' heavy reliance on information gathered through the visual sense, the effects of auditory fidelity in VR have not been as widely investigated as those of visual fidelity, even though, overall, auditory fidelity is generally believed to have a significant impact upon users' sense of presence within VEs (Begault, Ellis, & Wenzel, 1998).

8.2.3 Interaction Fidelity

In addition to components of visual fidelity and auditory fidelity, researchers have also investigated the effects of interaction fidelity on skill transferability. *Interaction fidelity* refers to the extent to which the VE simulates real-world behaviours and reactions to user input. This includes operational equipment and task environments (Mania et al., 2006).

Pausch, Proffitt, and Williams (1997) found that for a simple task, such as finding an object in a scene, subjects performed significantly better when using an HMD with head tracking instead of a standard desktop setup. The authors suggest that this was due to that fact that in the VR condition subjects moved their heads to search the scene and therefore were able to better remember where they had already searched in the scene around them. They also compared head tracking with a hand-based viewpoint controller and found that the higher interaction fidelity condition (i.e. head-tracking HMD) improved subject performance when searching for non-present targets.

Bowman, McMahan, and Ragan (2012) reports on a series of studies evaluating the influence of traditional input techniques (e.g. keyboard, mouse) versus more 'natural' input techniques (e.g. 3D gestures) on participants' performance during a first-person shooter (FPS) game. One output of the report found keyboard-based techniques outperformed the more 'natural' condition that required participants to physically move in the direction they wished to walk or turn towards when traveling over long distances. On the other hand, for searching or aiming a weapon the 'natural' technique requiring participants to move their head outperformed the use of standard input controllers.

Devices with higher degrees of freedom (DOF) have also been shown to enable better performance than those based on 2-DOF input (e.g. mouse) for 3D object manipulation and rotation tasks (McMahan et al., 2012; Ware & Jessome, 1988). Gruchalla (2004) also found that for spatially complex tasks, such as oil well path planning, participants performed better in the CAVE environment with head tracking and a 3D gesture input device (a wand with 6 DOF), as opposed to a stereoscopic desktop setup with traditional mouse input.

'Natural' interaction is enabled by a series of motion tracking technologies, such as the Leap Motion, the Myo Armband, the Kinect; sensor-based bodysuit technologies, such as the PrioVR; or sensor-based gloves such as Control VR. Although commercial devices such as the Leap Motion and the Myo Armband are now widely available, finger and hand tracking remains an open problem that has been investigated for more than two decades. Recognition for standard gestures such as pointing and grasping is now relatively accurate but recognition of free-form movements poses a more significant challenge (Ju & Liu, 2011). In an evaluation of Leap Motion for free-form shape modelling in a virtual environment, Cui and Sourin (2014) found that tracking fidelity is still largely constrained by the position of the hands in relation to the device, where finger detection functioned best for fully open hands directly facing the infrared camera. In addition, if fingers are occluded by one another, system behaviour becomes unstable and produces flickers and glitches in the rendered imagery of users' virtual hands (Cui & Sourin, 2014).

The Myo Armband, out of the box, permits recognising and tracking of a set of standard gestures but not free-form movement. In the author's experience with this device, movements need to be discreet and very intentional with a pause between one recognised movement and another. Similarly, for large body movements, Livingston, Sebastian, Ai, and Decker (2012) found that tracking fidelity on the Kinect was sufficient for general purposes, such as playing console games. Gesture recognition was found to be best within a certain range of the device and accuracy of skeleton tracking was 'reasonable' for tracking large gestures performed with the hands and arms. However, accuracy did not permit tracking finger positions and movements. Lag was also an issue, increased by the number of users being tracked.

A complimentary component to these interaction techniques is haptic feedback, which is the output of the system reacting to users' input. There are two types of haptic feedback: *tactile feedback* refers to the ability to transmit sensations relevant to identifying textures, temperature and pain, while *force feedback* resists motion and/or rotation, for example, by preventing a user's hand from going through an object they are attempting to pick up. Haptic feedback has been found to enhance surgical and laparoscopic virtual reality (VR) training (Van der Meijden & Schijven, 2009) and training of sensorimotor skills (Feygin, Keehner, & Tendick, 2002; Patel, Bailenson, Hack-Jung, Diankov, & Bajcsy, 2006) and sensorimotor force skills (Morris, Tan, Barbagli, Chang, & Salisbury, 2007; Tholey, Desai, & Castellanos, 2005). However, evidence also suggests that the benefits of haptic feedback may depend on the level of haptic fidelity, whether users are novices or experts in the skills they are training (Sigrist, Rauter, Riener, & Wolf, 2013) as well as the nature of the skills being learnt.

Weil et al. (2005) found that, in a military training simulator, soldiers performed better in teamwork and communication tasks with the VoIP feature than with text chat feature. The soldiers' opinion was that the VoIP system was a lot more like their existing radio system and therefore better at mimicking their real-world operational settings.

As is the case with visual and auditory fidelity, existing research seems to suggest that the level of interaction fidelity required in any given serious game depends on the particular skill, or set of skills, that needs to be learned. This opens the possibility of teaching different skills on different types of devices according to their particular capabilities.

8.3 CENTRIC Serious Games Design Framework

The design principles of serious games must factor in every facet of development and usability from pedagogical objectives to game mechanics and technological capabilities. This triumvirate of design considerations provides a good foundational structure to design any serious game. When used as scaffolding for the design of a serious game, both developers and end users gain a basic understanding of some of the developmental considerations which are important to both parties.

Utilising these design principles, we will explore the serious games design framework which has been used for co-development to underpin the designs, testing and validating, for instance, of both the AUGGMED platform (Chap. 6) and specific serious games such as ATLAS, CyberCentric and AEsOP featured in this book (see Chaps. 11, 12, and 13). It was developed by the serious games design team at CENTRIC (Centre of Excellence for Terrorism, Resilience, Intelligence and Organised Crime Research, Sheffield Hallam University, UK).

It addresses three components: functional and physical fidelity, game mechanics and pedagogical objectives. Figure 8.1 illustrates the CENTRIC Serious Games Design Framework components and their interdependent relationships with each other.

For a serious game designed to deliver different content and learning objectives to any type of device, it is essential to understand the particular functional and physical fidelity capabilities of each device. This allows serious game design teams to assess which learning objectives are best suited to various levels of visual, auditory and interaction fidelity. For example, on mobile devices a novel game mechanic is the ability to rotate the whole environment and have gravity move users' avatars, making use of the

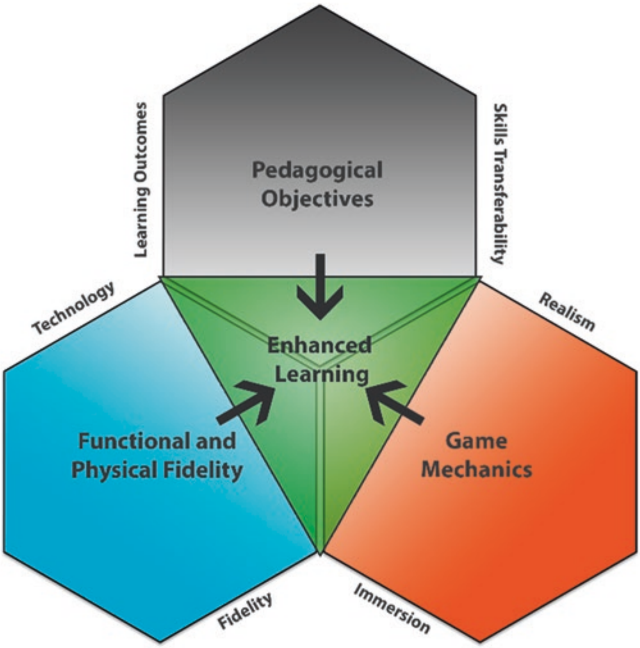

Fig. 8.1 CENTRIC Serious Games Design Framework

devices' accelerometers. With HMDs, enabled with head tracking, it is possible for users to move their avatar in a particular direction by directing their gaze in that same direction, which is not possible on mobile devices nor on desktop setups.

In AUGGMED (see Chap. 6), it was agreed in close collaboration with end users and based on existing literature that the mixed reality and virtual reality conditions are especially well suited for training spatial awareness in environments where training is otherwise impossible or costly, such as in airports, rail stations and maritime ports. The immersive 3D nature of the rendered environments – where high levels of visual, auditory and interaction feedback are possible – allows trainees to explore the environment in a natural way (or as close to natural as possible) while interacting with other trainees and the trainer in completing a given mission. Several trainees can participate in the same serious game, whether remotely or co-located, from the same team and/or from different emergency responder departments (e.g. police, firefighters or ambulance). All participants can interact and see each other within the simulated environment enabling multi-agency joint training. However, live training is only a single component in the larger picture of training emergency responders (see Chap. 10). Delivering theoretical content, for example, makes more sense on mobile devices that trainees can access at the office, at home or even in the field, while the desktop setup is currently being used for trainers to setup, control and overview a live training exercise running in the serious game. The high degrees of precision with which trainers are required to rotate, zoom in, zoom out, change camera views, etc. in order to adequately monitor trainees and gameplay in real time require the ease and precision of input offered by mouse and keyboard controls (Bowman et al., 2012).

As previously mentioned, the CENTRIC framework shown in Fig. 8.1 aims to provide support for development projects, similar to AUGGMED, looking at cross-device serious games by highlighting the links between learning objectives, levels of feasible fidelity and game mechanics. The following sections provide an overview of the main factors in these interdependent relationships between components in the framework.

8.3.1 Pedagogical Objectives and Fidelity

Visual, auditory and interaction fidelity have an impact on users' experience of serious games and on the skills that can be successfully learnt (Hulusic et al., 2012; Mania et al., 2006; McMahan et al., 2012;

cp. Sect. 8.2 above). Hence, a careful balancing of the learning objectives and the capabilities of the devices used to deliver the serious game are required. For instance, in end user interviews conducted with police force trainers in AUGGMED (Chap. 6), it became clear that they felt the VR and MR components of the system had a sufficient level of visual and interaction fidelity to train tasks involving 3D spatial awareness, visual scanning and decision making such as memorising the layout of a particular environment (e.g. airport) or looking for evidence after a terrorist attack has taken place. This agrees with existing literature (McMahan et al., 2012; Slater et al., 1996; Ware & Mitchell, 2005; Yeh & Silverstein, 1992). However, the interaction fidelity currently offered by movement-tracking technologies was thought to be insufficient for successfully delivering firearms training, for example.

This demonstrates that the trade-offs between learning objectives and achievable levels of fidelity will necessarily impact upon the skills being trained in a serious game and upon the devices on which the training is experienced. In the case of AUGGMED and further serious games based on the CENTRIC framework (cp. Chapters 11, 12, and 13 and *UnpackedVR* in Chap. 3), balance was achieved through a collaborative design process between technology partners and end users. This collaborative approach enabled the pedagogical objectives to inform the functional and physical fidelity and technological capabilities to inform the required learning outcomes.

8.3.2 Game Mechanics and Pedagogical Objectives

Previous studies have found that serious games can have a negative influence on skill transferability, exhibited when trainees apply behaviours in the real world that are only appropriate in a game-like environment (Rojas et al., 2012). On the one hand, game mechanics can be leveraged to make the training experience more engaging (King, 2005), while on the other hand, they may detract from the realism of the scenario and compromise skill transferability from the virtual environment to a real-life context (Rooney, 2012). Therefore, a careful balance needs to be achieved between making the serious game fun and engaging while still remaining useful for training. As an example, end users in the AUGGMED project identified that a high degree of realism was necessary.

There is a significant amount of discussion and research regarding the links between game mechanics and pedagogical objectives, too much to cover within the context of this design strategy. However, considerations should always be made when deciding how to implement any mechanic. If it influences a user's decision-making process and knowledge, both developers and end users must ensure it does so correctly; otherwise, it can promote unintended behaviours or misunderstandings around the knowledge being taught.

8.3.3 Fidelity and Game Mechanics

Fidelity and game mechanics impact each other directly on several levels. For example, a common gamification strategy such as displaying scores (e.g. number of shots on target; cp. Chap. 5) reduces the serious game's level of fidelity as compared to a real-life scenario where trainees would not have any way of accessing this information. However, scoring provides a positive feedback loop by reinforcing a person's actions and encouraging them to accumulate higher scores – thus improving immersion at the cost of fidelity (Adams & Dormans, 2012). Deciding on which mechanics to implement requires considerations for their effect on the fidelity of the game as well as the immersion of the user. As another example, while starting with an easier version of the game and progressing to more difficult levels may be of pedagogical use as it supports trainees in acquiring a select set of skills over a certain period of time, it inevitably reduces the level of functional fidelity of the serious game.

Depending on the serious game, a reduction in fidelity may enhance learning objectives, while higher levels of fidelity could retract from them. The delicate balance between game mechanics and fidelity of serious games is discussed in more detail by King (2005), discussing the military training and commercial game *Full Spectrum Warrior* as a case study.

8.4 Utilising Co-development Methodologies

Collaborative development is becoming increasingly important in software design, especially in agile environments, which need to be able to change to suit shifting end user needs. In development, a considerable amount of the resources and efforts are hidden, whilst the knowledge of how to carry out specialist tasks is tacit (Spinuzzi, 2005). This can lead to a discrepancy between expectations and results that often plague software development projects. Overcoming these challenges is a key criterion of co-development. In consequence, integrating end users into the design process can have multiple benefits compared to traditional development methods. However, this process needs to be managed effectively in order to avoid 'feature creep'[1] and other fundamental design challenges, which face every serious game developer.

Achieving a progressive and successful co-development strategy requires an open-minded approach to the work, with both developers and users collaborating on every aspect of design, testing and validation. Communication between co-developers must be open, critical and constructive, with an open discussion of observations and advise. This is key to ensuring that the development is successful and fewer errors and misunderstandings occur.

Co-development strategies can be supported by a number of activities and processes, especially when collaborators are working remotely. Workshops, meetings and teleconferences enable key stakeholders to have constant discussions regarding the design and progress of a project. Alongside these conversations, informal demonstrations and early access to development builds of a serious game can highlight problems early, enabling them to be fixed before a significant amount of work is lost.

Likewise, it is wise to hold live pilots throughout the development life cycle of a serious game. Conducted in a more formal setting, these can test the suitability of a serious game within the context of its intended use. For instance, if a virtual reality training simulation is being developed, it should be tested by end users at the intended location. This ensures environmental factors are considered throughout the development process by both the developers and end users.

8.5 Conclusion

Designing serious games requires an open perspective, which identifies and discusses aspects not only of the game itself, but also of who will be using it, where and why. This in turn needs a holistic view of the problem the serious game is trying to overcome or the learning objectives it aims to achieve.

When utilised for education and training, a game's mechanics, the interaction medium and pedagogical factors must all be carefully balanced as each component will influence the other. For example, training a user

[1] Feature creep is the potential for the requirements of a project to increase beyond the original scope of the product throughout the course of development.

on how to perform a room search will impart very different knowledge and experiences for virtual reality versus touchscreen users. This balance is best achieved through co-development, utilising the knowledge provided by the end users and using it to sculpt the serious game with the experience of the developers.

This collaborative approach to building a serious game not only ensures the product remains relevant to the end user but also that it can achieve even more successful forms of learning thanks to the immersive capabilities of serious games. The CENTRIC Design Framework discussed within this chapter aims to achieve this by considering every aspect of a serious game and identifying their influences on the platform as a whole. This framework has shown itself successful in delivering serious games to end users with drastically different training and learning needs. From virtual reality to online-based platforms, this approach of utilising co-development alongside mechanical, pedagogical and technical considerations has enabled each game to achieve or even exceed their original provision. The framework presented in this chapter can thus serve as guidance for design processes and decisions in the development of serious games for a wide range of contexts and purposes.

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CHAPTER 9

Evaluating Serious Game Trainings

P. Saskia Bayerl, Steffi Davey, Philipp Lohrmann, and Jonathan Saunders

9.1 Introduction

Developing and conducting serious game-based trainings can consume considerable resources and time. In order to ensure that such training methods provide optimal outcomes, it is therefore advisable to establish early on appropriate success criteria that quantify the acquisition or improvement of knowledge, skills, attitudes or behaviours. This chapter offers recommendations on how to plan and conduct evaluations of virtual reality (VR)-based serious games for training purposes. A concrete example of such an evaluation from the AUGGMED project (see Chap. 5) showcases the practical steps of running meaningful VR-based training evaluations as well as potential challenges that need to be taken into account.

P. S. Bayerl (✉) · S. Davey · J. Saunders
CENTRIC, Sheffield Hallam University, Sheffield, UK
e-mail: p.s.bayerl@shu.ac.uk

P. Lohrmann
ROQAS Solutions Limited, Hornchurch, UK

B. Akhgar (ed.), *Serious Games for Enhancing Law Enforcement Agencies*, Security Informatics and Law Enforcement,
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9.1.1 Why Game and Training Evaluations?

Virtual reality (VR)-based trainings using serious games are a relatively new development but are already changing the ways in which organisations such as police forces, military or first responders train their staff (see Chaps. 5, 9, 10 and 11). It is therefore imperative to ensure that such new training methods are (at least) as effective as traditional trainings. Systematic training evaluations are the primary tool for this purpose.

Generally, training evaluations aim to understand whether a training is effective in achieving the intended learning outcomes (for details on learning outcomes see Chap. 1). This is particularly important when developing new trainings to test whether the content, setup and presentation do deliver the expected results (*training validation*). Training evaluations can further establish which training format is better suited to a particular purpose, for instance, comparing learning outcomes using different materials, training durations or individual versus group settings (*comparative evaluation*). Lastly, evaluations can be used to test whether an existing training can be transferred to other settings (*training transferability*; e.g. establishing whether a training developed in one cultural context or industry can be used as effectively in another culture or industry) or whether an established training still delivers the expected outcomes or may need adaptation (*long-term viability*).

Thus, training evaluations can (and should) be conducted at various stages of the training process – from testing the original training concept, including the technological setup and scenario, to the continued and long-term performance of the training, once it has been deployed. To ensure valid results, evaluations need to be planned systematically, which means evaluation exercises are often quite resource-intensive. To help practitioners in this process, the following sections outline the main considerations in the planning and execution of training evaluations.

9.2 Aspects to Evaluate

What to evaluate hinges on the question what the purpose of the evaluation is: Is the intention to test the effectiveness of the complete training or only of specific aspects (such as the spacing of training sessions or specific VR materials or exercises)? In this chapter, we focus primarily on evaluating complete trainings, as our interest is in outlining a framework for evaluating the quality of VR-based serious games as a training method. (In the same regard, the steps and considerations presented in this chapter can easily be adapted to a more targeted evaluation of sub-elements of a training.)

Our discussion focuses on three aspects that together can establish the effectiveness of VR-based trainings:

1. ***Employed technology including the training scenarios*** – aims to understand whether the technology works as expected and is usable (user-friendly) for the intended target group. For VR-based trainings, this test should also include a check of the appropriateness of the scenario(s).
2. ***Training satisfaction of participants*** – aims to understand whether participants are satisfied with the experience, either in its totality (general satisfaction) or in specific aspects (e.g. setting, trainer, perceived usefulness).
3. ***Impact*** – aims to understand whether the training achieved the intended learning outcomes.

9.2.1 Evaluation of the Technology Including Training Scenarios

Technology evaluations aim to understand whether the technology works as expected and is usable (functional as well as user-friendly) for the intended target group. This step should also include an explicit test of the appropriateness of the scenario(s).

Functionality Testing

Functionality testing assesses whether the technology (hardware and software) meets all functional requirements as set out by the end user. This stage will also include checking for any bugs in the system. It is vitally important to evaluate the performance statistics and acquire minimum requirements for the hardware to run the game, as any lag can cause cybersickness in VR (LaViola Jr, 2000; see also Chap. 2) and a generally uncomfortable experience.

Focusing on the VR scenarios, this step needs to check for and eliminate any inconsistencies or inaccuracies in the scenarios. This includes assessing the accuracy of scenarios against the initial design as well as testing all interactions that are possible in the virtual environment (e.g. for interaction fidelity; see Chap. 7). Serious games and virtual reality trainings allow for considerable scalability, as simulations can be easily adapted to changing training needs. Whilst this is a key advantage of this training method, evaluators should consider that any changes to the simulations and scenarios may have an impact on the efficacy of the training. Thus, any scenario change or modification to the gameplay (including updates to hardware and game mechanics) should be re-evaluated.

Usability Testing

Virtual reality presents a new challenge for usability evaluations. Desktop applications tend to conform to a standard layout (Bevan, 2001), which utilises design techniques to ensure the application is as intuitive as possible – meaning that on first exposure to a desktop application, users will be able to make assumptions about interactions and where to find certain buttons and functionalities. Most users have not yet adapted to the immersive interfaces in VR. Therefore, it is important to evaluate the usability of an immersive virtual environment with the specific user group(s) for which the training is intended (also considering potential disabilities). This covers also simple issues such as the fact that users may be unsure where the intended interaction interface is located, which can cause confusion and aggravation. Already simple hints (e.g. arrows) can help to guide users' gaze to the correct location (cp. Chap. 2). Storytelling techniques[1] can also be employed to encourage users to face in the intended direction. As there are a multitude of interacting factors that may have an impact on the efficacy of such methods, a thorough comparative evaluating design choices is advisable.

Usability testing should further investigate duration scenarios, as users are advised not to spend a prolonged period of time in virtual reality. One recommendation is to take a break after 30 minutes (Fagan, 2018). Furthermore, as movement in VR can create cybersickness, it is important to test the controls of the movement, specifically their speed and acceleration (see Chap. 2). Important is also the required degree of immersiveness, i.e. the potential realism of situations. Immersiveness is one of the major benefits of VR-based trainings and a reason why they have found enthusiastic application from medical education (e.g. Alfalah et al., 2019) to psychotherapy (e.g. Morina, Ijntemaa, Meyerbröker, & Emmelkamp, 2015) to firearms trainings (Wei et al., 2019). In the same regard, highly realistic scenarios may be problematic when they lead to (unintended) stress or anxiety in participants (Slater, Khanna, Mortensen, & Yu, 2009).

Creating physical and mental stress reactions can be a necessary part of a training, for instance, if the training is meant to prepare first responders

[1] http://blog.leapmotion.com/art-storytelling-narrative-vr/

to physically and mentally handle the aftermath of bombings by highly realistic representations of the destruction, including wounds and people in distress (see Chaps. 5 and 9) or to train correct reactions in critical situations (see Chap. 10). In fact, indications are that stress as part of trainings may actually enhance learning (cp. Joël, Pu, Wiegert, Oitzl, & Krugers, 2006). However, stress may also inhibit learning when it is experienced at the wrong time (e.g. shortly before or a day after a learning task) or takes too long to abate (cp. Joël et al., 2006). In consequence, careful consideration should be given to the degree of realism in training scenarios in relation to the expected training effects (how much overall, for which elements, at which phase of the training process, etc.) and these elements tested accordingly with the intended user groups.

9.2.2 Degree of Training Satisfaction by Participants

Training satisfaction measures whether participants 'liked' or 'enjoyed' a training or whether they found it 'useful' for their work. Typical satisfaction questions are shown in Table 9.1. Such subjective evaluations are easy and quick to administer but will provide few insights into whether actual learning has taken place. Acceptance questions are therefore often considered the weakest indicator of training success.

Still, they can be helpful for gathering an overall impression by participants. Next to general satisfaction with or the perceived usefulness of the training, acceptance questions can also address a multitude of aspects from teacher(s) to class format, duration, size of the group, materials and assessment procedures to marketing and catering. They can thus identify potential irritants (e.g. materials that are hard to read or hear, examples that are too disturbing or seen as irrelevant, pleas for more or fewer coffee breaks) as well as strong points. Yet, while helpful, acceptance questions cannot replace proper impact assessments, and training evaluations should thus never rely solely on subjective assessments by participants alone.

Table 9.1 Examples of typical training satisfaction questions

1	Overall, the on-the-job training I receive is applicable to my job.
2	Overall, the training I receive on the job meets my needs.
3	Overall, I am satisfied with the amount of training I receive on the job.
4	I am generally able to use what I learn on the job.

Based on Schmidt (2007)

9.2.3 Impact Assessment

Impact assessments aim to establish whether the training has the expected (or any) influence on participants. To do this, impact measurements need to determine the type and degree of effects on participants in a systematic and repeatable way. A first consideration in the planning of impact assessments is the type of expected learning outcomes, i.e. the concrete aspect(s) or content(s) the training should teach or improve (see also Chap. 1). Secondly, evaluators must ask themselves whether they are primarily interested in testing the immediate effect of the training (i.e. training outcomes) or also in how well the leaning transfers to the workplace (i.e. its effect on job performance). Thirdly, a decision must be made whether effects are (only) assessed directly or shortly after the training (i.e. measuring short-term impacts) or also at later stages (i.e. measuring longer-term impacts). In the following, we provide more details on these aspects.

Different Levels of Learning Outcomes

The primary focus of an impact assessment depends on the purpose of the training (i.e. what are the aspects this training should teach or improve). This may be correct reactions in crisis situations (e.g. Haferkamp, Kraemer, Linehan, & Schembri, 2011; cp. Chap. 10), knowing the correct way to evacuate a building (Feng, Gonzales, Amor, Lovreglio, & Cabrera-Guerrero, 2018; cp. Chap. 9) or raising cyber security awareness (Jin, Tu, Kim, Heffron, & White, 2018; cp. Chap. 11). Hence, in planning impact assessments, a clear view on the outcome or outcomes is required: What is the purpose of the training?

A useful framework to support a systematic planning of impact evaluations is Kirkpatrick's model of training evaluation criteria (Kirkpatrick, 1967) and its extension by CAIPE (1999). This framework differentiates four different levels of outcomes (also Carpenter, 2011, p. 124):

1. ***Level 1: Reactions –*** participants' views of their learning experience and satisfaction with the training
2. ***Level 2: Learning***
    - Level 2a – modification in attitudes and perceptions
    - Level 2b – acquisition of knowledge and skills

3. ***Level 3: Behaviour***

   - Level 3a – changes in behaviour of the training participant
   - Level 3b – changes in organisational practice

4. ***Level 4: Results/benefits to training participants and others***

This framework systematically outlines the disparate levels of outcomes – from immediate reactions to the training (level 1) to internal states (emotions, attitudes, perceptions; level 2) and observable behaviours (level 3) to broader consequences to the individual, its organisation and related people or groups (level 4). Table 9.2 presents examples and possible methods for the assessment of each level.

As stated previously, which level(s) to focus on will depend on the training purpose. For a comprehensive understanding of training effects, it is often valuable, however, to consider multiple angles, i.e. include several levels in the evaluation. This is certainly recommendable for VR-based serious games trainings, as they allow for a high level of realism in their scenarios and are thus often employed for the training of complex and dynamic topics.

Training Outcomes Versus On-The-Job Performance

The real test for the usefulness and success of a training is whether new knowledge and skills are transferred into the work situation. This process is called *training transfer* and denotes the degree to which training participants manage to apply newly acquired knowledge, attitudes, behaviours, etc. in their work (Baldwin & Ford, 1988).

A simple differentiation between immediate training outcomes and training transfer may be stated as follows:

- ***Training outcomes*** – test whether participants can replicate the attitudes, knowledge, skills, etc. acquired during the training usually in the form of standardised tests (e.g. in the form of exams or during pre-designed VR scenarios)
- ***Training transfer*** – tests whether participants can apply the learned aspects as part of their job and thus in realistic, novel and usually non-standardised situations

Table 9.2 Methods to assess training impacts on different outcome levels

Evaluation level	*Examples*	*Method suggestions*
Level 1 – reactions	Satisfaction with the training, perceived usefulness for participants' work	Surveys/interviews with training participants
Level 2a – modification in attitudes and perceptions	Implicit biases in decision making, attitudes towards safety measures in the workplace	Surveys/interviews with training participants, assessment of reaction times in game (e.g. to test for implicit biases or stress reactions)
Level 2b – acquisition of knowledge and skills	Indicators for human trafficking, theoretical models for radicalisation	Written knowledge and skills, observation of skill/knowledge application in behaviours (in game or real life)
Level 3a – changes in behaviour	Compliance with safety procedures	Observation of the training participant (in game or real life), changes to indicators of job performance before and after the training
Level 3b – changes in organisational practice	Effectiveness of communication between agencies in crisis situations	Observations of people beyond the original training participant, objective measures of performance and practices at group and/or organisational level before and after the training
Level 4 – results/ benefits	Fewer incidents of stress-related disorders	For subjective benefits/internal states: surveys and interviewsFor objective/ quantifiable benefits: observations and objective measures

Hence, while training outcomes test the direct effectiveness of trainings, training transfer answers the much more relevant (as well as challenging) question whether the training actually improves job performance. Generally speaking, improved on-the-job performance can be considered as an even stronger measure of training effectiveness than successful training outcomes.

Training transfer is notoriously difficult. Not only do training effects often fade over time; learning from training sessions are often hard to apply in (work) situations that tend to be more complex, dynamic and unstructured than usually encountered in a training setting. According to some estimates, 40% of participants are unable to transfer learning directly after a training and 70% fail to do so after 1 year (cp. Saks, 2002).

Testing for training transfer must prove two things: 'the generalization *and* maintenance of newly acquired knowledge and skills on the job' (cp. Saks, 2002, p. 29; emphasis added). Saks gives further recommendations on how to assess transfer in a comprehensive way (p. 29):

- ***Establish rate of decay in learning*** – '[the assessment] should be specific as to the length of time following training'.
- ***Measure both outcome levels 3 and 4*** – 'estimates of the transfer of training should consider behaviour and results criteria'.
- ***Establish return on investment*** – 'a transfer estimate should … consider the percentage of training investments that result in transfer'.

Several things can support training transfer. While a comprehensive overview is outside the scope of this chapter, the following are examples of design decisions that facilitate training transfer (cp. Blume, Ford, Baldwin, & Huang, 2010; Burke & Hutchins, 2007 for a more extensive discussion):

- Trainees need to perceive a close relationship between training content and own work tasks (referred to as 'identical elements'; Thorndike & Woodworth, 1901 cited in Burke & Hutchins, 2007).
- A high number of practice elements and frequent feedback; especially for skills that are not used very often, a very high rate of practice repetitions beyond the point of first learning a skill (i.e. overlearning) helps retention.
- Active learning ('learning by doing').
- Systematic feedback not only when tasks are done correctly, but also detailed feedback about errors and mistakes.

Considering the above, VR-based serious game trainings already offer many of the elements that support training transfer (e.g. high level of realism and a strong focus on active learning). Although systematic evidence on this point is still missing, it suggests that VR-based trainings may be well-suited for trainings that require efficient transfer to real-world situations.

Short- Versus Long-Term Effects

The question of training transfer touches on the question of how long the acquired knowledge, skills or behaviours are retained. The successful retention of learned content is affected by many factors, not least by:

- ***Type of content*** **–** trainings for physical tasks and using natural tasks tend to result in better retention long-term compared to trainings for cognitive and artificial tasks (Arthur Jr, Bennett Jr, Stanush, & McNelly, 1998).
- ***Spacing of material*** **–** massed practice (i.e. trainings that present new knowledge in large chunks) leads to faster acquisition of learning and better immediate recall, while distributed practice (i.e. spreading smaller chunks of materials over more sessions) results in better retention long-term (Kim, Ritter, & Koubek, 2013; Schendel & Hagman, 1991).
- ***Type of training*** **–** game-based trainings seem to lead to better knowledge retention compared to paper-based trainings (Ricci, Salas, & Cannon-Bowers, 1996).

How long-lasting effects are can – and should – be tested. A post-test immediately after a training checks whether participants really understood the content and can replicate the new knowledge, skill, etc. directly after a learning session (short-term effects). Test(s) after a longer period – anything from days to years – indicates how much of the learning is still retained (long-term effects). Longitudinal approaches in the form of repeated measures can be used to assess the *degree of retention* (i.e. how much trainees still know after a given time) and the *rate of forgetting* (i.e. how much have trainees forgotten in the space of a given time). The next section presents longitudinal evaluation designs together with other common evaluation setups.

9.3 Common Evaluation Designs

Evaluations aim to establish whether a training serves its purpose, i.e. leads to the envisioned outcome(s) across participants (e.g. changes in behaviours, modifications in attitudes, improved knowledge, etc.). Several setups are feasible to accomplish this task: from the easiest – a simple test after the training – to more complicated ones such as longitudinal designs with systematically sequenced and mixed conditions to establish causal and differential effects among settings over time. Figure 9.1 presents an overview of common training evaluation designs. (Other options are available, of course, depending on the purpose of the evaluation; e.g. Hanley, Chambers, & Haslam, 2016; Howard & Jacobs, 2016.)

Below are short descriptions of the presented designs:

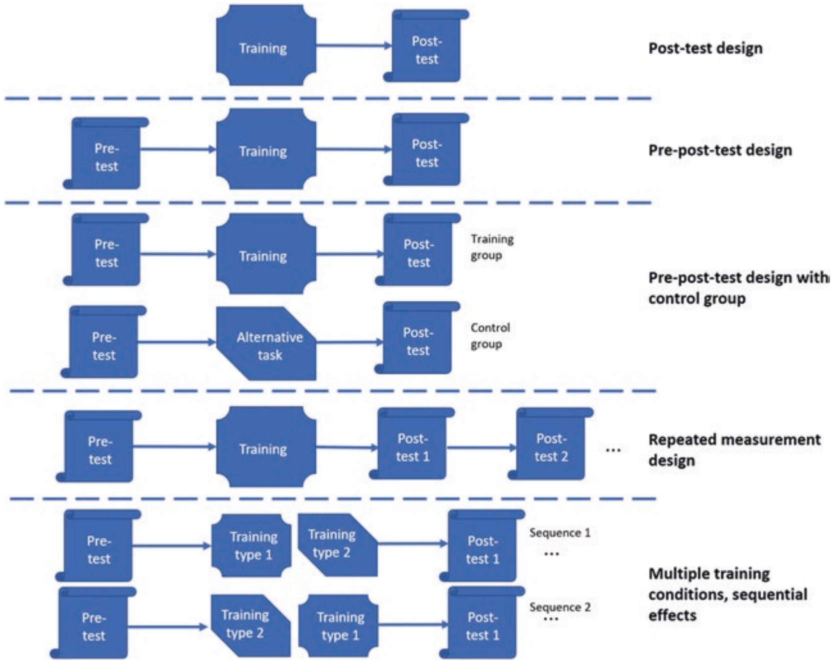

Fig. 9.1 Different evaluations designs

- ***Post-test design*** – All participants will complete the training and subsequently complete an assessment (post-test) in order to evaluate the extent to which the participants have achieved the learning outcomes. This evaluation design is the simplest to implement and requires the least resources and time commitment.
- ***Pre-post-test design*** – This design introduces an initial assessment (pre-test) to provide an indicator of the participants pre-existing knowledge on the subject area (baseline). Pre- and post-test should be identical – or at least similar enough – to allow a direct comparison between the two measurements and thus an indication of how much and which aspects the training has improved compared to what learners already knew before the training.
- ***Pre-post-test design with control group*** – This design adds a control group, i.e. a group that does not receive a training, but ideally an alternative task. The alternative task aims to ensure that it was the

training itself that improved participants' knowledge, skills, attitudes, etc., instead of other unrelated aspects such as the extra attention to trainees or the social interaction during the training. The alternative task should be unrelated to the training content but similar in nature to the training content (e.g. if the training is on a physical task, the alternative task also should be of a physical nature). This design can be easily expanded to compare training setups against each other by including additional groups that go through training variations.

- ***Repeated measurements design*** – Post-tests tend to be administered directly after the training and thus only measure immediate effects. Even if they are measured at a later stage, one test does not provide an indication of how the learned materials are retained or used over time. Repeated measures aim to do exactly that – assess how much and which knowledge is retained or forgotten. That is, using the same test multiple times can indicate whether the training leads to long-term changes to people's skills, knowledge or behaviours. These repeated tests can be either done in the same context (e.g. by using the same online knowledge tests) to facilitate direct comparability of results or conducted across different contexts (e.g. different work situations) to assess whether learning is transferred long-term and across situations.
- ***Multiple training conditions, sequential effects*** – This design is suitable when aiming to compare the effectiveness of combining multiple trainings to identify the best combination, sequence and/or spacing between trainings. This design can be expanded with sequences using the same type of training or adding intermediate tests between training blocks (not shown in Fig. 9.1).

The choice of the 'best design' is not always straightforward. Generally, the randomised controlled trial (RCT) design is considered a 'gold standard' for training evaluations. This design is a pre-post-test design with control group that also ensures that participants are assigned to training and control group conditions at random. Randomness in the assignment aims to reduce the possible impact of systematic differences among participants, i.e. random assignments should 'even out' potential effects of demographics, job function, educational background, etc. on training outcomes.

RCTs are resource intensive and can be problematic if participants in the control group may accrue negative effects from not being included in the training group (e.g. if it means not receiving knowledge or advice that may safeguard people's work performance or personal well-being). Sackett and Mullen (1993) advocate a pragmatic approach. They acknowledge that in the organisational reality running a full RCT study may not always be feasible given the time and resources. They further suggest clarifying whether the evaluation needs to establish a *change or improvement* in knowledge, skills or behaviours, or whether it is sufficient to test that the participants demonstrate a certain *level or degree* of learned content. In the first case, pre-post designs are required; in the second case, a post-test suffices (although in the understanding that is then impossible to say whether it was the training that led to the level of knowledge, skills, etc.). As stated above, this pragmatic approach is not commonly shared.

While we advise to conduct comprehensive and systematic evaluations whenever possible especially for newly developed trainings, we agree with Sackett and Mullen that more pragmatic approaches are still better than no evaluation at all. If full evaluations are impossible, less formal designs may be chosen in the understanding that their results may be less easy to interpret and less generalisable. Any limitations in the interpretability of results – given a chosen evaluation design – should be clearly formulated and communicated when reporting on the evaluation results.

9.3.1 Are There 'Minimal' or 'Optimal' Setups?

The main concerns when aiming to validate the quality and fit of a (newly developed) serious game-based training must be to rule out that factors other than the training itself are responsible for the observed outcomes. Hence, a minimum standard for any training evaluation can be formulated as follows:

1. Use of a ***pre-test*** to exclude the possibility that the serious game training had no effect on expected outcomes compared to participants' status before the training
2. Use of a ***control group*** to exclude the possibility that factors other than the serious game training are responsible for the training results
3. Use of ***participants that are representative*** in all essential features for the target population of the serious game
4. Use of a ***sufficient number of participants*** to allow statistical testing, where relevant: per condition and across all time points (for

longitudinal designs also considering that drop-out rates can be as high as 70% if using survey methods for assessment; Overall, Tonidandel, & Schmitz, 2009)
5. Use of ***adequate assessment methods*** for each relevant outcome levels

An optimal design is much less easy to formulate, as it will depend on the specific goals of the serious game and of the evaluation. Yet, in our view, ideally a training evaluation should include all relevant aspects (from technology to acceptance to impact) and ensure that impacts are assessed longer term and in the best case directly on the job.

9.4 A Training Evaluation Example from the AUGGMED Project

The AUGGMED project[2] was an EU-sponsored research project conducted from 2015 to 2018. The project developed a number of serious games in virtual and augmented reality for the training of first responders, including police officers, coast guard personnel and paramedics (see Chap. 5 for details). As part of the project work, an evaluation study was undertaken to investigate the use of virtual reality in the training of police officers. Its intention was to establish whether the VR-based training was as effective as the more resource-intensive traditional hands-on training.

For this purpose, a pre–post-test design with control group and random assignment was employed. The traditional training acted as control conditions, since it constituted the current standard the VR-based training aimed to improve on. In total, 80 UK police officers were recruited as participants. Most of them were trainee officers with only a few months' experience; however, a few long-standing officers were included to make up numbers.

The training objective for the officers was to learn the correct handling of a suspicious parcel. All participants first watched a number of video lectures on the topic, introducing them to the recommended procedures and best practices. Their baseline level of understanding was then assessed with a multiple-choice knowledge check.

[2] http://auggmed-project.eu/AUGGMED has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 653590.

Subsequently, the participants were randomly grouped into pairs, and each of the 40 pairs were randomly assigned to one of four training groups. Each group completed two consolidation exercises in which they had to apply the procedures they had learned to a simulated suspicious parcel scenario. These exercises were acted out either in VR or in the form of a live role play in a mock-up environment, which replicates realistic situations (see Fig. 9.2). To test for order effects of VR and live role play, the following four groups were tested against each other:

- ***Group 1*** **–** conducted two exercises in mock-up reality (representing the traditional training and thus the control condition)
- ***Group 2*** **–** conducted two exercises in VR
- ***Group 3*** **–** conducted the first exercise in mock-up reality and the second in VR
- ***Group 4*** **–** conducted the first exercise in VR and the second in mock-up reality

Each pair of officers was accompanied by a trainer throughout both exercises. The trainers actively took part in the scenarios by playing the

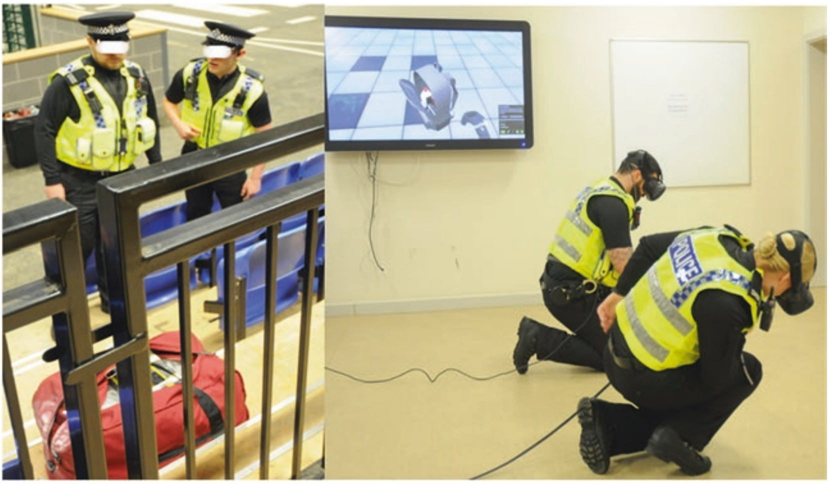

Fig. 9.2 Training participants investigate a suspicious parcel. Left: traditional training process using the mock-up of a re-created football stadium. Right: VR-based training

role of a local security guard who first meets the participants at the venue of each scenario. Throughout each exercise the trainer would stay in character and provide further background information when asked. In addition, the participants could use their radios to speak to the 'control room' in order to request the involvement of other services or to ask for further background information.

The participants using VR were given a brief technical introduction to the AUGGMED system before their first exercise in VR. This introduction was standardised and included familiarisation with the controls as well as a brief period of free play in a venue not used for any of the training scenarios.

All exercises were recorded with video cameras; in addition, the participants' body cams were used to capture further footage.

The impact of the training exercises was assessed in a number of ways. Immediately after completing their final exercise, participants were asked to retake the baseline knowledge check. In addition, the trainers used standardised marking sheets during the exercises to award points for following the correct procedures. These scores were later consolidated by an independent assessor using the video footage of the exercises. Finally, participants were asked to fill in another knowledge check 2 months after the training in order to assess the long-term learning outcomes.

The results of the knowledge check were used to compare the participants' level of competence before and after the consolidation exercises as well as to compare the four groups. Similarly, the trainers' scores were compared across the groups in order to assess the efficacy of the VR training in comparison to the traditional live role plays.

The evaluation showed that the training increased the overall knowledge of participants about correct procedures and their ability to correctly conduct checks. Further, the four groups did not differ significantly in their post-test outcomes (Saunders, Davey, Bayerl, & Lohrmann, 2019). This indicates that the VR-based training can be as robust and effective as the traditional, hands-on training. At the same time, it considerably reduced the resources needed to conduct the training sessions (i.e. no need to build large-scale mock-ups, to transport trainers and trainees to the location, etc.). In sum, the evaluation suggests that VR-based serious game trainings provide a viable alternative to hands-on trainings for the acquisition of complex procedures.

9.5 Additional Considerations

VR-based serious games have a number of attractive features for training in a law enforcement context. For instance, it is possible to put trainees in situations that are difficult or costly to replicate with sufficient realism in real life (e.g. the aftermath of natural disasters, humanitarian crises or war situations; cp. Chaps. 9 and 10). Furthermore, compared to mock-ups of locations such as in the AUGGMED evaluation, virtual scenarios are relatively easy to modify and adapt. VR-based trainings also possess characteristics that can support learning and training transfer such as an emphasis on active learning and the possibility to create a high number of practice elements that allow for immediate feedback (see Chap. 1).

One useful element of VR-based serious game trainings is that the medium used for the training can also serve as medium for the training evaluation itself. This reduces the disconnect that often occurs between what has been trained (e.g. the right way to search a suspicious bag) and the way it is tested (e.g. through online or paper-and-pencil tests). This similarity between training and testing increases the likelihood that trainees can correctly recall newly learned knowledge or behaviours. On the other hand, if the settings or scenarios used for training versus testing are too similar, testing can turn simply into 'rote repetition'. Test scenarios should thus at least vary in aspects directly related to the intended learning outcomes (e.g. if the intended learning outcome are cross-cultural negotiation skills, test scenarios could introduce variations in cultural context, the conflict that needs to be solved or the number and type of people engaged in the negotiation), with (well-reasoned) differences in the level of complexity between training and test.

It is not uncommon for users of virtual reality to experience symptoms similar to motion sickness (see Chap. 2). This can negatively affect learning as well as testing and thus skew results of an evaluation study. Factors that are said to affect the likelihood of cybersickness include gender (women tend to be more susceptible to cybersickness than men), age (susceptibility tends to decrease with age) and illness (individuals suffering from an illness may be more susceptible; LaViola Jr, 2000). These factors should be taken into consideration during training and testing to ensure that any confounds caused by cybersickness are accounted for. Recent research further suggests that there may be a negative correlation between the sense of presence[3] and cybersickness (Weech, Kenny, & Barnett-Cowan, 2019). Creating scenarios with higher presence thus may be advisable especially for groups with a higher likelihood for cybersickness.

Mancuso, Chlup, and McWhorter (2010) conducted qualitative research to investigate barriers of learning in virtual environments from the perspective of adult users. One of the barriers identified were glitches in the technology, which participants found annoying and stifled learning during the VR training. Hence, during evaluation studies any technical glitches should be documented to prevent technical problems that are falsely attributed to problems with the training itself. Another barrier was the learning curve for interacting with the virtual environment. Attempting to learn how to interact with new technologies can lead to poor retention of training content. Individuals who are well-versed in computer games or virtual reality technologies may thus have an advantage over users will little experience. This could create an 'experience divide' in results, i.e. systematically better scores for people with previous exposure to VR technologies. In a similar vein, the current lack of familiarity with virtual reality can create an initial sense of awe. This can equally detract from the intended learning outcomes of the serious game. Hence, previous experience with VR should be assessed prior to each training and included as a control variable in the analyses.

Another issue arises due to the difficulty of accurately replicating the real world in virtual reality; for example, if students are subjected to harsh weather conditions during the real-world training, this would be difficult to replicate in a realistic manner in the virtual reality training. Therefore, it is important to establish which elements of a training are essential and whether they can be replicated in VR – or in a combination of VR and real-world settings (see Chap. 3). If crucial elements cannot be replicated in VR, then this training form may not be best suited and real-life trainings the better option instead.

[3] The sense of being present in the virtual place and time rather than in the actual real-world location (Sanchez-Vives & Slater, 2005).

9.6 Conclusion

A key benefit of virtual reality trainings is that they are often cheaper and less resource-intensive than traditional live training exercises. Still, it is important to understand the effects of moving to VR-based serious games. By evaluating virtual reality trainings in a comprehensive manner, it is possible to achieve an accurate idea of how effective the training is as a whole and how it can compare to traditional training methods. This is important to ensure that skills are not being lost with the modernisation of training methods. A comparison of training methods can also help to create an understanding of what elements are better trained using virtual (or augmented) reality and which may benefit from more traditional training methods. This chapter outlined important considerations and recommendations in planning and conducting evaluations of VR-based serious game trainings. Evaluations can be time- and resource-intensive. However, without systematic evaluations the effectiveness of trainings will always remain guesswork. This chapter hopes to provide helpful guidance on how to set up and conduct evaluations that encourages organisations and practitioners to obtain ongoing and systematic evidence about the effectiveness of their VR-based serious game-based trainings.

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PART III

Application Areas and Examples

CHAPTER 10

Serious Games for First Responders

Andrea Redhead and Steffi Davey

10.1 Introduction

Tasks of first responders are complex and fast moving. Hence, first responder personnel must receive adequate training to execute their work in the often very challenging situations they face. For firefighters, tasks may range from community service tasks such as educating the public about fire safety procedures to more traditional experiences such as fire and rescue; paramedics may have to triage victims of traffic accidents or respond to biohazards. That said, even the experiences thought of as 'traditional' for these roles are becoming more complex; for instance, due to a closer integration of services, more intense scrutiny by the public and changing technologies. The training provided while the first responder is a student and any additional training alongside their job have to ensure that they are ready for these experiences physically, mentally and academically (for example, ensuring sufficient grounding in laws, regulations, relevant theories, etc.) in order to respond successfully and flexibly across situations (Smeby, 2005).

The training first responders receive has changed considerably over the years, from the way that training is carried out to the type of content that

A. Redhead (✉) · S. Davey
CENTRIC, Sheffield Hallam University, Sheffield, UK
e-mail: a.redhead@shu.ac.uk

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must be taught and the pedagogical methods involved. For instance, training for firefighters and paramedics must now handle the increasing likelihood that they may be the first to respond to a terrorist incident (Carnevale, 2005). Yet, the current approaches often understate the danger of such situations due to the lack of realism in the practice simulations (Goodale, 2005). In recent years, there has therefore been a shift to including e-learning within the syllabus, either that the content of a module is delivered online or in the form of virtual simulations and examinations (Williams et al., 2011).

This means that face-to-face learning as a pedagogical method has been expanded, since digital technologies also allow distance learning (Holmgren, 2014). Especially, the development of technologies such as virtual reality (VR; see Chap. 2) and augmented reality (AR; see Chap. 3) in combination with that of other digital enhancements improves distance learning capabilities (Birt, Moore, & Cowling, 2017). Distance learning facilitates the inclusion of large groups of people lowering overall resource requirements and costs and removes some limitations of real-life trainings (e.g. the size of physical locations no longer limits the number of trainees that can participate within a particular training sequence). In addition, an instructor is no longer mandatory for a training to take place, as the game itself can become the tutor and inform trainees of the missions and tasks that must be accomplished.

At the same time, serious games should not be seen as a replacement for traditional trainings or instructors. Instructors retain an important role also in serious game-based trainings, for example, by observing the trainee within the scenario, interpreting their results and performing debrief sessions after the training, in which the trainee and the tutor discuss actions, attitudes, experiences and decisions.

Simulations (see Chap. 4) are gaining in popularity as a training tool for first responders as they allow the training of situations that may be difficult or even unethical to recreate in practice (e.g. realistic hostage-taking scenarios in a civilian environment). Simulation-based serious games further facilitate training sessions across distances and in collaboration with people distributed across locations, and especially for large-scale exercises they are a cost-saving alternative. Game-based trainings further allow for built-in scorekeeping that can support a detailed and repeated review of participants' actions (McGrath & Hill, 2004).

The benefits of simulation-based serious games for first responders have been demonstrated repeatedly. For paramedics, for instance, the ability to participate in high-fidelity medical simulations facilitates learning and has proven superior to passive learning techniques (Cook et al., 2012). The positive effects stem at least partly from the fact that serious games offer first responders a safe and controlled environment for learning (Issenberg, Mcgaghie, Petrusa, Gordon, & Scalese, 2005).

One system developed to train paramedics is *MeRiTS* (Chodos, Gutierrez, & Stroulia, 2012). *MeRiTS* uses a virtual world to deliver scenario-based pedagogy using the scenario of a car accident victim. The objective for the student is to rescue and transport the victim to the emergency room. The students are able to work in pairs to complete the scenario with one acting as the lead and the second as an assistant. The game allows the instructor to watch the two students interact with the patient and with each other as well as to observe the handoff to the emergency room. This close observation of the whole process allows the instructor to provide feedback about trainees' communication skills, decision making and the sequence of their actions. After the scenario is completed, the students have a debriefing conversation with the instructor during which they can discuss such observations as well as their own experiences within the scenario.

The same technology can be employed to train collaboration between different disciplines of first responders, aiming for a better understanding of the way various organisations operate (collaborate pedagogy). Such experiences can build a vital link between first responder services, as they help to ensure that personnel from multiple services can respond collectively in an efficient and effective way. Serious games can further be valuable to train for situations that may not occur very often. A good example is the *Realistic and Adaptive Interactive Learning System* (RAILS) that was developed to train first responders to find, identify and determine the threats posed by radioactive sources (Winso et al., 2010). Determining a radioactive source is not something that first responders will have to do often. However, when they do have to, it is important that they know how to proceed. The *RAILS* software makes it possible for trainees to experience this situation alongside an instructor. The instructor can enable or modify training content, communicate with the participant, adjust the radiation source and control game style elements like the instruments available or the time limit in which the scenario has to be completed. The trainees have a variety of systems they can manipulate within the game scenario including during tutorial style scenarios in order to understand how to use the equipment. Trainees are further able to experience base radiation dose concepts to help them understand their effects. The game also offers challenge levels with various difficulties. Upon completion of the scenarios, trainees are provided with a debrief. According to Winso et al. (2010), follow-up questions about the scenario helped to cement the learning while also providing metric scores with respect to time taken to complete the scenario, the radiation sources identified and the dose that the trainee would have received.

For a more detailed view of serious games targeted at first responders, in the following we discuss concrete game examples in three different areas: fire and rescue, medical responders and command training.

10.2 Examples of First Responder Serious Game Trainings

10.2.1 Fire and Rescue

One of the common exercises that firefighters have to perform is entering a building and searching for victims. This involves a systematic search of the building where sight may be limited. This situation, when combined with rising heat levels, can require firefighters to crawl close to or actually on the floor. Once a victim has been located, they must be taken to a safe environment before the search can continue.

Traditionally, this type of training is performed in a building with dummies standing in for victims, which is effective but can incur considerable efforts and costs to plan and conduct. Firstly, a suitable area has to be found; for example, a hotel, factory or train and all have different requirements and different costs associated with them. In addition, dummies are required that represent a wide range of victims such as different genders, a variety of sizes and ages, also considering disabilities.

Backlund, Engstrom, Hammar, Johannesson, and Lebram (2007) investigated the effectiveness of virtual environments to complement the existing training methods for fire and rescue teams. Their study presented a search and rescue scenario in a game-based manner with the aim of making learning self-motivating and allowing for training outside of working hours. In the context of this research, the *Sidh* game was created and used in experiments with firefighter students. While playing the game, the students were equipped with masks, boots and a heavy coat. In addition, they were required to carry a heavy nozzle and navigate the game by body movements. The results of the *Sidh* experiment suggest that the game encouraged learning through repetition.

Even when the scenario changed slightly (for example, from a small apartment to a large office complex), the basic principles of handling the situation still apply. This allows students to learn from mistakes in previous scenes while also exposing students to a variety of environments they are likely to encounter in their work. The *Sidh* game further promoted a low body position, which is important in search and rescue scenarios. Not only does the low body position in the game force the participants to become used to the physical demands required for the job – especially as they were performing this movement with equipment; it also helps to ensure that the students perform this crouching behaviour automatically once they are on the job.

A considerable part of training for firefighters can take place within mock training scenarios. To test for the value of virtual trainings, Tate, Sibert, and King (1997) tested the benefit of a virtual environment on fire extinguishing tasks. Firefighters often have to extinguish fires within areas that they have not or only rarely encountered during training. A virtual environment gives users the chance to experience an environment that may be hard to get access to for practice runs. In their study, a group of firefighters was split into two conditions to examine whether a virtual environment could help them prepare better for the moment they have to enter an environment they may not have been exposed to before. One group trained using only traditional methods; the other trained also within the virtual environment that simulated the real-life location. Each group performed two tests: One was a navigation task, in which the firefighters had to reach a specific location while dealing with the visibility loss that occurs due to smoke from a fire. The second task required the participants to find the fire equipment and then extinguish a fire within the real location. The time taken to reach the goal, together with the number of wrong turns, was recorded for both groups.

The findings of this study showed that the participants who used the virtual environment navigated the area quicker and made fewer wrong turns than those who had trained only by traditional means. The team that used the serious game also was faster in extinguishing the fire at the scene. This suggests that they were better prepared for the environment and the situation they were presented with. When every second is vital, being able to minimise time and possibly dangerous mistakes such as wrong turns can make a significant difference to the outcome of the task.

10.2.2 Medical Responders

One of the crucial techniques that paramedics need to conduct is the triage system. *Triage* is the process of assessing injuries to determine their severity. First responders also need to quickly assess which patients need immediate attention and which have injuries that are not critical. This allows effective deployment of supplies, for instance, during the immediate aftermath of a major incident.

Although some research has been conducted into the possibility of remote triage (Acharya & Imani, 2017), triage is most commonly used by first responders in the field in response to major incidents using a methodology called the triage sieve (NARU, 2014; see Fig. 10.1). The triage system is heavily based on the perception of the paramedic, and therefore paramedics should refresh their knowledge on a regular basis. In a situation where triage is required, the paramedic must be certain about which label they apply, as an incorrect triage tag could result in loss of life.

The sieve process is commonly taught in practical workshops, where learners are introduced to the concept and given a short amount of time to practice, normally with mock patients like actors or mannequins within a classroom setting. Naturally this system is far removed from the situations in which these students will be utilising their skills and completely disregard any emotional resilience training. This leaves students vulnerable to experiences of stress, which could severely impact the students' performance during real-life events. This being said, large-scale scenarios that would accurately replicate a live disaster zone are not necessarily viable due to the costs, resources and time involved.

Serious games can help bridge this gap by allowing students to play a scenario in which their knowledge of triage can be applied in a realistic setting. Students can treat virtual patients in ways that they would not be able to with live actors. This gives students a safe place to fail and learn from mistakes.

The serious game *Triage Trainer* (Knight et al., 2010) was designed to allow students to play through a major incident and triage the casualties. The authors evaluated the effectiveness of this style of learning against a card-sorting exercise, which students traditionally received in a classroom environment. The results of the experiment concluded that the students who learned with *Triage Trainer* showed significantly higher accuracy on all casualties compared to those who practised with the card-sorting exercise. The act of learning from mistakes is well known as a tried and tested

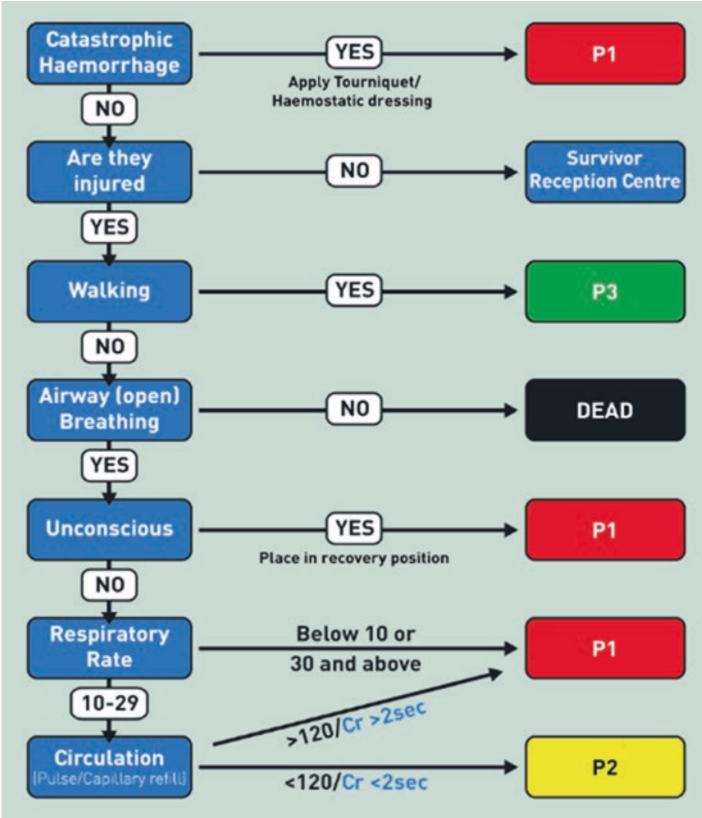

Fig. 10.1 2013 Triage sieve (NARU, 2014)

learning method (cp. Chap. 1 on learning theories), and serious games add another layer to that approach in the form of realistic scenario training.

Another study at a medical school (Vincent, Sherstyuk, Burgess, & Connolly, 2008) recruited volunteers to take part in a mass casualty triage training simulation. Participants were required to have a certain level of knowledge before they could participate and had to pass a criteria examination to ensure they met the requirements for the experiment. For each of the three scenarios that the trainee participated in, the following outcomes were measured: intervention score, performing the intervention correctly, the time taken to perform the triage and a triage score. The triage score was calculated as a combined score based on whether participants were able to correctly identify the main problem of each casualty, identify the correct intervention and whether they put the casualty into the correct triage category. Results indicated that students could learn efficiently and effectively within the virtual environment, indicated by improvements to their scores across the board.

Overall, the evidence suggests that serious games are a viable learning tool for medical responders by providing paramedics an environment in which they can fail safely. Virtual reality tools have the potential to take this sort of training even further by providing first responders with environments that are close to the ones that they may experience in the field, ensuring they are prepared for as many situations as possible.

10.2.3 Command Training

Although first-line staff has so far been the primary focus for serious game trainings, they are not the only ones who can benefit from serious games; staff at command centres or officers in charge of a unit can equally benefit from the training opportunities that serious games provide.

Traditionally, in command training tabletop exercises are performed that may be augmented by educational workshops or full-scale scenario exercises. However, these types of training methods are associated with high costs. Not only do they require the hiring of facilities that can hold a sufficient number of people, they also require equipment and often the closure of locations for the public. As communication is key within most of these exercises, people must be present at the same location.

Gamification (the process of adding game style elements; see Chap. 4) can be used to enhance command training and remove expensive restrictions while maintaining a focus on the communication and coordination as learning outcome (Kanat, Siloju, Raghu, & Vinze, 2013). Further, online systems can significantly reduce the costs of having to hire a location big enough for all attendees and equipment, as headsets and other communication devices allow for collaboration amongst widely distributed users.

In addition to collaborative serious games exercises, serious game trainings can also take on the role of an instructor for individual users. In this case, users can practice in their own time, rather than having to schedule training sessions around the availability of rooms, equipment, instructors, etc. The systems can also provide an interpretation of results and debriefings after the completion of individual or all training scenarios. Alternatively, the in-game debrief can be combined with a feedback session with an experienced instructor giving trainees and tutors the chance to discuss results, analyse what could have been improved or done differently and why the trainee chose to make certain decisions. Upon the replay of a scenario, or if the user embarks upon a different scene, the trainee will be able to compare and contrast their results across practice sessions adding valuable personalised information about their learning process.

Examples of serious games for command training can be found for fire and rescue contexts in the training of Fire Company Officers, amongst others. Each company of firefighters – often consisting of four to eight people – has a Fire Company Officer (FCO) in charge, who is responsible for ensuring the safety of the unit. FCOs traditionally perform mock training scenarios to practice and prepare for their duties. Training scenarios targeted at command levels allow users to play out situations that leaders might come across in their jobs and sometimes involve real fires and blazes in training buildings. However, mock scenarios are generally limited to a specific building that the firefighters and Fire Company Officers train in again and again. They may become used to the building schematic or structure, which may hinder the transfer of skills acquired in the training setting into a real-world situation.

As with the above examples for fire and rescue personnel, a serious game within a virtual environment allows FCOs to experience a variety of scenarios with less expense and without the risks involved in case of a real fire. St. Julien and Shaw (2003) created a serious game prototype in which the FCO could instruct teams of virtual firefighters to put out virtual fires. The simulation allows the FCO to watch virtual firefighters carry out the commands while also seeing changes in the fire and smoke in response to their actions. The damage to the building and the safety of the firefighters depend on the sequence of commands chosen. In a system like this, an FCO can test a variety of situations and the effect of different approaches. This more generic setup could be combined with the knowledge FCOs possess about their officers from mock training exercises to get an idea what kind of responses by their crew may be expected and with which consequences. Virtual and mock scenarios can also be conducted in sequence, meaning that FCO could take insights from the virtual training back to the mock exercises or vice versa. A similar virtual system could be built to allow for the FCO to join colleagues in a command team or to directly collaborate with members in their unit. The benefit of such a setup would be that the entire unit can train together in a variety of situations and thus obtain a better understanding of team dynamics under near realistic circumstances. It would also eliminate the gap for FCOs when moving from virtual actors to their own (real-life) units.

Systems for command training can of course be applied also in other contexts beyond firefighters. Law enforcement and medical personnel in leadership positions could use the same style of training with scenarios developed for their specific needs.

10.2.4 Virtual Reality Enhancements for Emotional Preparation

While fire and rescue and triage are skills firefighters and paramedics use once they reach the scene, the scene itself can be fraught with hazards. Often the intensity of the situation can affect first responders who are not used to the tension and sights. The training settings discussed so far are useful for learning, assessing and updating skills; however, training approaches often overlook the stress inherent in crisis situations. Preparing first responders emotionally for difficult situations can improve both short-term coping as well as long-term well-being.

Subjecting trainees to high-stake situations without danger is only possible through staged scenarios. These staged exercises employ moulage (i.e. mock injuries for the purpose of training) to provide realistic settings. Yet again, these exercises can be expensive and time consuming, and it is often difficult to capture important elements of real crisis situations. For example, medical personnel cannot accurately treat the actors who play victims, and symptoms of these actor victims do not deteriorate over time as they would in reality. Also, it is challenging to replicate real-life consequences; e.g. although paramedics might wear the necessary protective gear, they may not obtain a full understanding of what significance a tear in their suit might have in jeopardising their health. In virtual reality-based serious games, participants can experience crisis situations without harm to themselves or to others, yet in a highly realistic manner that may induce stress levels comparable to real crises.

One example is a system called *MediSim* (Stansfield, Shawver, & Sobel, 1998), which was created to provide training of emergency triage for personnel on the battlefield. It uses four sensors placed on the head, lower back and both hands of paramedics which provide input for a virtual avatar that represents the movements participants make. It further runs voice recognition software to allow the user to request vitals and issue commands. *MediSim* laid the foundation for another simulation focused on biohazards, *Bioterrorism Simulated Medical Emergency Response* (BioSimMER).

BioSimMER (Stansfield, Shawver, Sobel, Prasad, & Tapia, 2000) gives the user a scenario in which a small airport has been taken over and hostages are involved. The background information to the scenario mentions that the insurgents claimed a biological warfare agent had been released, but that they had not given any specifics as to the nature of the chemical. The scenario further states that law enforcement officers have entered the airport and an explosion has occurred. The participant enters the scene just after this point. Once the trainee enters the scene they are tasked with the triage of victims. The game allows the administration of medication, insertion of an IV and the application of dressings. As the trainees carry out their tasks, the only feedback they receive is the changing condition of the patient. This differs from a real-life exercise in which the participant would state what they intend to do, and the trainer would provide feedback instantaneously. *BioSimMER* records the trainee's actions together with the time and speed at which they were done. Taking these readings allows the participant's performance and actions to be analysed and discussed after the session and thus provides a more natural experience for the paramedic in training.

The *JUST VR* project investigated the realistic aspects of virtual reality for medical scenarios (Manganas et al., 2004). The system had two scenarios: a participant experiencing either an office setting or a city park. These were both similar in nature with the main difference a higher number of virtual people in the city park. Within both scenarios, the user initially has to navigate through the virtual environment until they come across a collapsed figure, while someone nearby calls for help. The virtual person calling for help will become the participant's virtual assistant. The trainee is expected to assess the situation until the ambulance arrives, during which time the virtual assistant is asking questions about what to do. The trainee is expected to answer the questions and make correct decisions within a certain time frame, the expectation being that the sense of urgency will cause a more realistic experience. If the trainee takes too long or hesitates with their responses, the virtual assistant will perform the correct action with the potential of adding to the participant's stress. The addition of extra people in the city park scenario is intended to increase the sense of urgency and potentially create more distractions, comparable to onlookers in real-life situations. After participants have completed one of the scenarios, they were asked to rate how realistic the scenario felt. The results indicate that in general users were convinced by the virtual reality scenario and that they felt they were participating in a real setting. Another example for the use of virtual reality-based serious games for emotional preparedness is the AUGGMED platform, described in Chap. 5.

Overall, findings show that virtual reality offers interesting enhancements to first responder trainings by allowing trainees to experience particular situations as if it were real – including situational factors such as time pressure, emotional impacts and the presence of bystanders.

10.3 Making Use of Collaborative Pedagogy

When a major incident occurs, first responders are the ones dealing with the immediate aftermath. Each profession trains to handle this, but they are often trained in isolation. In reality, a large number of first responder organisations will be at an incident at the same time and required to work together. Thus, as helpful as it is for each type of first responder to prepare for the unforeseen circumstances of major incidents, the benefits are compounded when collaborative pedagogy takes place. Yet, it is complex enough for one profession to obtain real-life training; the chances of two or more professions being available at the same time are even smaller, making collaborative pedagogy a daunting task.

With the advent of massively multiplayer online (MMO) games in the leisure games market, the learning industry has started to investigate how to employ this technology for serious games. Massively multiplayer online games can be a viable learning tool (O'Connor & Menaker, 2008), as they can provide multiple participants with consistent training in a flexible environment, generate scenarios specific to the learning objectives and mechanics for reflection and hence allow for specific knowledge and skills to be taught, enriched or reviewed.

Prasolova-Førland, Molka-Danielsen, Fominykh, and Lamb (2017) created a virtual reality simulation in which emergency management personnel from various professions can train together. This *VR-Active Learning Module* (VR-ALM) represents a crisis situation in which participants are expected to make decisions, while the situation evolves and changes in real time. Options are available for a desktop display in addition to the VR headset. Four professions are represented within *VR-ALM*: local workers, firefighters, paramedics and police officers. Each profession has a specific repertoire of actions based on their real-life responsibilities; for example, a firefighter is the only one able to operate the fire hose, whereas paramedics can perform triage and communicate with the injured. With the addition of time constraints and other changing factors, the participants are expected to make decisions similar to those in live exercises while having the opportunity to communicate with other professions. The benefit of this setting is that participants do not need to be in the same physical location in order to train together. One of the downsides of *VR-ALM* is a certain lack of realism.

Mossel et al. (2017) showcased a simulation tool called *VROnSite*, which aims to overcome the current limitations in training, realism among them. *VROnSite* is an immersive experience that simulates decision making while also requiring physical movement. It was tested with fire brigades and paramedic units. The study illustrated that especially the quick setup of the system afforded participants the chance to obtain valuable additional command-level collaborative training with minimal overhead for the participating organisations.

Allowing various first responders to train together helps to minimise the likelihood of mistakes in the field when an actual incident occurs. Technological advances allow for these training sessions to be carried out from anywhere around the world and to overcome the usual obstacles when trying to ensure a large amount of people can get to one location at the same time.

10.4 Conclusion

Training is slightly easier now that face-to-face learning can be enhanced and, in some cases, replaced by distance learning. Online courses and online course elements allow for first responders to train without necessarily requiring proximity to training grounds. This can cut cost, resources and time required for organisations to train new staff or to enhance their current staff's abilities. As the above discussion and examples show, serious games offer a worthwhile addition – or in some cases an alternative – to traditional training approaches.

Virtual reality-based serious games allow first responders to refresh old skills and learn new ones. Virtual reality further provides a platform to train situational awareness, which helps first responders to be better prepared for decision making and collaboration in fast evolving crisis. Especially the ability to learn from a distance opens opportunities for co-training and inter-professional learning amongst different disciplines of first responders. Not only can training times be scheduled across shifts, but at any time that suits the organisations involved. First responder organisations from around the world can train and learn together while minimising the costs and efforts this would usually entail.

Overall, serious games provide a viable platform for training and enhancing skills and emotional preparedness in first responders. The skills obtained through this style of training can dramatically alter the rate of mistakes as well as reaction times, both things that are vital in the effective handling of crises. Whether it be a firefighter learning to keep a low body posture and performing a search and rescue or a paramedic understanding how to identify a potential biohazard and triage casualties, all disciplines can utilise serious games to train and enhance their knowledge. This does not have to involve large-scale technologies, as many serious game-based trainings can be conducted in the form of tabletop or computerised games. Still, as illustrated in this chapter, virtual reality can be a powerful tool to increase the fidelity of serious games trainings with positive effects on the skills and physical and mental preparedness of first responders.

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CHAPTER 11

ATLAS: Preparing Field Personnel for Crisis Situations

Paul Hancock, Jonathan Saunders, Steffi Davey, Tony Day, and Babak Akhgar

11.1 Introduction

ATLAS (Advanced Training, Learning and Scenario Simulator) is a serious game that was developed in conjunction with an intergovernmental organisation to deliver bespoke training simulations in virtual reality to assist field personnel in making decisions in difficult situations during operations. This chapter describes the concept of ATLAS and the developmental process that led to the full-fledged game.

11.2 The ATLAS Concept

When members of humanitarian agencies work in areas of high risk or conflict, it is not uncommon that their safety is compromised. In life-threatening situations or times of immense stress, it can be hard to remain calm and faithfully carry out the correct actions. To prevent serious harm or even loss of life, it is thus vital that staff are trained appropriately and feel prepared should they encounter an emergency situation.

P. Hancock (✉) · J. Saunders · S. Davey · T. Day · B. Akhgar
CENTRIC, Sheffield Hallam University, Sheffield, UK
e-mail: ph5218@exchange.shu.ac.uk

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Realistic training simulations through virtual reality aim to make reactions in emergencies and stressful situations feel like second nature – based on the idea that trainees have encountered the full complexity of such situations before going into the field and are thus mentally and physically better prepared. ATLAS is a reaction to this need, with the objective to prepare trainees to make better decisions when they are faced with critical situations in the field.

ATLAS is a proprietary modular serious games development system for virtual reality simulations. This system allows for the rapid development of serious games scenarios and provides a platform to create highly customisable bespoke virtual reality training sessions for a range of security-based application domains. The approach is based on the understanding that a scenario-based learning paradigm helps to improve practical skills such as situational awareness, analytical thinking, problem solving and decision making (see, e.g. Chaps. 4 and 10). At the same time, the final design had to minimise potential adverse effects of using virtual reality (see Chap. 3).

The first iteration of ATLAS developed a virtual reality training simulation for field operatives working for an international non-governmental organisation. The scenario was developed in response to an attack on a convoy of humanitarian aid workers in South Sudan in 2017. Tragically, two people died of gunshot wounds as a result of this attack (Dumo, Houreld, & Williams, 2017). The scenario which was designed to replicate some of the events of this attack aims to train field staff on how to react if they encounter a similar situation. The scenario commences with the trainee sitting in a car which is part of a convoy. This convoy then comes under attack and the trainee has to vacate the vehicle and find a safe place to retreat.

11.3 Development of ATLAS

As the purpose of the serious game is to teach skills which could prevent harm during incidents to front line staff, it was necessary that ATLAS should be made as accessible as possible. Therefore, it was important that the system can be deployed easily and does not require a large space for participants to move around during training, as this limits the number of locations where the training can be deployed. This requirement was met by requiring trainees to press a button on a handheld controller to move in the simulation, as opposed to moving around physically in the real world.

Moving in this way can introduce problems of simulator or cybersickness, although there are ways to reduce the likelihood of such episodes (see Chap. 3). The first technique that was considered to help with this is teleporting. Teleporting in VR refers to a technique in which the user moves by either looking or pointing at the position where they would like to move to and then pressing a button on the controller to immediately move to that position. Often the user first presses a button to bring a marker into view. This marker is shown on the ground at the position to where the user will be teleported. The user can then move this marker, either by moving their head or by pointing with the controller in their hand. Once the marker has been moved into the position the user wishes to teleport to they can release the button to execute the teleportation. Whilst this technique is effective and does help to alleviate symptoms of cybersickness in some people, it does somewhat detract from the feeling of immersion the player experiences whilst engaging with the application. As this serious game is intended to recreate a potentially stressful scenario, it is important that the feeling of immersion is kept as high as possible to make the simulation feel real. As a consequence, it was decided that for this project, teleportation would not be an effective method for allowing the trainees to move within the simuation.

The next method that was evaluated is called 'tunnelling'. Tunnelling is a technique in which the user's peripheral vision is restricted whilst they are in motion (Tambovtsev, Floksy, & Pesh, 2016). When the user presses the trigger on the controller they will begin to move forward; simultaneously their peripheral vision will be restricted, so that they are effectively given tunnel vision (see Fig. 11.1). As soon as the trigger is released, the movement will stop, and the peripheral vision will return to normal. After an evaluation period, it was decided that this technique sufficiently lowered the potential feelings of disorientation linked to simulator sickness and was also more immersive than teleportation. Hence, for the ATLAS project the tunnelling method was used.

The next step in the game development was to generate the training scenario. As the intention was to train people in how to deal with a situation similar to the Sudan convoy attack, it was decided that the scenario should take the user through a simulation essentially replicating this attack.

To begin, the trainee is asked to sit in a chair and to put on the VR headset. The simulation begins with the trainee in the rear seat of a vehicle so the seated position helps to increase the feeling of immersion. The scenario then commences with a 2-minute gentle car ride through the desert,

Fig. 11.1 Use of tunnelling in ATLAS

giving the trainee time to adjust to and take in their VR surroundings. In the simulation, the car which the trainee is seated in is part of a convoy of similar vehicles. They can look around and see a virtual representation of their body; they can also move their hands if they wish. Once the car drives past the remains of old buildings, a gunshot is heard, followed by the sound of shattering glass, this signals the start of the attack.

The trainees are expected to assess the situation and respond in an appropriate manner. This means, they must evacuate the car and find a safe place to take cover. This scenario is designed to test their situational awareness, particularly to test whether the trainee noticed the ruins during the car ride as a suitable place to take cover. Once the trainee has taken cover in a suitable place, the scenario is complete and the simulation ends. At this point the trainee is debriefed and informed which of the decisions they made were correct or problematic and what they could have done differently. For instance, if they made no attempt to take cover behind the engine block of a car, if there was one close by, they will be advised that this would have been a good decision.

This preliminary application with one very specific scenario acted as a trial version for ATLAS as a training tool. The long-term intention is to develop further scenarios, using the same framework as in the first scenario. These new scenarios can be rapidly developed and deployed whenever a new threat for field personnel emerges that requires additional targeted training.

ATLAS is currently employed as a supplementary training tool within a classroom environment. As part of a hostile environment awareness training, the ATLAS platform is used to encourage social learning as students watch their peers' actions. Decisions during ATLAS training can then also serve as a platform for discussion. This form of cooperative training helps students prepare for real-world exercises, ensuring they respond appropriately and correctly to field situations similar to the ones encountered during the training.

11.4 Conclusion

ATLAS aims to ensure that field staff deployed in conflict areas are able to act to their full potential in a crisis situation. It aims to achieve this by training staff to control their emotions, organise their thoughts and develop a plan of action even in times of extreme stress. ATLAS supports trainees in improving their situational awareness by encouraging them to increase their level of attention towards their immediate environment. At the time of writing, ATLAS is at the prototype stage and consists of a single scenario. However, ATLAS has been successful in terms of demonstrating what can be achieved with a VR-based training application. The success of this initial development suggests that such serious game applications have considerable potential in the preparation of field personnel for crisis situations. Future updates and extensions with new scenarios using the framework may be added as needed.

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CHAPTER 12

CyberCentric: Increasing SME and Citizen Resilience Against Cyberattacks

Babak Akhgar, Jonathan Saunders, Paul Hancock, Alison Lyle, and D. S. Shelton Newsham

12.1 Introduction

CyberCentric[1] is a realistic cybersecurity scenario simulation platform. The objective of *CyberCentric* is to reach out to citizens and small- and medium-sized enterprises (SMEs) to provide them with the capability to share information on cybersecurity-related issues and allow them to experience the impact of cyberattacks as well as learn about means to mitigate against them. *CyberCentric's* overall goal is to provide SMEs and citizens with protective knowledge to improve their cyber resilience. This chapter provides an overview of the game, its developmental concept and key components from a user perspective.

[1] CENTRIC is the Centre of Excellence in Terrorism, Resilience, Intelligence and Organised Crime Research at Sheffield Hallam University, UK.

B. Akhgar (✉) · J. Saunders · P. Hancock · A. Lyle
CENTRIC, Sheffield Hallam University, Sheffield, UK
e-mail: b.akhgar@shu.ac.uk

D. S. S. Newsham
Yorkshire & Humber Regional Organised Crime Unit, York, UK

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12.2 An Overview of the Cyber Resilience Landscape

The prevalence and related risks of cybercrime are rapidly increasing posing a growing threat to citizens, society, businesses and national critical infrastructure. At the same time, law enforcement agencies (LEAs) grapple with the challenge of keeping pace with developments, including issues such as how best to approach the investigation of such crimes, how to protect the public and businesses against cyberattacks and how to increase society's resilience through better awareness of the threats posed by cyber-related risks. LEAs already offer such advice for more traditional crimes but advice on how to guard against cybercrime is currently less coherent. For example, the UK government provides schemes such as *Cyber Essentials*[2] for SMEs and *Cyber-Streetwise* for citizens,[3] and individual LEAs have their own schemes through regional cybercrime units. In the EU, ENISA promotes cybersecurity in the context of the 'cybersecurity month'.[4]

The education of citizens is paramount, since citizens not only protect and improve their own personal cybersecurity; these are the same people who work in businesses and public organisations, which means their lack of experience in handling cybersecurity increases the potential of vulnerabilities also for their workplaces. Consequently, cybersecurity needs to be tackled from the ground upwards starting with the education of citizens on good preventative practices in the hope that they take this expertise forward into their working environment.

The growing threat of cybercrime has been recognised at the EU level in the European Security Model,[5] which highlights the threat of and the fight against cybercrime as one of the EU's key priorities from 2015 onwards. The European Security Model is defined as being an 'integrated EU security architecture containing common tools for collaboration between law enforcement authorities and judicial bodies within the Member States'.[6]

[2] https://www.gov.uk/government/publications/cyber-essentials-scheme-overview

[3] https://www.cyberstreetwise.com

[4] https://cybersecuritymonth.eu

[5] http://ec.europa.eu/dgs/home-affairs/e-library/documents/basic-documents/docs/eu_agenda_on_security_en.pdf

[6] http://www.focusproject.eu/web/focus/wiki/-/wiki/ESG/European+Security+Model

12.3 Background to the Development of CyberCentric

The development of *CyberCentric* was initiated by observations in an earlier EU-funded project COURAGE[7] that many small- and medium-sized enterprises (SMEs) missed out from the typical cyber-awareness information and events, as these usually focus on larger companies and cities. Especially, the solutions discussed at these events address mostly larger businesses. In consequence, the resilience of SMEs against cyber-based attacks often remains limited. Another factor reducing cyber-preparedness in SMEs are the costs of both attending to and investing into resilience-focused solutions. These gaps lead to the idea of testing the effectiveness of a serious games platform that provides an immersive learning environment, allowing them to experience virtual cyberattacks and learn how these, and subsequent decisions business owners take, may impact their business.

The development of *CyberCentric* was led by a multidisciplinary team of experts formed through funding provided by the High Value Investments and Impact Fellows programme (2017–2018, Sheffield Hallam University, UK). The team consisted of experts in informatics, game design, game development, business resilience and cybersecurity as well as police officers. The game development used the CENTRIC serious games design framework (see Chap. 8) with scenarios developed in cooperation with subject matter experts and police officers.

12.3.1 *Iterative Development of* CyberCentric *Through a Consecutive Piloting Approach*

The development of *CyberCentric* followed an iterative end-user-based piloting approach (cp. Bayerl & Jacobs, 2017). Pilots in this context refer to preliminary small-scale investigations, which aim to assess the efficacy and feasibility of a product or process (Thabane et al., 2010). Pilot studies are also referred to as *pilot testing* or *pilot experiments* and are a subset of feasibility studies. *Feasibility studies* is an umbrella term, which also includes proof of concept studies. The latter is carried out before the work on a deliverable begins and aims at investigating whether there is an actual need for the proposed game or product. Pilot studies, in contrast, aim to

[7] EU Research COURAGE project. See Akhgar and Brewster (2016).

assess the quality of the product in development as well as the effectiveness of the developmental processes (Eldridge et al., 2016).

Pilot studies gather feedback from end users with the aim to identify areas of the game that work well and areas that end users would like to see improved (Van Teijlingen & Hundley, 2001). Sauro (2018) recommends the use of a combination of expert and novice users. Observing novice users interacting with the system can result in unexpected or unintentional means of interaction with the system (Dix, 2007). Novice end users may thus identify weaknesses that experts or developers may not have acknowledged or identified, as their experience can cause them to overlook fundamental usability issues (Sauer, Seibel, & Rüttinger, 2010). In consequence, a combination of expert and novice feedback will often lead to the most valuable input to improve the game's usability, aesthetic design and efficacy.

Pilot studies are often conducted early during the game development period. Such an early validation can save time and money by solving problems at an initial stage, preventing costly changes at a later stage. Still, even for the first pilot the game should be at a suitable stage to be tested by end users, meaning it has basic functionalities and sufficient features to obtain useful feedback for the further progression of the project. In addition, the game should be thoroughly tested in-house before it is taken to the piloting stage. If the system crashes or unexpected errors occur during the pilot, it may not be impossible to obtain feedback from the participants. To avoid technical issues during pilot testing, a stable build should always be available, whilst any last-minute alterations should go into a separate build. Similarly, if data collection methods have not been well planned, necessary data may not be captured which results in a waste of time and resources (Thabane et al., 2010). Thus, the pilot methodology should be as meticulously prepared as the game design and presentation.

In addition to the first pilot, serious games pilots should be planned in regular intervals throughout the life cycle of a game development project. This long-term focus creates milestones and deadlines to work towards, which ensures that the development does not fall behind schedule, the final product is validated by end users and fits their needs and the development team has not lost sight of the overall aims of the project (Van Teijlingen & Hundley, 2001). Later pilots may have different aims such as making additional improvements on its design and functionalities or may be more narrowly focused on a specific aspect of the game such as the artwork.

Generally, before a pilot study takes place, clear decisions must be taken about:

1. The aims and desired outcomes of the pilot study as a whole and for each iteration
2. The best methodology with respect to data collection methods, analysis of the data, sample size, sample demographics, pilot location, length of the study, etc.

Once the aims of the pilot study are defined, a strategy for the collection of data can be formulated. Defining specific and clearly identifiable outcomes facilitates the evaluation of the game and allows a direct comparison of results across several pilot iterations (see also Chap. 9). Examples for potential outcome measures for serious game pilot studies are:

- How user friendly is the system?
- To what extent do players achieve intended learning outcomes by using the game?
- What are barriers to achieving the intended learning outcomes (skills, behaviours, attitudes, etc.) with this game?
- Is the design of the game appropriate for the targeted user group?
- How long does it take a novice to complete the game or a stage of the game?

The above considerations underpinned also the validation efforts of *CyberCentric*. Using action research as underlying research methodology, the game was validated in five consecutive pilot events, in which participants from local SMEs could experience the serious game and benefit from the attendance of experts for additional information and support. The pilot events were planned and took place in smaller towns across one UK region. Care was taken to create and maintain new and mutually beneficial relationships with police cyber units, with the positive effect that all but one of the pilots were attended by police officers. The lessons learned during each event were fed back to the project team to improve the performance of the game and to fine-tune the scenarios. In addition, briefings and positive information campaigns provided by Europol EC3 (European Cybercrime Centre) enhanced the understanding of the overall risk areas for SMEs. In this refinement phase, the project team considered performance aspects from effectiveness of the serious game to user requirements and feedback. The feedback gathered throughout the five pilot events suggests that the game could be used successfully by the diverse group of participants, all of whom gave overall positive feedback about their experience and the value of the game for its intended purpose.

12.4 Concept of CyberCentric

The development of *CyberCentric* brought together experts from LEAs, businesses and academia with the intention to consolidate diverse knowledge about how best to protect businesses and citizens from cyberattacks using a serious game. The concept and content of *CyberCentric* is thus grounded in a wide-ranging and far-reaching exploration of the key factors that support (or threaten) cyber resilience of citizens and SMEs.

The overarching goal of *CyberCentric* is to comprehensively and iteratively address the interrelated facets that underpin protection and mitigation – including the motives, opportunities and networks around cyberattacks, whilst its main focus is to improve the protection and mitigation of cybercrime with a focus on strengthening businesses' cyber resilience and minimising the impact of attacks. In order to achieve this, *CyberCentric* has taken a comprehensive approach that brings together LEAs' knowledge of cybercrimes, the viewpoints of citizens, the actions and reactions of cyber criminals, current policy, strategy and legal governance and combined them with serious game expertise underpinned by an empirically developed design framework (see Chap. 8). The game content is presented as narratives in the form of scenarios around cyberattack and vulnerability issues within SMEs (see Fig. 12.1). The citizen version of *CyberCentric*, focused on SMEs, is freely available to the public. A second version addressing LEAs is intended to reside within the secure network of LEAs for an analysis of resilience issues pertinent to small- and medium-sized businesses.

CyberCentric was created with ease of use and accessibility in mind. To make the game accessible also to users with little to no technical knowledge, the entire system is built on a question and answer system, which requires the user to balance three factors: funds, reputation and resilience. This balancing act enables the game to gamify the resilience building process with actions costing funds but potentially improving or hurting a company's resilience/reputational score (see Fig. 12.2). The gamification approach aims to make the gameplay more attractive and engaging (see Chap. 5).

Fig. 12.1 Introduction page to the game presenting the game's scenarios

12.4.1 Scenarios

Since the cyberthreat landscape changes constantly, *CyberCentric* requires adaptability. The game is therefore split into two facets: The first is the story mode, which introduces users to the main challenges any business could face when trying to remain resilient to cyberattacks; the second presents emerging threats, which can be rapidly added to the game to

Fig. 12.2 Question and answer system

Fig. 12.3 The two facets of *CyberCentric* (main menu)

quickly update methods of responding to and mitigating new cyberattacks (see Fig. 12.3).

CyberCentric currently contains five story narratives. These are: (1) information security, (2) data theft, (3) malware attacks, (4) denial of service and (5) GDPR. Alternative scenarios can be added to the game as soon as new user requirements or new cyberthreats emerge. Through all scenarios, the user is encouraged and directed towards a better understanding of cyber protection issues. The latter is supported by the inclusion of cyber situational awareness performance elements relevant to SMEs (captured in the indicator's money, reputation and cyber resilience; cp. Fig. 12.2). This ensures that the different scenarios in *CyberCentric* do not appear as disconnected components but rather as a set of interrelated challenges of cyber resilience more generally.

Below, two of the five scenarios are described in more detail to demonstrate the setup of the game environment, how scenarios address the attack vectors used to carry out a specific cyberattack and the expected learning outcomes of the game.

Information Security Scenario: Business Information Security Breach

Scenario: The player's business has experienced a significant data breach, in which hackers have accessed the company's customer databases and stolen personal details as well as credit card information. The attackers have contacted the player's company and are requesting a significant payment for not selling the information on the dark web. The player's business has reviewed the situation and discovered that the hackers gained access by social engineering. The hackers posed as the Chief Information Officer (CIO) of the company requesting remote access rights to the database whilst abroad on holiday. It is believed that the hackers were monitoring the Chief Information Officer and, due to a personal social media profile, discovered that the CIO was on vacation. Upon receiving the email from the supposed CIO, the IT support staff immediately proceeded to update the database access rights as requested, giving the attackers direct access to the databases and all information stored within.

Attack vectors: This scenario presents common attack vectors of information security threats such as unauthorised access to databases through hacking, taking advantage of poor employee cybersecurity, social engineering and insider attacks. This initial approach is then followed up by a ransom request, threatening the public release of documents or the sale of documents online to other criminal organisations.

Expected learning goal – protection: Player should learn the necessity to have checks and policies in place to secure employees against social engineering methods. They also need to be aware of management decisions that may cause employee dissatisfaction, anger, etc. and consider which access levels individuals (need to) have as well as the level of cybersecurity education of their employees. Prevention measures proposed in *CyberCentric* are, for instance, increasing the awareness of staff about cybersecurity issues, threats and social engineering techniques and maintaining up-to-date cybersecurity policies.

Expected learning goal – mitigation: The player is made aware that each business requires policies that govern how the business must react in the event of a breach, including how to inform all those who need to know such as data protection authorities and the individuals involved. The game also raises awareness that preventative actions should be taken with respect to blocking accounts, updating passwords and additional vigilance in case of potential identity theft. It further advices to involve cyber police specialists at the earliest opportunity and to preserve evidence. Policies should be put in place that demand the validation of information requests and guide the sharing of any secure data or personal access requests.

Malware and Virus Scenario: Botnets

Malware has spawned a field of crime that is cyber-dependent (opposed, for instance, to phishing-based frauds, which are cyber-enabled). Malware, viruses and subsidiaries such as ransomware, keyloggers and adware are common threats faced by typical computer users. These threats are now also making their ways onto mobile and tablet devices.

Scenario: This scenario states that the SME owner has not updated the company's IT software system and that for cost reasons no cyber protection such as a firewall is in place. In consequence, the computers of multiple unwitting victims of malware have been linked to form part of a botnet, i.e. a network of infected computers that can be controlled by the criminal(s).[8]

[8] Botnets can be used to push other strains of malware, harvest users' credentials, compromise their online bank or other accounts, exfiltrate confidential information or facilitate other crimes such as denial of service attacks, spam email campaigns or ransomware attacks. Often botnets can compromise many thousands of computers. For example, *GameOver Zeus* had over 326,000 victims globally (cp. goz.shadowserver.org/stats/), and *Conficker* – a piece of malware known since 2008 – still has over 600,000 infections globally (cp. https://www.

Attack vectors: Malware at scale is typically propagated through mass email campaigns with an attached 'loader' or a hyperlink to malware or through so-called 'watering-hole' attacks where websites are compromised and systems of visiting users with unpatched or vulnerable systems become infected. This scenario presents common attack vectors for collecting personal and business information via a malware-based infection of the company's IT system.

Expected learning goal – protection: CyberCentric raises awareness of protective measures from technical solutions, which can block many of the malicious infection vectors, to proper Internet hygiene. The latter means that users are educated into maintaining healthy, patched operating systems with updated antivirus software and further avoid risky situations such as opening unsolicited emails and/or clicking on links. *CyberCentric* improves users' understanding of how malware-based attacks are propagated and why employees may not maintain or implement the security measures that are available.

Expected learning goal – mitigation: CyberCentric supports citizens and LEAs by:

- Educating businesses on the identification of infections and infection vectors and on the best courses of action, for instance, in the UK contacting hubs such as Action Fraud and NCA
- Seeking ways to clearly outline indicators of compromise and vendor name confusion to assist in the earliest possible identification of a malware threat
- Providing clear guidance for victims and investigators on how to prevent further losses and victimisation, how to identify and quantify losses and where clean-up tools/solutions may be found

grahamcluley.com/2015/12/seven-years-conficker-worm-dead-dominating/; http://www.shadowserver.org/wiki /pmwiki.php/Stats/Conficker). Crime of this scale requires a paradigm shift in approach for law enforcement globally.

12.5 Expected Outcomes for SMEs and Citizen's Perceptions and Behaviours

CyberCentric has an explicit focus on changing the perceptions and behaviours of citizens and SMEs with respect to cyberthreats through story boarding and up-to-date information on the latest cyberthreats. Despite repeated efforts, SMEs are often not as aware of cybercrime threats as they should be – or they do not behave according to the knowledge they have. This is borne out by results from the Eurobarometer Cybersecurity Survey,[9] which was carried out in 2013, 2014 and 2015 employing surveys and interviews combined with additional background research. According to this survey, only half of EU citizens felt well informed about the risks posed by cybercrime despite the fact that over one million people are victims of cybercrime every day. In particular, the Eurobarometer findings suggest that citizens are increasingly concerned about the misuse of personal data and the security of online payments, the prevalence of identity theft, malicious software, banking/credit card fraud, social/email account hacking, scam emails and general online fraud, linked with a declining level of trust in those who hold personal data including public authorities.

CyberCentric seeks to empower citizens and SMEs to understand and perceive the risks of cybercrime and its threat for themselves and their business processes. Identifying these gaps in citizens' knowledge and how they perceive cybersecurity enables the development of strategies to facilitate awareness and tools for taking preventative actions. With the help of *CyberCentric,* SMEs and citizens receive capabilities to:

- Develop a knowledge base that helps to build an accurate understanding of risks, threats and impacts of cybercrime on their daily business processes
- Explore the conflicts and contradictions in maintaining the balance between privacy and security, its applicability to cybercrime, its relevance to businesses and its impact on policy and data protection guidelines
- Inform citizens about the most critical vulnerabilities and privacy issues and adapt this information to a number of different groups (e.g. young people, elderly, those lacking technical knowledge, etc.)

[9] http://ec.europa.eu/COMMFrontOffice/PublicOpinion/index.cfm/Survey/getSurveyDetail/instruments/SPECIAL/surveyKy/2019

- Identify the role and rationale behind the current security behaviours of citizens and the opportunities these behaviours create for criminals and in consequence to develop techniques to raise awareness and incentivise the implementation of better, more effective preventative actions taking into account the failures and gaps in existing awareness-raising campaigns

12.6 Conclusion

CyberCentric addresses the rising threat of cyberattacks for citizens and business, putting a special emphasis on small- and medium-sized enterprises that often lack the knowledge or resources to harness large-scale cyber defences. The objectives of the game are to raise awareness of cyberthreats as well as to improve cyber-related knowledge on how to prevent and mitigate against such attacks. Instead of promoting large-scale investments, which may be unrealistic for citizens and SMEs, the focus lays on often simple, but effective means from employee training to the creation of data management policies. The current scenarios focus on five prominent threats, although the modular design of *CyberCentric* makes it easy to develop additional scenarios as new threats emerge or to modify existing scenarios to reflect technological or legal changes. The game has been translated into Croatian, demonstrating that the concept and content is transferable across national boundaries and communities. Overall, experiences from end users suggest that *CyberCentric* offers a meaningful approach to enhance cyber resilience for citizens and businesses. It can serve as a positive example for law enforcement agencies aiming to engage with the public and local businesses on how to better prevent modern forms of crime.

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CHAPTER 13

AEsOP: Applied Engagement for Community Participation

Paul Hancock, Helen Gibson, and Babak Akhgar

13.1 The Premise of AEsOP

There has been a renewed interest in placing citizens at the heart of resolving local safety and security issues rather than leaving them until they require direct police intervention. This is being addressed by the police through community policing (CP) strategies (Cordner, 2014). Several definitions of CP, its purpose and scope exist, but the below is a common perspective on the concept:

> Community policing is the delivery of police services through a customer-focused approach, utilising partnerships to maximise community resources in a problem-solving format to prevent crime, reduce the fear of crime, apprehend those involved in criminal activity, and improve a community's quality of life. (Morash & Ford, 2002)

Traditional CP approaches range from increasing police visibility to improving lines of communication between police and communities, building partnerships with other organisations and – most importantly – encouraging

P. Hancock (✉) · H. Gibson · B. Akhgar
CENTRIC, Sheffield Hallam University, Sheffield, UK
e-mail: ph5218@exchange.shu.ac.uk

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communities to 'help themselves' to prevent crime by providing advice, raising awareness and forming neighbourhood watch groups (Watson, Stone, & DeLuca, 1998). But many of these strategies are no longer practical given the growing strain on policing resources and the diversification of communities.

Work conducted as part of the Unity project[1] has indicated that the availability of technology itself does not necessarily drive engagement (Brewster, Gibson, & Gunning, 2018). However, existing research has identified many potential benefits of serious games across application domains (see, for instance, Chaps. 10, 11, 12, and 13) as well as possible improvements in encouraging civic participation by employing gamification approaches (Devisch, Poplin, & Sofronie, 2016). Due to the popularisation and near ubiquity of information and communication technologies (ICTs) and here particularly smartphones and tablets, serious games provide a vector – if not a direct solution – through which initiatives can instil a culture of proactive engagement with their intended audiences. Thus, developing serious games that can be consumed in a mobile format provides an opportunity to reach a wide audience in a highly accessible way.

The intention of *AEsOP* (Applied Engagement for Community Participation) was to put forward the case for creating a serious game as a tool to assist in overcoming factors that have traditionally served to block engagement between police, individual citizens and wider communities.

13.2 Background to Community Policing

At its core, CP is a strategy that seeks to establish and improve the relationships that exist between citizens, communities and the police in order to reduce crime and disorder (Cordner, 2014). In its modern form, community policing aims to empower communities by targeting the need to improve the relationship and level of engagement that citizens and police have with each other. It offers the police an alternative to traditional, often reactive, forms of law enforcement – a proactive philosophy that is more responsive to the wants and needs of the community.

It has been posited that CP can bring several potential benefits. These include improved relations between the police and public, increased job

[1] Project funded under the EU Horizon 2020 Research and Innovation programme, grant agreement no. 653729 (May 2015-April 2018); for more information see www.unity-project.eu

satisfaction for police officers, community mobilisation, an overall reduction in crime and a reduction in fear of crime (Segrave & Ratcliffe, 2004). Community policing represents a style of policing that, on the surface at least, appears to be desirable to members of the public. It places the community at its core and emphasises its receptivity to public needs, promotes genuine problem-solving and endeavours to empower communities to help themselves (Lloyd & Foster, 2009).

The challenge of working with communities that are considered to be disadvantaged or marginalised requires organisational and cultural changes to foster engagement with the public and ultimately empower communities to participate in efforts to tackle local crime-related problems (Cameron & Laycock, 2002). At the same time, CP is not a 'one-size-fits-all' model or template that can be cut and pasted to solve all of society's ills. Also, police officers are often ill-equipped to overcome the unwillingness of communities to work with them and to foster the working relationships, which are so fundamental to the success of the approach (Sarre, 1997).

A strategy for overcoming such difficulties may lie in changing the orientation of community policing to empower communities by assigning greater responsibility to citizens, aiming to make them more accountable and to give them greater agency to address problems in their respective neighbourhoods (Sherman, 1998). Historically, however, this has proven a challenge for police forces and an area in which they have faced criticism leading to the perception that the police have a fundamental unwillingness, or in some cases, a lack of skill or knowledge in working with diverse communities (Bain, Robinson, & Conser, 2014). It is through community policing schemes that the police have aimed to close this gap.

13.3 From Unity to AEsOP

Unity was an EU-funded project under the Horizon 2020 program (running from May 2015 to April 2018) that aimed to better understand the relationship between police and their communities realised through a range of ICT solutions. The empirical work conducted as part of the Unity project (which *AEsOP* formed part of) established that despite varying definitions of CP across Europe, there remain several common themes (Bayerl, van der Giessen, & Jacobs, 2016). The consolidation of these themes grew into six core principles (referred to as 'pillars') of CP, illustrated in Fig. 13.1. Within these principles, trust emerged as a vital

Fig. 13.1 The six pillars of community policing. (Redrawn from Vickers et al., 2018)

prerequisite for citizen participation and engagement with the police: Without trust, there is no communication, no information sharing, no collaboration and no accountability – the following four pillars of CP. Finally, without these underpinning pillars, it becomes nearly impossible to create a sense of security within communities and ultimately to prevent crime – the final pillar of CP. In *AEsOP*, these six pillars were key concepts guiding the game's development.

Within the Unity project itself, the concept of CP was conceptualised using realisations and scenarios from multiple European perspectives. Throughout the project's engagement with citizens and police forces, a clear need emerged to bridge the gap between the direct facilitation of CP enabled through the project's mobile communication tools and the need for a softer approach, whereby police could develop a better understanding of communities and communities a better understanding of the aims and outputs of a community-based approach to policing. It is this gap that *AEsOP* attempts to bridge.

13.4 Applied Engagement for Community Participation (AEsOP)

AEsOP was created to examine whether gamification – and games in general – could serve as a way to engage with local audiences about crime issues within their communities. The game is premised on a simple format that borrows from the visual novel and, to a lesser extent, adventure game genres. The ultimate objective of the game is to leave the player with:

- A basic understanding of the concept of community policing, its core principles, its aims and its overarching objectives
- An appreciation of the role and inputs of a diverse set of stakeholders and actors implicated in CP, including police and different community groups, and the roles they are able to facilitate within the community

In order to achieve this, *AEsOP* presents players with five scenarios, each based around a different problem that could be resolved or improved through the application of CP. The game implements several branching narratives (similar to a decision tree), giving the player a degree of choice in how each story progresses. Using these narratives, the player is guided through each story using character-based dialogues (see Fig. 13.2, right). As the stories play out, the player is presented with contextual choices that allow them to take different actions, each of which work towards addressing the challenges they encounter (see Fig. 13.2, left). Some choices permanently impact the direction of the story, whereas others return to a central hub where the other options can be explored, rewarding the player's curiosity to engage with a range of local community stakeholders.

The game adopts rich hand-drawn illustrations in a cartoon style as a means to enhance accessibility and engage diverse groups, including those that are often seen as under-represented, marginalised and socially or

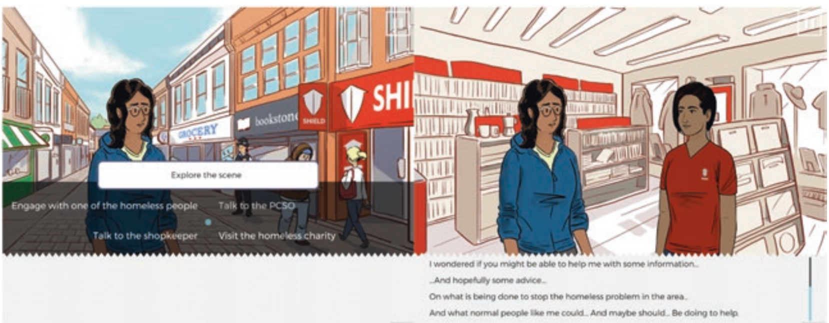

Fig. 13.2 Action choices (left) and character dialogues (right)

Fig. 13.3 Selected screenshot of AEsOP scenarios

digitally excluded. A number of screenshots from the game's scenarios are presented in Fig. 13.3. *AEsOP* leans on interaction mechanics that require no prior knowledge of or familiarity with established videogame principles and contains no fail states. *AEsOP* is designed to leave audiences with a basic awareness about the principles associated with CP and the potential roles of citizens, community groups and police in order to foster local collaboration and engagement.

13.4.1 Community Policing Scenarios

At the outset, twelve potential scenarios were identified through the Unity project and a wider analysis of the CP literature and real-world case studies, as being candidates for implementation within the game. For the game, five scenarios were implemented:

1. Modern slavery based around forced labour in a hand carwash
2. Domestic abuse focusing on intimate partner violence
3. Illegal parking and speeding outside a school
4. Begging and vagrancy
5. Antisocial behaviour and street drinking

These were selected deliberately as they represent a diverse range of issues from high-priority serious and organised crime threats such as modern slavery through to pettier, but visible issues such as illegal parking and speeding outside schools. Additional scenarios considered, but not implemented at this time, are based around acquisitive crime, drug use, mental health concerns, immigration and social tensions, the traveller community, rural crime and antisocial behaviour. A key point to note at this stage is that, whilst Unity was a project considering European-wide community policing approaches, the *AEsOP* game as a proof of concept focuses on UK-centric scenarios and issues.

13.4.2 Game Development and Mechanics

In the design and inception phases, it was decided that the game should be engaging for players with a low access barrier to encourage participation from as wide a spectrum of end users as possible (including those of different genders, national backgrounds, socio-economic backgrounds and age groups). This means that the interface needed to be as simple and intuitive as possible whilst allowing the game to be accessed through several channels (browser, iOS and Android applications).

During the development, specific care was taken to ensure equal representation of different groups and communities in the game, with additional considerations made to ensure that specific demographics are not placed in stereotypical or misrepresentative roles such as women playing the role of victims, white males as 'saviours' or ethnic minorities as criminals.

The game was further explicitly designed to be expandable so that additional scenarios can easily be added, allowing the game to evolve and represent new and pervasive community issues over time. As the tools to create scenarios are kept simple, the effort in developing and scripting additional scenarios requires little technical knowledge, allowing them to be added to the game with relative ease.

As an entry point to the game, players are presented with a short interactive tutorial introducing the core concepts and interaction mechanics. During the tutorial, players are encouraged to adjust the game settings such as the speed in which the text appears on the screen. Users can thus easily choose a setting that suits their reading speed, also accommodating players with disabilities, lower reading skills or less familiarity with the English language. Once a scenario begins, the only interaction required from users is to make choices when prompted. This is achieved by clicking a mouse or tapping touchscreen buttons on the device screen to make dialogue choices and make decisions which will effect the direction of the stories contained within each scenario.

13.4.3 Underlying Architecture

AEsOP was developed using a simple architecture that combined the games development platform Unity3D[2] with the scripting tool Ink.[3] Ink is a simple scripting language designed to support fast creation of the gameplay in each scenario. Using Ink to develop the scenarios required no previous technical knowledge and the scripts themselves contain all of the dialogue, decision questions and their consequences (including where to branch the story to and what effect each decision has on the six pillar scores explained below). The script format was customised to allow the background and foreground images to be set and simple animations for foreground characters to be authored for aspects such as changing facial expressions. Whilst Ink provided a simple and easy-to-use means of managing the game's scripting, Unity3D offered a robust and commercially tested game engine to run the game with built-in tools that allowed it to be optimised and easily compiled for release across a broad spectrum of user devices.

AEsOP is linked to an underlying database that captures and maintains a record of the decisions made by each player during their time with the game including anonymised demographic information submitted voluntarily by players during sign-up. As *AEsOP* is designed as both a standalone game and one which could be played as part of a facilitated focus session, users' data can also be linked to a specific session thus allowing the facilitator to explore the decisions – without individual user attribution – made by a given group in real time. This encourages open discussions and feedback on player choices and the impact they have. Such information could also be used as part of working sessions with community groups, in schools and other events to engage citizens with local issues and explore ways for them to more actively contribute within their local communities.

[2] https://unity.com/
[3] https://www.inklestudios.com/ink/

13.4.4 Gameplay

As the user enters the game, they are presented with a map screen from which to select a scenario. The map screen represents a fictional town (see Fig. 13.4), on which each location is linked to one of the scenarios. The locations are designed to visualise the setting of each scenario and act as buttons, which can be pressed to begin the underlying scenario. After each scenario the player returns to the map screen and can then enter a new scenario.

Upon entering a scenario, the player is presented with a short paragraph of background text to set the scene and to provide context and exposition to the story (see Fig. 13.5, top left). In some scenarios the issue is made clear in the introduction, whereas in others it is slowly revealed to the player based on their dialogue choices and the community actors with which the player decides to engage with. Whilst playing a given scenario, the player sees dialogue text between the characters on-screen (see Fig. 13.5, top right). The player follows along with the scenario text,

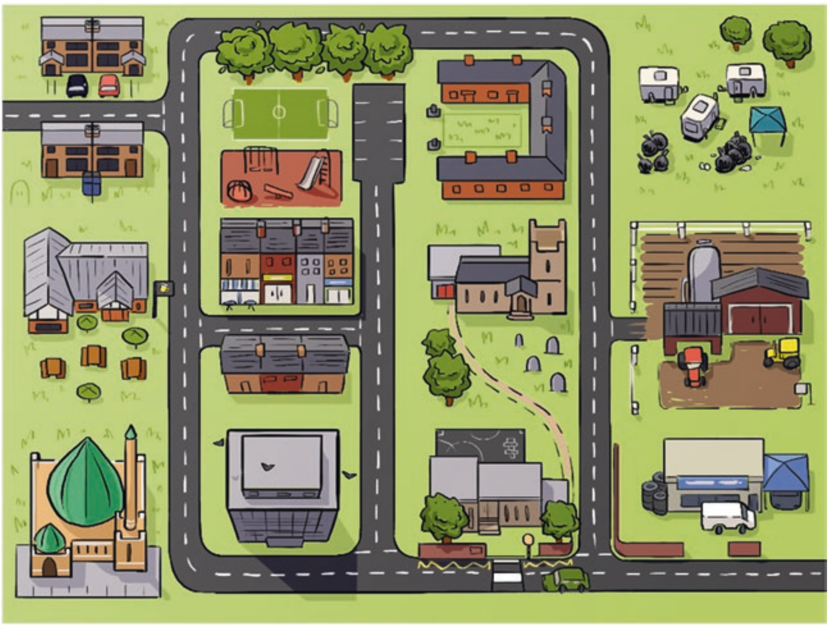

Fig. 13.4 Scenario selection map

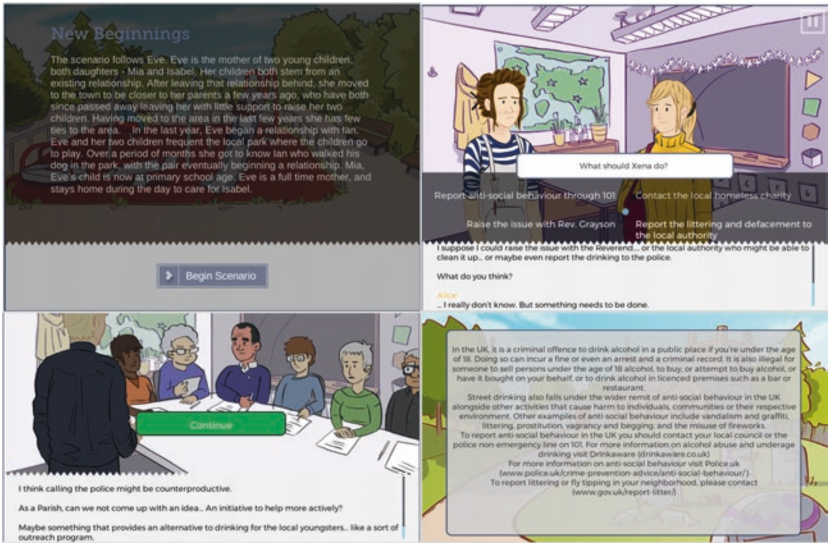

Fig. 13.5 Top left, the scenario entry text; top right, a decision point within the game; bottom left, a community-based outcome from a chosen decision; bottom right, scenario end-text providing further information

which includes both descriptive content and dialogue between the characters. As the dialogue concludes the player is faced with a question about the decision to take next (see Fig. 13.5, bottom left). These decisions often involve the player asking questions to other characters in the game, the opportunity for actions to resolve issues (such as contact police or community stakeholders) or the possibility to speak with additional actors in each scenario to uncover more information about the situation they are faced with. As the player moves through the scenario, they collect 'pillar points' (see next section). When the scenario draws to a conclusion, the player is presented with further information about support services or the implications of the particular crime type they have faced (see Fig. 13.5, bottom right), often encouraging them to seek out further information or directing them to advice on appropriate courses of action should they come across a similar situation in real life.

13.4.5 Role of the Six Pillars

When players are asked to make decisions during the course of the game, they are awarded a score against each of the six pillars of community policing. Each decision a player makes is linked to the six pillars of community policing with a player receiving pillar points depending on the action they chose. For example, if the player chooses to call the police to report concerns about potential domestic abuse of a neighbour, their ‘accountability’ score will increase, whereas electing to speak with additional community stakeholders may increase their ‘communication’ score. There is also a screen which shows the player the average score they have achieved for each of the six pillars across all scenarios they have completed. Rather than a ‘win’ or ‘lose’ state, the scoring mechanic is thus designed to provoke reflection, encouraging the player to question the impact of their actions on the people they are speaking to, the issue at hand and the wider communities around them.

If the player chooses to replay a scenario that they have previously completed, they are shown the results of the scores for each of the six pillars they achieved the previous time they played the scenario, before it begins again. This is to encourage the player to think more about the actions they have taken and alternative means of resolving issues which may be linked to other pillars. Whilst the overall final scores may be of interest to researchers, and ultimately the police, it is the reasoning behind each decision that is paramount. The player can access their current pillar scores through the settings menu (see Fig. 13.6) on the main page and are presented with their most recent scores if they choose to replay a scenario, as discussed above.

Figure 13.7 (left) shows an encounter between two women as part of a domestic violence scenario. One of the women notices that the other has bruises on her arm and is given the choice either to ask about the issue or let it pass. Throughout each of the game’s scenarios, certain dialogue choices are rewarded with points against each of the six pillars. For instance, if the player chooses to ask Eve (the second character’s name), they receive pillar points across each of the pillars (see Fig. 13.7, right). The way the points are awarded is contextual to the situation and scenario, but generally rewards inquisitive behaviour or behaviour that is designed to diffuse tensions or solve complex problems.

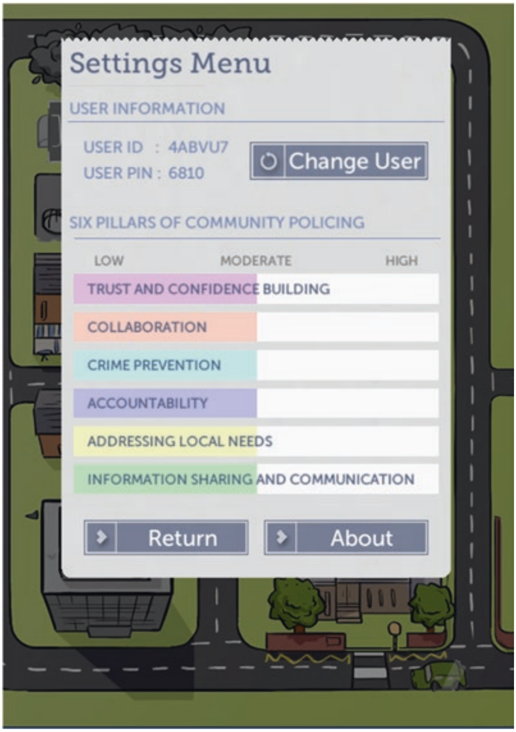

Fig. 13.6 Example for pillar scores

Fig. 13.7 An initial decision (left); impact on the pillar scores based on the chosen option (right)

13.4.6 Harnessing Demographic Information

When users first play the game, they are initially asked to anonymously fill in a short survey containing a number of questions related to demographics such as age range, religion and cultural identifiers. This information is then aggregated to discern whether there may be trends in the way specific demographics engage (or do not engage) with issues and different groups in their community such as police. During facilitated workshop sessions this can be used to prompt discussions around reasons for certain trends such as a reluctance to engage with authority figures.

Upon completing the survey, users are given a user ID and PIN number, providing a save state that allows them to continue from where they left off if they return to the game at a future date or using a different device or browser. Due to the game storing a minimal amount of data in save files, users can play a number of scenarios (e.g. during a focus group) and then easily continue playing by signing in at a later date without the need for any significant additional downloads to restore their progress. Users can also switch devices as many times as they like and continue playing using the same user account.

By recording demographic information for each user, the decisions that are made can be analysed to understand whether there are any significant differences between groups. This can be achieved in two ways: either by looking at the six pillar scores that different users achieved for a particular scenario or by looking at the users' responses to a particular question or group of questions. Looking at the six pillar scores gives a broad picture of how users responded to questions. In contrast, by looking at responses to specific questions, it is possible to be more explicit about why a specific (anonymous) user or user group achieved a comparatively low or high score for one of the pillars. For instance, considering the domestic abuse scenario, it is possible to analyse how users responded when asked whether to report a neighbour with bruising and investigate whether any group(s) is/are more or less likely to contact the police in such a situation.

13.5 Deployment and Analysis of the Game

Next to awareness raising for community policing issues, the purpose of creating the game was to determine whether there are any differences between how various demographic groups interact with the police in the context of community policing. The functionalities described above have practical value in this regard – not only for providing research possibility into disparate reactions to community policing challenges across groups – but also as a feedback mechanism and as a potential awareness raising and teaching tool. This can be achieved, for instance, by providing the game during focus group meetings with different demographics or citizen groups and then analysing whether there are any significant differences in responses to the hypothetical questions during each of the game scenarios.

In order to facilitate such analyses, the game communicates with a central server sending every decision a user makes for all scenarios they play. Once a scenario is complete, the score the user achieves for each of the six pillars for this scenario is also sent to the server. Due to the demographic data collected at the beginning, decisions can be analysed and compared across different communities to support the implementation of customised engagement measures depending on the choices they made. Further analysis can be conducted to investigate whether there are certain scenarios or questions where engagement is more or less common than in others. Findings can help identify sensitive aspects or factors that lead to lower engagement with police forces. This allows the development of awareness raising for these aspects or targeted trainings for communities as well as police officers.

13.6 Conclusion and Future Work

There are several opportunities in *AEsOP* to take the current design further. Firstly, the game itself has not yet been tested and evaluated within a local community setting. Such an evaluation would enable designers and practitioners to better understand whether such games achieve their objectives and whether they can provide sufficient information for police and community leaders (cp. Chap. 10).

AEsOP was developed to bridge a gap between police, citizens and communities to better understand how community policing approaches could improve local community environments. As such *AEsOP* can be seen as a pilot game to understand whether this serious game format is an effective engagement tool for local communities and can motivate greater civic participation in the long run. In the best case, *AEsOP* can act as a starting point or trigger to initiate a discussion within communities about how they can better help themselves and more proactively engage with the police in a way that is mutually beneficial to both sides.

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