EMPOWERING MEDICAL PERSONNEL TO CHALLENGE THROUGH SIMULATION-BASED TRAINING

by

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A thesis submitted to
The University of Birmingham
For the degree of
DOCTOR OF PHILOSOPHY (Ph.D.)

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Submitted November 2016 – Revised August 2017

Abstract

The rigid structure of medical hierarchies within UK hospitals can become the source of dissatisfaction and conflict for medical personnel, the repercussions of which can be disastrous for patients and staff. The research reported herein presents the results of an investigation into the use of Virtual Reality (VR) simulation and conventional story-boarded techniques to empower medical personnel to challenge decisions they feel are inappropriate. Prototype applications were crafted from a selection of transcribed 'challenge events' acquired from an opportunistic sample of clinical staff. Data obtained from an initial investigation were used to establish attitudes toward challenging and evaluate the findings of the literature to generate research questions and objectives. Medical personnel who engaged with both media as part of an experimental phase assessed their viability as potential training resources to help foster the ability to challenge. Analysis of this experiment suggested that both techniques are viable tools in the delivery of decision-making training and could potentially deliver impact into other applications within healthcare. To increase the realism of the training material, the technologies should be presented in a format appropriate for those with limited 'gaming' experience and allow a credible level of interaction with the environment and characters. Challenging decisions was found to be essential to safety, and experience in challenging was widely associated with experience. Consultants represented the least confident profession to challenge and the most frequently referenced grade involved with conflict in challenge scenarios.

Figure 0.1 on the next page shows the structure of this thesis and the content of each chapter.

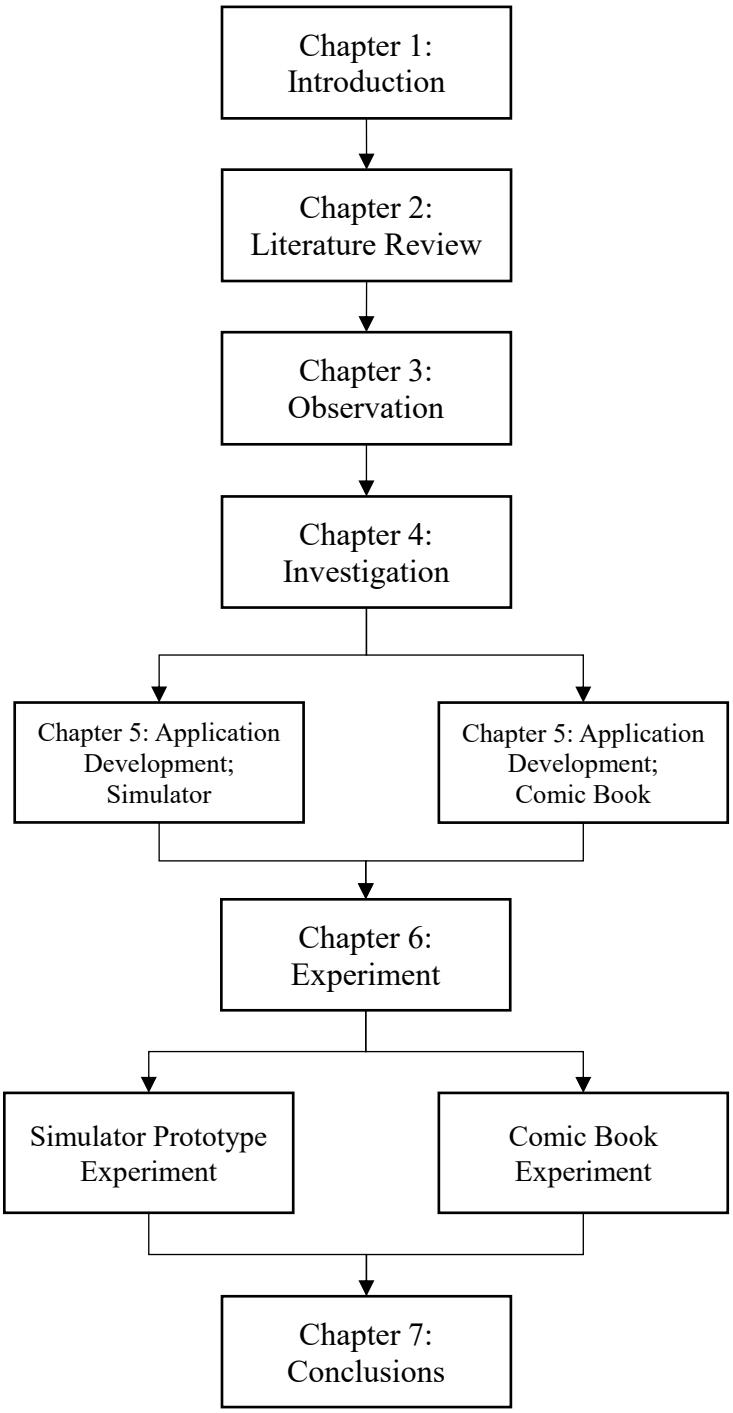

Figure 0.1 - A Flow Chart of the Content of Each Chapter

Acknowledgements

Professor Robert J. Stone – Dr. Neil Cooke
I would like to express my utmost gratitude towards my co-supervisors for assisting me throughout my time in Birmingham. Both of your support has helped me get through difficult times and overcome personal and professional barriers. I am forever grateful for your patience in getting me through the PhD programme. Thank you.

The HIT Team: Vishant Shingari, Christopher Bibb, Yuqing Gao, Mohammadhossein Moghimi, Laura Nice, Cheng Qian, Robert Guest and all the past, present and future members
A big thank you to everyone in 309 for all your unconditional support and friendship. I wish you all the very best in the future.

Mary Winkles – Samantha McCauley
Thank you for all your kindness and support throughout the PhD programme.

Dr. Charlotte Small – Professor Julian Bion – Dr. Katherine Laver – Dr. Bob Tipping
I am very appreciative for all your support in helping jump start my project and allowing me to conduct research at the Queen Elizabeth Hospital. Thank you to Charlotte and Katherine for providing me with various documentation and assisting with participant recruitment, and to Dr. Tipping for assisting in the development of the VR simulator scenario.

QEHB Clinical Skills Suite – Dr. Pete Isherwood – Urszula Jesson-Ward – Miss Grace Wright
I would like to express my gratitude towards the CSS staff at the QEHB for their help in allowing me to conduct my simulation experiments in their lecture room as well as assisting with participant recruitment. You have all been incredibly supportive in my project, assisting with handling the vouchers for prize winners and assisting with participant recruitment.

Hollier Simulation Centre Staff – Jon Stewart – Winmar Kyi - Charlotte
Thank you to all the staff at the Centre for letting me observe your simulation training days, providing recorded footage for my research and helping develop my questionnaire content.

Amy "Yee" Morgan
I am very appreciative for the effort you have put into the development of the comic book version of the scenario.

Family and Friends
Most of all, a big thank you to all my family and close friends for supporting me, helping me get through these past four years and helping me persevere and overcome many obstacles.

List of Abbreviations

2D	Two-Dimensional
3D	Three-Dimensional
AAR	After Action Review
AHP	Allied Health Professional
ALS	Advanced Life Support
CPR	Cardiopulmonary Resuscitation
CT	Core Trainee
CSW	Clinical Support Worker
DNR	Do Not Resuscitate
ECG	Electro-Cardiogram
FR	Francis Report
FY	Foundation Year
GIB	Gastrointestinal Bleed
HOF	Head of Faculty
HF	Human Factors
HMD	Head Mounted Display
HSC	Hollier Simulation Centre
ICU	Intensive Care Unit
JW	Jehovah's Witness
NHS	National Health Service
PE	Pulmonary Embolism
SA	Situational Awareness
SAGAT	Situation Awareness Global Assessment Technique
SD	Standard Deviation
SP	Simulated Patient
ST	Speciality Trainee
SpR	Specialist Registrar
QEHB	Queen Elizabeth Hospital Birmingham
USB	Universal Serial Bus
VR	Virtual Reality

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Chapter 1 Introduction

In UK hospitals, a patient ward round will typically occur each morning (C. Morrison *et al.*, 2008), assuming no other emergency event is under way that demands the involvement of key medical staff. The purpose of this event is to visit every patient on the ward, review their progress and outline an appropriate course of treatment (Carroll *et al.*, 2008). Each patient is visited by a medical team comprising various disciplines, including a consultant, registrar, bed nurse, senior nurse, pharmacist, and others if required. In addition, medical students with varying levels of experience may also be in attendance. Briefings involving all ward round team members take place before and after the event, with the aim of informing staff of the patients present on the ward, along with each patient's medical status or condition, history, current treatment and any relevant diagnoses (Stanley, 1998). According to Stanley, the nature of a post-ward round meeting can vary considerably, and may consist of a debrief involving a lengthy discussion of one or more specific patients or, as with the case for a typical pre-ward round meeting, providing an overview of the patients but to a wider range of disciplines, such as social workers. The ward round, pre-round and post-round meetings are also viewed as providing important training and education opportunities for undergraduate, medical, nursing and paramedic staff (Stanley *op cit*., Montague *et al.*, 2004).

Research literature has shown that medical environments, such as the Intensive Care Unit (ICU), are hierarchical (Calhoun *et al.*, 2013; 2014), in that clinical decisions made for patients

are predominantly issued from senior staff, to be then followed through by subordinates under their guidance (Kälvemark *et al.*, 2004). However, with respect to each individual patient review on the round, these events can sometimes be the source of disagreement or confrontation. Hierarchical conflicts resulting from issues of seniority, either due to disagreements on treatment, opinions or interests, can negatively impact most, if not all, individuals involved (Saltman *et al.,* 2006; Greer *et al.,* 2012). This is especially so when the conflict takes the form of a challenge from subordinates to an individual of a more senior position. Even when severe consequences to the patient are likely, the difficulty of questioning a more senior figure can form an emotional barrier that can reduce the likelihood of, or prevent entirely, a challenge from being issued (Kobayashi *et al.,* 2006; Pian-Smith *et al.,* 2009; Calhoun *et al.,* 2013; Srivastava, 2013). Calhoun *et al.* (2013) states regarding seniority: "Even where harm to others is a possibility, numerous psychological factors converge to create a strong bias toward remaining quiet". Hierarchical conflict is not only limited to UK hospitals but is also prevalent in other countries, including Denmark (Holm, 1995), Germany (Jurkat *et al.*, 2006), the United States (Srivastava, 2013), Sweden (Kälvemark *et al.*, 2004) and China (Zhang, 2014). Zhang describes a cultural difference between the medical hierarchy in China and other countries. She states: "The ranking title is deemed to be more valuable in China, because it not only is linked with the physicians' basic salary, but also is the symbol of prestige and reputation".

Training to help deal sensitively with negative influences, responses or outcomes can provide trainees with the knowledge and ability to issue challenges confidently (Sanderson, 2013). As

Leonard *et al.*, (2004) states: “Teaching people how to speak up and creating the dynamic where they will express their concerns is a key factor in safety”. In addition, Calhoun and colleagues’ studies, addressing hierarchical conflict, mentioned above, demonstrated that assertiveness can save patient lives. They conducted a series of simulated scenarios in which a confederate takes charge of a team of paediatric ICU clinicians and deliberately issues an incorrect order of treatment for a deteriorating patient. The confederate was instructed to acquiesce upon receiving subsequent challenges from the participants after attempting to initially justify their decision. Out of three sessions conducted, two teams of participants successfully challenged the inappropriate order. The remaining team failed to issue a challenge, and their simulated patient (SP) had died. Therefore, failing to assert, especially in a time of medical crisis, could, it was claimed, result in patient death.

Whether as part of their undergraduate education or as a component of continued professional development training opportunities, studies have shown that is it beneficial for medical staff to develop their abilities to be assertive (Deltsidou, 2008; Seren & Ustun, 2008; Sanderson, 2013). As highlighted briefly by Calhoun, psychological barriers can form as a conflict situation becomes exacerbated and this can impair a clinical staff member’s ability to judge the situation accurately as it develops and, therefore, take appropriate action. This, effectively, increases the difficulty of resolving a conflict. Conflict resolution is considered as one of the core components of effective communication, a skill that is "fundamental to medical practice" (Haq *et al.,* 2004). Therefore, relevant training in this area could be a crucial factor to overcoming

barriers and, ultimately, improving healthcare processes. Training in this particular area is now common within the medical sector, including professional development 'workshops' focusing on conflict resolution management, and such workshops have shown to be beneficial. Zweibel *et al.* (2008) conducted qualitative research both before and after a conflict resolution workshop that was delivered to anaesthesiology and surgical students. Drawing from various articles encompassing conflict resolution, the workshop focused on identifying sources of conflict, management styles and applying communication skills to resolve a conflict. They concluded that the short professional development course in conflict management had affected the participants' ability to assert. The session had empowered the participants to apply the principles and skills learned from the course to their own medical practice, and reported that these skills were used over a year following their workshop attendance. The skills acquired included awareness to conflict management styles (such as identifying and responding to habitual behaviours that could interfere with the situation), analysing the conflict rather than responding defensively or emotionally, and utilising effective communication skills (which can involve simply listening rather than responding) to reduce tension.

Issues with conflict do not always arise from disagreements with senior personnel. Manojlovich, & DeCicco (2007) conducted a study on communication and error occurrence between nurses and physicians. Their findings suggested that optimal communication between the nurse and physician can decrease the chance of medication error. Therefore, effective teamwork is required to maintain patient safety, as was also evidenced by Baker *et al.* (2003). Baker *et al.*

evaluated research concerning the relationship between teamwork and medical error. Utilising effective training methods such as 'cross-training,' the purpose of which is to evaluate coordination, communication and team performance, had previously demonstrated positive results in medical teams. The results include anticipating the needs of colleagues and, more importantly, committing fewer errors. They state: "These advantages are germane to training medical teams to perform in a manner that ensures patient safety". Despite this, and according to Ramsay (2001), conflict can develop within medical teams of various professions and non-medical personnel, such as "between physicians, between physicians and staff, and between the staff or the health care team and the patient or patient's family."

In general, an unresolved conflict or situation left 'unchallenged' can compromise patient safety (Srivastava, 2013). In a review of literature related to team conflict, Greer *et al.* (2012) identified three main types of conflict within a team: task, relationship and process. Task conflict refers to a disagreement of how to approach a task; relationship conflict refers to personal issues outside of a task; and process refers to task logistics such as the delegation of responsibilities. Greer *et al.* discovered that each type of conflict elicits negative responses, and effective conflict resolution training is essential to overcome them.

Despite the difficulties faced with hierarchical or team conflict, successfully demonstrating assertiveness can alleviate negative outcomes, sometimes helping to avoid them altogether. This was evident in Calhoun and colleagues' investigations into using simulation to address

hierarchical conflict, where failing to assert may result in patient death. However, the element of simulating patient death in their investigation was controversial. Various sources investigated the necessity of SP death with varying results (DeMaria *et al.,* 2010; Bruppacher *et al.*, 2011; Rogers *et al.,* 2011; Fraser *et al.*, 2014). For example, DeMaria *et al.* conducted an investigation that utilised SP death as a method to enhance the performance of year one and two medical students' advanced cardiac life support skills. During the training workshops, emotional stressors were introduced by actors (playing the role of distressed family members) taking part in the simulated scenarios. An example of a stressor was a scripted event that involved an actor (family member; son) entering the environment as the SP slipped unconscious. As the participant issued instructions to their team in response, the actor aggressively shook the SP in distress. In this instance, the patient had died, requiring the participant to pronounce the death and inform the family member. The results of this study demonstrated a significant level of anxiety (increased heart-rates, high anxiety scores) among those within the "emotional content" group when compared to the stressor-free control group. However, despite this, the emotional content group's overall performance was rated greater than the control group. Calhoun *et al.* (2013) stated that unexpected patient death is an unfortunate reality in the practice of medicine and should not be shielded from learners. This view is also shared by DeMaria *et al.*, who believe that future research in simulated training settings should involve the use of emotional stressors, with patient death very much a possibility, to enhance the experience and maintain realism. Furthermore, according to Bruppacher *et al.*, (2011), SP death can be a useful teaching tool, if the well-being of learners

is taken into consideration and that they are protected by "sound ethical principles."

The ability to assert, communicate effectively, express appropriate leadership and work well within a team are examples of 'non-technical skills' (Yule *et al.*, 2006), a term used regularly within healthcare training contexts to describe competency in other areas not directly related to specific skill-based tasks or domain technical expertise (Reader *et al.*, 2006). In a literature review of studies regarding the non-technical skills required in the medical domain conducted by Yule *et al.*, each of the non-technical skills were identified. The non-technical skills are also frequently discussed within Human Factors (HF) research. In very general terms, HF, or sometimes referred to as ergonomics (Holden *et al.*, 2013), is a term used to describe the study of the interaction between humans and their working environment (e.g. Stedmon & Stone, 2001; Stone, 2008) and the optimisation of this relationship (Brust-Renck *et al.*, 2013). Indeed, the purpose of HF is to improve well-being and performance by better understanding the human and environment relationship and further integrating the "human" into the system (Dul *et al.*, 2012). This can be achieved with a recursive analysis into the design, planning and evaluation of a system - a process not entirely achievable sequentially, as analyses and assessments at a stage of the development process can affect those before and after it (Dul, *et al.*, *op cit.*). Some examples of "important ergonomics issues", as described by Fujita & Mori (2008), are friendly working environments that are safe, healthy, with comfortable mobility and good social communications.

HF is an evolving concept also valued in the healthcare environment (Holden *et al.*, 2013; Carayon *et al.*, 2014), and is an approach described as essential to maintain patient safety. Timmons *et al.* (2015) conducted a qualitative, longitudinal study with a group of multi-professional NHS staff from both emergency departments and operating theatres. Each participant received HF training in the form of a short course, and the purpose of the study was to evaluate whether HF was an acceptable training paradigm and beneficial for healthcare professionals. The results of the study, though met with difficulties concerning implementation, were evaluated as a positive, useful, relevant and acceptable training tool for clinical practice. However, implementing a HF, systematic, approach to varying areas of the healthcare setting was met with some criticism. Mainly, as described by one participant's feedback provided as an example, the participants were unwilling to modify current ways of working to incorporate HF. This was especially so if the changes would inadvertently create additional workload for those already situated in demanding roles.

To increase teamwork and communication performance among medical teams, many authors have conducted research investigating training techniques and courses inspired by *Crew Resource Management* (CRM, e.g. Dunn *et al.*, 2007; Malec *et al.*, 2007; Hänsel *et al.*, 2012). CRM is a training programme originally developed within the aviation industry. Its purpose is to train aircrew to take advantage of all resources available, typically whilst in flight, including people, equipment and information (Salas *et al.*, 2001; Salas *et al.*, 2006). Research conducted between 1979 and 1980, focusing on a series of airline crashes (Cooper *et al.*, 1980; Dunn *et*

al., 2007) revealed that teamwork and communication failures were responsible for the clear majority (70%) of incidents investigated. For example, as highlighted by Jedick (2014) and Griffith *et al.*, (2015), a commercial aircraft carrying 181 passengers in 1978 suffered from a landing gear malfunction. However, due to the crew's "carelessness and inability to work together effectively", the aircraft exhausted all fuel reserves and crashed-landed in Portland, Oregon (U.S.A.), resulting in the death, or serious injury, of multiple passengers and crew. Furthermore, according to the accident report filed relating to the incident ("Aircraft Accident Report - United Airlines, Inc., McDonnell-Douglas DC-8-61", 1978), a lack of assertiveness from the First Officer (whose "main responsibility is to monitor the captain"), coupled with the captain's apparent inability to accept input from junior crew members (Helmreich *et al.*, 1999), ultimately contributed to the accident.

Thus, CRM was developed as a countermeasure to various threats to airline safety and error (O'Connor, 2002), including fatigue, workload stress, communication issues, ineffective teamwork and a lack of shared awareness (Dunn *et al.*, 2007). Some of the core topics of CRM include teamwork, leadership, situational awareness (SA), decision making, communication, and raising awareness of one's own personal limitations (O'Connor *et al.*, 2008). In a literature review of publications related to CRM training in the aviation industry, O'Connor (2002) and Salas *et al.*, (2001) concluded that the training method was positively received by trainees and resulted in positive changes to workplace attitude. In addition, a recent study conducted by Ford *et al.* (2014) produced positive results via the use of questionnaires administered both

before and after a series of CRM workshops attended by volunteer flight attendants. Their results indicated "significant" improvements in attitudes toward teamwork and communication following a CRM teaching session. They concluded that CRM is an effective and viable method to train flight attendants.

However, both the O'Connor *et al.* and Salas *et al.* studies identified limitations. For example, multiple studies reviewed did not directly clarify the methodology used to assess CRM's reliability and transferability of the results, and it was unclear whether CRM fully addresses what Salas *et al.* described as an "organisation's bottom line", safety. As O'Connor states regarding safety:

"it is not possible to be as certain about the influence of the training on the organisation as a whole. This is because there are few studies that have made a rigorous assessment of the effects of CRM training on organisational metrics such as safety or productivity."

Despite the supposed limitations highlighted above, CRM has influenced publications, guidelines and training courses in other areas not directly related to commercial aviation. For example, it is exploited in other studies related to the fire service (Griffith *et al.*, 2015), U.S. Air Force (Jacobson *et al.*, 2013), to the training of junior U.S. naval officers (Röttger *et al.*, 2015) and in the offshore oil industry (Flin, 1995), all of which produced positive results but also generated similar limitations to those put forward by O'Connor *et al.* and Salas *et al.*

Studies that evaluate the principles of CRM, such as leadership, SA and error management, in a healthcare context is not uncommon. In addition to the examples mentioned above, related research projects conducted by Sexton *et al.* (2000), Pizzi & Goldfarb (2001), Haerkens *et al.* (2012), Verbeek-van Noord *et al.* (2014; 2015) and Kasper & Jentsch (2016), are just some of the many examples of CRM investigation. However, these were found to have produced mixed results. For example, Kasper & Jentsch stated that, whilst CRM is currently in the process of implementation within various medical domains, including cardiology, paediatrics and radiology, "training transfer has not been properly assessed". In the literature, the term "training transfer" generally refers to the process of translating the knowledge and skills acquired in training into the workplace (Cheng & Ho, 2001; Saks & Burke, 2012; Grover, 2015). The process of transfer then occurs with subsequent training over a period whilst on the job (Baldwin & Ford, 1988). Indeed, other studies that set out to evaluate CRM as a technique to enhance effective teamwork in medical settings share similar views to those of Kasper & Jentsch (e.g. Malec *et al.*, 2007; France *et al.*, 2008; Reeves *et al.*, 2013; O'Dea *et al.*, 2014).

Despite the rather mixed view on the effects and outcomes of CRM in medical settings, there appears to be a consensus that its integration within training régimes is beneficial to the healthcare domain and further research that evaluates, or builds on the initial evidence of its efficacy is warranted. Furthermore, recent studies attempting to do just that, are now beginning to show positive results of importance to the healthcare domain (e.g. Haller *et al.*, 2008; Verbeek-van Noord *et al.*, 2015; Chan *et al.*, 2016). For example, Verbeek-van Noord *et al.*

investigated 149 staff members from four emergency departments taking part in a CRM training course. After the training course, a series of observations of the staff members were carried out. Participant numbers for these observations were reduced due to a variety of circumstances (e.g. several members left their position whilst the study was still being carried out), but complete observational data were obtained from 34 persons who completed the training (the 'intervention group') and 31 persons from a control group who did not receive CRM training. The purpose of the observations was to record all demonstrations of what was referred to as 'explicit professional oral communication' (EPOC). Inspired by the principles of CRM, EPOC is a recently-developed tool that measures the use of non-technical skills across six core areas: assertiveness, working with others, task-oriented leadership, people-oriented leadership, SA and planning (Kemper *et al.*, 2013). The observational data revealed that the intervention group's EPOC tally was 25% higher than the control group. The authors of this study believe that a 25% increase in explicit communication is a "clinically relevant difference," concluding that CRM is a "promising tool to instil safety-critical behaviour".

Verbeek-van Noord *et al.* (2015) stated that further research in this area is required to evaluate communication sustainability following the initial training. Indeed, communication is widely described as a primary factor in providing optimal healthcare (Leonard *et al.*, 2004; Renz *et al.*, 2013; Johnston *et al.*, 2015). Hence, studies in this area have utilised SP technologies to train staff in adopting structured communication techniques (Marshall *et al.*, 2009).

1.1 Research Questions

The literature had raised several research questions, which are addressed in later project phases, that relate to some of the issues discussed in this chapter.

1.1.1.1 Research Question 1

Is the ability to challenge clinical decisions an essential skill to develop?

The research so far, in both studies and real-life scenarios, has indicated that challenging leadership or reporting critical incidents, especially so in a time of medical crises, can save patient lives. Furthermore, anecdotal evidence provided by project stakeholders and Subject Matter Experts (SMEs) regarding this topic agree that it is essential to reduce communication error. The aim of this question is to provide further evidence that supports the research conducted thus far.

1.1.1.2 Research Question 2

Is challenging a decision an indicator of situational awareness?

During a simulation scenario that was observed at the HSC, a participant failed to pass on important information to another member of staff over the telephone. She could have challenged her colleague present in the room for not making this information initially available

to her. Based on anecdotal reports from project stakeholders, the ability to challenge or express appropriate leadership is an indicator of high SA.

1.1.1.3 Research Question 3

Is the ability to successfully challenge a decision associated with clinical experience?

Findings from the HSC observational data indicated trainees to be hesitant and less assertive than a more experienced, or senior, member of staff. Sufficient evidence was required to support this, and it was initially predicted that challenge confidence or ability would decline as a person challenged an individual more senior to them.

1.1.1.4 Research Question 4

Can VR-based training simulation aid in developing the ability to challenge clinical decisions?

It is evident that, whilst authors of studies remain critical on the efficacy of VR simulation in medical or surgical contexts, VR technologies can be adopted to good effect. However, even in situations where VR simulation has produced positive results, such as Touch Surgery, the medium is mostly associated with the development of relevant technical skills in the surgical space. This question, therefore, aims to address whether VR can be positively exploited in other applications within healthcare, such as the delivery of non-technical skills-based training.

1.1.1.5 Research Question 5

When is the optimal time of exposure to VR-based training simulation?

Whilst some studies have utilised simulation technologies with already experienced participants, the literature has mainly associated simulation training, both mannequin and VR-based, with being embedded into medical training régimes, and, therefore, targets those less-experienced. Studies reviewed have also demonstrated that simulation may also benefit those looking to refresh their skills (i.e. Touch Surgery) or education programmes as an adjunct to traditional forms of examination. Therefore, this question aims to identify the optimal timing of exposure to maximise any positive effect simulation may provide, and to identify who this

kind of training could benefit most within the medical hierarchy.

1.2 Overall Research Aims and Objectives

The present research set out to assess whether VR-based techniques could become a viable method in the delivery of enhanced decision-making training practices for clinical and nursing personnel in UK hospitals. The initial research into the literature in this area had demonstrated that staff who lack the ability to assert – even when realisation of the situation is acknowledged – can be harmful to, even fatal for, patients in their care, and, therefore, presents an issue that is both an area of considerable social importance and vital in providing optimal healthcare.

In the follow-up to their 2013 publication, Calhoun *et al.* (2014) concluded that simulation is a beneficial method to train staff on the topic of hierarchical error management. However, their methodologies – in both publications – including examples of other research from different authors, exploited traditional methods of simulation training, whereby teams of staff engaged on a role-playing exercise centred around a SP mannequin. Whilst there are examples in the literature that mention, and, indeed, are positive towards the potential of adopting future interactive technology for non-technical skills training, such as Virtual Reality (Cowan *et al.*, 2016), very few have considered the importance of assessing the impact of technology-based training on knowledge and skills transfer to real-world settings. In general, however, research regarding the use of VR-based technologies in a healthcare context, examples of which are

discussed later in this thesis, are primarily targeted at fostering relevant technical skills (Kahol *et al.*, 2008; Calatayud *et al.*, 2010) for specific tasks, such as surgical precision training or the analysis of three-dimensional (3D), patient scans (Bujara *et al.*, 1992; Crochet *et al.*, 2011; Burden *et al.*, 2013; Sugand *et al.*, 2015).

The first objective of the research reported herein was to conduct structured observational activities at a healthcare establishment, the purpose of which was to acquire evidence of hierarchical conflict that might support the issues discussed within Calhoun and colleagues' investigations concerning the topic of challenging incorrect orders (Calhoun *et al.*, 2013; 2014).

The second objective was to conduct further structured observational research at a medical simulation training facility to understand how a simulated scenario is presented and delivered to trainees, and how their performance is evaluated.

The third objective was to conduct a further investigation, again at a healthcare establishment, the purpose of which was twofold. Firstly, to collect both quantitative and qualitative information from a sample of healthcare employees of various positions in the medical hierarchy. These data would then be used to evaluate whether it is important to challenge the decisions, not just by those more senior, but anyone who issues an order to a team. Secondly, to provide a series of examples of scenarios where staff were prompted to challenge a decision made by a co-worker. The purpose of these examples was, in parallel with further research into the process of challenging a decision, to assist in crafting a bespoke, unique, and realistic

scenario based on real events that would be driven by the simulator prototype.

The fourth objective was to produce a simple VR simulator prototype to a specification based on the data received in the earlier investigations, where the information collected would define the method of presentation and the scenario content. This would be achieved, for example, by analysing the challenge scenarios provided by the investigation participants to discover the common role(s) of those who are challenged and why, including identifying who in the hierarchy staff are least confident to challenge and what form each challenge takes.

The fifth objective was to then conduct a clinical trial within a healthcare establishment, involving the invitation of multiple members of staff widely distributed throughout the medical hierarchy to interact with the VR simulator prototype. The purpose of this phase of the research was to evaluate the application's training viability and to obtain feedback on design, presentation and content for future research.

The sixth, and final, objective was to analyse the results of the trial to draw any conclusions from the data collected. Analysis of the simulator data and the collection of participant feedback would be essential to determine the principles for creating future VR-based applications for non-technical skills transfer and for suggesting future research.

1.3 Thesis Structure

The structure of this thesis is as follows and summarised schematically in Figure 0.1.

Chapter 2 presents the results of a literature review of research with relevance to the overall aims of this project, including a further discussion of assertiveness within the medical domain; training simulation techniques, including mannequin and VR technologies; situational awareness (SA) and the investigation of medical errors.

Chapter 3 provides an in-depth overview of observational research that was conducted at a local NHS Foundation Trust and medical training facility as per the requirements of the first and second research objectives defined in section 1.2.

Chapter 4 is a full account of the early investigation conducted at the Queen Elizabeth Hospital in Birmingham (QEHB) as per the requirements of the third research objective. This process was based on recruiting an opportunistic sample of fifty clinical members of staff of varying positions throughout the medical hierarchy to take part in a questionnaire and recorded interview session.

Chapter 5 is a detailed overview of the materials and technologies developed and exploited in subsequent experimental sessions with healthcare personnel as per the requirements of the fourth research objective. As well as the development of an innovative VR simulator, to provide

a more basic but nonetheless highly visual form of training media, this Chapter also describes the development of a paper-based, “comic book” style of training. The Chapter also discusses how the data obtained from the earlier investigations were used to sculpt the presentation and design of the content.

Chapter 6 is an account of the clinical trial conducted at the QEHB as per the requirements of the fifth research objective, where a total of 58 participants spanning across various positions in the medical hierarchy engaged with the simulator and comic book prototypes.

Chapter 7 is the closing section of the research that discusses the findings from the research and conclusions as per the requirements of the sixth, and final, research objective. This chapter also includes a discussion of the limitations with the project, considerations for future design and research and other healthcare applications this research could influence in the future, based on participant feedback.

Chapter 2 Literature Review

2.1 Introduction

The adoption of Virtual Reality (VR) technologies as a method to help develop the ability to challenge is a new area of research, building on existing studies that have utilised simulation training to address this issue. This chapter highlights research into current and previous literature relevant to the issues, areas of research and theories discussed in Chapter 1.

The chapter begins with a review of studies that concerns the ability to challenge or 'speak up' in the workplace (2.2 Challenging Decisions), including instances of where failing to assert can result in negative outcomes for patients. For example, this section discusses literature regarding the Francis Report (FR) and how more attention has been placed into team training, error reporting and communication as a result. The next section (2.3 Medical Error) is a review of literature that describes, quantifies and highlights the causes of medical error. This is then followed by a discussion concerning situational awareness (SA; 2.4 Situational Awareness). Early briefings with project stakeholders, including input from military subject matter experts (SMEs) from the Royal Centre for Defence Medicine, referred to SA as a crucial element in providing optimal healthcare. Therefore, this section highlights literature that defines what SA is and how it can be measured and assessed in both individual and team training across multiple areas.

The following sections (2.5 Training Simulation and 2.6 VR-Based Simulation) discuss various simulation training technologies. This includes mannequin-based training simulation and VR-based technologies. The review then finishes (2.7 VR Development Technologies) with an overview of VR development software, such as the creation of three-dimensional (3D) assets and 'avatars'.

2.2 Challenging Decisions

It has been widely reported that failing to challenge decisions, especially so in a time of medical crises, contributes to negative outcomes (Belyansky *et al.*, 2011; Gillespie *et al.*, 2013; Bould *et al.*, 2015). The term 'speaking up' or 'challenging' can be defined as the process of conveying a concern related to a decision of treatment within medical care. This includes differing opinions, doubts or factors associated with hierarchy that may cause unintentional or preventable patient harm should any issue not be raised or addressed when appropriate to do so (Christian *et al.*, 2006; Beament & Mercer, 2016).

Qualitative analyses on the role of hierarchy in medical settings has established attitudes towards seniority, identifying both positive and negative effects towards those situated in lower levels. For example, Bould *et al.* (2015) identified multiple emergent themes as part of a study that set out to establish how the medical hierarchy influences the decision making of anaesthesiology residents. A major finding was the diffusion of responsibility for patient care

as a form of coping mechanism for the residents, essentially describing themselves as a bystander and contributing nothing more than to follow the direction of their attending seniors.

Based on this study, the medical hierarchy plays a significant role in influencing the behaviour of medical personnel. As reported in the scenario of Elaine Bromiley (Bromiley, 2008), which resulted in the preventable death of a patient due to failure to adequately challenge the superior, silence or inadequate challenges are the foundation in which patient mistreatment can flourish. This finding, as was also the case in Bould *et al.*'s analyses, is consistent in other literature of a similar topic (Blatt *et al.*, 2006; Sydor *et al.*, 2012; Friedman *et al.*, 2015; Palanisamy & Jenkins, 2015; Leisy & Ahmad, 2016). There is also a growing concern at the frequency of bullying from senior staff, where allegations of harassment and sexual assault are among the worst-case scenarios (Kelly *et al.*, 2015; Chadaga *et al.*, 2016; Sánchez *et al.*, 2016).

Further to the research concerning hierarchical conflict and the ability to speak up or challenge decisions, Okuyama *et al.* (2014) examined a series of articles regarding factors that affected the ability to speak up or challenge as part of a literature review. Their findings had identified numerous influences that ranged from professional or career related factors to a breakdown of non-technical skills. For example: teamwork, the relationship between team members and leader attitude (Edmondson, 2003; Sutcliffe *et al.*, 2004; Greenberg *et al.*, 2007; Simpson & Lyndon, 2009), job satisfaction (Maxfield, 2005), patient responsibilities (Lyndon, 2008), confidence (Blatt *et al.*, 2006), and fear of response, conflict or appearing incompetent (Wu *et*

al., 2003; Attree, 2007; Ullström *et al.*, 2014). However, above all, Okuyama *et al.*'s findings associated hesitancy to challenge with communication error which, as discussed in chapter 1, is widely acknowledged in the literature as an integral component for safe and effective healthcare (Leonard *et al.*, 2004; Baker *et al.*, 2006; Bromiley, 2008; Bosse *et al.*, 2010).

Despite this, there is a consensus that relevant training in communication is still lacking supporting evidence of efficacy. For example, McCulloch *et al.* (2011) conducted a systematic literature review of 1036 articles, later condensed to a detailed analysis of 14 studies related to the delivery of communication and teamwork training. The analysed sample of studies all comprised devised models of intervention based on the recently discussed crew resource management (CRM; e.g. Shapiro *et al.*, 2004). Despite the mixed success of the studies analysed, their findings demonstrated various flaws that compromised the validity of the outcomes, with subjective measuring and Hawthorne effects among the most frequently cited issues.

The Hawthorne effect, in this context, is a term associated with the sudden increase in productivity or performance of research participants when under observed conditions (Wickström & Bendix, 2000), and is especially so when the participants in question are knowingly observed. Indeed, a more recent study that evaluated a teamwork training intervention modelled from CRM produced inconclusive evidence (Morgan *et al.*, 2015), the study design of which, as acknowledged in the discussion, was also susceptible to Hawthorne

effects.

Literature that discusses the process of speaking up to prevent negative outcomes is also present in other contexts, such as general office or corporate-like environments (Chew, 2013). It is, therefore, not limited to just the medical or aviation domains. For example, Detert & Edmondson (2005) conducted an anonymous investigation that set out to identify the various challenges employees face when attempting to speak up. Their study saw 190 employees within a large, complex technology organisation interviewed. The interviewees were situated across five departments, such as research and development, manufacturing and marketing, and job roles included executives, managers, engineers, sales and marketing professionals and financial analysts. Their findings revealed that the challenges of speaking up did not just affect those lower in the hierarchy, but also impacts employees much higher in the rankings, including individuals in more senior positions such as managers. Some of the challenges identified included stability issues such as job security (trying to build a career and fear of job loss), situational issues such as challenging in front of others (perceived embarrassment) and fear of response (felt that a situation could present a threat to him or herself).

2.2.1 Public Healthcare Enquiries

A breakdown of SA can result in increased error output (Schulz *et al.*, 2013) and disastrous outcomes (Francis, 2013). The Francis Report (Francis, 2013; FR) was published because of a public inquiry investigating a series of claims of poor healthcare and medical professionalism

and negligence. The investigation occurred at the Mid Staffordshire National Health Service Foundation Trust between January 2005 and March 2009. The full report is publicly available, and the aim of the investigation was to identify the causes behind inflated mortality rates, low standards of treatment and poor patient care (Francis, *op cit.*, p19).

A journalist for the *Nursing Times*, Calkin (2013) reported;

> "The public inquiry heard common themes of call bells going unanswered, patients left lying in their own urine or excrement, or with food and drink out of reach. Patient falls were also concealed from relatives."

In an article that emphasises the importance of incident reporting to prevent harm to patients, Sujan & Furniss (2015) cited the FR as an example where incidents were not reported or challenged due to a fear of punishment, lending further credence to the research reported on the role of hierarchy and its influence on clinical personnel decision making in this section. However, allegations of misconduct, including a major breakdown in communication and leadership and patient harm, was also evident in other publications.

Further research into the FR had revealed that similar incidents reported at the Mid Staffordshire National Health Service Foundation Trust occurred at Bristol Royal Infirmary (Walshe & Offen, 2001), where evidence of poor healthcare resulted in the death of 29 children and another four who were left with severe brain damage.

As long ago as 1967, allegations of abuse and mistreatment towards mental health patients and vulnerable individuals with learning disabilities were documented and discussed in Howe *et al.*'s 1969 publication concerning Ely Hospital in Cardiff. Referred to as the "Howe Inquiry", the publication is regarded as the first modern enquiry into the standards of care within the NHS (Kelly & Jones, 2013).

Following the Francis Enquiry, the Berwick report (Berwick, 2013), a subsequent report requested by the then Prime Minister, was published to convey the implications of the Francis Report and distil from the Government and NHS the lessons learned and how to ensure such egregious standards of care are never repeated. Both the Berwick and Francis publications have affected healthcare culture within the United Kingdom (Dixon-Woods *et al.*, 2013), with increased pressure to protecting the well-being of patients from mistreatment and establishing staffing needs amongst the most frequently discussed topics (Pannick *et al.*, 2014; Tomlinson, 2015).

They have also affected healthcare culture at an international level, where other countries, such as the United States (Mackenzie *et al.*, 2014) and Australia (Day & Casali, 2015), have drawn from the lessons learned to improve their own quality of care. Above all else, the Berwick report argued that the NHS should become a system devoted to learning and continual improvement, where, as Francis (*op cit.*) also advised, patient safety is placed at the forefront in place of meeting targets and financial goals (Russell & Dawda, 2014; Ham *et al.*, 2016).

2.3 Medical Error

There have been many studies that have investigated the common causes of medical error via a systematic review of literature, both from the perspective of a quantitative and qualitative analysis into hospital records, and from the results of observational-based research (e.g. Shulman *et al.*, 2005; Vazin & Delfani, 2012; Keers *et al.*, 2013; Ribeiro *et al.*, 2016). The most common error types identified in these studies are typically referred to as 'slips' or 'lapses', terms used to describe skills (or performance)-based errors, such as the misidentification of medication (Keers *et al.*, 2013). 'Mistakes' are also types of error frequently identified in error review literature, and are associated with incidents concerning rule-based incidents or limited knowledge in a particular subject. For example, in an observational study concerning medication error causes within an ICU in Arizona (U.S.A), Kopp *et al.* (2006) discovered that, of the 132 errors recorded in their investigation, 31 (23%) were the result of lack of drug administration knowledge and was the highest error type documented. This finding was also evident in a similar study conducted by Vazin & Delfani (2012), where a lack of drug knowledge was among the top three error categories recorded alongside slips and rule violations. In a review of fifty-four studies concerning causes of errors conducted by Keers *et al.* (2013), violations were discovered in fourteen cases. One example of a violation, which refers to the deliberate act of disregarding instructions, concerned the case of a nurse who intentionally provided a wrong dosage of medication to a patient, believing the prescribed amount to be excessive.

Usually referred to as “adverse events” (Vincent *et al.*, 2001), errors can also result in unnecessary, and sometimes preventable patient injury and fatalities (James, 2013). In complex medical departments, such as the ICU, medical errors that are harmful towards patients are common (Flaatten and Hevrøy, 1999). In 2001, in a retrospective review of 1014 records, Vincent *et al.* discovered that half of the reported incidents were preventable and a third of the incidents resulted in “moderate or greater disability or death.” As an example, a male patient who experienced an adverse event, after staff failed to aggressively treat his leg ulcers, suffered from the subsequent amputation of both of his legs below the knee. In a similar vein to Vincent *et al.*’s study, Flaatten and Hevrøy (1999) also reviewed 87 incidents across a 13-month period and graded them, based on consequence, using a 6-point scale. The lowest grade, zero, was allocated to incidents that produced no consequence. At the opposite end, a grade of five was allocated to incidents that resulted in a patient fatality. Representing the highest-grade category, although no specific examples were provided, 63% of the errors reviewed had no adverse effect, thus scoring a grade of zero. Despite this, emphasis on the importance of prompt intervention was maintained, and the authors clarified that these outcomes could have been much worse. Only one error reviewed resulted in the highest grade of five where the patient had died, although the exact cause of this was not clarified. However, examples of types of errors recorded included wrong medication and inappropriate dosage levels.

Medical errors can also affect those who commit them, especially so when reflecting on the experience afterward. Goldberg *et al*. (2002) stated: “little consideration has been given to the

emotional impact of errors on the practitioner". The experience of causing an adverse event for a patient can impact negatively upon the professional, such as loss of confidence or causing guilt or anxiety (Mira *et al.*, 2015). Those affected by adverse events have also been referred to as the "second victim" (Scott *et al.*, 2010). The impact of such errors on the second victim can also last a long time, becoming a traumatising experience and eliciting various negative emotional responses, such as fear, anger and embarrassment (Christenson *et al.* 1992; Seys *et al.*, 2013). Furthermore, in a study that discussed the emotional impact of medical error on physicians, Engel *et al.* (2006) discussed the importance of establishing training programmes, a feeling also shared by Schwappach & Boluarte (2009) who stated that training in this area is rare. Engel *et al.* concluded that it was "critical" for trainees to receive support both to help them cope with medical error and to develop skills to overcome the emotional impact that errors bring. Their findings indicated that poor patient outcomes and "greater perceived responsibility" contributed to intense anguish. Communication with colleagues and supervisors, combined with learning opportunities and reassurances, helped to alleviate the "intense emotional responses to their medical mishaps" with most of those interviewed in the study.

Several recent studies have discussed the impact of personal influences, such as distractions, to both clinical and surgery environments (e.g. Campbell *et al.*, 2012; Sevdalis *et al.*, 2012; Jothiraj *et al.*, 2013). The message from these studies is that distractions, such as during medicine administration as part of, or following, an operation, are a highly likely source of medical errors. For example, Krishna *et al.* (2015) investigated patterns of medication errors

within a teaching hospital. Of the eighty-six errors analysed in the study, 67% were committed by nurses who attributed them to repeated distractions. In this instance, the highest error type detected was “omission errors”, which referred to examples of medication not given to patients.

Medical errors of varying levels of type and urgency are seemingly inevitable, either from technical or personal sources. However, according to Larizgoitia *et al.* (2013), maintaining patient safety has been the top concern of health organisations for many years, and many studies have explored different solutions to alleviate medical error. For example, Starmer *et al.* (2013) investigated the adoption of a more structured approach to the handover process, the basis of their investigation being that miscommunication during the procedure is a likely source of medical error, and that studies to improve this process are lacking. Their study methodology consisted of providing training that consisted of communication and handover best-practices to resident physicians. When compared to the pre-intervention process (where this training had not yet been provided), the post-intervention results had revealed a decrease in medical error from 33.8% to 18.3%, results attributed by the authors to improvements in both verbal and written handover procedures.

As a further example, Lederman *et al.*, (2013) and Poorolajal *et al.*, (2015) concluded that introducing improvements to current error reporting processes is essential to reducing them. Poorolajal *et al.* discovered that half of the sample surveyed in their study (171 in total) had admitted to committing errors but had not reported them. 60% of the sample cited the lack of

an “effective medical error reporting system” as the reason for under-reporting. Interestingly, approximately 44% of the sample expressed a fear of repercussion, such as malpractice lawsuits (i.e. legal repercussions), losing patient trust or emotional reactions of patients or relatives. It is clear from the literature that an improved or more structured, and perhaps more sensitive, process of error reporting can assist staff with coping from their mistakes and, thus, maintain their well-being.

2.4 Situational Awareness

Situation awareness (SA) may be defined, in a very general sense, as a person’s ability to both perceive and understand their environment (Wright *et al.*, 2004). Therefore, it is an important element in the execution of appropriate, reactive decision-making. In a healthcare context, according to Wright *et al.*, maintaining SA is critical to avoid making bad decisions. Maintaining SA was also championed by a local medical simulation training faculty observed (Chapter 3 3.3.2 Hollier Simulation Centre) and is utilised across a variety of sectors, including military (Kaber *et al.*, 2013), aviation (Endsley, 2000a) and oil and gas (Sneddon *et al.*, 2013).

First developed in the 1980s, to effectively measure SA in teams or individuals, Endsley (1987) devised a method known as the Situation Awareness Global Assessment Technique (SAGAT) for use within the military and commercial aviation fields. Endsley (2000b) describes this model as a “global tool developed to assess SA across all of its elements based on a

comprehensive assessment of operator SA requirements". Endsley's SAGAT model revolved around the use of three hierarchical levels (Fioratou *et al.*, 2010):

- Level 1; perception, how the participant perceives the data
- Level 2; comprehension, what does the data mean
- Level 3; projection, projection of future events.

To exercise SAGAT, participants of simulators are queried at randomly assigned points after temporary suspension, or "freezing" of the simulation. It is during this suspension that educators discuss the events occurring now with the participant to explicitly assess their current level of SA. Authors of studies that have incorporated SAGAT as part of the methodology (e.g. McKenna *et al.*, 2014) would normally base their discussions or questions around the three hierarchical levels. For example, Schulz *et al.*, (2013) provided a sample list of questions designed around the SA levels for assessing SA in a critical incident scenario context. This included: "How is the patient's blood pressure?" (Level 1), "Does the patient react adequately on your medications?" (Level 2) and "Do you expect the patient's blood pressure to increase, stay equal, or decrease?" (Level 3).

Further from Schulz and colleagues' study, the SAGAT model was adapted and utilised in the medical domain in conjunction with mannequin-based simulation technologies (e.g. Hogan *et al.*, 2006; Hänsel *et al.*, 2012; Endacott *et al.*, 2010). Studies conducted by Cooper *et al.* (2010) and Hogan *et al.* (2006) incorporated SAGAT into their experiments to assess SA levels of individuals. Hogan *et al.* used SAGAT to assess the practical trauma skills of several grades of

medical personnel, such as a student or senior surgeon. The skills assessed were those relevant to the Advanced Trauma Life Support (ATLS) objectives and include airway assessment, cervical spine control, and circulation and haemorrhage control (Williams *et al.* 1997). They concluded that SAGAT is a "valid, reliable assessment tool for trauma trainees in the dynamic clinical environment created by human patient simulation". Endsley's SAGAT method has also been exploited extensively in other sectors such as military training. Lampton *et al.* (2006) incorporated SAGAT into their study that utilised virtual-based training scenarios. Participants, as with Hogan *et al.*'s study, were queried at particular points throughout the simulation to assess their current SA level. However, their use of SAGAT differed slightly from Hogan *et al.*'s approach. There was no suspension of the simulation as the queries were issued. They stated:

"Real-time probes involve verbally querying trainees regarding what they know about a given operational situation at the same time they perform required training tasks (i.e., neither the scenario nor training performance is halted for SA data collection)."

Further recent studies in the medical community incorporated SAGAT into their experiments. Cooper *et al.* (2010) conducted a study that assessed the SA levels of final year nursing students whilst they engaged with a mannequin-based simulator. Their aim was to assess each individual nurse's ability to uphold patient comfort by identifying and responding to patient deterioration. Their skills were assessed with a questionnaire and each nurse participated in two video-

recorded simulated scenarios. The method used to assess their SA level, like SAGAT, consisted of stopping the simulation at random intervals and issuing a series of questions related to perception, comprehension and projection (i.e. the three SA levels). The results of the study demonstrated a decline in skill performance when managing increased patient deterioration. This occurred despite an overall improved general skill performance by the conclusion of the second scenario session. In conclusion, they stated: "Participants' poor performance of basic assessment tasks, their failure to call for assistance in many situations and their limited data comprehension have implications for clinical practice." To assist with this, it was recommended that participants attend regular training, or "refresh" training opportunities to engage with high fidelity simulators.

2.5 Training Simulation

The widespread adoption of simulation to assist in the focused and relevant training of personnel is evident in settings such as the military (Maxwell *et al.*, 2014), in construction (Goulding *et al.*, 2012) surgery (Visser *et al.*, 2011) and throughout the medical domain generally (Bradley, 2006).

Observations conducted at medical training establishments such as the Hollier Simulation Centre (HSC) revealed a focus on the development of non-technical, HF-based skills such as communication, teamwork, SA and leadership. This is also supported in recent literature, where

the adoption of HF in simulation training can assist in trainees becoming proficient in these areas (Gilchrist *et al.*, 2015).

It is well recognised that there are various issues that make live patient involvement difficult in the development of effective medical training (Towle *et al.*, 2010; Good, 2003; Howe & Anderson, 2003). For example, acquiring informed consent to allow trainees to interact with live patients can be a complicated process. According to Towle *et al.* (2010), to ensure consent is given, "appropriate preparation and orientation processes which include clear explanations of the purpose and importance of patient involvement" are required. Furthermore, it is apparent that common concerns raised by patients who are involved in medical training include fear of their experiences being exaggerated in reports. In addition, their involvement may result in the development of anxiety from potentially revisiting negative or traumatising experiences, in addition to fear of judgement from learners present in the class.

A further concern with live patient involvement is that organisations are often granted access to more personal and confidential data than is required to conduct the training (Sayer *et al.*, 2002). Having access to these data, despite the apparent strict consent procedures in place, can run the risk of breaches in confidentiality. As a final example, live patient involvement is also limited to the point where more complex procedures, such as CPR (where the use of a defibrillator is required), are difficult to simulate.

Despite this, live patient involvement in medical education can be a beneficial resource

(Bokken *et al.*, 2008; Collins & Harden, 1998; Towle & Godolphin, 2013). Bokken *et al.* (2009) conducted a series of interviews with 38 experienced medical students about interacting with both live and simulated patients (SPs). Their results suggested that interacting with live patients can be a more instructive and authentic experience. This is further supported by Collins & Harden, who state they can "provide an adequate opportunity to assess a candidate's skills" both within simulation and clinical examination conditions. They also state that the requirement of "suspense of disbelief" is less necessary due their involvement, as they make the experience more credible.

The adoption of SP technologies to replace or limit the requirement for live patient involvement in clinical training has grown significantly since its inception in the 1960s (Barrows & Abrahamson, 1964). The original purpose of adopting SP techniques was to simplify the process of teaching the relevant medical skills and trainee examination processes (Gaba *et al.*, 2001; Wilford & Doyle, 2006; Bashankaev *et al.*, 2011). Since then, it is evident that the adoption of SP technologies in clinical education has grown considerably (e.g. Byrne, 2012; Motola *et al.*, 2013). One of the primary advantages is the ability to practise uncommon events (Wright *et al.*, 2004; Byrne, 2012). This includes technical skill scenarios such as malignant hyperpyrexia (abnormally increased body temperature; Moulds & Denborough, 1974), or emotionally-based scenarios such as breaking bad news; in other words, examples of complicated procedures that "cannot just be presented." A further advantage of SP technologies is that training events and activities are provided to trainees within a risk-free environment,

safe from repercussion (Lopez *et al.*, 2015).

Training simulation predominately targets the development of related technical skills, which are then transferred to the operating theatre or ward (Dawe *et al.*, 2014). In a surgical context, Dawe and colleagues obtained evidence suggestion that training simulation can develop trainee skills that are transferrable to the operating theatre. This is further supported in another surgical simulation study by Sutherland *et al.* (2006), whose literature review of studies comprising a total of 760 participants revealed mixed results. Whilst those who engaged with simulated surgical trainers produced positive results, they were significantly outmatched by traditional forms of surgical training.

In a paramedic setting, Alinier & Newton (2013) investigated the use of mobile simulation training during ambulance shifts. Ambulance teams participated in roadside sessions that lasted approximately two hours. Whilst taking part, an additional ambulance team was on standby to cover them. They concluded that training simulation, in a mobile form whilst on-shift, "addresses the timeless problem of maintaining clinical and non-technical skills in the workplace." In addition, and in response to the FR, they stated that clinical simulation is "one increasingly acknowledged strategy that can help provide counter measures to sub-standard clinical practice."

In the study design of Morgan *et al.* (2015), where they evaluated a teamwork training intervention modelled from CRM, they exploited the use of a tool designed for non-technical

skills assessment as part of their methodology. Adapted from an existing model used within the aviation industry (Mishra *et al.*, 2009), and later expanded with improved scalability (Robertson *et al.*, 2014), team performance was measured using Oxford NOTECHS II. The scale was developed to assess medical teams predominantly in the following four behavioural domains: leadership and management; teamwork and cooperation; problem-solving and decision-making; and situation awareness (SA). In a literature review of 26 publications concerning simulation for team skills training, Tan *et al.* (2014) identified multiple studies that utilised a bespoke form of NOTECHS to assess the non-technical skills listed above (e.g. Undre *et al.*, 2007; Koutantji *et al.*, 2008; Powers *et al.*, 2008).

Sevdalis *et al.* (2008) is an example of such a study that exploits a (modified) form of NOTECHS in conjunction with simulation technologies to assess the non-technical skills of junior surgical teams. Their study design comprised observing a series of simulation-based training sessions carried out by surgical teams consisting of surgeons, anaesthetists, scrub nurses, and operating department practitioners (ODPs). Data were collected on each participant, by senior trainers who observed the simulations using their revised version of the NOTECHS scale, for analysis. Their results demonstrated that the revised scale is a reliable and satisfactory method in training the non-technical skills in surgeons, which was further validated in a subsequent publication (Sevdalis *et al.*, 2012) and other relevant literature (Russ *et al.*, 2013; Wahr *et al.*, 2013).

Further to the research that associated hesitancy to challenge with communication error, such as Okuyama *et al.*'s (2014) findings, conventional training simulation methodologies has been described as an environment for the deliberate practice of communication strategies (Weller *et al.*, 2014). For example, Eppich (2015) described the Situation, Background, Assessment and Recommendation (Cornell *et al.*, 2014) method (or 'SBAR') as a "widespread communication tool to enhance structure and clarity". Its purpose is to ensure clearer communication between team members whilst developing critical thinking. Thus, avoiding broad, vague narratives between staff that that places effective teamwork and patient safety at risk (Leonard *et al.*, 2004).

SBAR is an effective communication training technique which has been utilised in several studies related to simulation training of teamwork communication skills, with evidence of efficacy reported (Thomas *et al.*, 2009; Klein, 2012). This included studies based around role-playing-based exercises (Chaharsoughi *et al.*, 2014) and evidence that SBAR eases the negative effects of hierarchy has also been reported (Randmaa *et al.*, 2014). In a study that set out to identify aspects of teamwork associated with clinical efficiency, Siassakos *et al.* (2011) found that participants who adopted an SBAR-like structure within the scenario sessions demonstrated an efficient handover of important clinical information between team members in emergency situations.

The observational research conducted at the HSC and the QEHB's education facility (described

later in Chapter 5 Application Development) revealed that the SP technology exploited to train their participants was a Laerdal SimMan. Based in Norway, Laerdal is a company that specialises in the development of customisable, bespoke, SP mannequins with many interchangeable parts and accessories. The SimMan technology was exploited in a study by Weller (2004) who conducted a series of simulation workshops for 33, 4th year medical students. The SP technology was described as "medium fidelity" and the mannequin could mimic various symptoms related to breathing and cardio-vascular-related illnesses. Although limited to student opinions from questionnaires, Weller's results showed that the participants found the workshop to be a beneficial experience and valued the technology highly. There was also evidence of increased teamwork skills, aspects of which were reportedly described as "key areas of learning."

Communication with a simulation training facility technician during the periods of observation described in Chapter 3 Observation, provided insight into the cost of maintaining the equipment. The initial approximate cost of their SP mannequin was £50,000 plus recurring fees for a warranty that covers all on-site repairs and replacement parts. Indeed, some of the hindrances of SP technologies described in the literature are regular maintenance, time constraints and costs (Good, 2003; Maran & Galvin, 2003; Weller, 2004; Issenberg *et al.*, 2005). Maran & Galvin linked the high costs of simulation to the level of engineering fidelity, where an increase in realism is inevitably accompanied by a significant increase in costs. However, as stated by Maran & Galvin, a significant increase in engineering fidelity beyond certain levels does not

produce a substantial improvement in performance when compared to simpler device designs.

2.6 VR-Based Simulation

As defined by Stone (2012), Virtual Reality (VR) refers to a form of simulation in which the end user interacts in real-time with multisensory, computer-generated databases (comprising predominantly, but not exclusively, visual imagery). VR scenes can be presented to the human using a variety of two-dimensional (2D) and 3D (stereoscopic) display technologies, including head-mounted displays (HMDs), conventional flat screens, smartphones and tablets, whole-wall displays and even room-sized enclosures (e.g. the "CAVE", or Cave Automatic Virtual Environment). Non-visual aspects of Virtual Environments ("VEs") include sound, haptics (delivering rudimentary sensations of touch and force), motion and olfaction (smell).

The use of VR has been studied in a very wide range of different application domains, including military (Armstrong *et al.*, 2013; Huguet *et al.*, 2016), surgery (Graafland *et al.*, 2014), snowploughing (Masciocchi, 2007) and construction (Goulding *et al.*, 2012). In a healthcare context, VR has been adopted in several different areas. For example, it has been evaluated since the 1990s as a method to overcome anxiety-related disorders such as various phobias (Gorini & Riva, 2014; Stone *et al.*, 2014).

Some VR-based simulation technologies can be operated by users away from the classroom, within their own time. For example, positively received mobile-based applications such as

Touch Surgery (Nehme & Chow, 2016) allows users to simulate, plan and rehearse different surgical procedures (e.g. drilling or incising) free of charge. It is an interactive, VR-based multimedia software application that renders 3D images of various surgical procedures, offering a step-by-step manual (Figure 2.1) to completing orthopaedic operations.

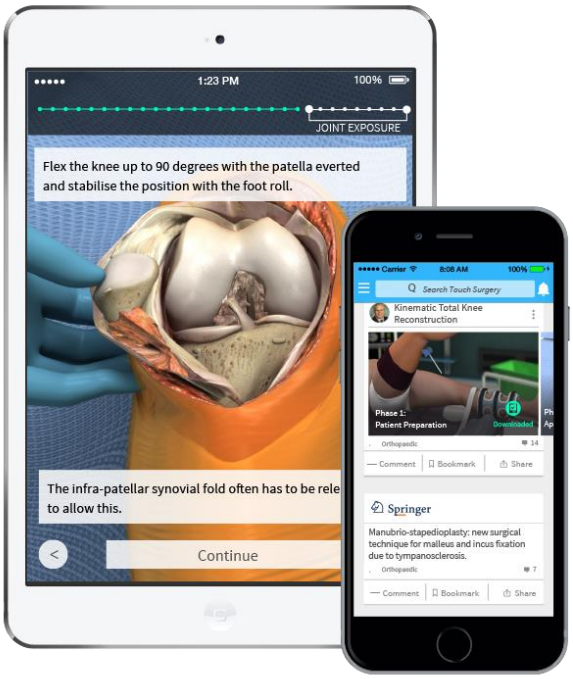

Figure 2.1 - Touch Surgery Surgical Simulator (Kinosis Ltd., 2015)

In a different VR-based study by Rahm *et al.* (2016), 20 medical students engaged with a VR simulator designed for arthroscopic knee surgery procedures. Each participant engaged with the simulator eight times, with each session lasting 30 minutes. Though the participants initially

improved significantly, providing higher scores by attempt four, the overall score improvement stagnated for the remaining four attempts, demonstrating lower score improvements. In conclusion, the study lacked any finding that could predict the magnitude of skill development.

Another study regarding the use of VR for surgical skills training was conducted by Lendvay *et al.* (2013). Their study involved 51 participants engaging with a VR-based robotic simulator to practice a series of warm up surgical procedures. Their investigation is based on previous research in this area conducted by Kahol *et al.* (2009) and Calatayud *et al.* (2010), who produced positive findings on the use of VR-based surgical simulators (non-robotic) as a warm up before repeating the same laparoscopic procedures. Their results revealed an improvement in surgical skill and, ultimately, a reduction in errors was achievable after pre-operative simulation warm up procedures were carried out. There was no evidence produced in the Lendvay *et al*. study that demonstrated the skills acquired were transferred to the operating room. However, the results of their study revealed an overall skill improvement and reduction of errors when the procedures were repeated.

According to Stone (2011), the adoption of VR-based training simulation in both medical and surgical contexts have been slower in comparison to mannequin-based SP technologies. Studies have also questioned the efficacy of 'serious games' (Stone, *op cit.*; Graafland *et al.*, 2012; Patel *et al.*, 2013), despite, arguably, significantly lower development costs to create. For example, a review of surgical simulators conducted by Sutherland *et al.* (2006) also assessed

the use of computer-based (including video) simulation training. The studies reviewed primarily targeted the development of related technical skills such as incision accuracy, speed and laparoscopic instrument handling. After reviewing all the studies, they concluded that "none of the methods of simulated training [including computer simulation, video simulation and model simulation] has yet been shown to be better than other forms of surgical training." The message from these studies therefore indicates further research is required, providing evidence of efficacy and benefits to medical settings.

Authors of studies, of both older and recent publications concerning the evaluation of VR techniques as a viable training methodology, suggest that immersion and interaction are essential mechanisms for maintaining realism (Marescaux *et al.*, 1998; Torkington *et al.*, 2000; Bhoir, S., & Esmaeili, 2015). The feeling of immersion refers to the degree in which an individual is engrossed into an experience (Alexander *et al.*, 2005). When immersion is 'perfect', it creates difficulty in separating the simulation from reality (Marescaux *et al.*, *op cit.*), but it is also a seemingly difficult process to achieve when technical constraints, or visual fidelity issues, interfere with the experience (Westwood, 2007; Stone, 2011). For example, Stone (2008) described a scenario where a demonstration of a VR-based application concerning the treatment of wounded frontline military personnel was presented to a series of potential surgical end users. A reflective 'material', attached to a 3D model of a laryngoscope, was rendered in such a way that it created a virtual glare and displayed a reflection that was incorrect from the perspective of the camera. It was so distracting that the end users had commented on

it. Stone (2011) referred to this instance as an example of hyper-fidelity, where “the inclusion of too little, too much or inappropriate sensory and/or behavioural detail” can negatively affect the potential training transfer.

Technical constraints such as the example described above are not limited to immersion-breaking events within the simulation itself. For example, studies that incorporate third-party hardware to enhance the immersive experience have also shown to negatively impact the transfer of training. This includes HMDs that have shown to be disorientating and cause reports of motion sickness or dizziness (Alverson *et al.*, 2005; Wilson, 2016). Indeed, motion sickness has been associated with HMDs since the early 1990s (Mon-Williams *et al.*, 1993).

2.7 VR Development Technologies

Several development tools, with accompanying documentation, community support and tutorials, for developing VR content has been publicly available in recent years. This section outlines several the different packages available with next to no costs.

2.7.1 Game Engines

Game engines are software that are made up of different subsystems that allow the use of audio playback, controller input, physics simulations, 3D rendering, scripting, networking and artificial intelligence, subsystems of which are the core mechanics that make a video game

product (Nilson & Söderberg, 2007). The purpose of a game engine is to provide a combination of these subsystems into a single programmable package to allow the development of two-dimensional (2D) or three-dimensional (3D) simulations or video games (Lv *et al.*, 2013). Game engine software has been exploited in several areas in the simulation space, including cultural heritage (Merlo *et al.*, 2012), fire simulation (Xu *et al.*, 2013) and the offshore oil industries (Shen *et al.*, 2016).

The Unity3D engine, first released in 2005, is a commercial game engine that supports a wide array of platforms, such as mobile, tablet, personal computer and current game console technologies (Unity Technologies, 2016). An example of a study that utilised the Unity3D engine for medical research is Wickens *et al.* (2015), who used the software to build a web-based otoscopy simulator.

Unreal Engine 4 (UE4; Epic Games, 2014) is an example of another commercial game engine initially released in 2014. As with Unity3D, it supports all the common platforms (such as computer, game console and mobile tablet) and game console technologies, and is renowned for its graphical fidelity and rendering pipeline. The engine allows developers to program functionality and gameplay using either C++ code or their built-in, node-based Blueprints system. An example of a study that utilised UE4 for medical research is dos Santos *et al.* (2016), who used the software for assisting foetal medicine studies.

2.8 Conclusion

2.8.1 The Problem

The ability to assert or challenge leadership is, seemingly, an essential skill to possess to ensure the safety of patients, as presented by Francis (2013), Berwick (2013) and findings from the relevant literature highlighted in section 2.2 Challenging Decisions. For example, Bould *et al.* (2015) reported that subordinates who fail to voice concerns "risks unethical practice or serious patient harm". As demonstrated in the widely documented case of Elaine Bromiley (Bromiley, 2008), the presence of hierarchical gradients within clinical environments can create a sense of hesitancy. In this event, two nurses in attendance of Elaine's surgery failed to adequately challenge the two consultant anaesthetists which resulted in her unfortunate death. This was despite, as reported by Sydor *et al.* (2012), the nurses in question possessing sufficient knowledge to intervene and prevent the negative outcome. These findings were consistent within other studies of a similar nature (Lewis & Tully, 2009), including literature reviews on patient safety culture (e.g. Sacks *et al.*, 2015), demonstrating that the medical hierarchy both presents itself as a direct influence on challenge abilities and precludes efforts to champion patient advocacy.

However, as was the case in Sydor and colleagues' findings, there is an apparent link between confidence, knowledge or experience and likelihood to make a challenge. Qualitative analyses

of participant interviews conducted by Bould *et al.*, following a series of simulations that involved a confederate issuing an incorrect order for treatment, found that resident experience affected the quality of challenges issued. Indeed, Okuyama *et al.* (2014) reported that a lack of relative experience presented a barrier in challenging, as was the case in several related studies analysed in their review (Blatt *et al.*, 2006; Lyndon, 2008, Lewis & Tully, 2009; Lyndon *et al.*, 2012).

In addition, further research into the FR had revealed that the mistreatment of patients at Mid-Staffordshire Trust was not an isolated case (While, 2015). A report published by Keogh (2013) had revealed that similar cases of communication breakdown were reported in 14 other large hospitals in the United Kingdom, 11 of which were, according to a then recent report, placed under immediate review by the Government's Health Secretary (HuffPost UK, 2013). For example, one of the 14 hospitals discussed in Keogh's review, Tameside Hospital NHS Foundation Trust, was criticised for failing to acknowledge patient safety concerns raised by junior staff (Black, 2013).

The issues, surrounding incident reporting, patient mistreatment and fatalities due to not voicing concerns, described in these publications illustrate a controversial issue of considerable social importance within the healthcare community. Furthermore, Okuyama *et al.*'s recent review of 26 studies in this area had also indicated that the ability to challenge is widely associated with communication error. In addition, the evidence acquired illustrates that

hesitancy to voice concerns is still a problem present in the healthcare environment, with fear of repercussion among the highest concerns cited by research participants in these studies.

2.8.2 Existing Solutions

Authors of studies have evaluated various forms of training, some of which, as already highlighted, were modelled from training programmes originally developed within the aviation industry (e.g. CRM; Dunn *et al.*, 2007), to enhance medical teamwork and improve patient safety culture. For example, Weaver *et al.* (2010) assessed the 'TeamSTEPPS' teamwork training program, where elements such as communication and leadership were among the core competencies targeted by the model. This included use of the communication model 'CUS', an acronym for "I am Concerned", "I am Uncomfortable", and "This is a Safety issue", as a method of conveying safety concerns (Greenwood & Heninger, 2010) and, as previously discussed, SBAR (Eppich, 2015).

In Weaver and colleagues' study two groups of surgeons were observed, half of whom received TeamSTEPPS training. Following the intervention, improvements in both communication and leadership skills were observed in the intervention group, suggesting evidence of efficacy, but it was performed on a small sample size (three in each group). In another study conducted by Sawyer *et al.* (2013), a series of simulated scenarios were observed where a physician deliberately ordered an overdose of epinephrine (adrenaline) for a patient. Nursing participants in attendance who had received TeamSTEPPS training challenged the incorrect order 77% of

the time, compared to just 55% before the training, but this was not compared with a control group who did not receive the intervention.

Some of the literature discussed in Chapter 1 (e.g. Calhoun *et al.*, 2013; 2014) attempted to address hierarchical conflict using mannequin-based simulation technologies to good effect, despite parts of their methodology being questioned (i.e. simulated patient death). In another study, Purva (2015) exploited traditional simulation techniques to assuage the effects of bullying and harassment in the clinical environment, claiming that participants felt more empowered to challenge such behaviour. Indeed, other studies discussed also supported the need for appropriate and relevant training to develop other skills associated with challenging, including conflict resolution, effective communication techniques and a more structured handover process. Although it is believed by some that simulation is unlikely to ever faithfully mimic the events and complexities of reality (Maran & Glavin, 2003; Byrne, 2012), simulation as a "teaching medium" could be used as a form of practice ground. This could allow trainees and staff to respond to specific situations encountered within exceedingly uncommon events "in a risk-free context" where "formative feedback is available" (Byrne, *op cit.*).

A study by Savoldelli *et al.* (2006) produced evidence that suggested simulation technologies could be implemented into existing training examinations to assess clinical competence. However, their results indicated that further research is required before such technologies could be implemented into formal evaluation procedures. Differing outcomes when comparing oral

examination with simulation examination were evident, and the authors were unable to predict how well participants would perform in either procedure. In addition, some authors have already suggested that optimal use of simulation is only achieved when embedded within training programmes (Kneebone, 2003; Byrne, *op cit.*). Therefore, timing of exposure to simulation to maximise any effect it could have on trainees and qualified staff has not been established.

The efficacy of VR technologies with respect to training transfer has also been questioned, though some VR applications discussed in this chapter utilised VR to good effect (e.g. Touch Surgery). For example, two controlled trials conducted by Sedlack & Kolars (2004) and Park *et al.* (2007) assessed the use of VR for training inexperienced surgical residents to perform a colonoscopy procedure. Following the training in both studies, the cohort who engaged with VR simulation outperformed the control groups. In Park *et al.*'s case, they produced evidence that effectively demonstrated a skill transfer to live patients. However, other studies describing similar efforts (e.g. intravenous catheter insertion) have been inconclusive, demonstrating no difference between the use of VR simulators and traditional training methods, such as live patient demonstration (Prystowsky *et al.*, 1999; Engum *et al.*, 2003).

Studies that evaluated the adoption of VR-based technologies to train medical students were exploited mainly in the surgical space. Though they were featured in the context, most of the studies reviewed predominantly targeted the training of relevant technical skills, such as

precision and drilling, and did not directly assess the delivery of the non-technical skills associated with HF. However, other studies in healthcare contexts have utilised VR technologies in other areas not related to skills transfer, such as a tool for therapeutic use to increase recovery rates and maintain comfort from injuries (Stone *et al.*, 2014; Small *et al.*, 2015).

2.8.3 Adoption of VR and Comic Book Technologies

Discussions with medical Subject Matter Experts (SMEs) during the initial stages of the project's development highlighted the need to consider other forms of media for training. For example, the adoption of an innovative model of training that could offer trainees additional support as an adjunct to conventional forms of clinical education, a model that is both cost-effective and still able to produce positive outcomes. The chosen media had to take the form of a visually stimulating, yet informative production, and offer the possibility of comparing the real-time dynamic qualities of technologies such as VR with a more static, but equally appealing, technique. For example, producing a storyboarded version of a simulated clinical scenario, but presenting it in a 2D, as opposed to 3D, form.

Adopting VR alongside 2D forms of narrative media, where the focus is directed more so in the development of appropriate and reactive decision-making techniques to challenge leadership (with an emphasis on the non-technical skills), is an area of new research. Literature that discusses the adoption of 2D media techniques, such as narrative-based, traditional, comic-

books, graphic novels or story-boards, describe it as an effective method for enhancing the trainee learning, reflection and preparation process within clinical and surgical settings (Babaian, 2014; Babaian & Chalian, 2014; Pender, 2014). As an example, Moreno-Ger *et al.* (2008) developed a low-cost medical training simulator presented in the form of a 2D adventure game, whereby the player was tasked to perform the insertion procedure of Central Venous Catheters to reduce central line infection. The project exploited the use of 2D images to create an interactive storyboard to present the scenario and, upon completing the simulation, players were presented with a score of how well the performed the procedure. Their development methodology suggested that the project could benefit medical training, suggesting high educational value. Other studies that exploited similar techniques in clinical settings have demonstrated evidence of enhanced learning and reduced costs to good effect (Torrente *et al.*, 2014; Escribano *et al.*, 2015; Boada *et al.*, 2016).

The present research has, therefore, adopted a focus to evaluate the use of 2D and 3D simulation techniques, not for relevant technical skills transfer as most similar studies discussed in this chapter have explored, but as a way of building on research conducted by authors such as Calhoun *et al.* (2013; 2014) and Okuyama *et al.* (2014). The emphasis would be more towards the development of non-technical skills associated with HFs, such as effective use of communication, with the ability to successfully challenge incorrect decisions being the primary focus.

Although studies that produced positive findings on the use of VR in medical education justify the adoption of such technologies, other literature has provided considerations. For example, the present research will not adopt the use of HMDs due to a lack of research that offers a wide solution to some of the human factors issues identified, such as motion sickness or unreliable input schemes, as discussed by authors in similar areas (e.g. Stone, 2012; Wilson, 2016).

The simulator project will take the form of a 3D virtual environment that will be developed as a prototype, with functionality and presentation to be defined in later sections and chapters of this thesis. Unity3D has been selected as the development tool for the project. In comparison to UE4, Unity3D's third-party support, such as a combination of free and low-cost 'plugins' that extend the software functionality, coupled with extensive support from the tool's online community, will assist in maintaining an overall shorter development time. In addition, as UE4 is still relatively new software, time set-aside to grow accustomed to the workflow of the engine would be required. UE4 also currently lacks low-cost third-party support to shorten the development time of the project, therefore requiring a lot of work (that already exists in Unity3D) to be made from scratch. Unity3D also supports an array of 3D model formats that permits content to be imported from 3D Studio Max (Autodesk, 2015). 3D Studio Max, a 3D modelling program, is the chosen software for the creation of required models due to familiarity with the software. 3D model assets ready to be imported into Unity3D for the virtual environment were also provided by project stakeholders.

The 2D media project will take the form of a traditional graphic novel or ‘comic book’ developed by a freelance comic book illustrator, based on requirements later defined in Chapter 5.

Chapter 3 Observation

3.1 Introduction

At an early stage of the project's development, the author was given the opportunity to shadow a team of medical professionals during ward rounds and at a medical education faculty as they planned, executed and evaluated the delivery of multiple simulation training sessions. The observational research reported in this chapter represent research objectives 1 and 2 of the project, as highlighted in chapter 1, and was conducted at two medical establishments within the West Midlands: The Intensive Care Unit (ICU) at Queen Elizabeth Hospital Birmingham (QEHB) and the Hollier Simulation Centre (HSC), located at the Heart of England Trust's Good Hope Hospital.

The main purpose underpinning the acquisition of observational data was to assist in the development of the project (particularly in terms of future simulation scenario generation), acquire first-hand knowledge on both the ICU ward round process and, more generally, the role of simulation training in healthcare. Throughout the periods of shadowing and observation, attention was focused on both the evolution of the medical scenarios and the interplay between the medical trainees and healthcare representatives, some of these latter roles being "played" by the session instructors. Any incidences of conflict were given special attention, as were the outcomes of the conflict, in terms of impact on the Simulated Patient (SP) or the challenge

instigator.

3.2 Research Methodology

The methodology adopted in the acquisition of data was based on an ethnographic approach, or 'structured observational research', which involves the monitoring of domains to gather data on organisational culture (Gerdtz, & Bucknall, 2001; Carthey, 2003). In a medical context, this will include the monitoring of team performance, 'adverse events' and errors. An adverse event is defined as an injury or incident of patient harm caused by medical treatment (Brennan *et al.*, 1991; Bates *et al.*, 1995; Clarridge *et al.*, 2010). Structured observational research is also like other existing research-based, observational methods such as the 'critical incident technique', a "methodology for gathering direct observations of people at work to gain understanding of human behaviour in context" (Boreham *et al.*, 2000).

Observational-based research is a valid methodology in which to capture reliable data related to various scenarios (Mann, 2003). For example, Barach *et al.* (2008) conducted an observational-based study to examine the impact of HF on intraoperative adverse events within paediatric cardiac surgery. Observers performed real-time observations of 102 paediatric cardiac operations over a two-year period, where an average of 1.2 major events and 15.3 minor events occurred per scenario that included both cardiovascular and bleeding related incidents. The authors claimed that the observers used for the study successfully captured the majority of

identified major adverse events identified. In addition, it was discovered that the number of minor events (e.g. equipment problems) captured increased as the study progressed, suggesting that they became increasingly familiar with identifying adverse events as they occurred. With these observational data, the authors identified the complexity of surgical procedures as a predictor of major adverse events.

As a further example, Weigl *et al.* (2012) examined the association between workflow interruptions and workload of clinical personnel. In this observational-based study, 29 doctors were observed throughout 43 full shifts where 1521 workflow interruptions were captured. Interruptions included equipment malfunctions and telephone/beeper calls, with colleague interruptions representing the highest interruption recorded (1138 counts, 2.73 interruptions per hour on average). With these results, Weigl and colleagues were able to successfully demonstrate the association between workflow interruptions and, albeit subjectively rated, workload of staff.

Validated methods designed to capture reliable observational data in healthcare settings has been widely reported (Sevdalis *et al.*, 2012). For example, the Observational Teamwork Assessment for Surgery (OTAS) model was developed as a measure of evaluating methods of team training in both simulated and clinical settings (Healey *et al.*, 2004), where non-technical behaviours such as communication, leadership and awareness are assessed (Undre *et al.*, 2007). Studies that utilised OTAS effectively for observational-based research and captured reliable

data has been documented (Sevdalis *et al.*, 2009; Hull *et al.*, 2011; Russ *et al.*, 2012).

Based on the OTAS model, the Observational Skill-based Clinical Assessment tool for Resuscitation (OSCAR) is a further example of an observational-based methodology designed to, in addition to communication and leadership, assess decision making performance of resuscitation teams (Walker *et al.*, 2011). Observational-based studies have also reported positive results when adopting OSCAR as part of the study design. For example, McKay *et al.* (2012), whose study saw two resuscitation experts observe 24 pre-recorded simulations, concluded that the model "can be used to assess reliably teamworking of cardiac arrest teams".

In an article discussing the "strengths, weaknesses, and future challenges facing observational researchers", Carthey (2003) evaluated studies that involved HF specialists observing several paediatric cardiac surgical procedures conducted across 16 UK hospitals (de Leval *et al.*, 2000; Carthey *et al.*, 2001; Carthey *et al.*, 2003). The surgical procedure referred to in the article(s) as an 'ASO' was a neonatal arterial switch operation, a procedure used to correct the transposition of the primary arteries located in the heart. The structured observational approach assisted in identifying the types, frequency and severity of clinical error, together with examples of satisfactory performance, whilst highlighting the role of HF in negative surgical outcomes. For example, it was discovered that, when multiple minor incidents occur during surgery, even if they do not trigger any adverse repercussions, they can accumulate to create a negative outcome. Errors committed were categorised into two groups, major and minor. Minor

errors were defined as incidents that do not cause any adverse events but may disrupt the flow of the operation. Major events were defined as incidents that cause severe harm to the patient including death. Some examples of major events recorded included surgical precision errors (e.g. accidental laceration), delayed diagnoses and failure to gain vascular access. Examples of minor events included communication issues with the surgical team and blood bank, inappropriate task delegation to inexperienced team members and instrument mishandling.

Although 243 ASOs were conducted for the study in total, only 173 were evaluated from an HF perspective. Twenty instances were removed due to complications with an observer (see below), or were not sufficient in terms of detail, and a further 50 were discarded as they were not witnessed by any observers. The study authors concluded that, despite how minor they can be, even when negative events occur during surgery, "human factors defense mechanisms can lead to a successful outcome". Considerations or "lessons" were also drawn from the studies evaluated by Carthey and colleagues. One such 'lesson' concerned the importance of using video techniques to accompany, maximise and optimise observational data collection. Other studies have demonstrated that observational-based video recordings to evaluate team performance are helpful (Halamek *et al.*, 2000; Pian-Smith *et al.*, 2009), and have produced reliable data (Jalil *et al.*, 2014; Roberts *et al.*, 2014). Another example highlighted was described as 'Observer training and competency assessment'. Throughout the investigation, three HF observers were assigned with observational data collection duties. As highlighted previously, complications with one observer had resulted in the dismissal of 10 ASO reports.

According to the author, that observer had failed to develop sufficient comprehension of the ASO procedure and, therefore, the data collected by the observer were inconclusive and, therefore, not reliable.

This methodology was also exploited in other areas of observational-based research (e.g. Galvan *et al.*, 2005; Healey *et al.*, 2006; Healey *et al.*, 2007). For example, Healey *et al.* (2007) conducted observational-based research on 30 surgical operations to quantify distraction and interruption events (the consequences of the distractions were not the focus of this study). Using this method, they had discovered a mean interruption or distraction count of 20.47 across the observed procedures. The mean rate of distractions was 0.45 events per minute, and the most common causes of these distractions included conversations, work environment complications (e.g. noise caused by personnel) and telephone calls.

In a similar context to the present project, other studies have utilised a form of structured observations to gather data on clinical errors committed in the ICU (e.g. Bracco *et al.*, 2001; Donchin *et al.*, 2003). Bracco *et al.* (2001) set out to "determine the incidence and identify risk factors of critical incidents in an ICU" across a one-year period. They concluded that critical incidents (an alternative term used to describe adverse events; Arora *et al.*, 2005) add unnecessary workload and financial burden to hospitals. Their findings had revealed that 241 human errors were committed across 161 patients in that period. Whilst most incidents generated no major consequence (57% minor repercussions, 16% no repercussions

respectively), they were consistent with planning, execution and surveillance errors. The authors defined surveillance errors as a supervision failure after a therapy had been instituted.

In addition, and in a similar vein to the papers critiqued by Carthey, studies that incorporated structured observational approaches have been found that help to identify the frequency, and severity, of other types of errors. For example, Barker *et al.* (2002) conducted research on drug administration errors. Utilising a structured observational approach, their findings helped identify the prevalence of drug administration errors across 36 medical establishments in the US. Out of 3216 observed drug doses given to patients, 605 (~19%) were administered in error. Of the 605 errors, 43% of doses were given at the wrong time, 30% were omitted, 17% were the wrong dose, and 4% were unauthorised drugs.

The structured observational research for the present project primarily involved shadowing multiple ward rounds taking place at the ICU of the QEHB, seeking clarification where necessary on the events that occurred as the round was in progress. Clarification was sought only at times where the appropriate staff could provide it without distraction to their main tasks. This ensured minimal intrusion during the medical assessment of patients. As the round continued, notes were recorded on all events that transpired, including most clinical discussions that occurred, either within the shadowed team or directly to the author. As the events occurred at a time where the primary focus of the research was not finalised, this phase was necessary to acquire a series of discussion points derived from the data. Ultimately, this culminated in the

development of the project's primary topic, initially conceived from comments provided by the leading consultant of the first ward round observed (which is clarified further later in this thesis). Overall, data were gathered from a variety of sources spanning an 18-month period. Each of the sources is listed briefly in Table 3.1 and later expanded in detail across Chapter 3 and Chapter 4.

Table 3.1 - Observational Data Sources

Source	**Description**
Medical Training Environments	Preliminary lectures on HF and the benefits of simulation training Hands-on introductions to simulation technology (such as the SimMan instrumented mannequin series detailed further in chapter 2) Simulated scenario sessions, viewed from both a "concealed" simulator control room and a session debrief room with other attending participants Scenario debrief sessions for each participant (often referred to as 'after action reviews', or AAR, it is another element discussed in chapter 2).
Clinical Staff	Face-to-face audio-recorded interviews with clinical staff and educators with varying levels of experience and grades Presentation of project progress to, and feedback from multiple members of training faculties Questionnaire responses.
ICU Ward	Shadow and observe a ward round carried out in a ICU Query staff in attendance if opportunity allows
Clinical Supervisor	Meetings with clinical supervisor to clarify medical terminology, assistance with questionnaire wording and guidance on ICU environment.

3.3 Observation Overview

3.3.1 Queen Elizabeth Hospital Birmingham

Structured observational research of two ward rounds was conducted within the Intensive Care Unit (ICU) at the Queen Elizabeth Hospital Birmingham (QEHB). A full overview, consisting of details of events and findings, is provided in Appendix A. This process involved the author shadowing and recording notes on the clinical team assigned to conduct the ward rounds. Each individual observation was carried out on a separate day, with both sessions commencing in the morning (08:00am). The observation started upon commencement of the handover and ended upon the conclusion of the round, which occurred after the team finished examining the final patient in the ward. Each observational session lasted approximately four hours.

The first session was conducted in the General/Surgical/Hepatobiliary Critical Care Area (‘Area A’) and the second in the Cardiac/Cardiothoracic Critical Care Area (‘Area D’). The primary aim of both sessions was to obtain a clear insight into the daily activities, duties and responsibilities assigned to staff working therein. Identified trends or behaviours were outlined in a report that was used for subsequent discussions with academic and clinical stakeholders.

Also, and with a limited pre-existing level of medical knowledge on the part of the author, this exploratory phase was an invaluable experience and a necessary step to (a) carry out relevant and domain-focused research in this area and (b) to develop credible medical scenarios for

simulation-based testing later. Ultimately, these observational opportunities culminated in the development of the principal research topic and its specific research questions outlined later in this chapter.

After an initial meeting, where an overview of the research and aims were discussed, permission to carry out this observation was granted by Professor Julian Bion – Professor of Intensive Care Medicine at the University Department of Anaesthesia & ICM and a co-opted member of the Council of the Royal College of Anaesthetists, representing the Faculty of Intensive Care Medicine, and Dr Catherine Snelson, Consultant in Critical Care at QEHB.

3.3.1.1 Clinical Supervisor Briefing

As is the case with most observational-based studies, observers are usually trained or "calibrated" prior to data collection to ensure that they can identify and record the event or scenario their study set out to observe or quantify. This process is necessary as it is acknowledged that novice assessors (i.e. those unfamiliar with the setting or observational tools such as OTAS) are vulnerable to producing unreliable or inconsistent data without sufficient training when compared to an expert (Sevdalis *et al.*, 2009; Russ *et al.*, 2012). Training methodology varies between cases. In the case of Morgan *et al.* (2015), the observers completed a two-month training phase to become familiar with surgical procedures and how to record events. In the case of Barach *et al.* (2008), two observers were trained in cardiac surgery theory, observed videotaped cardiac surgery procedures and engaged in discussions on

observational methods with the trainers.

In this scenario, the author liaised with the clinical supervisor in two meetings that commenced prior to the first observational session at the QEHB and was briefed on the ICU environment. This included an overview on the ward round structure, expected attendees, and opportunities to be mindful of that may assist in acquiring any relevant qualitative information as the round was in motion. To further assist the author, the clinical supervisor was also in attendance of both ward rounds. As each round progressed, guidance was given to the author in the form of a quick discussion as the team transitioned from one ward bed to the next. Any relevant question or topic that was raised was communicated during this moment, which resolved issues such as medical terminology or clarification of any instructions issued.

3.3.2 Hollier Simulation Centre

Following the decision to focus on the topic of hierarchical conflict, the author was invited to visit the Hollier Simulation Centre (HSC). A full overview and report on the events encountered is provided in Appendix B. Contact with the HSC had already been established by the author's research supervisor, who had previously collaborated with the organisation. Following the success of the earlier observational sessions conducted within the QEHB ICU, it was felt that a refinement of the emerging training and simulation ideas would benefit from a period of observation at an accredited medical simulation centre. The HSC is an organisation specialising in the training and education of medical staff, students and nurses via the use of (physical)

mannequin-based simulation technologies.

Based at the Good Hope Hospital in Sutton Coldfield, they exploit current simulation technologies, with the aim of providing an interactive and holistic training experience within a safe environment. According to the then Head of Faculty of the Centre, Mr Jonathan Stewart (referred to hereafter as HOF), a retired senior surgeon, the Centre aims to provide participants with a safe, relaxed and open environment. Relevant clinical skills, medical practice attributes and patient communication techniques were not the focus (though participants were required to put these skills to practise where necessary). Rather, attending the Centre is an opportunity to improve clinical skills for the benefit of the trainee and their prospective patients without the fear of failure or repercussion. The Centre training revolved around HF, and a lot of emphasis is placed on the non-technical skills discussed in earlier chapters. In addition, all the training or experiential scenarios carried out at the Centre are based on real data. Therefore, participants are provided with scenarios that are realistic, both common and rare, and are not fabricated.

The first visit to the Centre consisted of a meeting to provide an overview of the project and to discuss its agreed research focus. The meeting also provided an opportunity to meet the Centre staff, undertake a tour of the facilities and to acquire feedback on the design of an early questionnaire draft, under development for a future phase of the research (see Chapter 4). Following this initial meeting, the author was invited to visit the centre as necessary to observe

the training provided to participants.

Six observation sessions in total were carried out at the HSC throughout the summer of 2013. The aim of these sessions, as with the previous QEHB observations, was to obtain data that would provide a full overview of the simulation-based training events, briefing (with training outcomes definition) and debriefing periods, scenario generation examples, and evaluation and feedback techniques that occur at the Centre on a regular training day. In addition, several forms of data were obtained to assist with the project as it developed (these are detailed in Chapters 3 and 4), including video footage of simulation sessions and documentation that provided an overview of scenario content, script and lists of events to be invoked during the play-out of those scenarios. Scenario play-out and review sessions took place in a variety of locations, including a main briefing room, where the participants discussed the events and received lectures, and a simulator control room, from where the scenarios were conducted and videoed. Concealed from the participants by a two-way mirrored glass panel, HSC staff could also remotely control the behaviours of the SimMan mannequins from this room, and relay vocal effects and messages to telephones within the simulated hospital cubicle. Scenarios were observed both from the simulator control room (directly) and remotely from the briefing room, via closed-circuit television (CCTV), with non-simulation participating trainees acting as observers.

The HOF would regularly provide the training in person. Otherwise, training was provided by

senior members of HSC-associate staff from surgical, nursing or medical professions as volunteers. The grades of the participants vary across all grades and professions, including medical students and qualified staff with varying levels of experience.

3.3.2.1 Literature Discussion

The HOF discussed topics concerning HF within the clinical space. This section highlights some of the topics within the literature. For example, The HSC HOF stated that fatigue can negatively affect clinical decision making, a topic that was evident in the literature (e.g. Croskerry, 2002).

The issue of clinical interruptions is widely discussed in the literature. It has been described as a common occurrence (Weigl *et al.*, 2012; Thomas *et al.*, 2014) and is associated with clinical errors (Chisholm *et al.*, 2000; Palese *et al.*, 2009; Westbrook *et al.*, 2010; Raban & Westbrook, 2014), supporting the claims put forward by the HSC's HOF. Westbrook *et al.,* conducting observational research across two hospitals concerning interruptions and medication errors, convincingly demonstrated this association. Of the 4271 drug administrations observed in the investigation, interruptions occurred in 53.1% (roughly 2267) of them. Their results illustrated that each "interruption was associated with a 12.1% increase in procedural failures and a 12.7% increase in clinical errors." An example of a 'procedural failure' was failure to check patient identification (which was the highest failure recorded in the study) and an example of a clinical error was administering the wrong dosage of a drug. Furthermore, Chisholm *et al.* (2000)

conducted observational research addressing interruptions across multiple emergency departments. Their findings, as with the work of Westbrook and colleagues, indicated that distractions are frequent (their results indicated ten per hour), with many participants having to undertake additional workload.

Recent literature involving the training of physicians and nurses that aims to address issues related to interruptions and multitasking currently exists, but with mixed results. For example, Smith *et al.* (2016) conducted an investigation that set out to evaluate graduate staff's task-switching abilities using simulation, a skill that is "a core competency for emergency medicine". Scenario sessions were carried out by trainees at postgraduate level between one and three years of training. As their simulated patient (SP) began to deteriorate, participants were interrupted by an assistant technician and given an ECG reading of another patient requiring attention. Therefore, the participants were required to manage both SPs, provide appropriate treatment and to ensure their recovery. However, of the 91 participants who took part, 79 (around 87%) completed the overall task successfully. Because of the high success rate, the data were not able provide a measurable difference in performance between all participants, and comparisons of skill could not be conducted between those more senior. The authors referred to the scenario content as being compliant with a "level 2 milestone", which is a skill level aimed at less-experienced trainees. This was deemed as the likely explanation for the inconclusive evidence, as the authors believed that the scenario was not overly difficult enough.

Conversely, Thomas *et al.* (2014) produced findings that were more positive. 28 final year medical students took part in a simulated ward round during which 14 of them received extensive, individual and immediate feedback upon completion (the intervention group). The remaining 14 students, the control group, received no feedback. Whilst the ward rounds were in motion, observers deployed several realistic forms of distractions and interruptions, including initiating a telephone call into the ward, triggering a doctor's pager and allowing vacuum cleaners to be used around a patient's bed space. In the first set of ward rounds (before the training had taken place), both groups committed a high number of clinical errors, such as failing to provide an accurate diagnosis and misreading dosage records, resulting in accidental overdose. The amount of errors committed by the intervention and control group were 72 and 76 respectively.

After training was provided to the intervention group, the simulated ward-round process with the same two groups was repeated four weeks later. The simulation training had an overall positive effect on both sets of participants, and a comparable reduction of errors between groups was evident. In the follow-up ward round, the intervention group committed 17 errors and the control group committed 44. In a subsequent and related study, Ford *et al.* (2016) recreated the conditions of Thomas *et al*.'s simulated ward round study with a new set of participants. However, feedback was provided to the whole group at once via the use of a video-recorded debrief rather than individually. The aim of the follow-up was to provide more cost-effective simulation training without compromising the positive educational Thomas *et al.* had

produced. Fortunately, the results of the follow-up, with the revised method of training, successfully repeated the outcomes of the previous study. In addition, the overall cost to carry out such training was reduced (costs were reduced from ~ $186 per student to ~$70).

In surgical settings, distractions and interruptions that occur within the operating room are also associated with errors and typically result in extended surgery times (Goodell *et al.*, 2006; Feuerbacher *et al.*, 2012). Therefore, distraction control in this safety-critical area is essential to achieve a successful surgical outcome (Wilson *et al.*, 2011; Cowan, *et al.*, 2016). Distractions and their association with declining performance of surgical trainees in a simulated environment is discussed and demonstrated in the literature. For example, Pluyter *et al.*, (2010) investigated 12 medical trainees engaging with a VR training simulator (model Xitact LC 3.0). The trainees were required to attempt a laparoscopic cholecystectomy ("keyhole" gall bladder removal) procedure with no distractions (control condition) and then to repeat it under distracting conditions. Distractions were committed via the use of music playing in the background and by observers engaging in non-relevant, social communication with the participants as the procedures were in progress. According to the authors, these distracting behaviours are both common and realistic when working within a surgical environment. Under distracting conditions, the results demonstrated a significant increase in procedure time and error count, in addition to an overall decline in task performance when compared to the control condition. The participants indicated that social distractions were "irritating" whilst carrying out the procedure, therefore increasing overall stress levels. The authors concluded that

simulation-based training can be a beneficial resource for managing distractive behaviours. They stated that:

"Working environment conditions in the operating room and preclinical training programs should cater accordingly by managing social and technological distracting sources and by providing comprehensive, integrated technical and non-technical training programs."

3.4 Discussion

Throughout both observations carried out at the QEHB, as reported in Appendix A, the ICU department was a noisy, active and cluttered environment. As the observational data report highlighted, the medical and nursing staff were very busy, distractions were common throughout and, as with the conflict example, discussions occasionally became confrontational. Distractions ranged from other staff entering the group to clarify an instruction, to members temporarily leaving the group, effectively placing the ward round on hold until they returned.

Although room to navigate through the department was plentiful, the overall space was limited. Multiple corners, including separate rooms, were occupied with assorted items of equipment and furniture (as illustrated in Figure 3.1). Side rooms that once acted as a separate room for patients became storage rooms cluttered with various sized items (including an unused bed). After pointing this room out during the ward first round, a staff member present in the group stated that if there is space available, something will occupy it. This was evident across all

areas of the hospital visited during the project. For example, several interviews as part of the later investigation phase were conducted in the same room discussed.

Figure 3.1 - ICU Side Room Used for Storage

Overall, the observation sessions at the QEHB had proven to be beneficial. Described below in Table 3.2, they aided in identifying several interesting potential areas of research focus. Academic and clinical advisors alike had demonstrated a strong predilection towards Research

Idea 3 of the areas identified, following a series of follow-up discussions, debriefs and meetings. This idea would explore the point raised by the leading consultant's comments regarding issues of conflict arising within medical teams concerning patient treatment. Current research and anecdotal evidence (e.g. the comments provided by the leading consultant) concerning the ability to assert had suggested it is a fundamental skill in providing optimal healthcare. A breakdown in this form of communication, as evinced by Calhoun and colleagues' research, can negatively affect patient mortality rates and is, therefore, required to maintain patient safety (Leonard *et al.*, 2004). In addition, the early debriefs following the observations had coincided with the publication of the Francis Enquiry. The publication's content previously discussed highlighted a major breakdown in communication and incidents that were not being challenged or reported. Therefore, it presented a controversial issue of importance that had garnered interest in the medical community. For example, as the later section of this chapter will highlight, the Francis Enquiry was commonly referred to either verbally by clinical educators or as part of presentation material.

Table 3.2 - Early Conceptual Ideas Addressing Potential Simulation Solutions for Key Training Needs

	Note	**Comments**	**Project Idea**
1	Bed management concerns	There is, throughout the NHS, a major concern relating to the issue of bed management. As the wards are limited in the number of patients that can be admitted, there is a constant worry of insufficient bed counts to occupy patients. In extremis, patients are temporarily relocated to different wards until they can be moved back to their original or intended location. This can cause stress with staff and can, potentially, cause management issues.	An interactive (e.g. VR) bed management/triage simulator that portrays a ward in top-down ("exocentric") view. The user would assign beds to patients as they arrive, taking care to ensure patients with more severe illnesses are given priority and that others are allocated to other hospital locations better suited to their immediate medical needs.
2	Drug prescription management.	A computer running patient management software would occasionally accompany the staff throughout the ward round. During the first observation described in this thesis, there were some issues of mismanagement of drug prescriptions. In this case, drugs that were given according to the software differed from what the patient received.	A drug management simulator. Users could assign drugs for treatment as they progressed on a virtual ward round whilst taking care to highlight any discrepancies or allocating the wrong type of medication.
3	Decisions for treatment are encouraged to be challenged.	During the second observation, the lead consultant stated that it is beneficial for decisions of further treatment to be questioned and/or challenged when discussions occur during the ward round. This helps to ensure that the appropriate course of treatment is always given the patient.	An interactive (e.g. VR) simulator presenting users with ward-based scenarios in which they are required to challenge the decision(s) made by members of their team to prevent a negative outcome to a virtual patient.
4	Distractions	Frequent distractions occurred throughout both observation sessions. Some of these were subtle and did not affect the patient observation/assessment. However, some distractions interrupted the inspection, with members of the group occasionally leaving. Distractions included members of staff interjecting the inspection, physical obstructions to movement within the cubicles or patient bed areas and members of the group dispersing and having to leave the immediate area temporarily.	An interactive (e.g. VR) simulator where the users assume the role of a junior medical doctor or nurse in a first-person ("egocentric") view. When requested to assess a patient, within a specified amount of time, random events attempting to distract them would occur throughout the scenario.

5	Communication.	Research discussed in the Introduction had indicated that effective communication between staff throughout the ward round is essential and contributes to maintaining efficiency and patient safety. A breakdown of communication can introduce complications that trigger various complications, either immediately as the breakdown occurs or much later.	An interactive (e.g. VR) simulator in which users observe a series of avatars, representing medical staff assessing a patient. The users would be tasked to highlight moments where communication has ceased and an error has occurred consequently.

However, preliminary research related to the issue of challenging decisions and hierarchical conflict was initially required to justify proceeding with this topic. As previously discussed, studies that review conflict, including hierarchy-related scenarios, in healthcare settings and across multiple countries and sectors were not uncommon. The 'message' from the literature (for example, Saltman *et al.,* 2006), was that conflict within teams, and not just teams within healthcare settings (e.g. aviation; Helmreich & Davies, 1996), is primarily a negative experience. It harms team management skills and communication, and is directly linked to the safety and well-being of others, be it a patient, co-worker or, as shown in the literature on CRM, a commercial flight passenger. Furthermore, apart from Calhoun's publications, literature and training that *specifically* focused on the use of simulation to address hierarchy-related issues in a medical environment was lacking, a trend also discovered from further investigation into this area (see Chapter 2). Therefore, further discussions with academic and clinical supervisors regarding this subject, and a review of the relevant literature, culminated in the development of project Research Question 1 (Section 1.1.1.1).

The aim from this point in the research onwards, then, was to build upon the medical team conflict evidence gathered from the literature combined with the anecdotal evidence acquired from the observational data. To achieve this, the method decided upon to collect further evidence in a structured subjective manner consisted of developing appropriate content for a questionnaire and face-to-face interview. Questionnaire administration and interview organisation would be carried out at the QEHB under the supervision of the clinical supervisor, Dr. Charlotte Small – Specialist Registrar (Year 5; ST5) Anaesthetist (QEHB), further assisted by Dr. Katherine Laver – Specialist Registrar (Year 5) Anaesthetist (QEHB). The aim of the questionnaire was to obtain quantitative information on a participant's role within the Trust and to acquire data concerning their views on challenging a decision (including if they agree that challenging decisions is an essential skill for medical personnel to develop). After completing the questionnaire, the participant would take part in a recorded interview for acquiring further qualitative information, including asking the participant to recall an example of a scenario where a decision was challenged, and to record their opinions on the use of simulation training in healthcare. This phase of the research was supported by further observational activities undertaken carried out at another medical organisation (See Section 3.3.2).

With evidence to support the claims made by members of the medical community engaged thus far, a secondary aim of this research phase was to utilise any findings to undertake a study that would support the development of a cost-effective, distributable training technique, possibly based on current-generation Virtual Reality (VR) and/or associated interactive multimedia

technologies. Such a development, it was felt, would provide an effective and engaging method of supporting the empowering of a wide range of medical personnel, equipping them with a risk-free technique to rehearse the challenging of decisions they feel are inappropriate. Such an approach would also, it was argued, help to raise the awareness of senior medical personnel to the importance of encouraging and dealing sensitively with such challenges. Some of the early possibilities developed from the investigations up to this point are also summarised in Table 3.2.

The observational sessions conducted at the HSC provided insight into alternative approaches to training medical staff and students. The participants observed within the observation timeframe seemingly found their experiences enjoyable and beneficial, based on their verbal and informal responses in the various debrief sessions and discussions. The HSC training styles and delivery methods emphasise a holistic and affable approach to medical skills and teamwork teaching, essentially deviating from more traditional methods of classroom-based education. Halamek *et al.* (2000), in a study that assessed the use of high-fidelity simulation to assist paediatric training, stated that classroom settings lack "the multiple cues found in dynamic, complex, technical domains." According to the authors of this study, these cues include auditory events such as crying, breath sounds and heart tones, and visual events such as skin colour, all of which can occur within normal working environments. Furthermore, Davis *et al.* (2013) conducted a study that evaluated the use of similar simulation techniques to complement traditional classroom-based, lecture style settings for advanced cardiac life support training

(ACLS). Despite some mixed outcomes, such as the simulation phase of the study not significantly enhancing the cohort's ACLS skills when compared to the lecture, they presented overly positive results, such as higher overall student satisfaction when engaging with simulation. The outcome of the Davis *et al*. study suggested that simulation elicited a positive response and helped maintained trainees' confidence and satisfaction with ACLS skills training when complimented with lecture-based, classroom settings. Further research into similar areas also reveal positive results. In one case, Chin *et al.* (2014) compared the use of simulation with 'case-based' learning (CBL) for pharmacist training. CBL involves small groups working together to solve a presented problem (Dupuis & Persky, 2008). Chin's findings indicated that simulation sessions "appeared to be more effective in improving student understanding and knowledge retention compared to CBL sessions" in addition to increased satisfaction and critical-thinking skills among the cohort.

However, one issue that was discussed during the sessions observed at the HSC was that some participants (no exact figures were recorded) struggled with demonstrating an active suspension of disbelief. Referring to Calhoun's studies (Calhoun *et al.*, 2013; 2014), where simulation was evaluated as a method to reduce hierarchical conflict within medical teams, the authors addressed issues related to suspension of disbelief. They addressed the issues via discussions with the participants concerning the realism of the scenarios and assessing whether they invoked the stressful emotional responses typically experienced within medical crises. Assessing the suspension of disbelief was essential to accurately measure the impact of the

scenarios on the participants. Presenting as a potentially serious limitation in simulation technology, Halamek *et al.* (2000) stated that effective simulation-based training is achieved when trainees can successfully suspend their disbelief, a process that is "necessary" (Collins & Harden, 1998). They state: "subjects must be made to think and feel as though they are functioning within a real environment." If the participants observed failed to achieve a suspension of disbelief, it may have effectively skewed their perception, performance and, ultimately, they may have been unable to obtain the most they could have done from their training programme.

3.5 Conclusion

This chapter provided a full overview of the observational process carried out at a real and simulated ward round environment. Where the observations carried out at the QEHB ICU defined the topic of the research, the HSC observations provided an overview of how an alternative method of training is delivered to both medical students and qualified medical staff using SPs.

3.5.1 Findings

3.5.1.1 Observational data indicated trainees to be hesitant

This finding was based on the observational research conducted at the HSC. Mainly, the first scenario and subsequent video recorded sessions (Session A) discussed in the thesis was not rated highly by the Centre staff, as issues with communication, assertiveness and teamwork was evident throughout.

3.5.1.2 Timing of a challenge is unclear, and how it should be issued

The Francis Report (FR) recommended that employees not only consider reporting an incident with regards to patient safety, but "insist on it." In addition, the HSC recommended that challenges also be issued immediately as the situation occurs to resolve the situation quicker. It was not possible to identify the optimal moment to issue a challenge to secure a more desirable outcome as the current research regarding this was limited.

3.5.1.3 Team conflicts can become confrontational

An incident recorded during the second observation at the QEHB consisted of the leading consultant becoming visibly irritated concerning an apparent mismanagement of drug administration for a patient. Though he did not act aggressively, his colleagues did not immediately respond, creating a moment of silence before resuming the patient inspection.

The next step was to conduct further investigations at the QEHB to compile both quantitative and qualitative data. The purpose of this phase was to analyse any data acquired and evaluate the research questions discussed in Chapter 1.1 Research Questions.

Chapter 4 Initial Investigation

Initial data collection phase conducted at the QEHB comprising an opportunistic sample of staff members of varying clinical experience who were required to complete a questionnaire and to take part in a recorded interview.

4.1 Investigation Methodology

The overriding 'message' from the anecdotal evidence and findings obtained from the literature and evidence collated during interactions with subject matter experts (SMEs), together with the early institutional observations, served to confirm that demonstrating assertiveness assists in achieving a high level of situational awareness (SA) in medical and healthcare settings, by minimising the likelihood of error. To evaluate this theory in both clinical and ward round settings, a further investigation was conducted at the QEHB over a nine-month period. The investigation consisted of primary research that sought to generate data in support of the research questions discussed in Chapter 2. This was achieved via the acquisition and analysis of both quantitative and qualitative information with the aim of affirming, or nullifying, the 'challenging decisions' theory.

The method in which this information was obtained involved recruiting several participants (an opportunistic sample) to complete a preliminary questionnaire, described in detail later

(Section 4.2), but, in brief, designed to obtain quantitative data to establish the importance (or lack of importance) of challenging clinical decisions. Having been compiled with the invaluable input from clinical SMEs at the QEHB and the HSC, it was designed to establish attitudes to, and experiences of, challenging clinical decisions. Anecdotal evidence obtained for Research Question 2 suggested that, by developing the ability to challenge clinical decisions, improvements in individual and team situation awareness may be observed. Further discussions with academic and clinical advisors, assisted by research findings, defined an initial set of research aims (listed in Table 4.1), the aims of which were not only to discover whether it is important to challenge decisions, but also to identify some of the common explanations for doing so. This is in addition to obtaining statistical data relating to staff who challenge a decision, such as their gender, level of experience and medical grade, to identify any trends. For example, the data may illustrate those with a higher level of experience have rated their confidence to challenge a decision highly.

Table 4.1 – Investigation Research Aims A-I

	Research Aim	**Description**
A	Discover whether challenging decisions is an important factor to providing optimum levels of healthcare.	The SMEs interviewed and the results of Calhoun's earlier studies (Chapter 1) indicated that it is important to challenge decisions to provide efficient healthcare. Primary research was required to support this theory.
B	Discover the reason(s) behind challenging any kind of clinical decision.	Okuyama *et al.* (2014) indicated that explanations behind challenges can vary depending on the situation, but assertive communication is always done so for the benefit of patient safety (Leonard *et al.*, 2004; Lyndon *et al.*, 2012). This includes avoiding missed diagnoses, rule breaking or poor clinical judgement. Because of this finding, it was predicted that patient safety would be the primary outcome of this aim.
C	Discover when best to challenge a decision after it is made, and how best to do so.	The research findings, including the Francis Report (FR), have suggested a challenge can be issued at varying moments, including immediately as the situation occurs or privately after the event.
D	Discover some of the contributing factors that either positively or negatively impact a person's decision challenging ability.	HF research had demonstrated that areas such communication and leadership are associated with error. Furthermore, anecdotal evidence provided from HSC staff suggested that more personal issues, such as fatigue, contribute to error.
E	Discover alternative approaches to challenging, such as events where an unsatisfactory response was given or what prevents a challenge from being issued.	Data were required to establish reasons for not following through with a challenge if, for example, it was both necessary and justified. This could be attributed to experience or knowledge (see aim F). It would also assist in identifying alternative approaches in the event of challenges being rejected.
F	Estimate staff decision challenge ability and confidence levels to issue a challenge to others at different levels in the medical hierarchy.	The ability to challenge a decision could be associated with clinical experience. Findings from the HSC observational data indicated trainees to be hesitant and less assertive than a more experienced, or senior, member of staff. Therefore, sufficient evidence was required to support this.

G	Recruit and acquire statistical data (e.g. profession, gender, years qualified) from participants from as many different positions and professions within in the medical hierarchy.	In addition to Aim E, this would assist in identifying any trends present within the overall data that could be attributed to, for example, gender or experience.
H	Discover if participants have previously received a form of training that targeted the management of hierarchical conflict or the development of assertiveness.	Evidence to support this aim could suggest how prevalent conflict resolution, assertiveness or decision challenging training is.
I	Identify other sources of training that targets assertiveness, challenging decisions or conflict resolution.	If participants have received a form of training, it was important for them to clarify what this training consisted of. Any identified sources would assist with further research in this area.

Following the questionnaire, the second phase of the recruitment sought to develop more qualitative data, focusing on the simulation aspect of medical education and training via a recorded face-to-face interview. The primary aim of the interview was to discuss past situations (causes, perceived risks, challenges, patient outcomes, challenger outcomes, etc.) that prompted the participant to challenge the decision(s) made by a co-worker within their group. There were no limitations to the scenario that could be given, if they accurately described the events leading to the challenge; clarified who it was they challenged and why; clarified if the outcome was altered based on the challenge; and stated whether they were satisfied with the eventual outcome. They were also asked to include any post-challenge events arising from the scenario (such as professional or personal disagreements). However, the interview also sought to obtain participant views on simulation training in healthcare, and whether they agreed that a

simulation course dedicated to assertiveness training would be a beneficial resource to clinical staff. Furthermore, it set out to obtain current opinions on simulation training in healthcare and whether they had been exposed to simulation at any point during their careers and training.

Ultimately, this investigation would produce supporting data that would help to determine whether further research, evaluating the adoption of VR-based simulation technologies as a solution to enhancing trainee decision-making abilities, was a valuable way forward. Various literature sources had already provided insight as to how simulation technology is a viable tool for both assessing performance level and training personnel from various sectors (as described in Chapter 2). This included medical, military and the aviation sectors. Both the quantitative and qualitative data obtained in the present research would also be used to influence the presentation ("look and feel") of the simulator, drawing on the challenge scenario examples provided during the interviews for simulator design and content development. This would include scenario content ("storyboard"), virtual characters encountered within the environment and roles that those characters would play, including staff members and personal relations (family and/or friends). The aims of the second part of the recruitment process are listed in Table 4.2.

Table 4.2 - Investigation Aims J-T

	Aim	**Description**
J	Collect a series of scenario examples where staff were prompted to challenge a clinical decision or event occurring within their areas of work.	Many examples of scenarios involving a decision being challenged provided insight into the impact of challenging, highlighting events occurring both before and after the challenge, and any consequence of the challenge, both negative or positive. This also assisted in the development of content for a unique scenario in the later simulator development phases.
K	Identify the roles of the person(s) challenged in the scenarios, and list common explanations for challenging.	The findings in the literature related to hierarchical conflict suggest that confrontations occur primarily between a trainee and a senior member of staff. However, research into the literature and early project observations have also shown that conflicts can occur within a group comprising varying grades. Evidence to support this aim identified the individuals most challenged and influenced the grades of the virtual medical characters, ultimately to be represented within the simulator.
L	Discover if challenges are usually positively or negatively received.	Calhoun's first investigation (Calhoun *et al.*, 2013) portrayed senior staff members as confident and defensive of their decisions. However, the leading consultant of the first observation described herein, at the QEHB, both welcomed and encouraged the questioning of his decisions. Therefore, sufficient data for this aim would provide insight into how challenges are received and why.
M	Discover if outcomes are altered based on the challenge.	It was assumed that team members would intervene where possible to prevent a negative outcome for a patient. Data to support this aim indicated whether challenging can impact the outcome of a scenario.
N	Discover if staff are satisfied with eventual outcomes after challenging.	Further from aims K and L, it was hoped that the data would suggest explanations as to why scenario outcomes were positive or negative.
O	Discover if participants receive a form of feedback after their	Most the literature examined (Chapter 2) together with the early observational findings (Chapter 3), focused primarily on the initial conflict. Data to

	challenge scenarios or whether further action is taken.	support this aim would provide insight into 'what happens next' when a conflict occurs, and what consequences, if any, they bring.
P	Discover if participants consider the process of 'challenging a decision' to be a difficult task to carry out.	Building on Research Aim D, data to support this should expand beyond the responses predicted in the questionnaire and instead provide a personal account of a participant's decision challenge process.
Q	Discover if participants were aware of current public events and literature that involved issues with unresolved conflicts (for example, the Francis enquiry), and whether these resources affected their clinical practice.	The FR was widely publicised via newspapers, television reports, medical training (frequently referred to in the HSC lectures) and various websites. Data to support this aim would provide insight into current views of such publications, and whether they have made an emotional or professional impact on staff in terms of their decision challenge abilities and general practice.
R	Discover if, and how frequently, medical staff have been exposed to a form of simulation training.	Research findings (Chapter 2, Section 2.5) have indicated that simulation training, including VR, is prevalent within various sectors, including medical and military and aviation. The research has also demonstrated a link between these sectors in terms of training approaches and methods (for example, how CRM was adapted from aviation for exploitation in medical settings). Data to support this aim would determine how simulation is utilised, discover how widespread it is and identify any other relevant training programmes or technologies.
S	Discover whether medical staff consider simulation training to be a beneficial resource within healthcare.	Leading on from aim R, it was essential to determine how desirable simulation is in the medical trust investigated and to identify whether it is positively received (and if not, why not).
T	Justify the development of the VR simulator concept as a possible tool for hierarchical conflict training.	To continue with the VR concept as a possible future training solution, useful data from each previous aim was required. This is especially so for aims R and S.

The recruitment process lasted some 7 months and invitations to participate were distributed throughout many levels of the healthcare employee hierarchy, with the aim of attracting those who possessed clinical and ward round experience. The expected employee grades accompanying positive responses to participate ranged from medical student through to consultant level, which would provide a wide varying set of perspectives within the hierarchy. Participants were recruited under the aegis of clinical supervisors attached to the project, who were responsible for approaching staff members working within the hospital and politely requesting their participation.

However, it was not known how many participants could be recruited at any one time in addition to uncertainty with the clinical supervisors' availability. However, Roscoe (1975) recommended that a minimum sample size of 30 is appropriate for most research. Therefore, an initial target of 30 responses was set, both complying with statistical significance and ensuring plenty of time to achieve said target.

After the target number was met, further participant recruitment opportunities available within the timeframe would be pursued. The recruitment process concluded once the participant count reached 50. There were no plans to exploit any external or public methods of recruitment, such as posters or letters, and participants were invited to take part on a voluntary basis. Participants were also provided with a detailed consent and participation form (Appendix A) before commencing the study. These forms clarified the aims of the project and assured that their

participation was voluntary, anonymous and confidential, and that they were free to withdraw after a set amount of time.

Questionnaire administration and interviews took place at the QEHB under the close clinical supervision of Dr. Charlotte Small – Specialist Registrar (Year 5; ST5) Anaesthetist (QEHB) and Dr. Katherine Laver – Specialist Registrar (Year 5) Anaesthetist (QEHB). The NHS sponsor for this research was Professor Julian Bion – Professor of Intensive Care Medicine at the University Department of Anaesthesia & ICM and a co-opted member of the Council of the Royal College of Anaesthetists, representing the Faculty of Intensive Care Medicine.

4.2 Questionnaire Design Methodology & Content

The questionnaire content (Appendix D) was subjected to several iterations and adjustments to optimise the content. The base content and presentation of the questionnaire was developed in collaboration with clinical supervisor, Dr. Charlotte Small, which was then revised numerous times following research into effective questionnaire design methodologies. Based on this research, the following sections highlight the design choices for the questionnaire.

The content of the questionnaire was developed in a format that saw smaller and simpler questions, such as questions that required the participants to only circle an answer, presented first to better ease the reader into completion (Burns *et al.*, 2008).

An initial pilot test was conducted involving an opportunistic sample of ten participants taking part in the study (including the interview) which culminated in further revised content. According to D. H Stone (1993) and Burns *et al.*, (*op cit.*), a pilot test is required to identify and resolve design faults. An example revision based on the pilot test responses was the final question (Question 8). Participants were originally requested to provide an answer for two separate boxes in response to terminology that was evidently confusing, as three participants simply repeated the example answers that were displayed in the question body and a further three participants left at least one of the boxes blank. Therefore, the question was simplified from two text boxes to a single text box, and the question body was re-phrased to avoid confusion (with example suggestive answers also removed from the text).

Additional input had also been provided by project clinical stakeholders Mr. Jonathan Stewart and Prof. Julian Bion and academic advisors. Collaboration with these third parties had ensured that the content was relevant, and displayed in the correct internal "language". The final content within the document was condensed and distributed across two pages in accordance with research conducted by Kellerman & Herold (2001), whose study suggested that shorter content (i.e. one or two pages) had a positive effect on response rates.

Following the series of revisions, the final content (Table 4.3 and Table 4.4) of the questionnaire was designed to obtain quantitative data to establish the importance (or lack of importance) of challenging clinical decisions whilst highlighting any trend(s) within the statistical data (e.g.,

comparing challenge confidence values with gender, experience, and professions/grade). It also sought to generate data to clarify the underlying mechanics surrounding the decision challenge process (such as how, when and why do you challenge a decision). Finally, it sought data to identify some of the factors considered when forming and attempting a challenge, including those that otherwise prevented the challenge from being issued.

Table 4.3 - Questionnaire Quantitative Data (Research Aim G)

Question Body	**Description**
Profession	Participants would state if they were a Doctor, Nurse, Student, Surgeon or of any other related primary medical profession.
Grade	From the above, the participant would state their current grade. For example, medical student year 5 or speciality trainee year 7.
Speciality	Regarding their profession, the questionnaire requested their speciality. For example, a speciality trainee could specialise in anaesthesiology (pain relief for surgical operations) or cardiology (study of diseases associated with the heart).
Number of years qualified	Participants would state the number of years they have been qualified in their profession. The results of this question could demonstrate a link to challenge confidence, supporting Research Question 3: Is the ability to successfully challenge a decision associated with clinical experience?
Number of years at current post	Participants stated the number of years they have been working at the QEHB. It was stated that staff are frequently assigned to multiple trusts.
Country of training	The QEHB attracts medical staff from a diverse ethnic background. Research has shown that assertiveness can vary between world cultures, and this may be reflected in the results; hence the question.
Military	Participants would clarify whether they were military. Responses to this question could be compared with other elements, such as level of experience and challenge confidence.
Gender	Direct comparisons between genders would be achievable with these data.

Table 4.4 - Investigation Questionnaire Content and Research Aims Met

	Question Body	**Answer Type**	**Aim**
1a	Is it important to challenge clinical decisions?	Circle Yes/No.	A
1b	Regarding 1a, why?	Text box.	B
2	On a Likert scale of 1-5, with 1 representing not very confident and 5 representing very confident, how confident are you to challenge the decisions made by staff of the following positions?	Likert Scale (1-5) for a series of grades categories: Consultant Speciality Trainee 5-7 Speciality Trainee 3-4 Core Trainee 1-2 Foundation Year 2 Foundation Year 1 Medical/nursing Student Nurse – Band 6 and above Nurse Band 4-5 Clinical support worker Allied Health Professional. Optional box for comments.	F
3	On a Likert scale of 1-5, with 1 representing not very confident and 5 representing very confident, how confident were you to challenge any decision throughout your previous grade/tier?	Likert scale (1-5) representing participant challenge confidence. Optional text box (for each option) for comments.	D, F
4	How would you rate the following methods of challenging, with 1 being not very important and 5 being very important?	Likert Scale (1-5) representing a series of methods to challenge a decision: Immediately, and overtly in front of others who are present at the time. By attracting attention discretely. By attempting to engage in a private discussion. By seeking assistance from a staff member outside of the group By forming a huddle to ensure everyone in the team are involved in the challenge.	C

5	What would you do if you did not receive a satisfactory response to your challenge?	Text box.	D, E
6a	Have you received any training in assertiveness or how to challenge the decisions of team members?	Circle Yes/No.	H
6b	If so, how did you receive this training?	Text box.	I
7	What might stop you challenging a member of a team?	Text box.	D
8	What factors do you feel affect your ability to make a challenge?	Text box.	D

4.2.1 Question 1

"Is it important to challenge clinical decisions?" ... "Why?"

Question 1, which asks whether a participant agrees that challenging decisions is important, required either 'Yes' or 'No' be circled. Then, participants were required to state their reason(s) for their response. Both research into the literature and observational investigations had made it evident that, above all reasons stated, patient safety and reduced medical errors are the highest priority (e.g. Leonard *et al.*, 2004; Lyndon *et al.*, 2012; Okuyama *et al.*, 2014). Therefore, it was very likely that patient safety would be given. This question targeted Research Aim A, and contributed to supporting Research Question 1.

4.2.2 Question 2

"On a Likert scale of 1-5, with 1 representing not very confident and 5 representing very confident, how confident are you to challenge the decisions made by staff of the following positions?"

Question 2 also contributed to Research Question 1 and targeted Research Aim F, which sets out to establish the level of confidence of the participants who took part in the study. With the assistance of the clinical supervisor, participants were presented with the following established list of employee grade categories that encompassed all positions of staff within the trust:

- Consultant (senior)
- Speciality Trainee (ST) 5-7
- Speciality Trainee (ST) 3-4
- Core Trainee (CT) 3-4
- Core Trainee (CT) 1-2
- Foundation Year 2 (FY2)
- Foundation Year 1 (FY1)
- Medical/Nursing Student
- Nurse – Band 6 and above (senior)
- Nurse Band 4-5
- Clinical Support Worker (CSW)
- Allied Health Professional (AHP)

The AHP category brought together 'miscellaneous' staff professions such as psychiatrists and social workers. The CSW category consisted of support staff, such as clinical audit clerks, 'scrub' nurses (who handle sterile equipment while assisting a surgeon) and healthcare assistants. For each category, participants were required to circle a number on a Likert Scale

that represents their confidence to challenge that grade. The following list clarifies the values on the scale:

1. ‘Not at all confident’
2. ‘Not confident’
3. ‘Somewhat confident’
4. ‘Confident’
5. ‘Very confident’

The final element of question 2 consisted of an optional text box, labelled as “any exceptions?”, in each row for comments. These text boxes permitted a participant to add any exceptions where their confidence to challenge a grade could be irrelevant. For example, it could be possible that a participant, who rated their confidence to challenge a consultant as ‘2’ (‘not confident’), may identify a staff member of the same grade they know personally. Therefore, their confidence may not be a factor when challenging (or questioning) this staff member’s decision or behaviour due to this relationship. Conversely, a participant may rate their confidence to challenge an ST5-7 employee as ‘5’, but may identify a member of staff of the same grade who they are reluctant to challenge. Therefore, participants were encouraged to list any exceptions where possible to account for these scenarios.

4.2.3 Question 3

“On a Likert scale of 1-5, with 1 representing not very confident and 5 representing very confident, how confident were you to challenge any decision throughout your previous grade/tier?”

Following Question 2, the questionnaire then requested participants to state their 'overall' challenge confidence throughout their previous grade/tier. For example, an FY1's previous grade would be medical student and a ST 5-7 would list their previous grade as ST 3-4. This question was condensed to a single Likert Scale, as opposed to repeating the grade categories listed in Question 2, to keep the content minimal and avoid creating more pages. This question aims to support Research Question 3, that the ability to challenge decisions could be attributed to gaining clinical experience as a staff member progresses up the hierarchy. Based on this hypothesis, it was predicted that the results for Question 3 would demonstrate a decline in challenge confidence when compared to the current challenge ability (Question 2).

4.2.4 Question 4

"How would you rate the following methods of challenging, with 1 being not very important and 5 being very important?"

Aiming to support Research Aim C, this question was developed to establish the best method in which to issue a challenge. On a Likert Scale of 1 to 5, with 1 representing not important and 5 important respectively, participants were required to rate the importance of a series of different challenge methods, listed in Table 4.5.

Table 4.5 - Questionnaire Challenge Method Options

Method	**Description**
Immediately, and overtly in front of others who are present at the time.	Championed by the HSC, their HOF stated that conflicts are quicker to resolve when challenged immediately. This method was also utilised in Calhoun's investigation, with the simulated patient (SP) coming to severe harm if an intervention was not issued in time.
By attracting attention discretely.	Observations at the QEHB had shown that members of the team sometimes disconnect from the main cohort, forming their own group. Although the nature of these groups was not clarified, this could be an opportunity to raise concerns of a patient or another team member more privately.
By attempting to engage in a private discussion.	As evidenced by the Francis enquiry, private discussions in a secure environment and under formal settings could be an important method to issue a challenge, preserving anonymity if needs be.
By seeking assistance from a staff member outside of the group.	Observations at the HSC, based on discussions concerning the Francis enquiry, indicated that escalating to a more senior member of staff could be an important method to issuing a challenge, if a direct approach was not successful.
By forming a huddle to ensure everyone in the team are involved in the challenge.	Not based on any findings in the research literature, this method was suggested by the HSC's HOF. The theory behind this method is that a challenge should be issued in front of all those involved in the team, but away from the patient.

4.2.5 Question 5

"What would you do if you did not receive a satisfactory response to your challenge?"

Calhoun *et al.* (2013) and Pian-Smith *et al.* (2009) adopted the 'two-challenge' rule within their respective studies, a method that empowered trainees to issue an additional, sustained challenge if their first attempt was unsuccessful. Pian-Smith's results, after evaluating the method in simulated surgical training settings, produced positive, though limited, results. Nevertheless, use of the two-challenge rule had shown increased performance in communication skills. Based on these findings, it was predicted that participants at the QEHB would repeat their challenge. However, building on Question 4, it could be possible that participants may redirect their concerns to another, possibly senior, member of staff.

4.2.6 Question 6

"Have you received any training in assertiveness or how to challenge the decisions of team members?" ... "If so, how did you receive this training?"

Participants would circle either 'Yes' or 'No.' Attached to this question is a text box that requires the participant to clarify what this method of training consisted of. Other than some of the studies already discussed in detail in this thesis, literature that focuses on developing the ability to challenge clinical decisions in ward round settings are limited. Therefore, this

question sets out to discover whether staff at the QEHB have received a form of training that focuses on, or features assertiveness and, if so, what this training consisted of.

4.2.7 Question 7

"What might stop you challenging a member of a team?"

This question set out to identify factors that may prevent a challenge from being delivered. Based on the literature, it was predicted that responses concerning seniority may be given.

4.2.8 Question 8

"What factors do you feel affect your ability to make a challenge?"

Participants would use this question to list factors they think would identify, or perhaps suggest, the main barrier(s) that decide whether a challenge is carried out or not in as much (or little) detail they would care to provide. Example responses predicted, although based on the anecdotal evidence provided by SMEs, included stress, fatigue and, based on the research concerning HF, communication and teamwork skills.

4.3 Interview Design Methodology & Content

The recorded interview process commenced immediately after the questionnaire was completed. Whereas the questionnaire mainly obtained basic statistical data, the objective of the interview was to obtain qualitative data, split across two topics. The first topic in the interview consisted of participants providing a scenario where they were prompted to challenge the decision, or event witnessed, of a co-worker within either their team or working environment (examples are detailed in Section 4.5.2). They were requested to provide as much detail as they could when attempting to remember and clarify the role of the staff member challenged. Then, the questions listed in Table 4.6 (and in Appendix E) below sought information concerning the eventual outcome of the scenario and whether they were satisfied with their challenge, and if their intervention resulted in an altered outcome in their favour. The second topic set out to capture their views on simulation training in healthcare, seeking information on their experience of simulation technologies, and a brief overview of courses undertaken or technologies interacted with.

Each interview was recorded via the use of a battery-powered voice recorder that was placed in between the participant and author. The pilot test conducted before the investigation (Section 4.2) commenced had shown that both interviewer and interviewee voices were recorded clearly with minimal noise, including a test with participants sitting a large distance from the interviewer. After each interview was recorded, the records were transcribed and kept in a

separate document. As well as the recorded material, notes were written on an accompanying document, to minimise any risk of data loss.

Table 4.6 - Investigation Interview Content and Research Aims Met

	Question	Description	Aim
1	Do you recall a recent scenario that has prompted you to challenge the decision or event?	Participants were requested to provide an account of a recent scenario that prompted them to challenge a clinical decision or incident. Although the scenarios acquired were later used for developing unique content for the VR simulator project, they were analysed to provide further insight into team conflicts. Despite most articles on the topic, it was found that team conflicts are not limited to seniority, as shown by the Manojlovich, & DeCicco (2007). Therefore, this was a potential opportunity to collect further data to support this finding. Depending on the amount of detail provided, an example challenge scenario could support most research aims, listed in the column to the right.	A, B, C, D, E, F, J, K, L, M, N, O, P
2	What was the role of this particular staff member?	The participants were asked to clarify the role of the staff member challenged. Role positions were placed into the hierarchy categories listed in Question 2 of the questionnaire. This question builds on the findings of Interview Question 1.	K
3	Was the outcome of your challenge positive or negative?	It was important to establish whether challenging a decision produced a positive outcome or initial response in the eyes of the interviewee. Evidence that suggests that challenging a decision is likely to produce positive outcome or response would further support the importance of assertiveness, as emphasised by clinical educators and authors of relevant literature.	L
4	Was the outcome altered based on your challenge?	The interview requested that the participant clarify whether their challenge had altered the outcome of the given scenario in their favour. Following on from the previous question, it was also important to discover how a challenge could affect the outcome of a scenario. As evidenced in the literature, particularly in Calhoun's investigations, an intervention in the form of a challenge can prevent adverse, even fatal, events. Evidence that suggests a challenge can alter	M

		an event in the challenger's favour would further support the importance of this method of intervention.	
5	Were you satisfied with the eventual outcome?	Each participant was asked to clarify whether the eventual outcome of the scenario was positive. Evidence that suggests challenging a decision is likely to produce a satisfying conclusion to an event or conflict would further support the importance of assertiveness.	N
6	Did you receive any feedback from the staff member challenged?	The FR had recommended that feedback be given to all staff following any incidents reported (Francis (2013); Executive Summary, p.86). However, it was not clear from the research conducted if staff or trainees receive feedback unrelated to the initial response following a challenge. This question set out to clarify this uncertainty.	N
7	Was further action taken as a result of your challenge (i.e. disciplinary or perhaps personal disagreements between you and said staff member)?	Following on from the previous question, these data may identify examples of consequences due to challenging and conflict, including personal or professional fallouts or disciplinary actions related to, for example, unprofessionalism. However, given the research that supported the development of assertiveness, it was predicted that the chance of severe, even small, repercussions due to challenging was unlikely.	O
8	Do you consider challenging decisions to be difficult?	Irrespective of how confident participants rate themselves in the questionnaire, this question sought to identify factors that make the decision challenging process difficult to carry out. Where question 8 of the questionnaire would likely result in short, possibly one word-based, responses, recorded data related to this question may provide more detailed explanations to support their initial response.	P
9	Are you familiar with the scope and conclusions of the Francis Report?	The FR was prevalent in the medical community, referenced in literature, the HSC learning material, etc. Therefore, this question set out to evaluate the awareness, and employee perspective, of the publication.	Q
10	Has it affected your clinical practice?	Following on from the previous question, having established an idea of the awareness of the report, this	Q

		question set out to evaluate whether the FR had strengthened or created awareness and a strong sense of importance of some of the issues discussed in the document, such as incident reporting.	
11	Have you ever been exposed to any form of simulation training?	This question set out to discover participant experience with simulation-based training. Simulation-based training is seemingly widespread in medical education, and this question set out to further evaluate this.	R, T
12a	What are your opinions of simulation-based training? (Ask both physical and virtual based).	Following on from the previous question, the interviewer requested the participant to clarify and list any simulation technologies interacted with or courses undertaken. It was likely, given the local exposure, that the HSC would be mentioned here. In addition, and regardless of whether a participant had been exposed to simulation or not, this question sought to identify the employee perspective of simulation in healthcare, and whether it is a beneficial resource.	S, T
12b	Would you be interested in taking part in a simulation course dedicated to assertiveness training?	As the project intended to evaluate the use of simulation technologies as a method to develop the ability to challenge decisions, it was important to determine whether there would be interest in this area. Data that support this would, in turn, support further research.	R, S, T
13	Any other comments?	Participants were finally asked if they had any other comments regarding anything concerning the interview or questionnaire content. Any comments were added to the relevant section.	All

4.4 Ethical Review Process

A clinical audit application was submitted to the QEHB's Clinical Governance Support Unit in compliance with the clinical research regulations of University Hospitals Birmingham. The detailed the nature of the research and methodology outlined in this chapter. An application for ethical review form similar content was submitted to the Research Ethics Team as part of the University of Birmingham's Ethical Review Process. The purpose of this, as with the clinical audit application, was an overview of the research topics, methodology, use of research participants, recruitment, consent, participant withdrawal process and clarification of any data that was to be collected.

Finally, a Hazard and Risk Assessment Summary application was submitted as per the University of Birmingham's health and safety regulations. The submitted application required the author to ensure that any room or location within the QEHB used for the questionnaire and interviews were safe for both the author and all research participants from trip, equipment or electrical hazards.

Participants were given detailed project information and consent forms that clarified their purpose for taking part, that their participation is voluntary and they could withdraw from the studies within an certain amount of time.

4.5 Results

4.5.1 Questionnaire Results

4.5.1.1 Overview

An opportunistic sample of 51 medical staff based at the QEHB took part in this part of the investigation, all of whom were recruited by the clinical supervisors attached to the project. Most participants successfully responded to all questions, leaving very few blank or un-answered entries. One participant was removed from the study due to unprofessional behaviour, and none had requested to be withdrawn from the study. Therefore, a total of 50 responses were deemed valid for further research and analysis. Each participant successfully recounted a challenge scenario for further analysis and provided an in-depth breakdown of the events leading to their challenge, clarifying who it was they challenged and why; how they issued their challenge; the initial and eventual outcome of the challenge; and any events or repercussions that occurred following the scenario.

The investigation had also successfully obtained data from multiple roles within the hospital, including a wide variety of specialities. This included students, junior trainees, consultants, operating department practitioners (ODPs) and surgeons, specialising in areas as diverse as cardiology (heart), anaesthesiology, critical care and clinical audit. Each participant's role on the hierarchy was placed into the categories defined earlier in this Chapter by the clinical

supervisor.

Percentages of all statistical information were calculated from the total number of unique responses given, and did not include empty answers. For example, a few challenge scenarios involved more than one member of staff, causing the total number of staff members challenged to increase above 50. A further example is that three participants did not answer Question 3 ("How confident were you to challenge any decision throughout your previous grade/tier?"), which reduced the total number of responses for this question to 47.

Finally, similarly worded responses to text-based questions were categorised into groups for easier analysis. For example, in response to Question 1 of the questionnaire, two participants stated "If patient safety is at risk" and "To promote best care for patients". Therefore, these answers were placed into the 'Patient Safety' category.

4.5.1.2 Preliminary Statistical Section Results

Table 4.7 to Table 4.10 list all the responses for this section.

Most of the participants (24; 48%) were of the Doctor profession, 17 of which (34% in total) specialised in anaesthetics. Other professions recorded included nurse, senior house officer and operating department practitioner. Other specialities recorded included critical care, theatre and vascular. The joint highest-grade category recorded was a Band 6 Nurse and Allied Health

Professional (10; 20%). The average number of years qualified as a medical professional was 9.3, with a standard deviation (SD) of 8.7. The average number years at their current post at the QEHB was 3.2 with an SD of 3.6. Most of the participants (41; 85%) received their medical training in the UK. Only three (6%) participants were military personnel. 54% of the participants were female and 46% male. Both the Doctor and Nurse professions represented the highest recorded, at 24 (48%) and 15 (30%) respectively.

Table 4.7 - Investigation Results - Participant Professions

Profession	**Count**	**%**
Doctor	24	48%
Nurse	15	30%
Operating Department Practitioner	5	10%
Surgeon	1	2%
Clinical Audit Clerk	1	2%
Theatre Practitioner	1	2%
Senior House Officer	1	2%
Auxiliary Nurse	1	2%
Physician Assistant	1	2%

Table 4.8 - Investigation Results - Participant Specialities

Speciality	**Count**	**%**
Anaesthetics	17	34%
Critical Care	9	18%
ITU	7	14%
Theatre	7	14%
No response	4	8%
Critical Care Data Officer	1	2%
Recovery	1	2%
Auxiliary	1	2%
Vascular	1	2%
Plastics	1	2%
Donor Management	1	2%

Table 4.9 - Investigation Results - Participant Grade Categories

Grade Category	Count	%
Nurse - 6+	10	20%
Allied Health Professional	10	20%
Consultant	6	12%
Speciality Trainee 5-7	5	10%
Nurse - 4-5	5	10%
Core Trainee 1-2	4	8%
Speciality Trainee 3-4	3	6%
M/N Student	3	6%
FY2	2	4%
FY1	1	2%
Clinical Support Worker	1	2%

Table 4.10 - Investigation Results - Participant Country of Training

Country of Training	Count	%
UK	41	85%
India	3	6%
Sudan	1	2%
South Africa	1	2%
Scotland	1	2%
Germany	1	2%

4.5.1.3 Question 1 Results

"Is it important to challenge clinical decisions?" ... "Why?"

With 62% of respondents citing patient safety in answer to 'Why?', as predicted, 100% of participants agreed that it is important to challenge clinical decisions and stated 'Yes' for Question 1. Eight participants' (16%) responses were placed into the 'Learning/Understanding' category. Six participants (12%) challenged decisions because they felt the decision may be wrong. Less common, more obscure responses included three who stated 'seeking an explanation' (6%), four who stated 'preventing mistakes' (8%) and three who stated 'effective teamwork' (6%). All responses to Question 1 are listed in Table 4.11.

Table 4.11 – Participant Responses to Question 1

Response	Count	%
Patient safety	31	62%
Learning/Understanding	8	16%
Decision may be wrong	6	12%
Prevent mistakes	4	8%
Effective team work	3	6%
Seek explanation	3	6%
General safety	2	4%
Ensure best decision	2	4%
Evaluate performance	2	4%
No answer	1	2%
Communication	1	2%
Right situation	1	2%
Confidence	1	2%

4.5.1.4 Question 2 Results

"On a Likert scale of 1-5, with 1 representing not very confident and 5 representing very confident, how confident are you to challenge the decisions made by staff of the following positions?"

This question required participants to rate, on a Likert scale of 1 to 5, their confidence in challenging a staff member for each grade category. For each grade category, the responses were used to calculate averages. The consultant grade represented the lowest confidence average of 3.06 and the highest SD with 1.35. Numerous ratings of 'not confident' values (1-2

on the Likert scale) and ‘confident’ values (4-5 on the Likert scale) were equally distributed across all grade categories. This analysis also illustrated that most of the ‘confident’ values were attached to those more senior in the hierarchy (e.g. nurse bands 6+ and ST5-7 and above) with most lower-ranked participants attached to the ‘not confident’ values. The overall average confidence to challenge a decision across the whole population was 4.11 with a SD of 0.75.

The highest challenge average and, subsequently, the lowest SD is the medical/nursing student grade with 4.72 and 0.49 respectively. 49 (98%) participants stated they were ‘confident’ or ‘very confident’ to challenge a medical/nursing student, with one (2%), in the Nurse Band 6+ category, rating a ‘3’, representing ‘somewhat confident.’

A full challenge confidence matrix comparing each grade confidence values is provided below in Table 4.12. Using the left-most column, the average estimated confidence of each grade category, based on the results, is displayed in each subsequent column. For example, a student’s estimated confidence to challenge the decision of a staff member at FY2 grade is 3.67. A further example is the estimated confidence of a CT 1-2 when challenging a consultant, which is 2.5.

Table 4.12 - Decision Challenge Confidence Matrix

	Consultant	ST 5-7	ST 3-4	CT 1-2	FY2	FY1	Student	Nurse - 6+	Nurse 4-5	CSW	AHP
Consultant	4.00	4.83	4.83	5.00	5.00	5.00	5.00	4.83	5.00	5.00	5.00
ST 5-7	3.20	3.60	4.40	4.60	4.60	4.60	4.60	4.20	4.40	4.40	4.40
ST 3-4	3.00	3.67	4.33	4.67	4.67	4.67	4.67	3.67	4.33	4.67	4.67
CT 1-2	2.50	3.00	3.25	3.75	4.25	4.25	4.75	3.75	4.00	4.50	4.50
FY2	2.00	3.00	4.00	4.50	5.00	5.00	5.00	4.00	4.50	4.00	5.00
FY1	1.00	3.00	3.00	3.00	4.00	4.00	4.00	3.00	3.00	3.00	3.00
Student	1.33	1.67	2.00	2.33	3.67	4.00	5.00	2.00	2.00	2.67	2.67
Nurse - 6+	4.00	4.10	4.20	4.50	4.50	4.50	4.60	4.40	4.40	4.40	4.40
Nurse - 4-5	3.20	3.60	3.60	3.60	4.00	4.00	4.60	4.20	4.80	4.60	4.60
CSW	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
AHP	2.50	3.40	3.60	3.90	4.00	4.30	4.80	3.80	4.10	4.40	4.30

Table 4.13 below lists the cohort's average confidence to challenge each grade category along with their respective SDs.

Table 4.13 - Average Confidence to Challenge Each Grade Category

Grade Category	**Mean**	**SD**
Consultant	3.06	1.35
ST 5-7	3.62	1.15
ST 3-4	3.88	1.03
CT 1-2	4.14	0.98
FY2	4.36	0.87
FY1	4.44	0.83
M/N Student	4.72	0.49
Nurse - 6+	4.00	0.98
Nurse 4-5	4.24	0.93
CSW	4.36	0.82
AHP	4.38	0.85

As Table 4.14 below highlights, some exceptions were stated and, interestingly, they applied to either a consultant or were referred to all grade categories.

Table 4.14 – Challenge Confidence Rating Exceptions

Profession	Grade Applicable	Rating given	Exception stated (as written)
ST 5-7	All	3	If person is nice, approachable, past experience, confidence.
Consultant	Consultant	3	Occasionally, challenging a senior colleague is difficult.
Nurse - 4-5	Consultant	4	Some are easier to challenge than others/more approachable.
CT 1-2	Consultant	3	Depends on the consultant.
ST 5-7	Consultant	2	Obvious ethical or clinical decisions.
Nurse - 6+	Consultant	3	Depends on the consultant.
Consultant	Consultant	4	Very senior colleague, especially ones I don't know.
Consultant	Consultant	4	Within areas of expertise.
ST 5-7	All	4	Will always depend on scenario.

4.5.1.5 Question 3 Results

"On a Likert scale of 1-5, with 1 representing not very confident and 5 representing very confident, how confident were you to challenge any decision throughout your previous grade/tier?"

This question required participants to rate their overall confidence to challenge a decision when they were less experienced than present (i.e. at their previous grade, prior to the conduct of the present investigation). The responses illustrated that most participants were less confident when compared to their current average challenge value (which is the average between grade category ratings). 77% of participants rated their previous confidence value less than that of

their current. This is in addition to an overall average "then and now" difference of -0.91. Table 4.15 below is a sample of responses for Question 3 and represented the only responses with comments provided.

Table 4.15 - Previous Challenge Confidence Sample

Grade Category	Resp.	Mean Current Challenge Confidence	Diff.	Comment
CT 1-2	3	4.64	-1.64	Questioning a senior is less daunting than challenging.
AHP	1	4.00	-3.00	As a student ODP.
AHP	4	3.91	0.09	Felt valued as a student, the same as a qualified member.
Nurse - 4-5	3	5.00	-2.00	I was not as experienced as I am now.
AHP	-	3.55	-	No grade change since inception to job.
Nurse - 4-5	2	4.00	-2.00	When I had less experience, it was much harder.
Consultant	4	4.91	-0.91	Confidence improves with experience and seniority.

4.5.1.6 Question 4 Results

"How would you rate the following methods of challenging, with 1 being not very important and 5 being very important?"

Using a Likert scale of 1 to 5, representing 'not important' to 'very important' respectively, the responses revealed that attempting to conduct private discussions with the person being

challenged was the most favoured challenge method with an average response value of 4.12 (important). This result was followed by 'attracting attention discretely' with an average Likert response value of 3.6; 'seeking assistance from a third-party staff member' with 3.32; 'immediately in front of others' with 3.12; and 'forming a huddle involving everyone in the challenge' with 2.78.

4.5.1.7 Question 5 Results

"What would you do if you did not receive a satisfactory response to your challenge?"

A total of 66 responses were recorded for this question (summarised in Table 4.16). If a challenge did not provide a satisfactory response, 32 (64%) participants stated they would escalate to a more senior staff member, followed by 17 (34%) who stated they would re-issue the challenge. Other responses included five (10%) who stated they would seek clarification for the challenge's rejection, another five (10%) who stated they would seek another staff member and two (4%) who would ensure that the reasons for their challenge were understood. Interestingly, a single participant stated they would intervene or act in the event their challenge was dismissed and two participants stated they would do nothing and accept the decision.

Table 4.16 - Unsatisfactory Responses to Challenges

Response	Count	%
Escalate to senior	32	64%
Attempt to re-challenge	17	34%
Seek another staff member	5	10%
Ask for reasons behind challenge rejection	5	10%
Research / Review	2	4%
Check if reason behind challenge is understood	2	4%
Accept challenge rejection / Do nothing	2	4%
Intervene / Take action	1	2%

4.5.1.8 Question 6 Results

"Have you received any training in assertiveness or how to challenge the decisions of team members? If so, how did you receive this training?"

In terms of training in managing hierarchical conflict, only 13 (26%) participants confirmed they had received a form of training that featured assertiveness or focused on similar topics such as conflict management. Methods of training included team training courses provided by local trusts, conflict resolution training sessions and E-learning. Only one participant stated training delivered at the HSC when answering this question. Table 4.17 below contains a sample of responses from 12 of the 13 participants who provided comments.

Table 4.17 - Question 6: Sample of Responses with Comments

Response	If so, how did you receive this training? (As written in questionnaire)
Yes	Leading effective teams course - lead by the trust
Yes	E-learning
Yes	Study day organised by the trust some years ago
Yes	Hollier
Yes	Conflict resolution training
Yes	Nurse training/conflict resolution
Yes	Conflict resolution in trust induction
No	Not directly - all training has aspects of challenging decisions.
No	No specific training but acquired through generic [handwriting illegible]/professional development
Yes	Band 6 study day
Yes	Human factor courses, military training
Yes	Conflict resolution training PowerPoint/group work
Yes	Part of original job training
Yes	In MSC/PGDip training as part of advanced course.

4.5.1.9 Question 7 Results

"What might stop you challenging a member of a team?"

This question sought to highlight factors that would prevent participants from committing to their challenge, irrespective of their overall confidence. A wide variety of responses were recorded and, as highlighted in Section 4.5.1.1, were subsequently grouped together with those similar in wording, and are listed below in Table 4.18. The highest three responses were recorded from 14 participants (28%) who stated seniority/hierarchy, ten (20%) who stated the

attitude, behaviour or personality of the other person and eight (16%) who stated the uncertainty of the challenge in terms of the response given or repercussions. A single participant stated the gender of the other person would prevent their challenge.

Table 4.18 - Unique Responses to Question 7

Responses	**Count**	**%**
Seniority / Hierarchy	14	28%
Attitude / Behaviour / Personality of other person	10	20%
Uncertainty of challenge	8	16%
Knowledge	6	12%
Timing of challenge	5	10%
Relationship to decision maker	4	8%
Family / Patient / Other staff present	4	8%
Nothing will stop challenge	4	8%
Outvoted on decision	2	4%
Confidence	2	4%
Being ignored	2	4%
If the challenge is not necessarily important	2	4%
Knowing you wouldn't get a satisfactory response	1	2%
If challenge is more likely to cause more harm than good	1	2%
Fear of repercussion	1	2%
Urgency / Importance of situation	1	2%
Subject / Topic of decision	1	2%
Not compromise relationship between staff	1	2%
Their gender	1	2%
Experience	1	2%

4.5.1.10 Question 8 Results

"What factors do you feel affect your ability to make a challenge?"

This question requested participants to list any factors that they consider when attempting to make a challenge. This included listing any factors that might positively or negatively affect their decision challenge ability (for example stress, fatigue, knowledge or confidence). As illustrated below in Table 4.19, when compared to other content in the questionnaire, this question garnered the most responses. The highest-scoring factors were recorded from 20 (40%) participants who stated 'knowledge and/or experience', 13 (26%) who stated 'seniority' and another 13 (26%) who stated 'confidence'. As with the previous question, the attitude, behaviour or personality of the other person was identified.

Table 4.19 - Challenge Factor Responses

Challenge Factor	**Count**	**%**
Knowledge / Understanding the details / Information / Experience	20	40%
Seniority	13	26%
Confidence	13	26%
Attitude / Personality / Behaviour / Approachability of the other person	12	24%
Hierarchy / Role of other person(s)	9	18%
Relationship to other person(s)	8	16%
Settings / Environment / Location	7	14%
The situation / Circumstances / Urgency / Timing	6	12%
Lack of knowledge / Experience / Understanding	5	10%
Patient safety	4	8%
People present - e.g. patient and/or family, other staff, etc.	4	8%
Not seen as important / Insignificant / Ignored	3	6%
Team status / Size / Business	3	6%
Your own sense of security / Beliefs / Opinions / Views	3	6%
Tiredness / Fatigue	2	4%
The topic/theme under discussion	2	4%
Fear of repercussion / Fallout / Argument / Negative outcome	2	4%
Anticipated / Expected response	2	4%
Who you are challenging / Talking to	1	2%
Work benefits (i.e. job references, promotion, etc.)	1	2%
Reasoning / Clarification of the decision	1	2%
Frustration	1	2%
Cultural / Religious issue	1	2%
Response of previous challenge	1	2%
Stress	1	2%
Recent similar scenario/situation	1	2%
Current junior role	1	2%
Experience of other person(s)	1	2%
Age of other person	1	2%
Gender of other person	1	2%

4.5.2 Interview Results

Each participant successfully provided a challenge scenario example. A total of 55 individuals were challenged across all the scenarios provided. In three scenarios, a challenge occurred more than once and a total of 51 challenges were issued across all examples given. Despite asking specifically for a scenario that involved a challenge, there were two instances where a challenge was not issued, but involved an event that was appropriate for the study. For example, in one scenario, the participant felt that an excessive drug dosage (exact type not specified) was administered which may have been the cause of the subsequent occurrence of a patient entering cardiac arrest. The participant remained quiet despite their concern. Moreover, whilst 51 scenarios involved challenging a single person, four examples involved multiple individuals. This included three instances where multiple staff members were challenged simultaneously, and two cases where a patient was involved in the challenge.

Furthermore, in the three cases where more than one challenge occurred, all of them involved the use of multiple methods for the challenge to occur. For example, in a scenario example highlighted below (Table 4.22 - Example Interview Data 3), the initial challenge was issued immediately to a consultant over the telephone. However, the participant sought assistance from a third party, as their initial attempt was rejected, to repeat the challenge to another member of staff.

The amount of content in each scenario also varied, ranging from examples consisting of short, simple cases to more in-depth, extensive and detailed instances. When each participant was asked who it was they challenged, 47% of scenario examples (26 recorded, including one instance where two were challenged at once) involved conflicts with consultants.

The following four tables (Table 4.20 to Table 4.23) are examples of interview transcripts.

Table 4.20 - Example Interview Data 1

A newly qualified nurse was looking after a patient and, with respect to their level of consciousness, felt that something was wrong. Doctors had approached the patient and discussed their status while the nurse stood by and remained quiet. The patient was deemed fit to be transferred to the ward - a decision which the nurse disagreed with and challenged. The challenge, however, was rejected and the patient was transferred to the ward. The patient deteriorated thereafter and was returned to the ICU. Unfortunately, the patient passed away due to severe respiratory failure. On reflection, the nurse regrets not sustaining the challenge. However, should a similar situation occur in the future, the nurse vowed to push harder with the challenge and now documents events extensively in reports.	
What was the role of this particular staff member?	Senior nurse
Was the outcome of your challenge positive or negative?	Negative
Was the outcome altered based on your challenge?	No
Were you satisfied with the eventual outcome?	No
Did you receive any feedback from the staff member challenged?	No
Was further action taken as a result of your challenge?	No
Do you consider challenging decisions to be difficult?	Yes
Are you familiar with the scope and conclusions of the Francis Report?	Yes
Has it affected your clinical practice?	No
Have you ever been exposed to any form of simulation training?	Yes. Resuscitation training, team building exercises.
What are your opinions of simulation based training?	Positive. It can be a useful tool.
Extra notes: Agreed that a course dedicated to challenging decisions would be beneficial.	

Table 4.21 - Example Interview Data 2

A nurse was looking after a patient when a surgeon arrived and stated they would not be able to offer them surgery. Having discussed this with a consultant also present, they had agreed to withdraw care. The nurse did not agree with this and felt both the surgeon and consultant had not spent enough time with the patient (according to the nurse, the patient had not been assessed, reviewed or visited on that day so far) to justify their decision. The nurse challenged this decision and stated they should "at least assess the patient and reconsider their decision." The challenge was rejected, but the consultant had agreed to visit the patient shortly afterwards. Feeling upset, the nurse spoke to a senior nurse regarding the matter who then told them to speak to an alternative consultant. During the next ward round, the nurse's patient was next in line to be reviewed by the current team on duty. The nurse explained how she felt to the leading consultant on the round who agreed to assess the patient and check their condition later in the day. This, however, was seemingly overruled by the previous consultant, who persisted with his insistence that care should be withdrawn. This resulted in both the original and current consultant entering a conflict. In the end, the patient's care was withdrawn as originally decided. However, the patient, unfortunately, passed away shortly after the decision.	
What was the role of this particular staff member?	Consultant
Was the outcome of your challenge positive or negative?	Despite being frustrated and upset, the outcome was positive.
Was the outcome altered based on your challenge?	No
Were you satisfied with the eventual outcome?	Yes
Did you receive any feedback from the staff member challenged?	Yes. Participant was informed of the eventual outcome.
Was further action taken as a result of your challenge?	No
Do you consider challenging decisions to be difficult?	Yes. However, only sometimes.
Are you familiar with the scope and conclusions of the Francis Report?	Yes
Has it affected your clinical practice?	Yes. Participant felt that it had raised their awareness to a higher level, hence the persistence of her challenge. It has done a lot for nurses and highlighted the shortage of nursing staff which can compromise the quality of care.
Have you ever been exposed to any form of simulation training?	Yes. Resuscitation training.
What are your opinions of simulation based training?	Positive. Felt that it helps mentally prepare staff.
Extra notes: Agreed that a course/simulation of challenging decisions would be beneficial and should include being challenged. More relevant to junior positions, participant felt that there was a problem with challenging decisions.	

Table 4.22 - Example Interview Data 3

The participant, who was a junior doctor at the time of this example, was given a referral from a consultant via telephone stating a plan for treatment for a patient. The participant felt this course of treatment was not right and subsequently challenged it, requesting more tests be conducted. Her challenge was rejected and the consultant proceeded to shout at the participant. According to the participant, examples of dialogue included: "What do you know?" and "I've been a consultant for 13 years."

Feeling angry and intimidated, the participant was ordered to take the referral before the consultant abruptly hung up the phone. The participant clarified that they tried to explain their reasons behind the challenge before the consultant hung up. Shaken and upset, the participant attempted to speak to an alternative consultant regarding this matter but the incident was dismissed. Apparently, the second consultant to whom this incident was reported responded with "that's the way it is."

A critical incident form containing complaints of bullying was completed and submitted. Shortly thereafter, the consultant from the original telephone call summoned the participant to their office. The critical incident form had been collected a very short time after submission and was delivered to said consultant. The participant was again subjected to shouting and was told that if they had a problem they should have said so. Again, the participant attempted to explain the reasons behind the initial challenge, although then felt that it was again dismissed without hesitation. Fortunately, the patient in question was stable, and no further action was taken after the challenge scenario had occurred. However, the personal issues with the consultant were never resolved. The participant concluded by stating she felt that no help was available and did not know who to turn to.

What was the role of this particular staff member?	Consultant
Was the outcome of your challenge positive or negative?	Negative
Was the outcome altered based on your challenge?	No
Were you satisfied with the eventual outcome?	No
Did you receive any feedback from the staff member challenged?	Yes. Was informed she should not have filled in a critical incident form and, instead, spoken to the consultant directly.
Was further action taken as a result of your challenge?	No
Do you consider challenging decisions to be difficult?	Yes. Mainly, seniority and unsure of the team you are working with (i.e. junior/new).
Are you familiar with the scope and conclusions of the Francis Report?	Yes. Attended lectures on it.
Has it affected your clinical practice?	Yes. People are more aware of the importance of incident forms, hence the form submitted in this scenario without hesitation.
Have you ever been exposed to any form of simulation training?	Yes. HSC, airway scenarios, rapid sequence inductions, role playing, Advanced Life Support (ALS). Is an ALS instructor.
What are your opinions of simulation based training?	Positive. Really good.

Extra notes:
Agreed that a course dedicated to challenging decisions would be beneficial. Spoke highly of the HSC and their staff.

Table 4.23 - Example Interview Data 4

The participant witnessed and challenged a consultant not adhering to trust policy whilst taking blood from a patient. Before issuing the challenge, the participant observed the consultant so as not to distract them whilst they were carrying out the procedure. The participant then took the consultant aside and voiced their concerns. Said consultant had apparently not followed the correct procedure and was in danger of harming the patient. In addition, a junior member staff was also observing the situation. This was raised as it was felt that the junior may - and indeed did so shortly after - emulate the behaviour. To correct the behaviour resulting from the consultant's actions, the participant demonstrated the procedure again, this time in the correct manner. The senior member accepted what they were doing was wrong. However, the consultant repeated the procedure incorrectly to another patient shortly thereafter. This situation occurred at the same time as the participant entered the area it was being carried out. This time, the participant issued a final warning and threatened to commence disciplinary proceedings. Again, the consultant accepted the challenge and ensured it would not happen again.	
What was the role of this particular staff member?	Consultant
Was the outcome of your challenge positive or negative?	Positive
Was the outcome altered based on your challenge?	Yes
Were you satisfied with the eventual outcome?	Yes
Did you receive any feedback from the staff member challenged?	Yes. Junior had appreciated being shown the correct procedure.
Was further action taken as a result of your challenge?	Yes. Threatened with disciplinary proceedings if this incident occurred again. Voiced concerns of junior members of staff witnessing this event.
Do you consider challenging decisions to be difficult?	Yes
Are you familiar with the scope and conclusions of the Francis Report?	Yes. Had "skimmed" through it. Feels that the report is biased – "nurses are crucified to a large extent."
Has it affected your clinical practice?	No
Have you ever been exposed to any form of simulation training?	Yes. Resuscitation training. IV training. Cannulation. Phlebotomy. Dissection.
What are your opinions of simulation based training?	Positive. It is essential to training. Safe environment.
Extra notes: Agreed that a course dedicated to challenging decisions would be beneficial.	

Table 4.24 illustrates the overall responses to the interview questions. After each challenge scenario was provided, as discussed in the interview design methodology, participants were asked questions relating to their examples. Consisting of mainly Yes/No questions, each participant was asked to elaborate on their answer, providing a brief account as to why they gave their answer. For example, if they stated that further action was taken because of their challenge, they were asked to clarify what the further action consisted of, the events that followed and the eventual outcome.

Table 4.24 - Interview Overall Response Percentages

Question	**Y%**	**N%**	**N/A**
Was your challenge positively received?	74	18	4
Was the outcome altered based on your challenge?	50	44	6
Were you satisfied with the eventual outcome?	78	20	2
Did you receive a form of feedback?	34	66	0
Was any further action taken?	16	84	0
Do you consider challenging decisions to be difficult?	68	26	6
Are you familiar with the Francis Report?	88	12	0
Do you feel it has had an effect on your clinical practice?	32	60	8
Have you ever been exposed to simulation?	90	10	0
Do you think simulation is a beneficial resource within healthcare?	94	0	6
Would you attend a simulation course on handling hierarchical conflict?	95	0	5

4.6 Findings

4.6.1 Is it important to challenge clinical decisions (Research Question 1)?

As the research has so far has demonstrated, including the example challenge scenarios provided by members of the healthcare community, patient safety is the top priority for medical staff and educators. This was also reflected in the questionnaire results, where 100% of participants agreed that it is important to challenge clinical decisions. Of the 50 participants interviewed, 31 suggested that patient safety is the reason decisions should be challenged, thus further lending support to the findings uncovered in the literature, observational research conducted and studies (such as Pian-Smith *et al.*, 2009; Calhoun *et al.*, 2013; 2014 and Okuyama *et al.*, 2014) concerning this topic.

4.6.2 How and when do you challenge?

The observational research findings suggested that the best method of challenging to resolve a conflict is to do it immediately, and overtly, as the situation occurs. As evidenced by the leading consultant of the first ward round observation, this behaviour is sometimes encouraged to ensure patient safety. Based on the transcripts, and as can be seen in Table 4.25, there were 40 instances where a direct and immediate challenge was issued in the scenario examples. However, despite this, the most favoured method of challenging (mean = 4.12), according to the questionnaire results, was to 'attempt private discussions.' The mean for 'immediately, and

overtly in front of others who are present at the time' was 3.12 and was the third highest overall average of the categories provided. Of the six participants who were in trainee categories (either a student, FY1 or FY2), four of them rated the immediate challenge method as a 3 or above (mean = 3.17).

Of the 40 instances where a challenge was issued immediately, 20 (half of the) scenarios were altered or resolved in the participant's favour. In the three cases where multiple challenges occurred, an ineffective immediate challenge was first issued followed by a subsequent challenge using an alternative method. In all three cases, the outcomes were not altered. However, a small number (eight) of scenarios involved a challenge that was not immediately issued but was instead given only via an alternative method, such as private discussions. Of these cases, five outcomes were altered (63%).

Despite the mixed results, the interview data and subsequent challenge scenario examples suggested that challenging decisions immediately is likely to occur in events involving conflicts, and to be the most effective method. Therefore, as with the previous finding, this supports the anecdotal evidence, concerning when challenges should be issued, as provided by clinical SMEs from both the HSC and QEHB.

Table 4.25 - Scenario Example Method of Challenge

Challenge Method	Instances	%
Challenged immediately, in front of others who may be/were present	40	78
Sought third-party assistance	8	16
Held a private discussion	3	6

4.6.3 Is the ability to challenge linked with experience (Research Question 3)?

It is evident that there is a link between the ability to challenge decisions and experience. Sections 4.6.3.1 to 4.6.3.4 below lists a summary of the analysis to supports this.

4.6.3.1 Comparing the Least and Most Confident

With an overall mean of 4.72, the analysis of Question 2 revealed that the participants were most confident to challenge students when compared to the other grade categories. Conversely, the consultant represented the grade the participants were least confident to challenge. According to the challenge confidence matrix (Table 4.12), with a mean of 2.67, students also represented the cohort with the least overall confidence to challenge the other grade categories, and are also the only grade category with an overall mean less than 3 on the Likert scale. This was followed closely by FY1s (mean = 3.09).

4.6.3.2 Comparing each of the grade categories

Illustrated in Figure 4.1 and Figure 4.2, the cohort's confidence to challenge the other grade categories increases as one ascends the hierarchy. Indeed, further analysis, as illustrated in Figure 4.3, indicated that the overall confidence of the cohort to challenge the grade categories increased as one "descends" the medical hierarchy. Finally, Figure 4.4 suggests that the confidence of each participant is positively correlated (correlation coefficient of 0.65) with the number of years qualified, illustrating that participants with greater than 20 years of experience have an average confidence of 4.91 or higher.

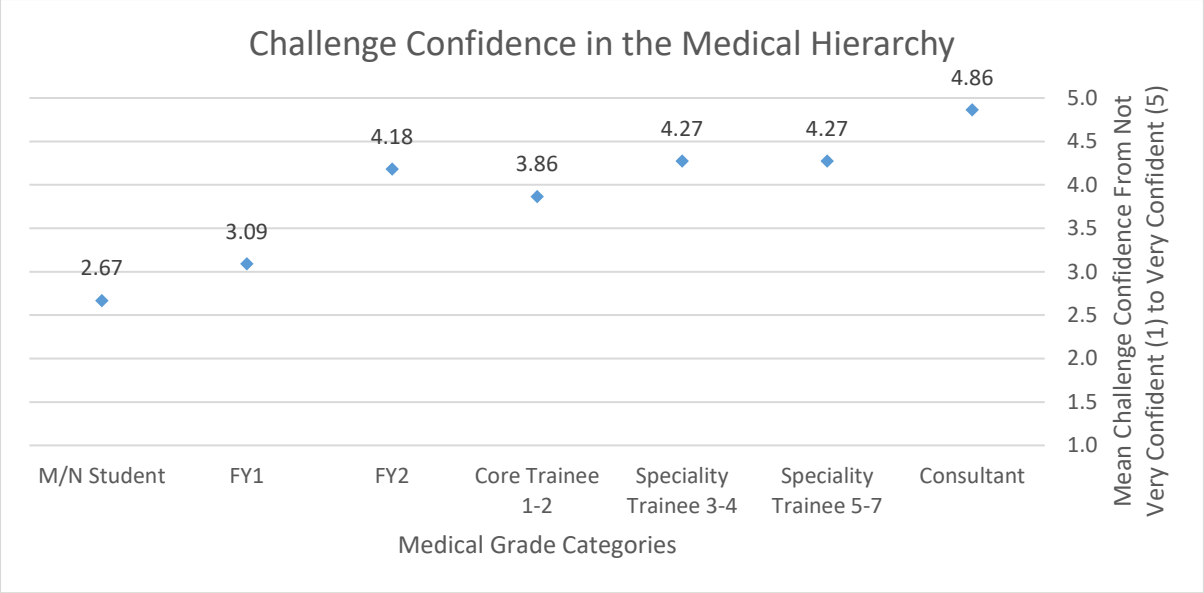

Figure 4.1 – Line chart demonstrating the increase of confidence between grade categories as one ascends the medical hierarchy

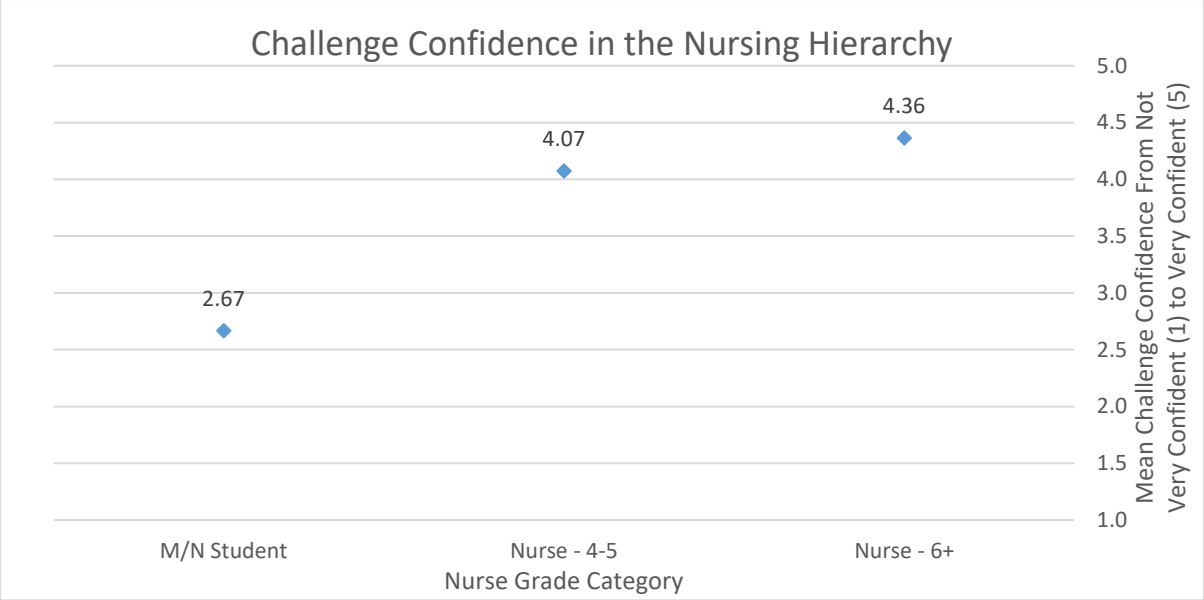

Figure 4.2 - Line Chart Demonstrating the Increase of Confidence as One Ascends the Nursing Hierarchy

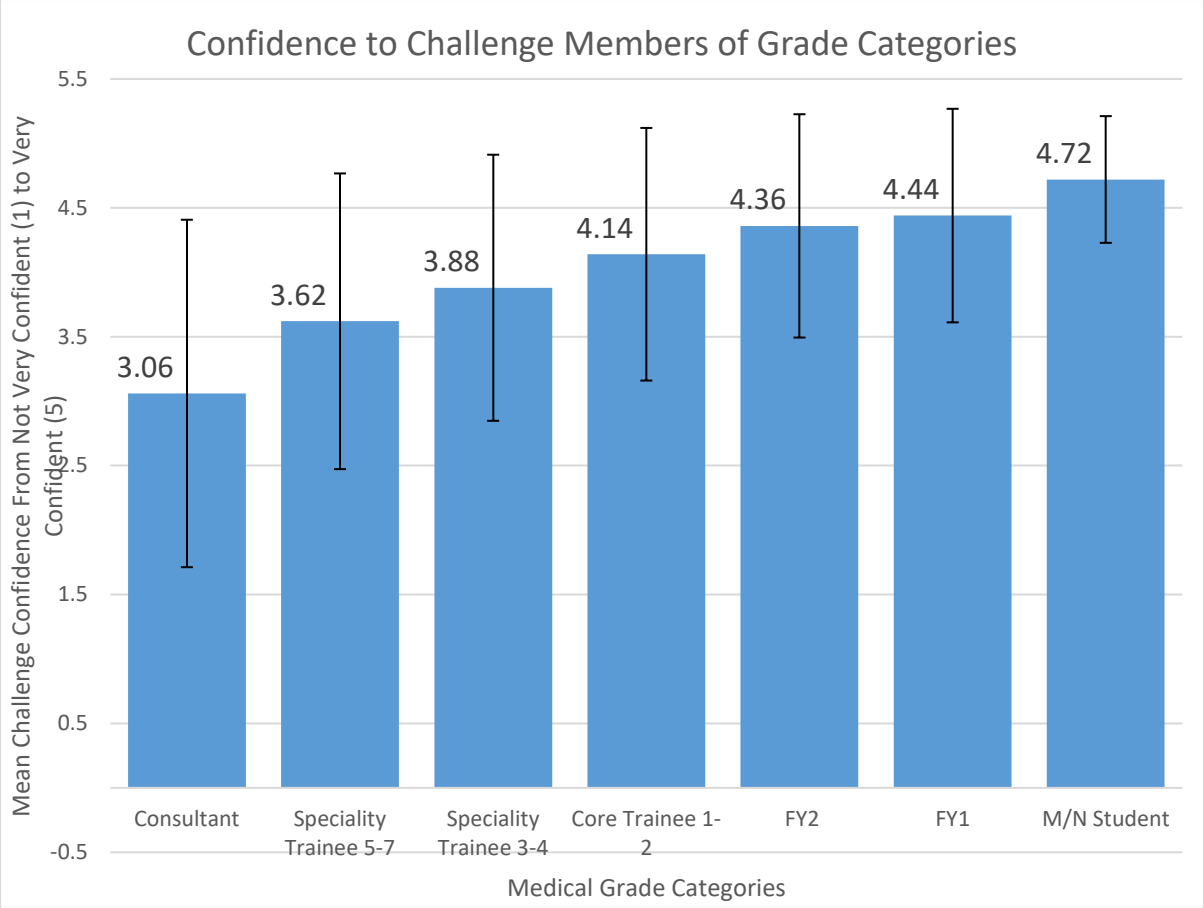

Figure 4.3 – Histogram to Illustrate Confidence to Challenge the Grade Categories

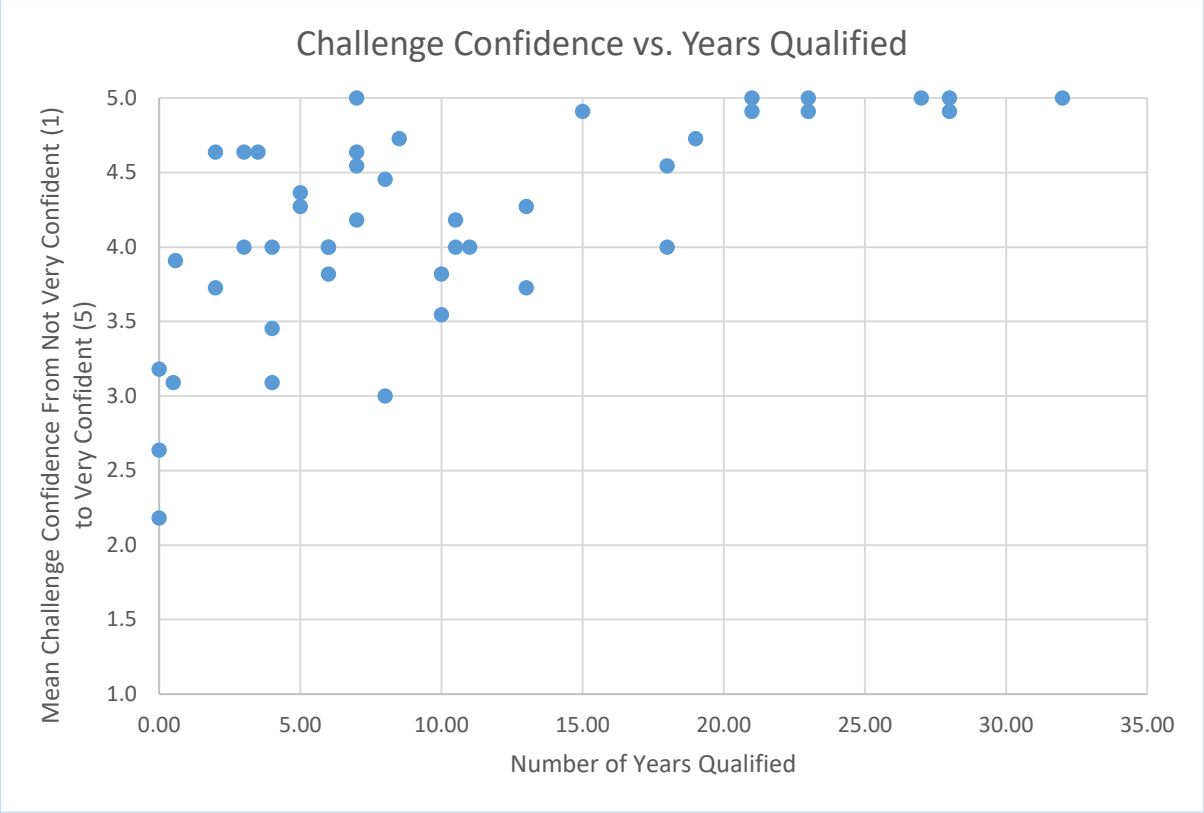

Figure 4.4 - Scatter Chart Comparing Challenge Confidence with the Number of Years Qualified (r = 0.65)

4.6.3.3 Comparing Previous Grade Confidence

The overall mean (i.e. the 'current mean') confidence value for the participants is 4.11. The results of Question 3 of the questionnaire, asking participants to rate their overall confidence in their previous grade, revealed an overall mean of 3.19 (i.e. the 'previous grade mean'). When this value is subtracted from the current mean, the difference is almost one rating below with 0.92, suggesting that the participants were less confident to challenge when less experienced.

4.6.3.4 Analysis of Participant Responses

Question 8 of the questionnaire asked participants to list any factors that might affect their ability to challenge clinical decisions. As previously highlighted in 4.5.1.10 Question 8 Results, this question had garnered a wide variety of responses and similar answers (again, as stated in Section 4.5.1) were placed into categories for easier comparison. 20 (40%) participants' responses to this question were placed into the 'knowledge', 'understanding', 'information' or 'experience' category. These responses were also given for both Question 7 (6 instances; 12%) - "What would prevent the participant with moving ahead with their challenge?", and Question 1b (8 instances; 16%) - "Why is it important to challenge decisions?"

Though there were not many responses to the accompanying text box for Question 3 (challenge confidence at previous grade), some participants had stated that experience is a factor when challenging. Example responses for this question were: "I was not as experienced as I am now", "When I had less experience it was much harder", and "Confidence improves with experience and seniority".

According to 13 (26%) participants, seniority and confidence also affect the ability to challenge, followed by 12 participants who stated that the attitude of the other person is also a factor. These responses were also evident across other areas in the study. For example, seniority, attitude and confidence were stated in Question 7 of the questionnaire by 14 (28%), ten (20%) and two (4%) participants respectively. These topics were also referred to in the interviews,

with consultants representing the highest involvement in the challenge scenarios.

4.6.4 Who are you most likely to challenge?

As illustrated in Table 4.26, the consultant grade represented the cohort most challenged in the scenario examples given, followed by any grade of nurse and then a registrar. A total of 22 scenarios were provided that involved a consultant who reacted positively or negatively to a challenge. Of these scenarios, 17 (77%) challenges were positively received and five (23%) were negatively received. Examples of reasons behind the challenges include disagreements over treatment for a patient (for example, drug types or the number of drugs given). In ward round settings, observational research (Chapter 3) has shown that a consultant would normally lead a team of medical staff of varying grades and experience, including students, and these consultants are responsible for suggesting a plan for a patient's treatment. Because of their overall presence and responsibility in the team and across the department, consultants are most likely representing the highest cohort to be involved in challenges, a finding which is evident in the results. Analysis of the data also found that, in most cases, the consultants were very defensive of their decision or actions. This gives further credence to Calhoun and Pian-Smith's research and their adoption of the two-challenge rule, a communication technique used to empower trainees to persist with their challenge in the event it is rejected or dismissed.

Table 4.26 – Grades of Staff Challenged in Examples

Challenge Role	**Count**	**%**
Consultant	26	47
Nurse (any)	9	16
Registrar	6	11
FY1-2	2	4
Patient and/or family	2	4
ODP	2	4
Senior Nurse	1	2
Clinical Support Worker	1	2
Healthcare Assistant	1	2
Surgeon (any)	1	2
Anaesthetist	1	2
Doctor (any)	1	2
M/N Student	1	2
Allied Health Professional (any)	1	2

4.6.5 How effective is the ability to challenge decisions?

It was evident that issuing a challenge, regardless of the circumstances surrounding the nature of the decision, as described in the scenarios, can be a harmless and rewarding experience. This finding was based on the interview data, which showed that, of the 37 (74%) participants who stated their challenge was positively received, 24 (65%) stated the outcome was altered due to their challenge. In total, 25 (50%) of the participants felt that the outcomes of their scenarios were altered because of their challenges, irrespective of their comments being positively or negatively received. Furthermore, of the eight cases where further action was taken due to their challenge, only one example was matched to the criteria of ‘worst case scenario.’ The

conditions of this were: the challenge was negatively received, the outcome was not altered due to the challenge, the participant was not satisfied with the eventual outcome, the participant did not receive any feedback and further action was taken. Overall, 39 (78%) participants were satisfied with the eventual outcome, not accounting for the outcomes of the challenge and scenario.

4.6.6 How do you respond to an unsatisfactory response?

32 (65%) participants stated that, if their challenge did not elicit a satisfactory response, they would escalate to a more senior staff member. This included any events that saw their challenge rejected, resulted in a conflict, or in cases where they were subjected to unprofessional behaviour. Based on this finding, it is, therefore, likely that a conflict would result in the intervention of a senior member of staff to resolve the issue(s). However, as the second highest response, 17 (34%) participants also stated that they would attempt to re-issue the challenge, supporting Pian-Smith's research concerning the "two-challenge rule."

4.6.7 What happens if decisions are not challenged?

Research into the literature, such as the Francis Report (FR) concerning allegations of unreported incidents of poor healthcare at the Mid Staffordshire National Health Service Foundation Trust, had shown that the consequences of decisions not being correctly challenged in a timely fashion can result in disastrous, sometimes fatal, outcomes, even in simulated

scenarios (Calhoun *et al.*, 2013). An example where challenging a decision has benefitted the safety of the patient was a participant who attempted to convince a consultant that their plan for treatment was ineffective. Having conducted a series of blood tests and observations to build evidence of the plan's inefficiency, the participant presented her results to the consultant who had then agreed to listen for alternative approaches.

However, four scenario examples provided by participants within the interviews resulted in patient death. Although the decision was challenged in three of the four cases, these challenges failed to alter the outcome. In the case where a challenge was not issued, the participant stated that they felt the dosage of anaesthetic given to a patient being prepared for surgery was excessive, but was uncertain of the outcome. Shortly after this, the patient entered cardiac arrest and could not be recovered. In one of the incidents provided that was challenged, a participant stated that he regretted not sustaining his challenge (after his initial challenge was rejected) and vowed to affirm his challenges in the future, should similar incidents occur. In another case, a participant informed a patient that the surgery he requested had a small chance of success. Despite her challenge, the patient pushed for the procedure and unfortunately passed away shortly after surgery, which was initially aborted due to complications in the operating theatre.

4.6.8 Is there sufficient training to help develop the ability to challenge (Research Question 5)?

Findings to support this topic were inconclusive. Currently, simulation training courses are available at both the HSC and the clinical skills suite situated at the QEHB. They are an invaluable opportunity for trainees and qualified clinical staff to learn and practice the various non-technical skills that underpin the teaching of Human Factors (HF) issues, including the ability to challenge. However, it was not possible to establish how much training was on offer that specifically focused on developing assertiveness. Only 13 (26%) participants in the study claimed to have received a form of training to develop the ability to assert, including one trainee who stated they received training but did not specify what it was. Further research in this area is required.

4.7 Conclusion

Given that challenging decisions is important to the well-being and recovery of patients, not to mention the avoidance of fatalities, it is vital that trainees feel confident and comfortable to challenge or at least question a decision being made. As trainees are welcome to attend ward rounds (at least within the QEHB), this form of early participation could become an ideal opportunity for them to gain knowledge and build confidence to challenge or question the decisions of the team members. The ability to challenge is – and should be – inextricably linked

with experience, and students or trainees need more opportunities to practice to gain that experience. With examples listed below (including scenario examples highlighted in Table 4.20 to Table 4.23), the negative aspects that occur alongside hierarchical conflicts were evident in some cases:

- A participant who did not follow along with a plan that was made by a consultant told them that their word is “the law that you have to follow” and you must not go against it

- A participant analysed a patient and thought something was wrong with their neurological state. Though the patient had recovered, the participant (who was in the AHP category) received a derogatory comment from the patient’s consultant over the analysis

- A staff member (role not clarified) had reported a case of bullying from a healthcare assistant to the participant, who had resolved the matter privately.

However, based on the results, the likelihood of receiving a positive resolution to conflicts arising in the clinical space, including the initial response and eventual outcomes from challenging, is, overall, favourable. Coupled with overly positive feedback with regards to the importance of challenging clinical decisions, the data obtained supports Research Question 1 and Research Question 3, which set out to discover whether challenging decisions is an

essential skill to develop and if the skill is associated with clinical experience respectively.

The factors described by participants that interfere with – or affect – an individual's ability to challenge decisions (e.g. experience, seniority, confidence, stress), coupled with an apparent lack of training in this area, exposes a critical, yet controversial, topic worthy of further investigation. This aspect of training could be enhanced directly using simulation, either as part of conventional medical training programmes or via courses provided by regional NHS trusts. As part of this preliminary investigation, it was discovered that 90% of participants interviewed have been exposed to some form of simulation training. In addition, 94% of participants also agreed that simulation is beneficial to medical education and training. However, only 26% of participants who took part in the investigation stated that they had received a form of training specifically targeted towards developing assertiveness. Finally, participants were asked whether they would be interested in taking part in a training simulation course (in any form, VR or otherwise) dedicated to helping develop staff assertiveness, with 95% responding positively and 5% unsure.

With data that fulfilled the entirety of the research aims listed in Table 4.1 and Table 4.2, it became possible to investigate whether the skill of challenging decisions could be potentially enhanced through the VR training tool concept. The original idea for this tool, possibly working in conjunction with traditional or established simulation technologies such as the Laerdal SimMan product, was to provide opportunities for staff to practice their decision challenging

abilities in a safe, non-formally assessed, environment. If any data obtained after testing the tool proved inconclusive, it was hoped that the tool would inspire – and raise staff confidence levels – to be more assertive. At the very least, the development and exposure of such a tool would, it was further hoped, help to raise awareness to the importance of challenging decisions and develop considerations for further research in this area.

4.7.1 Recommendations for VR Project

The research participants provided realistic examples of situations where they were prompted to challenge a decision or event. They included various examples of how they were issued and who to, why they were issued and any outcomes. This included an overview of any repercussions for the challenger and, ultimately, the patient. The scenario featured in the VR project will be based on one of the provided examples. As part of the next project phase (Chapter 5), each of the examples were evaluated and discussed with clinical and project supervisors, including further discussions with clinical personnel based at the QEHB who assisted with finalising the content. The 'theme' of the chosen scenario was important, as it must reflect some of the prevalent issues identified within the investigation, such as conflict with other team members, seniority and the attitude of the other person.

It is evident that, based on the results of the investigation and interviews, there is an issue with seniority (Section 4.6.4), as consultants were rated as the most difficult grade category to challenge and were the most referred to in the given scenario examples. The issue regarding

seniority was also a common topic in some of the literature discussed (Calhoun *et al.*, 2013; 2014, Okuyama *et al.*, 2014). Therefore, the scenarios evaluated for the VR project were mainly those that involved conflict with more senior team members (e.g. senior nurse or consultant). Choosing a scenario that primarily involved interaction with a senior team member also coincided with Calhoun and colleagues' scenarios, where a confederate takes charge of a situation and whose decision must be challenged to prevent a negative outcome.

Chapter 5 Application Development

This chapter outlines the creative process behind the development of the two main types of media to be investigated – the VR simulator and more conventional (2D) comic book formats, including the development process underpinning the generation of the scenarios featured in both applications. To assist with the simulator and comic content development, the author was invited to further observe the delivery of training simulation at the Clinical Skills Suite (CSS) situated at the QEHB. As development of both applications progressed, the scenario content was developed, verified and finalised by regular exposure of the material to Subject Matter Experts (SMEs).

5.1 Scenario Development & Methodology

The base content for the scenario consisted of a combination of elements from two challenge scenario examples provided by participants in the previous investigation (0), both of which are detailed in Table 4.22 and Table 4.23. The scenario detailed in Table 4.22 involved a participant who was subjected to a strong negative reaction from her consultant. The reaction was due to her questioning of his decision regarding treatment for a patient. The second scenario, detailed in Table 4.23, concerned a participant who witnessed and challenged a consultant for not adhering to trust policy whilst taking blood from a patient.

The aim of this scenario, then, became one where it was necessary to challenge a consultant who had issued an inappropriate order to withdraw a blood sample from a patient in their care. To discover why the order was not appropriate, participants would be required to examine the patient's medical history, diagnosis and consider other elements for them both to form and successfully issue a challenge. However, elements such as an explanation for the blood needing to be withdrawn required clarification. A military consultant anaesthetist posted at the QEHB had taken part in the previous investigation (0), and had offered to attend a follow-up interview after the base content of the scenario had been established to assist with further development. His level of experience assisted the author in maintaining the realism, medical content and internal language featured in the scenario. The outcome of the interview is detailed below.

5.1.1 Why would the patient have come to the hospital?

The patient might have presented at the hospital with a history of haematemesis (vomiting blood). The symptoms could be due to either a Gastrointestinal Infection or Bleed (GIB) or stomach ulcer. Symptoms could include high levels of stress, severe diarrhoea and painful abdominal cramps, and be caused by an accidental overdose of drugs such as paracetamol. The patient would not be actively vomiting, but blood tests would come back highlighting that the patient's haemoglobin levels were low. Therefore, s/he would benefit from a blood transfusion.

5.1.2 How might the patient arrive at the hospital?

Three scenarios were given that clarifies how the patient might be brought in to the hospital.

Firstly, the patient could have self-admitted through the emergency department. If s/he could do this, then s/he would not usually be in a critical state. Therefore, there would be plenty of time to acquire the patient's background information before assessing symptoms.

Secondly, s/he could have been brought in via an ambulance. This would suggest that the patient is in a critical state, and time to acquire patient background information would be limited. Prompt assessment and treatment would be necessary and there could be no advanced warning of the patient's arrival.

Thirdly, the patient could have been transferred from another department. S/he could be suffering from another condition and might start to present symptoms for either a stomach ulcer or GIB, hence the transfer. The level of severity surrounding the patient's status would vary, but information such as blood tests, observation data and history should already be on record at the other departments. Advanced warning of the patient's transfer would be possible, and arrival time could, therefore, vary.

5.1.3 What would the patient's status be?

The patient's heart rate could be higher than normal; their blood pressure might be low and s/he may look somewhat flushed or sweaty. Under these circumstances the patient would not require a blood transfusion immediately. As an element of randomness, the patient could suddenly vomit without warning, despite being in an otherwise (or apparent) stable condition. This could introduce immediate pressure on the medical personnel to act. An example of this occurring could be the patient talking to staff before suddenly vomiting.

5.1.4 What scenarios would prevent a blood transfusion?

Upon requesting a transfusion, a bag of blood would be delivered by a member of staff from the blood bank. The blood within the bag must be compatible with the patient's needs, both in terms of blood type (i.e. the labelling of blood based on red blood cell antigens – A, B, AB, O and proteins – the 'rhesus' factor) and match ('cross-matching' ensures that donor blood is compatible with the patient's). Blood bag automation machinery located within the blood department fills an empty bag with blood that is cross-matched with each patient. According to the military consultant anaesthetist, the chance of this machine dispensing the wrong blood for a patient is next to impossible. In the event a member of staff identifies an incorrect blood bag, when time is not critical, a new blood bag can be requested and no harm should come to the patient. However, should the patient begin deteriorating (for example, they could start vomiting or their heart rate may increase significantly), time pressure becomes a factor and prompt action

should be taken. Examples of moments where time pressure is an issue includes excessive bleeding from a stomach ulcer, or, for even greater pressure, if the patient has been a victim of a knife or gun attack.

Where time is limited and the delivered blood bag given is not suitable, a bag of type ‘O’ can be given. Blood type ‘O’ is universal, and can be given to almost everyone with no adverse reactions. Blood bags of type ‘O’ are kept in refrigerators located in theatres and emergency departments, but they are usually given only as a last resort. A common issue is that junior doctors do not usually know where they are located, and sometimes do not think to use them.

Common scenarios that require the blood bag to be sent back and replaced usually involve issues concerning the label. This includes being given type-specific and matching blood type for a patient, but delivered to the wrong person (i.e. the label on the bag has a different name from the recipient patient). When requested, this situation is usually corrected and a replacement is delivered within 15 minutes. A further issue could be that the blood bag given contains a type that is not matched to the current patient, but their name is correctly displayed on the label. In such an event, the correct blood bag is usually returned within 45 minutes. The blood type and name label could also be correct but with a slight error in the printing. For example, one number in the patient’s date of birth on the label could be incorrect or a letter might be missing from their name. If time is not an issue, regardless of the circumstances, it is standard practice that the bag should be sent back to the bank for a correctly labelled

replacement. However, if the situation is urgent and time is limited, the bag could be used, irrespective of an incorrect label, if the blood type matches.

The military consultant anaesthetist stated that, depending on the personality of the consultant, s/he could insist on the blood being administered despite incorrect labelling. According to the consultant, this was more likely to occur with junior staff, who usually "give in" to a senior's insistence and administer the blood.

"The patient could be a Jehovah's Witness"

Research has shown that patients who refuse a blood transfusion, including refusals on religious grounds, and present with a low haemoglobin level of 60-80 g/l are manageable (Fung *et al.*, 2009). However, treating a patient who is a member of the Jehovah's Witness (JW) community presents challenges in operating theatres due their religious rejection of blood transfusions (Cothren *et al.*, 2002; Tanaka *et al.*, 2003; Boom *et al.*, 2015). The bible of a JW states that they are not permitted to consume or 'ingest' blood as a tribute to their God, who is described as the giver of life. Such complications have reportedly been the cause of fatality, due to excessive blood loss in the operating room despite bespoke procedures designed to avoid the use of transfusions (e.g. Jassar *et al.*, 2012). These scenarios had also been witnessed by the military consultant anaesthetist, where patients had died due to rejecting a blood transfusion.

Further to this, it is NHS policy that patients reserve the right to refuse treatment if medical staff are satisfied that any patient making this decision are doing so of their own free will (for example, they may be influenced by effects of their condition, injury, or drugs). The decision must be upheld and respected, and if treatment is given regardless of their decision, it is considered an assault and staff can be prosecuted. Some patients may also arrive at the hospital equipped with a legal document (such as a 'Do Not Resuscitate' order; DNR), stating that under no circumstances shall they receive treatment, such as a blood transfusion. These documents would also contain evidence that they acknowledge the risk they face due to their medical condition and/or requests.

5.1.5 Final Scenario Content – "Blood Bag"

Combined with the topics discussed with the military consultant anaesthetist, the final VR scenario was crafted from individual elements highlighted within a series of challenge scenarios acquired in the first investigation. The final scenario was presented to the military consultant and clinical stakeholders attached to the project who verified its content as realistic. It was advised by the project's clinical supervisors that any elements that refer to knife wounds, gun attacks or patient death should be avoided. Despite the research conducted that promotes the possibility of patient or simulated patient death, it was believed that any combination of these elements could cause unnecessary (and research-confounding) emotional distress.

The scenario outline consisted of a participant, representing their grade in real-life, being asked via telephone to carry out checks on a patient by the name of 'James Patrick Walton', lying semi-conscious in his bed. He arrived at the ICU from another department with a history of haematemesis (vomiting blood; Davies *et al.*, 2015) and was severely unwell because of the condition. His heart rate was higher than normal (tachycardia - high resting heart rate more than 100 beats per minute BPM; Members *et al.*, 2015), blood pressure was low (hypotensive - abnormally low blood pressure, < 90mm; Sacchetti *et al.*, 2007) and was looking slightly flushed. He was also dazed and confused and was, therefore, unable to respond to any questions or queries. The symptoms would be indicative of a GIB. The patient may suddenly vomit without warning despite being in a relatively stable condition - this will introduce an immediate pressure on the participant to act. Blood tests indicated that the patient's haemoglobin levels were low and would, therefore, benefit from a blood transfusion.

The participant will start the scenario outside of the room in a corridor where they will be greeted by an assisting nurse. The nurse who greets the participant will either be male or female. There is also a chance the nurse will be missing, and the participant will instead enter the room on their own. An examination of the patient's notes and the subsequent dialogue between the nurse and the consultant (see further below) will reveal the patient's various health issues detailed above.

However, issues concerning the patient's circumstances should, in the simulated scenario, prevent any transfusion procedure from being carried out. In this scenario, the blood transfusion should not be carried out on the patient due to the random selection of one of the following three reasons at the beginning of the simulation:

1. The patient is a JW. The participant should not be willing to carry out the procedure whether or not a DNR order is available.

2. A blood bag, sitting beside the patient's bed on a table, displays a label with an incorrect initial. The label was not printed in error, and instead refers to another patient on the ward with a different initial but very similar name. For example, 'James A. Walton.'

3. The patient in all variations of the scenario will not have an identification (ID) wristband attached to either wrist. Whilst this would not pose any immediate or significant deterrent for administering blood, in a high time pressure situation it could be enough to delay the treatment. This is because the participant would not be able to verify the patient's identity, regardless of the other information present in the room.

The simulated scenario will rotate between issues 1 and 2 and may include elements that are shared between them. For example, the patient may be a JW but the blood bag could still display an incorrect label. A further example could be that the patient is not a JW and the blood bag also displays a correct name label. However, issue 3 will always be active regardless whether

elements of issues 1 and 2 are used. Based on all the above, therefore, the procedure should **never** be carried out when asked or instructed to. The scenario will also permit and encourage the participant to explore the environment and interact with several items that provide them with information. These items are listed with descriptions presented below in Table 5.1. By examining these items, the participant should be fully informed of the situation regarding any of the three patient situations, and, therefore, can take any action accordingly.

Table 5.1 - Examinable Items in the Scenario

Item/Character	Location	Description
Patient	Lying in the bed, semi-conscious, located in the middle of the room.	Due to the patient's confusion, he is unable to respond to any queries or questions. Therefore, when the participant attempts to examine him, they are greeted with a message (e.g. via the use of a text box user interface element): "The patient is confused and is not responding to your queries." This object will always be active in the environment.
Patient Notes	Foot of the bed, on a table.	A graphical model of a clipboard with a piece of paper that represents the patient's notes. Using the notes, the user will learn of the patient's history of vomiting blood and low haemoglobin level. This object will always be active in the environment.
Patient's Belongings (Bag)	On a chair, next to the bed.	Examining the bag will reveal a signed DNR order. The order consists of a piece of paper containing a message that confirms the patient is a JW. The message reads: *"NO BLOOD TRANSFUSION!* *As a God-fearing Christian and a believer of Jehovah's word, the Bible, I hereby demand that blood, in any way, shape or form, is NOT to be fed into my body; however, blood substitutes may be used in case of extreme loss of blood.* *'YOU MUST NOT EAT THE BLOOD OF ANY SORT OF FLESH' – LEVITICUS 17:14"*

		This object will not always be active in the environment.
Ward List	In the corridor at the other side of the room window.	A bed list that displays the name of all patients in the ward. In addition to the name of the patient of immediate concern ("James P. Walton"), a patient with the name 'James A. Walton' (see blood bag) is also present in the ward, and examining the ward list will reveal this. This object will always be active in the environment.
Bed Number Sign	On top of the door used to enter the room.	Examining this item will support the ward list item. The sign will illustrate that the patient is in bed number 4, as displayed on the ward list. The patient with a similar name is located nearby in another bed. This object will always be active in the environment.
JW Wristband	On the patient's right wrist.	A red wristband attached to the patient's wrist confirms that the patient is a JW. The message displays: "JEHOVAH'S WITNESS – NO BLOOD TRANSFUSION!" This object will not always be active in the environment.
Observation (Obs) Chart	Foot of the bed, on a table.	A template patient observations chart was provided, pre-filled with data that matches the patient's status, by the clinical supervisor. This object will always be active in the environment.
Blood Bag	Left hand side of the bed, on a table.	Two patients in the ward share the same name but have different initials. The blood bag label will display either of these names. This object will not always be active in the environment.

After a brief period, a confederate (in the form of a virtual consultant) will enter the room and assume leadership of the situation. Their gender, like the nurse, will either be male or female. In addition to this, their attitude will also vary between scenario sessions and will present as either very calm or aggressive. The consultant's behaviour differences are based on scenario examples provided by research participants in the first investigation. For example, a seemingly aggressive consultant was discussed in Table 4.22, behaviour also present in other scenarios. However, consultants challenged in other examples given were calm and accepting of the challenge. The purpose of the personality differences was to evaluate whether the attitudes would produce a different reaction from participants. This is in addition to whether a more aggressive attitude would make the process of challenging difficult when compared to someone more calm and accepting.

In addition to being represented as having limited time and being late for theatre, the aggressive consultant will attempt to push the participant towards carrying out the blood transfusion. Based on the issues surrounding the patient, as described above, the participant should not agree to carry out the procedure. At a random time, the patient will appear to vomit and, subsequently, begin to deteriorate. Their heart rate will further increase, triggering the consultant to issue a decision. The consultant's decision will present the participant with three options: 'challenge', 'refuse' or 'agree'. The scenario will then conclude, regardless of which action the participant takes.

There is a chance the consultant will reject the first challenge attempt. The scenario adopted the two-challenge rule that allowed the participant to re-issue their challenge like the technique described in the literature (Pian-Smith *et al.*, 2009; Calhoun *et al.*, 2013; 2014). This also allowed them to explore the environment once more before responding to consultant. Upon responding for a second time, the participant was given the same three options as with the first decision. However, if the participant took too long to respond, the consultant automatically overruled any challenge and ended the scenario prematurely. Although multiple endings exist in the scenario, each ending will result in the consultant taking charge and attempting to administer the blood themselves. Therefore, the action of administering the blood is never carried out by the participant's character.

Figure 5.1 on the next page illustrates the structure or 'game flow' of the scenario in diagrammatic form.

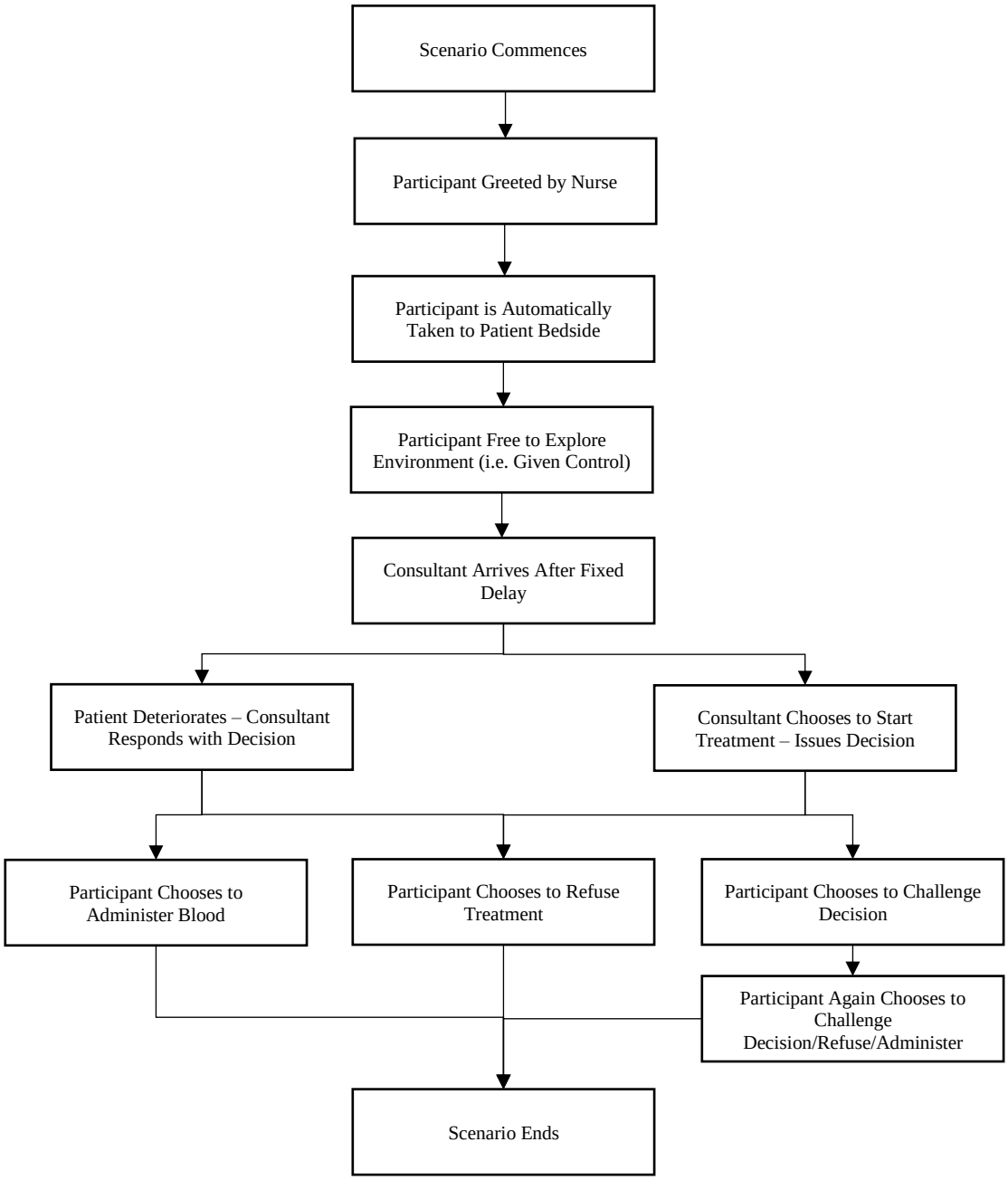

Figure 5.1 - Flowchart of the Scenario

5.2 Prototype Development

5.2.1 VR Simulator

The purpose of this section is to describe the groundwork for the development of a digital simulation-based training solution, designed to train medical personnel to be confident in challenging the clinical decisions of their peers and seniors. Research findings and data collected as part of the first project investigation were used to craft an appropriate virtual scenario.

The presentation was designed to emphasise simplicity and present users with an intuitive interface design (e.g. by adopting a simple “pick-up-and-play” style of interaction), to avoid confronting participants with complicated controls, functionality or the need to develop an extensive tutorial sequence. The eventual experiment undertaken using the simulator provided an additional opportunity to evaluate the design, presentation and control scheme, whilst ascertaining knowledge and experience of video game technologies among staff within the QEHB. A full overview of the VR simulator’s development process, including creation of characters and animations is provided in Appendix F.

5.2.1.1 Simulated Scenario Presentation

The simulated scenario was presented in a first-person perspective (illustrated below in Figure 5.2), a popular frame of reference for many action game players and an important factor in enhancing the sense of immersion within the virtual environment (Drachen *et al.*, 2010; Nacke *et al.*, 2010; Cho & Lee, 2014). Each participant assumed their own role and identity within the scenario. They were guided into the patient's side room where they could explore the environment and engage with virtual characters representing colleagues in a fictional hospital setting. The room used for the scenario was designed to partially mimic a traditional side room used in the QEHB (Figure 5.3).

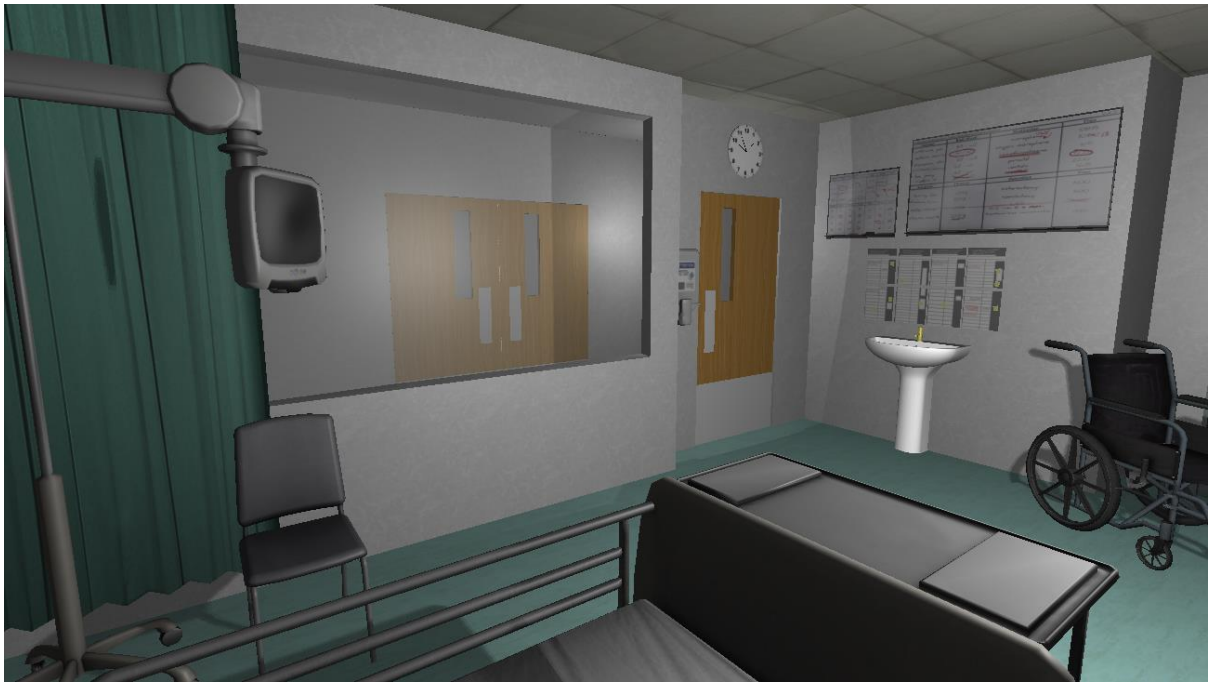

Figure 5.2 - ‘Game View’ of the simulator environment in first person perspective

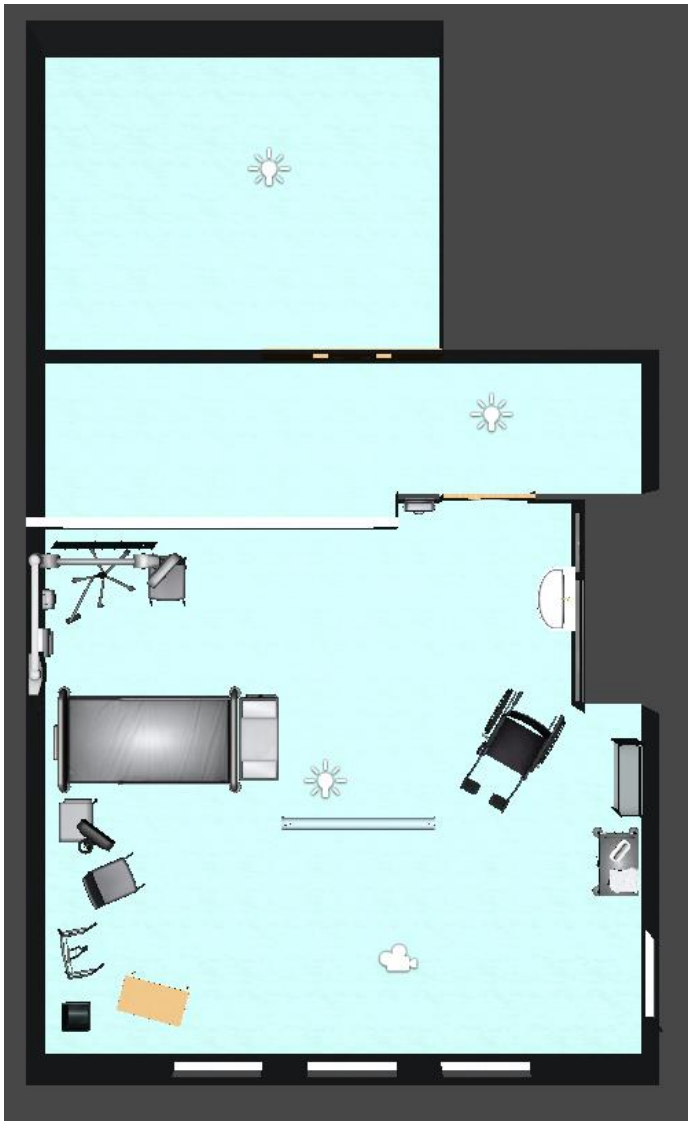

Figure 5.3 - Simulator environment in a top-down view

Figure 5.4 below is a screenshot from an open source video clip of an ECG monitor displaying a name that was then given to the virtual patient, James P. Walton. The footage was assigned to a material that was attached to a 3D model of a monitor in the simulator environment, enabling the footage to be played during the simulation run-time. It was later replaced with updated simulated footage created specifically for the patient by the simulation technician situated at the CSS at the QEHB (detailed further below in Section 5.3).

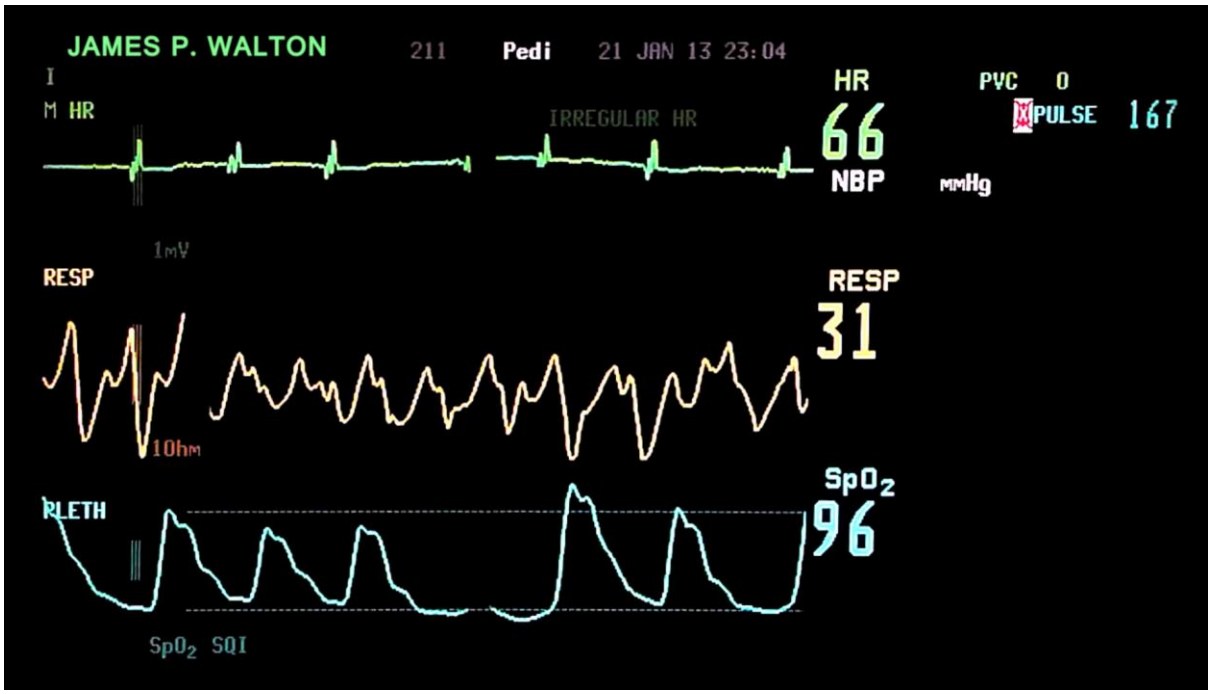

Figure 5.4 - Open source ECG monitor footage used as placeholder (Robinson, 2013)

Figure 5.5 - The male consultant talking to the participant's character

In addition to the differing sets of dialogue, to further emphasise the attitude difference of each consultant an alternative set of animations were used for each type, as illustrated below in Figure 5.6. A generic talking animation was used for the calm version, and a slightly exaggerated 'shouting' animation for the angry version. No differences in facial expressions were used.

Figure 5.6 - Consultant attitude animation comparison

5.2.2 Comic Book Project

Developed alongside the simulator, the comic book version of the scenario (samples available in Appendix H and Appendix I) was created by a freelance comic book illustrator, based on requirements and guidance from the author, to ensure compatibility of content with the digital counterpart. Featuring the same scenario content used for the VR simulator, the comic presents the 'story' in the form of a 2D storyboard. Each 'cell' of the comic contains a hand-drawn, digitally illustrated still of key points in the scenario (for example, meeting the nurse in the corridor). Two versions of the comic were created that featured both the calm and angry versions of the consultant. The art style exploited resulted in exaggerated character visuals that further emphasised the difference between each attitude of the consultant, whilst also mimicking the style of traditional graphic novels. For example, this included the nurse visually reacting differently to each consultant version. As illustrated in Figure 5.7, the facial expressions of both consultant versions were also exaggerated to further emphasise the difference between attitudes.

In comparison to the VR simulator, the comic book version of the scenario content was altered slightly and simplified but followed the same script as shown in Appendix F. Alterations included a cell that illustrated the consultant having a conversation on his mobile telephone in the corridor, removal of examinable items such as the patient's observational chart and no gender switches. In addition, there was no cell that illustrated the time of day or weather

conditions outside.

Including those outlined above, the comic book illustrations were the focus of multiple iterations. following reviews of the revised content after each delivery. The purpose of the alterations, including the addition of extra tiles (e.g. the illustrated consultant's telephone conversation) and refinements to the distinct graphical style of the comic book content were undertaken to ensure that the illustrated material would effectively set the context to a level similar to that achieved using the more dynamic, animated content of the VR simulator. For example, the style of the comic book media, including speech balloons and exaggerated gesturing, represented the best way of establishing the background to a specific scenario, including helping the end user to gain a rapid appreciation of the "personalities" and "attitudes" of the actors. This is difficult to achieve in "static" forms of media, especially when compared to the more animated real-time capabilities of the VR simulator, where gestures, sound and other forms of non-verbal forms of communication can be programmed relatively easily.

Figure 5.7 - Calm and Angry versions of the consultant character

Unlike the simulator, the comic book followed a fixed pathway, with branching endings that were determined by the choice of the reader following the consultant's decision for moving ahead with a blood transfusion. In this version of the scenario, all three issues concerning the patient defined earlier in this chapter were present, apart from a missing JW wristband and, therefore, no transfusion should take place.

As with the simulator, the reader assumed their own role within the scenario and the characters appeared to speak directly to them in a first-person perspective. Only the patient, female nurse and male consultant were present in the environment. In addition, they were required to make a choice that determined their 'ending.' The choices were: "challenge the consultant", "refuse treatment" and "administer the blood". However, all endings, despite the choice of the reader, led to the same conclusion, as the consultant overruled every challenge or refusal. Nevertheless, the ending page participants were given contained different content (see Figure 5.8 below for an example).

Figure 5.8 - Ending cell if the reader refuses to follow through with the blood transfusion

5.3 Simulator Demonstration at the Clinical Skills Suite at the QEHB

Late into the project, the author was invited to conduct further observational research at the CSS at the QEHB. Two observational sessions were conducted and guests consisting of various QEHB staff consultants and educators were in attendance. The purpose of this additional observation opportunity was to further observe simulated scenarios and to present the then-current progress of the simulator project, which had passed an initial testing phase and was almost complete.

The flow of a traditional training day was similar to the events that occurred at the HSC and, additionally, followed the same structure regarding lecture content, learning activities, engagement in simulation and debrief sessions. As with the HSC, the simulation technology provided was a Laerdal SimMan (Figure 5.9). Participants interacted with the simulated patient (SP) in the same way as those who attended training days at HSC. All observations were carried out in the simulator technician room, located remotely from the simulator room, via the use of microphones and a CCTV system. In the neighbouring lecture theatre (Figure 5.10), live CCTV footage of the scenarios was presented to a screen, allowing other participants in attendance to also view the session.

Figure 5.9 - Simulation session carried out at the CSS at the QEHB

Figure 5.10 - Simulation debrief session carried out at the CSS at the QEHB and location of simulator presentation

5.3.1 Project Feedback

The simulator had already passed an internal testing phase to fix any software or visual issues and only required external verification on the final scenario content. However, the only exception was the voice dialogue which, although recorded, had not yet been implemented. Therefore, subtitled text boxes were added as a temporary 'placeholder', and this was clarified to the team beforehand. The simulator was demonstrated in the same lecture room where the debrief sessions were conducted, and, as well as the consultants and educators already present, three extra members of staff were also in attendance to view the project.

The simulator was launched with an initial test run controlled by the author to clarify the elements of the scenario and control scheme. This was then followed by leaving the scenario to run on a loop (with no input from anyone), whilst the staff queried element and asked questions related to the project. Time was also allocated to present the comic book version of the scenario to medical students in attendance of that day. Printed copies of the first finished version were handed out to the participants for feedback and they were also provided with a document containing information related to the project, author contact details and information regarding the upcoming experiment phase (including an invitation to take part).

The overall response to the project was positive. However, feedback on improvements were provided that were implemented following the demonstration day. This feedback is listed below.

5.3.1.1 ECG Monitor

The simulator was using an open source video clip of an ECG attached to a 3D model of a monitor (Figure 5.4). This was not initially designed to function as a dynamic object, but instead remain in the form of a static "prop" that could not be examined. However, the review team was evidently distracted by the fake footage. They stated that an ECG monitor is an essential tool in the diagnosis of a patient, and requested that real data be used to match the patient's condition.

The recording of live simulator ECG footage to replace the stock footage occurred at the CSS later. Communication with the clinical supervisor regarding this topic had provided the values required for the patient, and two sets of footage were acquired.

The first part of the footage represented patient life signs as if in a stable but semi-conscious state, with a heart rate of ~70bpm. The second part of the footage consisted of the patient's heart rate elevating more than 100bpm (tachycardia) with a flashing indicator to alert staff of the event. The clips were edited to loop infinitely and integrated into the simulator in place of the stock footage. An event trigger was added that replaced the stable looping ECG clip with the second, deteriorating looped footage which would be invoked once the simulated patient began to vomit.

5.3.1.2 Dialogue Content

The team had identified several issues concerning the then-current script for the characters. The main concern was that some lines of dialogue were considered unrealistic and comments were mainly directed towards the lines provided for the 'angry consultant'. The reason for this was that the content was not appropriate language for a consultant to use, even if acting aggressively. A visiting member of staff had requested a copy of the script so he may correct any issues with the content. When the script was returned, several differences were noted. Some of the changes are highlighted below in Table 5.2.

Table 5.2 - Revised Script Dialogue Content

Previous dialogue	**Revised content**
When referring to when the nurse was not present at the patient's bedside… "For God's sake... I will be noting this down! I don't have time to spare so let's get on with this. He needs a blood transfusion, right?"	"For God's sake... I will be noting this down. As the patient is deteriorating he needs the blood now and we are wasting time. Are you going to administer it?"
When the nurse states that the patient is deteriorating… "For God's sake, you heard the nurse! Get that blood in him now!"	"As the patient is deteriorating he needs the blood now! Are you going to administer it?"
When challenging the consultant for the first time… "Excuse me? Are you questioning my approach? For a second, I thought I was the one in charge here...?"	"Excuse me? Are you questioning my approach? The patient clearly needs a blood transfusion!"
When the consultant first enters the patient's room… "OK, I'm really stressed at the moment so I don't want to waste time - what do we have here?"	"OK, I'm running late for theatre and so I do not have much time. Tell me what you know about the patient."

1.1.1.1 Character Animations

The final feedback given by the team concerned some of the animation clips used for the characters. Throughout the scenario, when no conversations were taking place, random events would occur that would trigger either the nurse or consultant characters to play various forms of idle animations. These animations consisted of moments where they would look around the

room or swing their arms slightly. These clips were described as distracting, and it was felt that it would be more appropriate for them to either be removed or adjusted so as not to distract the user of the simulator. In addition, there were moments where the animations would transition between states rather rapidly, resulting in a sudden, stiff-like movement. Following this feedback, the distracting animations were removed and replaced with simpler, less distracting idle clips. This was in addition to a reduction in animation transition event speeds, which resulted in more natural, less sudden, movements.

5.4 Conclusion

Time constraints had limited further development of the project. However, the content that was presented to the CSS team was verified as a realistic scenario if their criticisms discussed earlier in this chapter were reviewed. The revised alterations proposed by the CSS team were implemented, and a pilot test of the simulator and comic book were conducted to further verify the content following the feedback.

A final (fifth) year medical student from the QEHB, in attendance of one of the observed simulation training days at the CSS, took part in a pilot test of the simulator, modified as described above. In addition to the modifications, all character voice dialogues were edited and implemented within the simulator. Due to limited space in the testing environment, the projector and screen were not, on this occasion, usable and the session was undertaken using

the author's laptop.

The participant was first subjected to a blind test, essentially simulating the conditions expected in the experiment. This consisted of two runs of the scenario with no assistance on how to progress. Additional sessions were then carried out, this time with assistance from the author to clarify the scenario content as it was in motion. This process also allowed the participant to ask questions or query any of the content as she engaged with the simulator.

The feedback given following the pilot test was positive. However, the participant suggested that a practice round or tutorial session be considered to explain the controls and that time should be allowed for participants to adapt to the simulator's controls before the scenario was presented. As the experiment for the simulator and comic book was arranged a short time after the events of this day, no development time was possible to create a tutorial sequence. However, it had been noted for future reference. Although the comic book version of the scenario was demonstrated, no constructive feedback was given.

The next chapter is a full overview of the experiment phase, where a further opportunistic sample of clinical personnel situated at the QEHB engaged with the VR simulator and comic book prototypes.

Chapter 6 Experiment

6.1 Experimental Aims

This phase of the project set out to establish whether virtual simulation and printed media technologies could aid in the development of the decision-making abilities of clinical and nursing personnel at the QEHB. The data obtained from the questionnaire and interviews conducted in the previous investigation described in Chapter 4 provided sufficient evidence to support further investigation. The primary objective of the project phase described below was to obtain evidence to support Research Question 4, namely: "Can VR-based simulation techniques help develop an ability to challenge clinical decisions?" With supporting evidence, it may indicate that a simulation tool designed to help develop the ability to challenge decisions could be beneficial within healthcare establishments. Potential benefits include improving ward round team dynamics, individual and team Situational Awareness (SA) and, ultimately, patient safety and well-being.

As detailed in Chapter 5, a proof of concept simulator prototype that focused on the topic of challenging decisions had been developed and experiments using this tool, and the associated comic book version, were undertaken at the QEHB. Development of the simulator tool and the subsequent adaptation of the scenarios to a comic book style of delivery combined the research and findings accumulated from the earlier investigations. The present experimental phase

sought to generate data to evaluate their effectiveness in enhancing the decision-making abilities of medical staff. The tools focused on developing the traits associated with challenging that were identified in the investigation analysis, such as confidence, seniority and the attitude of the other person (i.e. the one being challenged).

The simulator and comic content presented a scenario that was developed from accounts provided by various participants in the earlier investigations. The accounts consisted of scenarios where a research participant was prompted to challenge the decision of a colleague in their team or department. The final content of the scenario was subjected to various iterations and changes and was verified by medical SMEs from the CSS and other departments within the QEHB, focusing on use of language, abbreviations and overall 'clinical realism.' The results of the experiment, including a full overview of the experimental methodology, is highlighted in this chapter.

As with the first investigation, the experiment was designed around a series of Experiment Aims that are listed below in Table 6.1. The research aims were the basis of hypotheses and subsequent content developed for the questionnaires highlighted further below.

Table 6.1 - Experiment Research Aims A-P

	Experiment Aim	**Description**
A	Recruit participants from as many different positions and professions within in the medical hierarchy, and various statistical data.	As with investigation Research Aim G (Table 4.1), this would assist in identifying any trends present within the overall data that could be attributed to, for example, gender or experience. It also featured questions that were present in the investigation questionnaire (detailed later).
B	Discover the extent to which clinical staff are experienced or familiar with computers and how often they interact with them.	As the simulator in this project utilises computing technology, data to support this aim could potentially predict technical performance within the simulated environment. For example, failure to adapt to the simulator (such as the control scheme or navigating the environment) could be associated to low experience with computers.
C	Discover the extent to which clinical staff are experienced or familiar with printed media, such as newspapers or books and (particularly) comics, and how often they interact with them.	Like Aim B, data to support this aim could potentially predict performance when navigating the flow of content within the comic book. For example, a participant who did not understand the content presented to them in the comic, or the layout in which it is presented, may have a low experience with this kind of media anyway, due to lack of exposure.
D	Discover the extent to which clinical staff are experienced or familiar with gaming technologies/ comic books and how often they interact with them.	Like Aim B, data to support this aim could predict performance with gaming technologies. For example, as the scenario was controlled using an Xbox One controller, a participant who demonstrated poor performance when using the controller could be associated with low experience in the gaming arena.
E	Discover the extent to which clinical staff are experienced or familiar with virtual reality simulation technologies (for training or other applications).	As shown in Section 4.5.2, conventional simulation experience (e.g. SimMan, Advanced Life Support courses) was high among the investigation cohort and research was found to be lacking in this area prior to the experiment being undertaken. It was important to obtain data to support this aim, as could identify considerations and could also be a predictor of performance in the

		simulation sessions, as highlighted in Experiment Aims B and D.
F	Discover the extent to which clinical staff are experienced or familiar with mannequin-based simulation training technologies.	The previous investigation revealed that experience with traditional mannequin-based simulation technologies was high, with 45 of 50 participants having been exposed to simulation at some point throughout their careers. The experiment could be a further indication of this.
G	Further evaluate whether medical staff consider simulation training to be a beneficial resource within healthcare.	As with the previous investigation, it was essential to determine how desirable simulation is within the medical space and to identify whether it is positively received (and if not, why not).
H	Further record the abilities and confidence levels of medical staff to issue a challenge to multiple positions in the hierarchy.	The results from the previous investigation suggested that the ability to challenge a decision is associated with clinical experience. Further evidence was required to support this finding.
I	Assess participant Situational Awareness in the virtual environment.	Research concerning SA in a medical environment emphasises its importance in the avoidance of errors. It was a topic widely discussed in the literature reviewed in Chapter 2 and frequently mentioned during the observations of the HSC and QEHB CSS training. Given the structure of the scenario in the simulator, observations of the sessions can determine how aware the users are of objects and events within the environment.
J	Evaluate whether participants experienced a sense of "immersion" within the media.	According to the research concerning immersion in virtual environments (e.g. Alexander *et al.*, 2005), the extent of skills transfer to real world settings may be associated with how users are immersed into those environments. Observational and post-use feedback data gathered from the experiment could demonstrate this association.
K	Evaluate the visual fidelity of the media.	Research into visual fidelity in simulation training had produced mixed results (Section 2.6). Despite positive feedback with the adoption of higher levels of visual fidelity in VR, it can, as shown by Stone (2011), be unrealistic in some cases and, therefore, distracting. Both the VR simulator and comic book projects targeted a medium level of

		visual fidelity (in line with common medical simulators such as SimMan) and feedback would be sought to evaluate this from the participant's perspective.
L	Evaluate the realism of the scenario.	Feedback from clinical SMEs, as highlighted in Chapter 4, had identified issues in the scenario that were later remedied with their assistance. This feedback helped to verify the realism in terms of the medical 'language' used, virtual character behaviours and the events occurring within the scenario.
M	Discover how rare this type of scenario is.	One advantage of simulation training, as highlighted in the literature, is the ability to practice 'rare' (i.e. uncommon or extreme) events (Wright *et al.*, 2004; Byrne, 2012), an advantage for junior trainees. With the help of feedback from clinical SMEs, the scenario was developed based on a combination of scenarios, all of which were 'rare' occurrences. Therefore, this assisted with creating a unique, realistic scenario not commonly experienced by many.
N	Evaluate each project's effectiveness to develop the ability to challenge decisions.	Evidence was required that supported the impact of either tool on a participant's ability to challenge. In addition, feedback was required to improve the tools and, ultimately, maximise the effectiveness.
O	Compare the results of each project.	This aim helped establish which of the two projects performed better or worse.
P	Obtain feedback and suggestions of improvement.	Various sources of feedback were sought that might offer suggestions for improvement to the future design of the simulator and related media.

6.2 Experiment Design Methodology

The experiment consisted of four phases and was conducted over the course of one month under the medical supervision of one of the QEHB's Consultants in Critical Care & Anaesthesia, who also held the position of Clinical Lead for Simulation, the Clinical Skills Centre Manager and the Clinical Skills and Simulation Administrator. The first three phases, forming the initial experiment, required participants to complete a preliminary questionnaire, interact with either the VR simulator or comic book application and then to complete a short 'post-use' feedback questionnaire. The fourth phase consisted of a follow-up questionnaire, with both online and emailed word document versions available, emailed to the participants approximately six months after taking part in the initial investigation.

6.2.1 Recruitment

Unlike the previous investigation, where an opportunistic sample made up the participant cohort, the recruitment method for this investigation involved creating an invitation email that was sent out internally by the CSS.

6.2.2 VR Simulator Experiment Environment

Following the earlier observational research conducted at the CSS, the staff working therein provided space for the experiment to be carried out. Shown in Figure 5.10, the room provided

was also used for simulation lectures on training days and featured window blinds to darken the room, creating an ideal setting for the simulator and projector.

Respondents to the invitation who were selected for the simulator were offered a choice of timeslots dependent upon the room's availability. The duration of timeslots was set at 45 minutes, as the experiments were expected to last up to a maximum of 30 minutes, with 15 minutes allocated for overrun and resetting the room for the next participant.

Figure 6.1 illustrates the experimental set-up in the room. Participants were asked to sit on a 'lecture style' chair located approximately in the centre of the room. The chair was attached to a miniature desk on the right-hand side, allowing them to complete the questionnaires with relative ease. A table holding the projector was placed in front of the participant. Its position was adjusted beforehand to ensure that the accompanying laptop and cables were in a safe position on the floor to the left.

Every simulation session was recorded using a handheld video camera that was attached to a tripod and placed to the right of the participant (oriented towards the screen and not the participant). However, participants were informed of the role of the camera and were made aware that their voices would be captured if they spoke during the session. All paperwork, refreshments and other items of miscellaneous equipment were placed on a table located out of view and behind the participant.

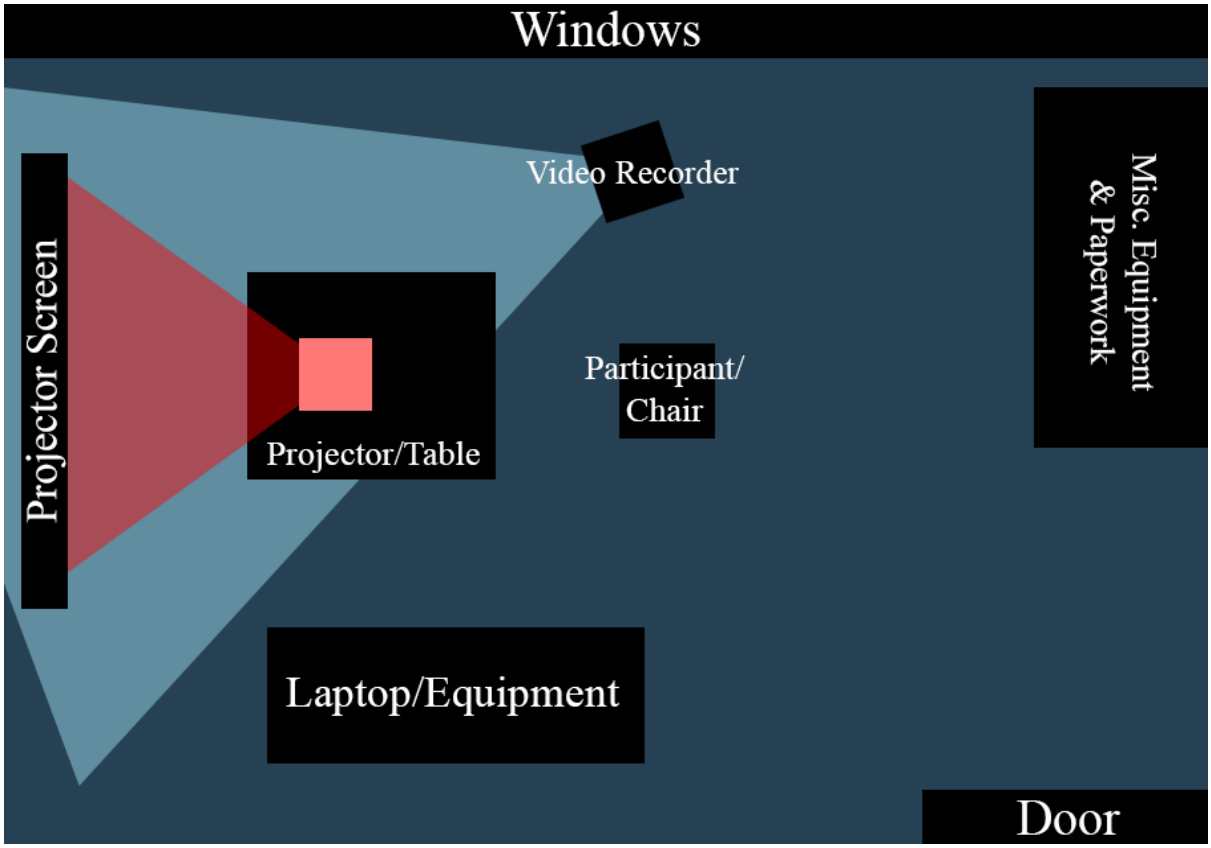

Figure 6.1 - Simulation Experiment Room Layout Diagram

6.2.3 Comic Book Experiment Environment

In contrast to the sessions for the simulator experiments, the comic book experiment did not require a designated room. Instead, the participants selected for this experiment either came to the CSS where the session was conducted in the main office, or the author travelled to their location. Locations included a student recreation room located near the CSS, the office space of a participant and a lecture theatre within the Trust.

6.2.4 Experiment Procedure

6.2.4.1 VR Simulator

The VR simulator experiment procedure was planned and structured to accommodate the limited availability of the lecture room and, therefore, remained consistent throughout the experimental phase. This was partly due to the substantial amount of equipment required, coupled with the size and layout of the room offered, which made the possibility of hosting the experiment elsewhere difficult. Where much of the equipment was transported to the hospital for each group of sessions arranged for a day, the projector screen was temporarily stored within the CSS and collected following the conclusion of the experiments. Supervision of the author was a necessity, to ensure that any issues encountered, software or otherwise, were resolved quickly to minimise any impact on the data recorded. The VR simulator experiment was not designed to accommodate more than one participant to take part simultaneously.

Participants who were invited to take part were asked to report to the CSS reception area and were taken to the room where the simulator equipment was set up (as laid out in Figure 6.1). The participants were asked to sit on the chair in the middle of the room where the author briefly introduced the project and research. The project information and consent forms were completed by the participants first if not submitted prior to their collection from the reception.

Before commencing the experiment, the author instructed the participant to complete the pre-use questionnaire. They were invited to ask the author any questions, only related to the clarification of any content, as they completed it and were informed that no answers could be given as examples. Upon completion of the pre-use questionnaire, the author ran through a checklist that ensured each participant were informed on, for example, the purpose of the simulator and how to control the camera. The checklist items are listed, in order of events, in Appendix N.

Following the checklist of items, the author offered to complete the UI element of the simulator (i.e. the main menu that starts the simulation), otherwise the participant commenced the experiment when they were ready to do so. As the simulator program transitioned from the menu to the scenario, the video camera commenced recording. Finally, upon completion of the five scenario runs, the video recording was stopped and the participants were asked to complete the post-use questionnaire. The author commenced resetting the room as the participant completed the questionnaire, and they were again invited to ask any questions related to their participation before leaving.

6.2.4.2 Comic Book

The portability of the comic book experiment when compared to the simulator allowed for more flexibility when carrying out each session. For example, the equipment required to carry out a comic book experiment was substantially smaller and could be transported to any location

if necessary. However, the procedure of the comic book experiment was relatively similar, in that the structure followed the same steps carried out for the VR simulator which included the checklist of items (i.e. items that were applicable to the comic, such as, for example, the simulator purpose).

The differences between the VR simulator and comic book procedures were the flow and duration of events, as, overall, the comic book sessions were significantly shorter to complete. In that, where the VR simulator followed a very strict set of events which were consistent in timing, the comic sessions permitted the participant to read through the pages as many times, and for as long, as they wished. The procedure also permitted, as discussed later in this chapter, multiple participants to take part simultaneously as less supervision was required. The comic book procedure was not limited by time or room availability, and were instead carried out in accordance with each participant's schedule.

However, as the author could report to the location of each participant who took part as per the study design, the procedure for the comic book was vulnerable to distraction or interruption from external sources which may impact or skew the data captured. Expectations of each participant's environment was unknown, rendering the ability to account for this vulnerability limited. In one case, a participant was unable to leave their department as they were on shift which prevented any alternative (and more private) location difficult to arrange. This scenario is discussed further in this chapter, as it presented a limitation associated with the flexibility

and portability of the comic book procedure.

6.3 Questionnaire Designs and Content

Three questionnaires were created for the experiment: a ‘pre-use’, ‘post-use’ and follow-up document respectively. The content for each document was designed to support the generation of relevant data for the research aims defined in Table 6.1. Where the content for the first of the three documents targeted the acquisition of basic participant information, the second mainly sought to elicit constructive feedback for the project. The follow-up document, provided to participants approximately six months after they took part, set out to establish whether the study had made an impact on the decision-challenging performance of participants and/or if any such incidents had occurred since their participation.

In line with the development process of the first questionnaire in the earlier investigation phase of this research, all documents were subjected to several iterations and adjustments to optimise format and content. As well as medical subject matter experts, further input for these iterations was provided by the medical and academic project supervisors.

6.4 Pre-Use Questionnaire Content

Designed to obtain preliminary general information from participants, the 'pre-use' questionnaire (Appendix J) was provided before their engagement with the simulator or comic book. As with the questionnaire provided to participants in the earlier investigation, the opening section of this document (Table 6.2) was designed to capture information such as profession, grade, years of experience and speciality. It also contained content from the earlier investigation, such as whether participants had received any training that involved challenging a team member. Following the introductory section of this questionnaire were a series of 5-point Likert Scale questions (detailed in Table 6.3).

Table 6.2 - Pre-Use Questionnaire Opening Section

Question	**Description**	**Aim (Table 6.1)**
What is your profession?	Participants would state if they were of the Doctor, Nurse, Student, Surgeon or other related primary medical profession.	A
What is your current grade?	From the above, the participant would state their current grade. For example, Medical Student Year 5 or Speciality Trainee Year 7.	A
What is your speciality?	As well as their profession, the questionnaire requested their speciality. For example, a Speciality Trainee could specialise in anaesthesiology or cardiology.	A
How many years have you been qualified?	Participants stated the number of years they have been qualified in their profession.	A
How many years have you been at your current post?	Participants stated the number of years they have been working at the QEHB.	A
What is your gender?	Research that compares challenge confidence between genders is limited as there were no identifiable trends in the previous investigation data.	A
Are you a member of the Armed Forces?	Participants would clarify whether they were military. Responses to this question could be compared with other elements, such as level of experience and challenge confidence.	A
Have you taken part in a study like this before? If so, can you provide a description?	This would help identify any previous studies in a similar area to this thesis.	A
Have you received any training that involves challenging decisions/being assertive? If so, can you provide a basic description?	Other than some of the studies already discussed in detail in this thesis, literature that focuses on developing the ability to challenge clinical decisions in ward round style settings is limited.	A

Table 6.3 - Pre-Use Questionnaire Content

No.	Question	Likert Scale Point Descriptors	Description	Aim (Table 6.1)
1	How many hours a week do you usually interact with: Computers / Printed Media?	Hours; 0, <1, 1-4, 4-8, 8+	Aimed to assess the amount of time clinical staff spend on computers, either at work or at home, and time spent reading any form of printed media (including books and newspapers).	B, C
2	What is your current experience with: Computers / Printed Media?	None, Low, Moderate, Good, Excellent	Aimed to assess how knowledgeable in/familiar with computing or printed media each participant is. The rating given may be reflected in their simulator/comic performance (e.g. ease of use, engagement, outcome).	B, C
3	How many hours a week do you normally interact with: Video Games / Comic Books?	Hours; 0, < 1, 1-4, 4-8, 8+	Aimed to assess how much time clinical staff spend interacting with any form of gaming technology, including a game console, computer or handheld device.	D
4	What is your current experience with: Video Games / Comic Books?	None, Low, Moderate, Good, Excellent	Following on from the previous question, this aimed to evaluate how knowledgeable in gaming or comic books each participant is. The rating given may be reflected in simulator performance, with respect to the presentation and control scheme (e.g. how fast they adapted to the controller and on-screen motion/interaction).	D
5	What is your current experience with virtual reality simulation training technologies?	None, Low, Moderate, Good, Excellent	Aimed to identify if clinical staff had previously interacted with a form of VR training simulator.	E
6	What is your current experience	None, Low, Moderate,	Aimed to identify if clinical staff had previously interacted with any other form	F

	with mannequin-based simulation training technologies?	Good, Excellent	of simulation-based training. Based on observational research conducted in earlier phases of investigation and the literature review, it was predicted that responses for this question would be high on the Likert Scale.	
7	In general, what is your opinion on simulation training in healthcare?	Very poor, Poor, OK, Good, Very good	This question aimed to add further support to the positive response obtained following the interview results of the previous investigation.	G
8	How confident are you in taking part in a study that makes use of gaming technology?	No confidence, Low, Somewhat, Good, Excellent	It was anticipated that participants' experience in the use of VR technologies would be low. Having read the associated project information sheet for this study or responding to the invitation email, participants were aware that they were taking part in a study that involved VR/gaming technology. This question aimed to evaluate the initial confidence of participants before taking part, which could then be compared to other areas such as performance, challenge confidence, and so on.	D
9	How would you rate your overall confidence to challenge a clinical decision?	No confidence, Low, Somewhat, Good, Excellent	It was important to continue obtaining data for the challenging decisions topic to build on the evidence obtained in the earlier investigations.	H
10	Any comments?	None	This part of the questionnaire was designed to elicit feedback, comments or initial concerns of participants before commencing with the simulator/comic presentation experiments. Any data gathered here was used to generate considerations for future research and design "upgrades" or "modifications".	P

6.5 Post-Use Questionnaire Content

Following the conclusion of the simulation or comic book experimental sessions, each participant was instructed to complete the post-use feedback questionnaire (Appendix K). Where the pre-use document took the form of only a single page, this questionnaire consisted of two pages in total. The opening section of the document consisted of a short retention assessment (Table 6.4), requiring the participants to list items they may have encountered during the sessions, including questions related to the virtual surroundings. Based on the design of the scenario, each participant would have been given the opportunity to encounter everything in the scenario, such as examinable items and characters, at least once in their session. The only exception to this was the comic book scenario, which did not feature a cell that presented participants with a representation of the weather conditions outside of the environment. After completing the simple SA assessment opening section, participants were then asked to complete a mixture of Likert Scale and free text response questions (Table 6.5).

Table 6.4 - Post-Use Questionnaire SA Assessment – Section 1

Question	Description
Which characters do you remember being present in the environment?	Excluding themselves, the scenario involved both a male and female nurse, male and female consultant, a male nurse in the background and the patient.
What examinable items do you remember being present in the environment?	Items included the patient's notes, blood bag, wrist band and Jehovah's Witness note.
Do you remember if it was day or night, and what the weather conditions were outside?	The scenario was set at night and it was snowing outside. The windows that allowed the user to see outside were initially located behind them and out of view of the bed space. The purpose of this element of the questionnaire was to evaluate how much the participants would explore the environment.
Do you remember what the patient's name, age and gender was?	James Patrick Walton, aged 32 and male. This information was discovered by examining the patient notes and was partially repeated in the dialogue as the simulation progressed.
Do you remember what different issues there were with the patient in the scenarios?	The patient was confused, hypotensive and suffering from increased heart rate (tachycardia) after initially receiving surgery to treat a gastro-intestinal bleed.
Do you remember any of the patient's medical history?	Suffered from vomiting of the blood (haematemesis).
Do you remember what bed number the patient was in?	The patient was in bed number 4, as illustrated by the virtual sign above the door into the room.
Anything else in particular you noticed about the environment?	This question requested participants list anything else they noticed in the environment, again to assess observance. Items included a chair, Zimmer, sink and a wheelchair.

Table 6.5 - Post-Use Questionnaire Content

	Question	Response	Description	Aim
1	How would you rate your immersion into the media?	Likert Scale, 1-5; Very low, Low, Somewhat, High, Very high.	A Likert scale for participants to rate their immersion within the media application.	J
2	How would you rate the room conditions surrounding the experiment with regards to the room spacing, lighting, projector screen or other environmental conditions?	Likert Scale, 1-5; Very low, Low, Somewhat, High, Very high.	A Likert scale for participants to rate the room conditions where they engaged with the media application. Although the conditions for the simulator were unchanged between sessions, the location where the comic book scenario was presented varied from a quiet room to a large noisy lecture theatre, and this could be reflected in the results. This question complements Question 1, as noise could be a factor in lower ratings not only for the room conditions, but also lower ratings of immersion, as evidenced by W.E. Morrison *et al.* (2003), whose study concerning noise in healthcare environments resulted in elevated heart rates and is associated with lower concentration and poor task performance.	J
3	How would you rate the realism of the (base content) scenarios and their outcomes?	Likert Scale, 1-5; Very low, Low, Somewhat, High, Very high.	Meetings with SMEs regarding the scenario in the simulator, including a live demonstration of the tool, had elicited feedback that, once adopted and used to modify the simulation, helped to verify the content's validity, including the behaviour of the virtual characters. Data collated for this question would further support this verification.	L

4	How would you rate the realism of the consultant character?	Likert Scale, 1-5; Very low, Low, Somewhat, High, Very high.	As with the previous question, this would provide further support for the design of the scenario, but would specifically focus on the consultant character. The character's design and attitude, as highlighted in Chapter 5, were based on specific challenge scenario examples such as Scenario Example 3 (Table 4.22).	L
5	How would you rate the realism of the nurse character?	Likert Scale, 1-5; Very low, Low, Somewhat, High, Very high.	As with the previous two questions, this further supports the design of the scenario, but specifically focuses on the nurse character.	L
6	How would you rate the visual quality/ fidelity of the media?	Likert scale, 1-5; Very poor, Poor, Somewhat, Good, Very good.	A Likert scale for participants to rate the visual fidelity of the VR and comic book media types.	K
7	Did you notice anything in the environment that seemed out of place or unrealistic?	Yes/No. Text box for description.	This question provides feedback for both the visual fidelity and scenario realism, whilst also assessing participant observational behaviours.	L/K
8	Have you ever encountered this particular scenario (or something very similar) before?	Yes/No. Text box for description.	This question could determine how rare or uncommon the scenario was to the participants.	L, M
9	How rare would you say this scenario is in real life?	Likert Scale, 1-5; Never encountered/not sure, Very rare, Rare, Common, Very common.	As above.	M
10	Do you feel the media has had an immediate effect on your ability to challenge clinical decisions?	Likert Scale, 1-5; Not at all, Not very much, Somewhat, Much, Very much.	The primary research objective was to evaluate whether VR simulation techniques could help develop an ability to challenge. Data for this question would directly support this objective.	N

11	How do you think the media could be improved in order to develop your ability to challenge clinical decisions?	Text box.	An opportunity for participants to provide feedback on how to improve the effectiveness of the tool.	P
12	Do you have any other comments or feedback for the media regarding its design, usability, or visual quality?	Text box.	An opportunity for participants to provide feedback, suggestions, comments or criticisms that would contribute to the formation of recommendations for future design and research.	P

6.6 Follow-Up Questionnaire Content

Approximately six months after taking part in the study, the participants were contacted again with a request to complete a follow-up questionnaire (see Appendix L for an example). The aim of the questionnaire was to obtain data that determined whether taking part in the study had changed participants' behaviours in terms of their confidence in challenging decisions made by their peers or seniors. It also set out to obtain information related to any incident that may have occurred since taking part in the original experiments and how well they remembered the events of the study. Finally, it also permitted the participants to comment on possible future developments of this project, including changes or enhancements to the tools used (or may be used, such as VR headsets) and whether a digital simulation course, based on the VR technologies developed as part of the present research and dedicated to assertiveness training, might be a beneficial resource to the NHS.

Using the contact details provided on their original consent forms, the participants were individually emailed an invitation to complete an online, browser-based version of the final questionnaire using 'Google Forms.' The primary advantage of using an online, browser- based system to submit their responses meant that the questionnaire could be completed remotely, by using a personal tablet or smartphone device, for instance. Email alerts notified the author of every questionnaire that was submitted, and the analysis tools used provided up-to-date charts that illustrated the responses to each question. The Google Forms system also allowed the data to be exported in a worksheet-friendly format that could be imported into programs such as the latest version of Microsoft Excel (Microsoft, 2016).

Unlike the questionnaires completed in each study session, the follow-up document was optional. Participants were also informed about the possibility of receiving future questionnaires related to the research on the day they took part, and contact permission was sought on the day of their participation regarding this. As an incentive to encourage participants to respond, each completed questionnaire submitted within the first month of contact was entered in to a prize draw for two gift vouchers. However, completed questionnaires could be sent in up to six months after the invitation. The content of the questionnaire bridged several sections, covering different topics that contributed to the Experiment Aims listed in Table 6.1 and supported a further set of aims (defined below in Table 6.6). As with all other questionnaires in the project, the content of the questionnaire was designed, developed and optimised, with assistance from clinical and academic supervisors, and closely followed the

questionnaire design methods highlighted in section 4.2.

Table 6.6 - Experiment Research Aims Q-V for follow up questionnaire

	Aim	**Description**
Q	Obtain further examples of scenarios where a decision is challenged, including the individual(s) challenged, and an explanation for doing so.	In addition to providing further examples where challenges occur, this aim sought to discover if an actual incident had occurred since each participant's involvement in the study. This was done to evaluate whether the study had produced any long-term impact on participants' challenge behaviours. Even if a participant's decision-challenging behaviour was unaffected by the study, the scenario might, at the very least, remind them of their involvement, thereby supporting the value of the research in terms of raising awareness to the importance of challenging.
R	Assess whether participants remembered their involvement and were still interested in the study.	This would further evaluate the project's value to the medical community.
S	Discover if participants had experienced any scenarios or events like those "encountered" within the simulator or comic sessions.	The scenario was intended to be representative of a rare medical occurrence. However, elements, such as the involvement of a Jehovah's Witness, were predicted to be less rare.
T	Further evaluate whether VR simulation or comic book technologies/styles could be a beneficial resource to medical training.	This aim would add to the project's overall value to future training regimes in healthcare and would justify further research into this area. It could also help identify potential limitations, concerns or criticism from participant feedback.
U	Identify other applications where VR or comic book technologies/styles could deliver benefit.	VR and comic book technologies or presentation styles are not limited to a single application domain area, as was evidenced by the literature (e.g. Section 2.6). Therefore, this aim set out to identify other areas in medical training where VR or comic book technologies could potentially deliver benefit.
V	Asses participants' current confidence to challenge a decision and compare it with the data obtained after taking part in the study.	Evidence here could establish whether the study has made an impact on each participant's ability or confidence level to issue a challenge. Their current confidence levels to challenge could then be compared to the response they provided in the pre-use questionnaire.

6.6.1 Follow-up Questionnaire – Section 1

Section 1 of the document opened with an introductory statement. The statement, highlighted below, clarified the participants' involvement in the project, reminding them of the project topic and their earlier participation. It then required participants to enter their name, which was only used for matching their responses to the data already on file from the earlier experiment. Their name was then replaced with a unique identifying number.

"In June of 2015 you kindly offered to take part in a study that set out to establish whether or not virtual simulation and printed media technologies can aid in developing the decision-making abilities of clinical and nursing personnel at UK hospitals. Specifically, the research explored the issue of challenging the decisions made by staff of various positions, professions and specialities within, and around, the Intensive Care Unit.

As part of the study, we would like to invite you to complete the following questionnaire that represents a small follow up on your experience with either the virtual simulator or comic book scenario. It should require no more than approximately 5-10 minutes of your time."

6.6.2 Follow-up Questionnaire - Section 2

As with the interviews conducted in the earlier investigations, the follow-up questionnaire set out to obtain a brief account of any incident where each participant found themselves having

to challenge the decision of another member of their team or department (Table 6.7). Further challenge scenarios were requested on the basis that the event could have elicited a response that reminded them of their participation and the research areas of the project. Such responses would certainly help to support the research as a viable training method in the medical domain, and it was important to capture evidence to support this.

In addition, and as before, the questionnaire sought to gather information that clarified who it was the participant challenged and why. The previous investigation had shown that consultants, despite representing the least confident group to challenge, were nevertheless involved in most challenge scenario examples described. Therefore, this questionnaire acted as an opportunity to add to the existing data and evaluate this trend further.

Table 6.7 - Follow-up Questionnaire Section 2 Content

Question		Response	Description	Aim (Table 6.6)
A	Since taking part in the study, have you encountered a scenario that prompted you to challenge a decision made by a co-worker?	Yes/No.	There was no limit to the amount of detail required for an example, if the incident occurred after the date the participant took part in the original study.	Q
B	What was the role/grade of the individual(s) challenged?	Text box.	The research has, so far, shown that consultants are most likely to be challenged in events. In ward round settings, where most research had taken place, this could be attributed to their role as the primary decision-maker of the group. Data from this question could further support or nullify this.	Q
C	What was the reason for your challenge?	Text box.	This question would gather further explanations as to why challenges are issued. Based on the research conducted so far, patient safety was predicted to be the most likely response.	Q
D	How was your challenge received?	Likert Scale, 1-5; Very negatively to Very positively.	The previous investigation had shown that challenges are usually positively received. However, participants were offered only two choices, positive or negative. This question should provide more detail into how challenges are managed.	Q

6.6.3 Follow-up Questionnaire - Section 3

Section 3 of the follow-up document (Table 6.8) consisted of questions related to each participant's experience with either the virtual simulator or comic book scenario. They were asked to describe as much as they could remember of their participation, and whether they had encountered a real-life scenario that resembled their virtual or comic book "experience". Section 3 also sought to establish the presence of further interest in the project via an offer of engagement with the other media application each participant was not able to engage with before.

Table 6.8 - Follow-up Questionnaire Section 3 Content

Question		Response	Description	Aim (Table 6.6)
A	Do you remember what scenario was featured in the simulator or printed media?	Likert Scale, 1-5; No, not at all to Yes, very much.	This was used to assess the level of impact the study may have had on the participants. A highly-scored response number might suggest that the study was a memorable one and of perceived value to the participant.	R
B	Could you provide a description of the scenario?	Text box.	It was not predicted how much information would be given in response to this item. Any amount of detail was welcome to assess the impact the project may have had on the participants.	R
C	Regarding questions 3A/B, since the study, have you encountered any form of real scenario similar to the one featured in the simulator or printed media?	Likert Scale, 1-5; No, nothing similar at all to Yes, something very similar.	Exact experiences of the simulated scenario were unlikely. However, as the scenario was the result of the integration of a handful of smaller, realistic, samples, certain elements of the scenario (for example, the JW note) may have been encountered, or a smaller combination of other elements such as the stressed consultant and GI bleed.	S
D	Regarding section 3C, if you have experienced a similar scenario, can you provide a basic description of it?	Text box.	Further to the information collected from the above questions, data for this question would be used to identify which elements of the scenario were most and least common. Therefore, it assessed the design validity of the scenario and how likely it would be for a similar incident to be experienced in real life.	S
E	If presented with another opportunity to	Likert Scale, 1-5; Very	A positive response for this question would support the validity and value	R

	take part in this study, either to try out the other form of media (VR simulator or comic book version) or engage with an improved version of either media, how likely would you be to take part?	unlikely to Very likely.	of the project and would contribute to further development.	
F	Regarding section 3E, why do you feel this way?	Text box.	As above.	R
G	Do you have any other comments regarding any of the questions in section 3?	Text box.	An opportunity for the participant to raise any concerns of the project related to Section 3 and to offer feedback for further improvement in this area.	R, S

6.6.4 Follow-up Questionnaire - Section 4

Section 4, listed below in Table 6.9, the final section of questionnaire content, contained questions related to the application of simulation technologies generally in the medical domain.

Table 6.9 - Follow-up Questionnaire Section 4 Content

Question		Response	Description	Aim (Table 6.6)
A	Do you think virtual reality technologies (such as headsets or 3D-based 'gaming' technologies) integrated into healthcare training could provide a beneficial future training resource to the NHS?	Likert Scale, 1-5; No, not at all to Yes, very much.	A positive response for this question would support the validity, value and further development of the project, with respect to gaming or VR technologies.	T
B	Regarding Question A, above, which applications do you think virtual reality might help?	Text box.	As above. In addition, this could present an opportunity to explore other areas in the medical community with an approach like that described in the present project.	U
C	Do you think printed media (such as comic books or graphic novels) integrated into healthcare training could be a beneficial resource?	Likert Scale, 1-5; No, not at all to Yes, very much.	A positive response for this question would support the validity, value and further development of the project, with respect to comic book or graphic novel applications.	T
D	Regarding Question C, above, which applications do you think printed media might help?	Text box.	As above. In addition, this could present an opportunity to explore other areas in the medical community with an approach like this project.	U
E	Since finishing the study, do you feel the media you interacted with has had any long-term effect on your	Likert Scale, 1-5; No, not at all to Yes, very much.	A positive response for this question would support the validity, value and further development of the project.	V

	ability to challenge clinical decisions?			
F	Regarding section 4E, why do you feel this way?	Text box.	As above.	V
G	How would you currently rate your overall confidence to challenge a clinical decision?	Likert Scale, 1-5; No confidence to Excellent.	Data for this question could be compared with the responses given in the pre-use and post-use questionnaires. It would certainly assist in identifying whether confidence has increased, and could be associated with the response provided in answer to Question E.	V
H	Do you think a simulation-based training course or workshop dedicated entirely to assertiveness or how to successfully challenge a decision would be a beneficial resource to NHS trusts?	Likert Scale, 1-5; No, not at all to Yes, very much.	Following on the positive data obtained from the interviews conducted in the earlier investigation, this question aimed to add to the evidence that a course dedicated to developing the ability to challenge would be beneficial to medical education generally and add to the value of the project.	T
I	Would you be interested in taking part in such a course?	Likert Scale, 1-5; No, not at all to Yes, very much.	This question aimed to build on the responses collated from the above.	R
J	Do you have any other comments regarding your experience with the simulator or printed media?	Text box.	An opportunity for the participant to raise any concerns about the project and to offer feedback for further improvement in this area.	T, U, V

6.6.5 Follow-up Questionnaire - Section 5

Consisting of a single Yes or No question, this section of the follow-up questionnaire required participants to state whether they would like to be updated on project progress following the conclusion of the PhD submission process. Any participants who stated ‘Yes’ would be contacted using the details provided on their participation consent forms.

6.7 Experimental Results

A total of 58 participants took part in the experiment, with 24 engaging with the VR simulator project and 34 interacting with the comic. There were no withdrawals. All VR simulator sessions ran successfully with no equipment, interruption or pause issues occurring whilst the simulation was in progress. No bugs occurred with the software, proving a stable performance throughout the sessions. The simulator successfully recorded performance logs, consisting of small text files, detailing each participant’s engagement with the scenarios. Video footage of each VR simulator session was also recorded to support later analyses.

All locations where the experiment took place are listed below in Table 6.10. The VR simulator room environment remained consistent throughout the duration of the experiment. As the volume of the projector was high, there were no detections of noise or outside interference. In contrast to the VR simulator sessions, the comic book experiment was conducted within a variety of locations, including a recreation room situated near the CSS (although empty at the

time), lecture theatres and offices of staff within various departments throughout the QEHB. Consequently, the circumstances surrounding the comic varied with respect to overall noise levels and general interference. For example, the final session consisted of 20 participants engaging with the comic book in a large lecture theatre situated in the QEHB. As most of the cohort were sat in groups, interruptions were frequently observed, including discussions among one another and general noise that may have affected their responses or provided distractions.

Table 6.10 - Locations Where Experiments Were Conducted Sorted by Total Percentage of Cohort

Location	**Type**	**Participant Count n=58 (%)**
CSS Room - QEHB	Simulator	23 (40)
CSS Lecture Room (3) - QEHB	Comic	20 (34)
CSS Lecture Room (5) - QEHB	Comic	8 (14)
CSS Reception Office - QEHB	Comic	3 (5)
309 – UoB Campus, Gisbert Kapp Building	Simulator	1 (2)
Theatre Office – QEHB	Comic	1 (2)
CSS Mess Hall - QEHB	Comic	1 (2)
Nuffield House - QEHB	Comic	1 (2)

6.8 Pre-Use Questionnaire Results

6.8.1 Opening Section Results – Profession, Grade & Experience

Table 6.11 to Table 6.15 below illustrate the results of participant responses to the opening section questions.

Forty participants who took part were doctors by profession, followed by 14 who represented the nursing community. The complete set of professions identified are highlighted in Table 6.11. Of the 54 participants who represented both the doctor and nursing professions, four were students (4 doctors and 1 nurse, respectively). None of the students disclosed their current year of study. When professions were placed into their respective categories identified earlier in the project, the largest group to take part were FY1s with 20, all of whom interacted with the comic. Nine participants were members of the military and were placed within Consultant, CT 1-2 and FY1 categories. Of these nine participants, only one member engaged with the simulator, with the remaining eight taking part in the comic book experiment. The VR simulator experiment comprised the most senior cohort and, therefore, included those with the greater levels of medical experience. Of the 24 participants who took part in the VR experiment, eight, three and a further three were placed into the Nurse Band 6+, Consultant and ST 5-7 categories respectively. Illustrated in Table 6.11, this is contrast to only one, three and zero placed from the comic book cohort. Again, the simulator cohort represented the most senior group of the

two, with a high number of those in the Nurse 6+ and ST 5-7 category taking part (number of consultants were equal with three each).

Table 6.11 - Pre-Use Questionnaire Participant Professions Sorted by Total Percentage of Cohort

Unique Professions Identified	Sim n=24	Comic n=34	Total n=58 (%)
Doctor	9	30	39 (67)
Nurse	9	2	11 (19)
Student Nurse	3	0	3 (5)
Auxiliary Nurse	1	0	1 (2)
Clinical Educator	1	0	1 (2)
Pharmacist	1	0	1 (2)
Surgeon	0	1	1 (2)
Student Doctor	0	1	1 (2)

Table 6.12 - Participant Grade Categories That Took Part in The Experiment Sorted by Total Percentage of Cohort

Grade Category	Sim n=24	Comic n=34	Total n=58 (%)
FY1	0	20	20 (34)
Nurse - 6+	8	1	9 (16)
Core Trainee 1-2	0	8	8 (14)
Consultant	3	3	6 (10)
Allied Health Professional	6	0	6 (10)
M/N Student	3	1	4 (7)
Speciality Trainee 5-7	3	0	3 (5)
Nurse - 4-5	1	1	2 (3)

Overall, the participants were predominantly female, with a gender ratio of 36 (62%) females to 22 (38%) males. Females mostly took part across both experiment types, with a gender ratio of 14 (58%) females to ten (42%) males for the VR simulator and 22 females (65%) to 12 (35%)

males for the comic book.

The specialities of the cohort were very also widely distributed. The highest speciality, general medicine, accounted for 12 participants, followed by nine who stated their profession as critical care. Some other, less common specialities included elderly care, medical education and neurology. When compared between each type, there was a wider range of specialities who took part in the comic book experiment than the VR simulator. The specialities of the VR simulator experiments consisted of, mainly, critical care and neurology. In contrast, the comic book sample of participants mainly comprised general medicine, which could be attributed to the number of FY1s who took part.

Table 6.13 - Pre-Use Questionnaire - Identified Specialities Sorted by Total Percentage of Cohort

Speciality	Sim n=24	Comic n=34	Total (%)
Medicine	0	12	12 (21)
Critical Care	6	3	9 (16)
Neurology	4	0	4 (7)
Elderly Care	0	3	3 (5)
Clinical Skills	3	0	3 (5)
Medical Education	2	1	3 (5)
Everything	3	0	3 (5)
Urology	0	2	2 (3)
Ear, Nose & Throat (ENT)	0	2	2 (3)
Dementia	2	0	2 (3)
Microbiology	1	1	2 (3)
Haematology	0	1	1 (2)
Psychiatry	0	1	1 (2)
Anaesthetics	0	1	1 (2)
Oncology	0	1	1 (2)
Cardiovascular	0	1	1 (2)
Renal	0	1	1 (2)
Blood	1	0	1 (2)
Identification	1	0	1 (2)
Medication Safety	1	0	1 (2)
Trauma	0	1	1 (2)
Rheumatology	0	1	1 (2)

In terms of experience, the overall mean years qualified was 8 with an SD of 9.5, slightly lower than found in the earlier investigation which was 9.3 (SD of 8.7). The mean number of years spent at current post was 3 with an SD of 4.3. This was also slightly lower than the first investigation, which was, in comparison, 3.2 (SD of 3.6). Of those who took part in the simulator experiment, the mean number of years qualified was 12.9 with an SD of 9.8. This

was significantly higher that than those who took part in the comic book experiment, where the mean number of years qualified demonstrated a greater spread with a mean of 4.6 and an SD of 7.8. The participant with the highest amount of experience, at 34 years, was a Band 7 nurse who specialised in critical care. Predictably, as students took part in the study, the smallest number of years qualified was zero.

6.8.2 Opening Section Results – Similar Studies & Assertiveness Training

Two participants stated they had taken part in a study like this project. However, the descriptions of these were not clear, and were simply reported as a "simulation course" and a study addressing "optical adjustment & dyslexia."

25 (43%) participants stated that they received a form of training that involved assertiveness, or how to successfully challenge a decision. Similar responses for this question were grouped together into categories (for example, two participants stated 'Simulation' and 'SimMan' and were each placed into the 'Simulation Training' category). The highest categories consisted of a 'Leadership Course', 'Any Simulation Training' and 'Misc. Medical Course'. Six participants from each of the Consultant, Nurse 6+ and FY1 categories were in the highest qualification group to receive a form of assertiveness training.

Table 6.14 - Pre-Use Questionnaire – Assertiveness Training Methods Identified by Participants Sorted by Total Percentage of Cohort

Training Method	Sim n=24	Comic n=34	Total (%)
Any Simulation Training	5	1	6 (10)
Leadership Course	2	4	6 (10)
Misc. Medical Course	2	2	4 (7)
Conflict Man/Res Course	3	0	3 (5)
Military Training	1	2	3 (5)
Nurse Training/Education	2	0	2 (3)
Any Human Factors Training	1	0	1 (2)
Assertiveness Course	1	0	1 (2)
Doctor Training/Education	0	1	1 (2)
Videos/Documentaries	1	0	1 (2)
Total	**18**	**10**	**28**

Table 6.15 - Pre-Use Questionnaire - Assertiveness Training by Grade Category Sorted by Total Percentage of Cohort

Grade Categories	Count (%)
Consultant	6 (10)
FY1	6 (10)
Nurse - 6+	6 (10)
Allied Health Professional	4 (7)
Core Trainee 1-2	1 (2)
M/N Student	1 (2)
Nurse - 4-5	1 (2)
Total	**25**

6.8.3 Likert Scale Question Responses

The responses for the pre-use questionnaire indicated that participants' experience, and time spent interacting with gaming or comic book technologies, was low when compared to other, slightly more broad questions such as experience with simulation or computers. This is illustrated in Table 6.16 and Table 6.17 below, where most Likert responses to the four questions related to gaming and comic books (Questions 3a, 3b, 4a and 4b) were rated as 2 and below. Experience with VR-based simulation technologies was also low among the cohort (Question 5), with a combined mean response of 2.10 and SD of 1.01.

Table 6.16 - Pre-Use Questionnaire – Response Means, SDs and Comparisons

Question No.	VR Simulator		Comic Book		Combined	
	Mean (SD)	Likert	Mean (SD)	Likert	Mean (SD)	Likert
1a	4.58 (0.58)	8+ Hours	4.71 (0.58)	8+ Hours	4.66 (0.57)	8+ Hours
1b	3.75 (1.11)	4-8 Hours	3.24 (1.21)	1-4 Hours	3.45 (1.18)	1-4 Hours
2a	3.92 (0.78)	Good	4.18 (0.72)	Good	4.07 (0.74)	Good
2b	4.08 (0.97)	Good	3.68 (1.12)	Good	3.84 (1.06)	Good
3a	1.54 (1.18)	< 1 Hour	1.62 (0.95)	< 1 Hour	1.59 (1.03)	< 1 Hour
3b	1.21 (0.41)	0 hours	1.26 (0.62)	0 hours	1.24 (0.54)	0 hours
4a	2.17 (1.09)	Low	2.38 (1.33)	Low	2.29 (1.22)	Low
4b	1.96 (0.95)	Low	1.74 (0.99)	Low	1.83 (0.97)	Low
5	2.00 (1.06)	Low	2.18 (1.00)	Low	2.10 (1.01)	Low
6	3.21 (1.02)	Moderate	3.29 (1.09)	Moderate	3.26 (1.04)	Moderate
7	4.08 (1.02)	Good	4.18 (0.76)	Good	4.14 (0.86)	Good
8	3.33 (0.82)	Somewhat	3.35 (1.01)	Somewhat	3.34 (0.92)	Somewhat
9	3.79 (0.88)	Good	3.18 (0.94)	Somewhat	3.43 (0.95)	Somewhat

Table 6.17 - Pre-Use Questionnaire - Grade Category Mean Response Matrix

Grade	1a	1b	2a	2b	3a	3b	4a	4b	5	6	7	8	9
Consultant	4.67	3.67	4.50	4.33	1.17	1.33	1.67	2.33	3.00	4.50	4.67	3.33	4.50
ST 5-7	4.67	3.67	3.67	3.67	2.33	1.33	2.67	2.00	1.67	3.00	4.00	3.67	3.33
CT 1-2	4.75	3.50	4.25	3.50	1.50	1.25	2.25	1.63	2.00	3.38	4.00	3.13	3.13
FY1	4.75	3.15	4.20	3.70	1.80	1.25	2.65	1.65	2.10	3.15	4.10	3.35	2.95
M/N Student	4.25	3.25	3.75	3.25	1.50	1.25	2.50	2.00	1.75	2.75	4.00	3.75	2.75
Nurse - 6+	4.44	3.67	3.67	4.33	1.67	1.33	2.00	2.00	1.89	3.22	4.56	3.00	4.00
Nurse - 4-5	4.50	3.00	4.00	4.00	1.50	1.00	2.00	1.00	1.00	1.50	3.00	3.50	4.00
AHP	4.83	4.00	4.00	4.00	1.00	1.00	2.00	2.00	2.50	3.33	3.83	3.67	3.83

6.9 Simulator and Comic Book Media Data Analysis

The following sections outline the performance of the participants in the simulator and comic book experiments. Directions of the camera (i.e. the participant's viewpoint) in the virtual environment were recorded every second, along with each instance of an examinable item being looked at and picked up. Challenges, refusal of treatment and agreeing to transfuse the patient were also instances that were recorded for later analyses. All logs were entered in to a spreadsheet where they were analysed, to provide details of any trends that might emerge across the participant population.

6.9.1 Engagement with the VR Simulator

A total of three hours, 20 minutes and 26 seconds were spent engaging with the VR simulator. Each participant in the simulator group engaged with the scenario five times in a single setting, making a total of 120 runs. The mean scenario length was 1 minute 40 seconds with an SD of 8 seconds. The mean experiment duration for each participant was 8 minutes and 21 seconds with an SD of 42 seconds.

6.9.1.1 Examinable Items

A total of 1929 examinable items were recorded as having been "looked at" within the experiment (i.e. the camera was focused on an item which prompted the 'examine' UI prompt to appear). The mean number of items looked at in an individual participant session was 80.38 with an SD of 32.49. The mean number of items looked at in each individual scenario was 16.08 with an SD of 6.5.

To examine an item, the participant was required to press the 'A' button on the controller. This action 'picked up' up the item within the environment which was then brought closer to the camera. The participants achieved this action a total of 542 (28% of items looked at) times across all sessions. For each participant session, the mean number of items examined was 22.58 with an SD of 10.19. The mean number of times items were examined within each individual scenario was 4.52 with an SD of 2.04.

6.9.1.2 VR Scenario Outcomes

A total of 52 challenges were issued across all participant sessions with the VR simulator. The mean number of challenges in each participant session was 2.17 with an SD of 2.03 challenges. Of the 120 total VR scenario runs, 39 (33% of scenario runs) involved the participant challenging the decision of the consultant. Of the three options, available to the participants when the Consultant's decision is issued (challenge, refuse and administer blood), challenging the decision represented the most common response to the consultant's request (Figure 6.2). In comparison, participants refused to treat the patient in 20 cases, and agreed to transfuse the patient in a further 27 cases (17% and 23% of scenario runs respectively). Of all 120 runs of the scenario, there was a single instance where the participant agreed to transfuse the patient even though the JW status was active. 34 (28% of scenario runs) outcomes were interrupted by the consultant, who ended the scenario prematurely before the participant could respond. However, of the 34 remaining scenario runs ended by the consultant taking charge, analysis of the video footage revealed 13 cases where the user attempted to select an option, but was interrupted before the action could be committed. These attempts were, therefore, not recorded by the simulator.

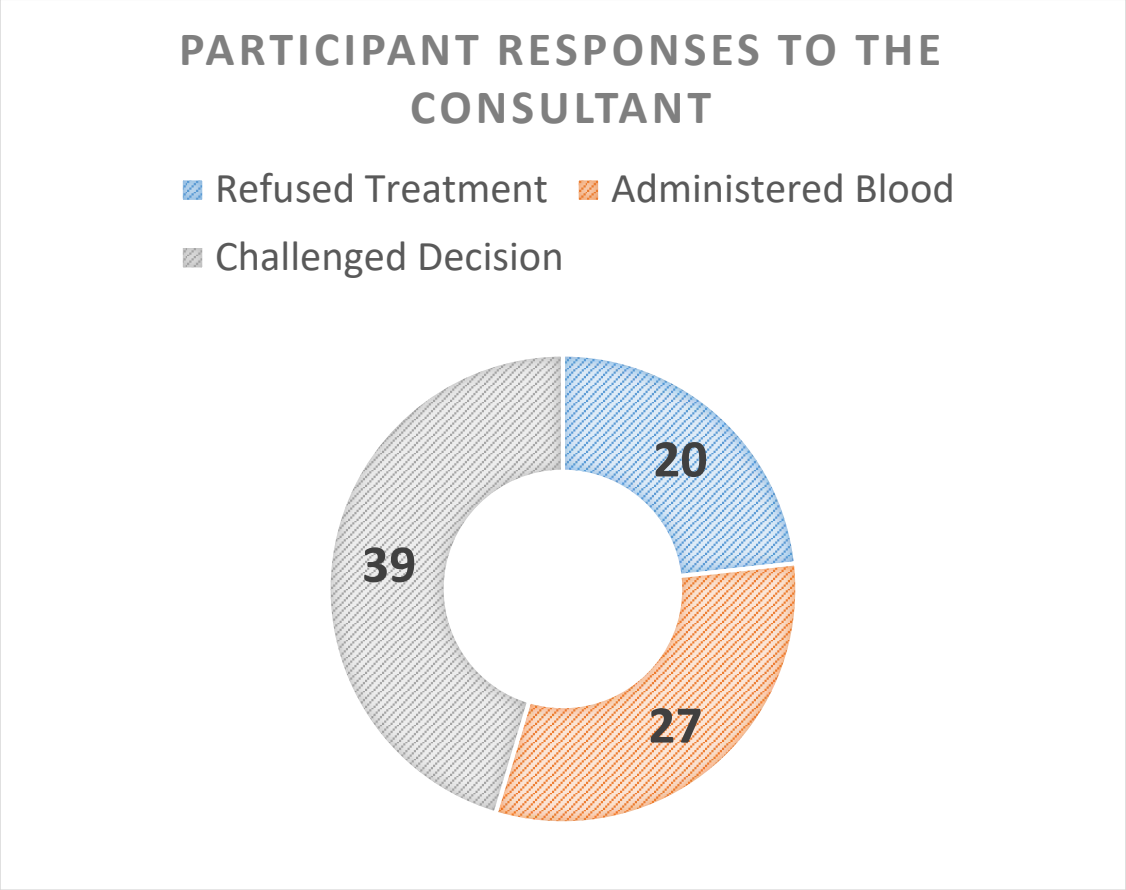

Figure 6.2 - Participant Choices in Response to the Consultant

No instances occurred where an issued challenged was followed by agreeing to transfuse the patient. In 26 scenario runs (22%), there were instances where only one challenge was issued, and two challenges were issued in 13 (11%) cases. Of those 13 cases, six (46%; 5% of total scenario runs) resulted in the consultant backing down, and subsequently delivering a response dependent on their "attitude". The consultant in the 'calm' state backed down willingly, whereas the consultant would acquiesce in the 'angry' state.

There were only two cases (2%) where an initial challenge progressed to a refusal to transfuse. After a challenge was issued, there was a 50% chance the consultant would reject it and attempt to take charge of the situation (which would bring the scenario to an end), otherwise the participant might respond a second time. However, based on the findings, it was likely that the participant would have sustained their challenge had there been another opportunity to do so.

The simulator did not provide any records supporting participants' accounts for their reasons to challenge. However, issues concerning the patient's status were recorded in the background and revealed if he was a Jehovah's Witness (JW) or if the blood bag was wrong. Based on this, of the 52 total challenges recorded across all the participant sessions, 48 (92%) of them were issued when either the patient was a JW or the blood bag was wrong. Of these 48 challenges issued, 18 (35%) were issued where the patient was a JW, 30 (58%) were issued when the wrong blood bag was present, and 18 (35%) were issued when both patient issues were active at the same time (i.e. both the blood bag was wrong *and* the patient was a JW).

6.9.1.3 Environment Focus

The position and direction of the camera (i.e. the participant's viewpoint) was recorded at one-second intervals in the background as the simulation was in progress. Time stamps, logging the camera's direction, started once the participant's character first moved to the patient's bedside, and ended upon the conclusion of each run of the scenario. As illustrated below in Figure 6.3, the starting point was the left side of the patient's bed. For each participant's individual scenario run, their camera direction stamps, expressed as 3D vectors (a quantity representing direction and magnitude/length), were averaged and saved to a text file. The text file was then fed into a script programmed within Unity3D to visualise these directions in the environment. The purpose of this script was to identify areas of the environment that each participant focused on most as they interacted with the scenario. Illustrated in Figure 6.4 to Figure 6.6, five coloured lines, starting from the participant's character camera position, representing the mean camera directions for each participant's engagement with the scenario, were rendered. To differentiate each participant's sets of averages, colours were assigned to them before they were rendered.

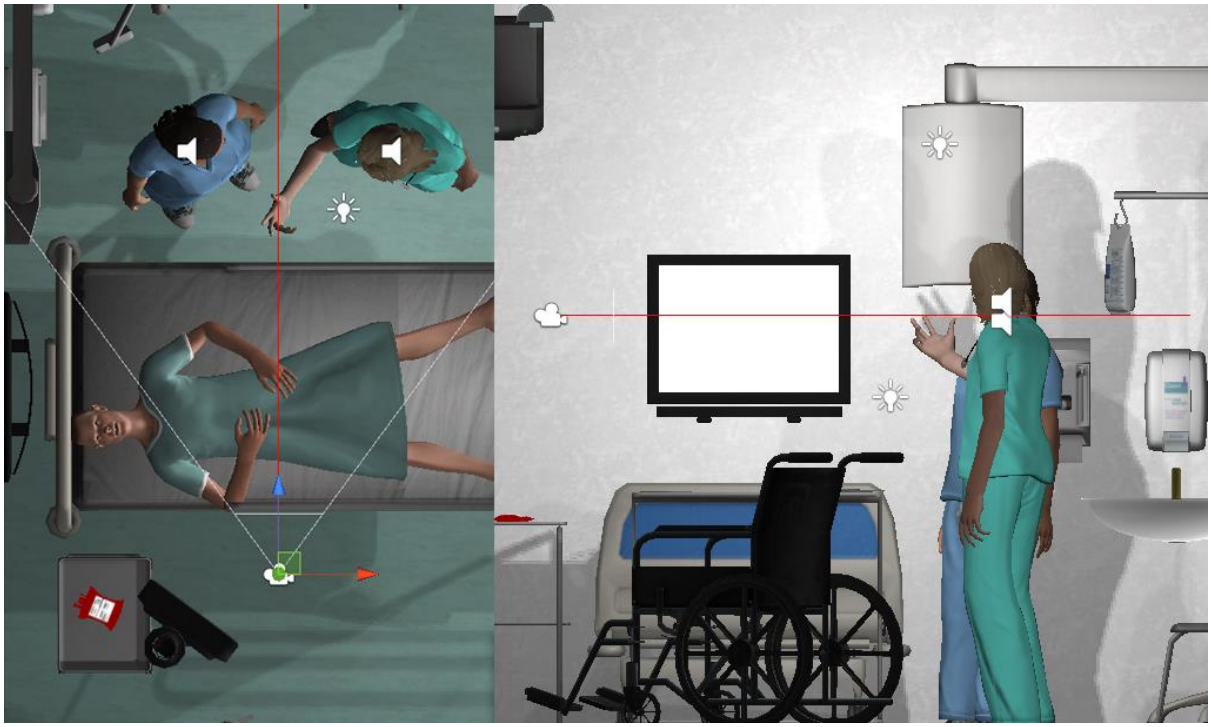

Figure 6.3 - The Camera Starting Position in The Scenario (Red Line Depicts Face Direction)

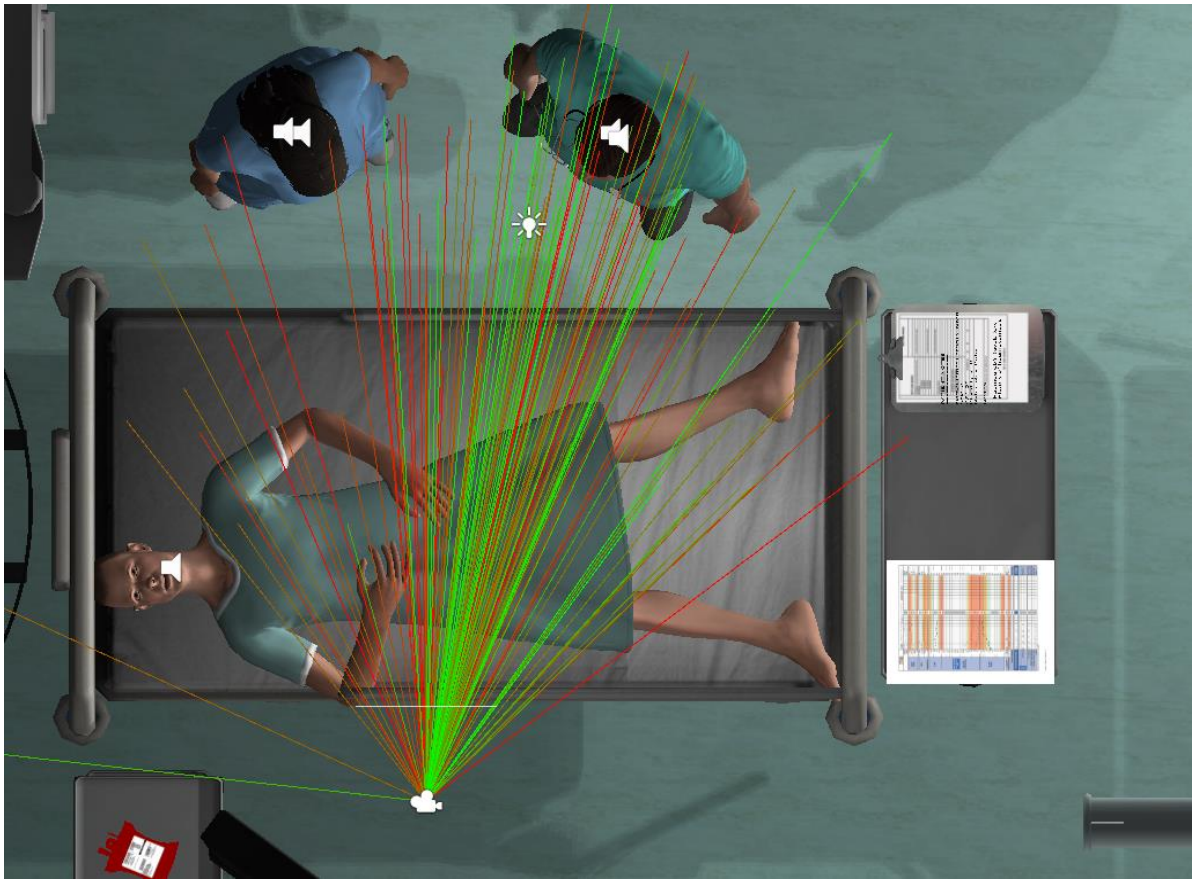

Figure 6.4 - Mean Participant Camera Direction for Each Scenario Run - Top View

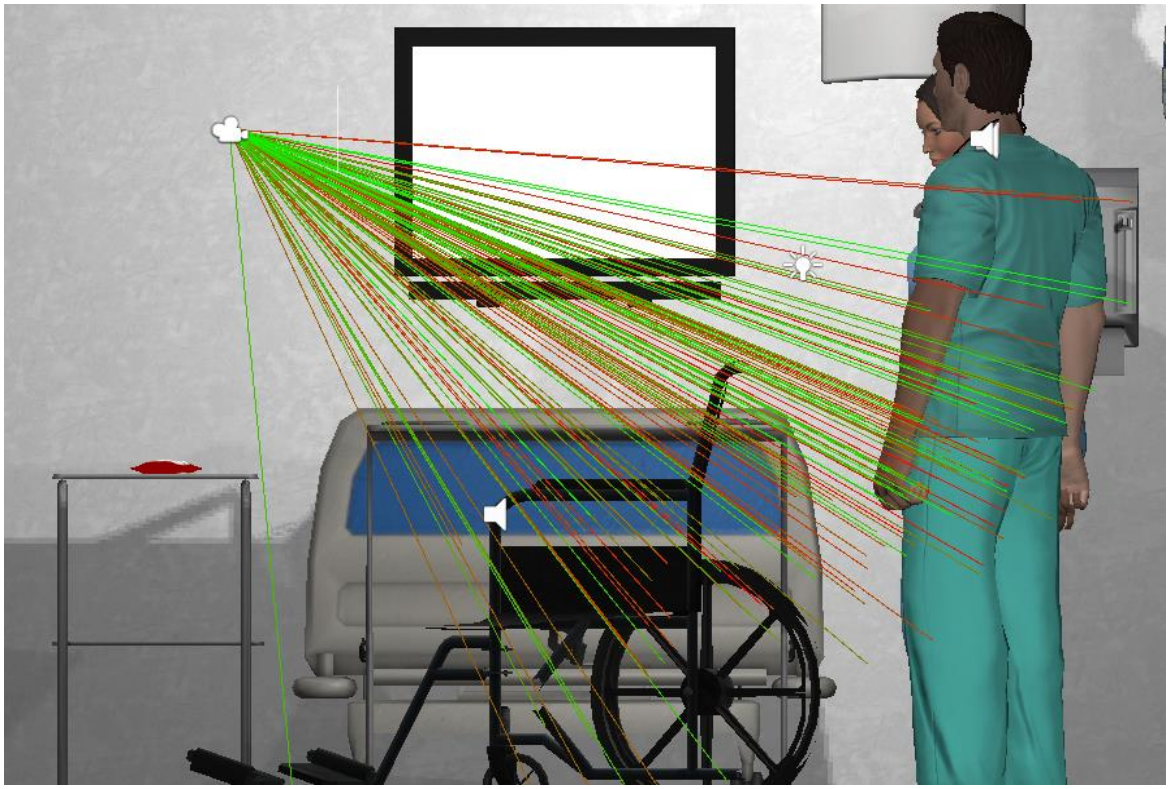

Figure 6.5 - Mean Participant Camera Direction for Each Scenario Run - Side View

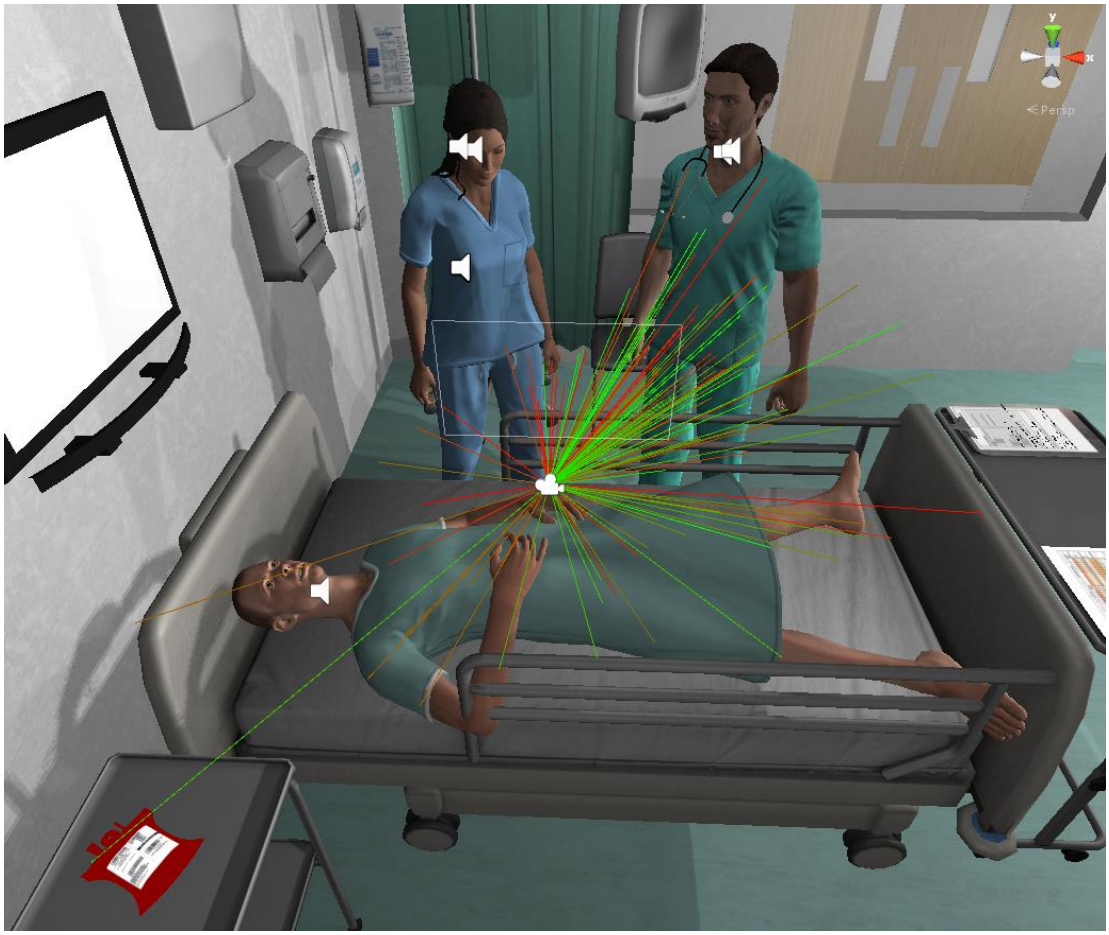

Figure 6.6 - Mean Participant Camera Direction for Each Scenario Run - Perspective View

Evident from the output of the script, most mean camera directions pointed at the consultant. Best illustrated in both Figure 6.4 and Figure 6.6, a large cluster of lines can be seen to point in this direction. This is also supported in Figure 6.7, which illustrates the overall mean direction of the camera, which, after each set of directional vectors was averaged, points towards the consultant. However, a slightly different result is demonstrated in Figure 6.8. The

overall mean direction of the camera also points in a downward direction, where items such as the patient notes and obs chart were in direct view if the participants' camera was rotated towards their location along the horizontal plane.

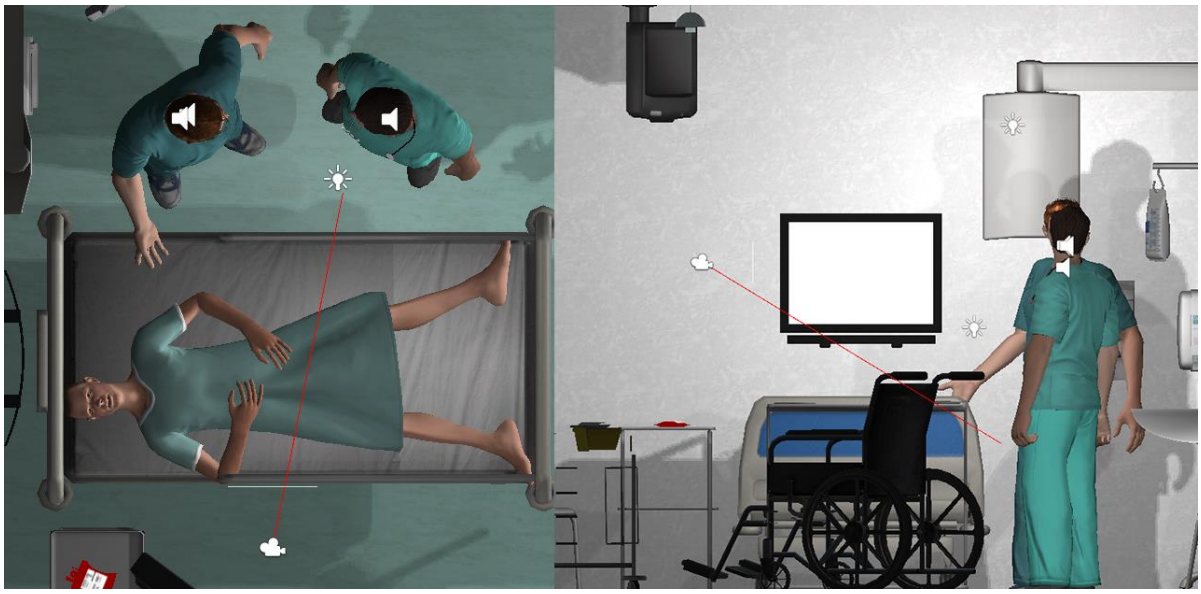

Figure 6.7 - Overall Mean Camera Direction - Top and Side Views

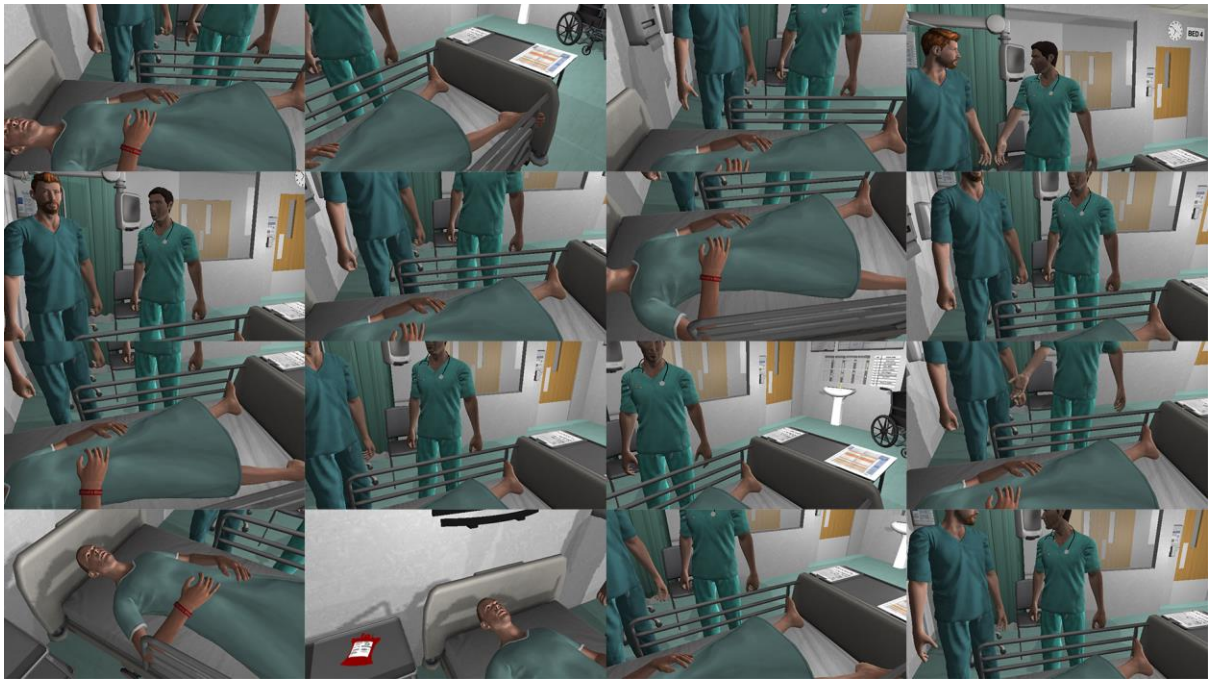

Figure 6.8 - Selection of Participant Mean Camera Directions in First Person View

Overall, the results from this analysis revealed that each participant focused primarily on the consultant for most of their engagement with the simulator. However, they were also focused on the areas effectively below eye height. These findings were most likely associated with (a) the consultant being the focal point of the scenario, with respect to character interaction, dialogue and outcomes, and (b) six of the eight examinable items being placed in areas in and below the camera position. Furthermore, these findings were also supported by the post-use questionnaire results (details of which are provided later). For example, the lowest items identified by participants as being examinable were the patient's bag and the ward bed sign, listed by four (17%) and nine (38%) participants respectively. The patient bag was situated

behind the participant's starting point, also below the camera, and the bed sign was placed on the front wall opposite to where the participant would be looking when they started the scenario, albeit to their right and above eye height. Therefore, both items were located outside of the area of the mean camera directions. In comparison, all other items (notes, blood bag, ward list, etc.) were within this "zone of attention" and each of them were identified by 12 (50%) or more participants.

Indeed, the participants retained full control of the camera within the scenario, and the simulator did not, at any time, 'force' the participants to look at any of the characters whilst the scenario was in progress, even when the virtual characters were talking directly to them. The only exception was the ending of the scenario, where the camera controls were frozen, but the time-stamped recordings were also stopped from that point. However, an interesting finding within the analysis of the recorded footage revealed that 18 (75%) of the 24 participants turned the camera to face the consultant when they spoke. Of the 18 participants who turned the camera, seven (39%; 29% of total) only rotated when the 'Response Required' prompt appeared. The remaining six (25%) participants who did not turn the camera remained fixed in place as they opened the choice dialogue window and selected their response(s).

6.9.2 Engagement with the Comic

Unlike the VR simulator, data were unable to be recorded on usage as the experiment sessions were in motion due to the media's physically printed format and overall presentation. Session

durations ranged from approximately ten minutes to one hour. Where the longer sessions comprised two groups of participants who engaged with the comic simultaneously (see 6.9.2.2 Environmental Differences further below for more detail), individual participant experiments were generally shorter in comparison. Of the six experiment sessions that consisted of a single participant, the noise level was quieter given the short space and overall privacy compared to the group sessions. Participants were relatively silent as they engaged with the comic (as instructed), except for when they communicated to the author to clarify their decision at the end of the second page (i.e. the decision to challenge, refuse or administer blood).

6.9.2.1 Scenario outcomes

Of the 34 participants who took part in the comic book experiment, 32 (94%) challenged the decision of the consultant. The remaining two (6%) participants refused to transfuse the patient. In other words, none of the participants agreed to the consultant's decision. When a participant selected an option that represented their response to the consultant, they were provided with a scenario ending that matched their choice. Unlike the simulator, there was no cell or ending that represented the consultant accepting the challenge and backing down. However, in each case where a participant challenged the decision, they had the choice of two cells both printed on separate paper, and presented face down so they may pick but not see their choice. Of the 32 participants who challenged the decision, 14 (44%) picked a tile where the consultant accepted the challenge, but maintained the decision to administer blood. In these instances,

participants were provided with another opportunity to respond (i.e. they were presented with the three options a second time; Figure 6.9). In all 14 of these cases where this situation occurred, every participant sustained their challenge, and they were subsequently given the other tile they could have originally chosen.

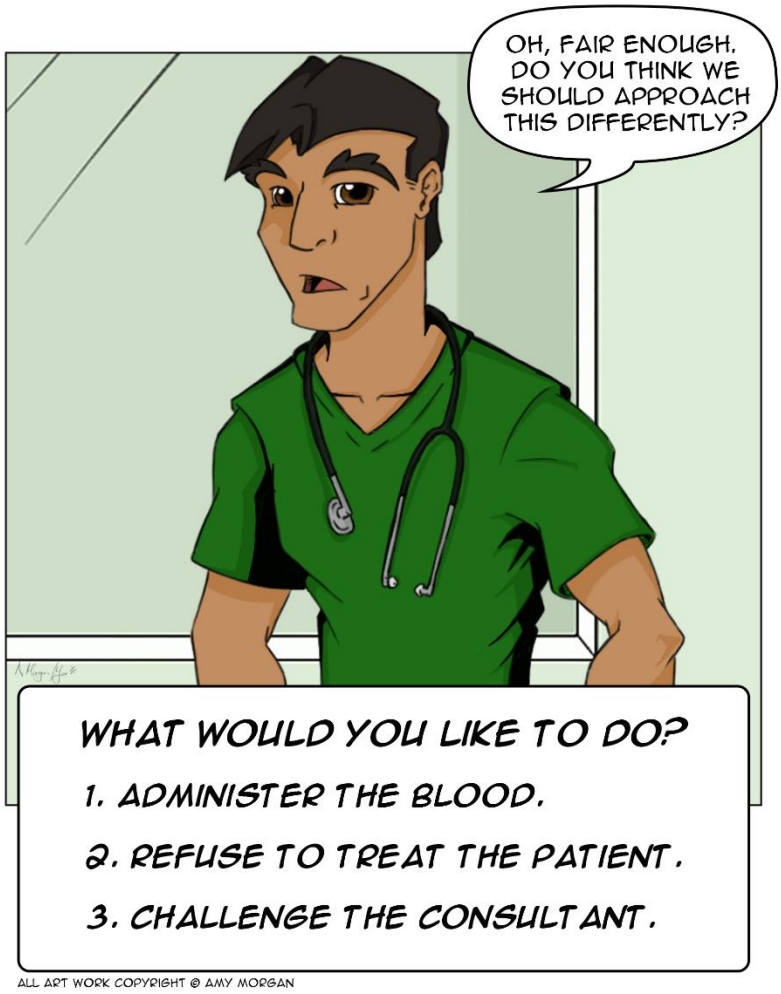

Figure 6.9 - Ending Cell That Provides a Participant the Opportunity to Select a Response

6.9.2.2 Environmental Differences

As highlighted earlier in this chapter (Table 6.10), the comic book cohort engaged with the media in various locations within the QEHB. When compared to the VR Simulator experiment, where the location remained consistent, the environmental conditions of each comic book session varied with respect to room size, noise and those present as the experiment was in motion. The most extreme case comprised 20 participants, all of whom were trainees (FY1), who engaged with the comic simultaneously within a large lecture theatre. In addition, multiple individuals, in some cases clusters of participants, were sparsely seated. In this scenario, the author delivered the comic book to each participant where they were situated in the theatre and completed packs (consisting of the comic and both the pre-and post-use questionnaire) were gathered from each individual as they left the room. The overall noise level was loud, as participants communicated amongst each other throughout the process. In contrast, this method of carrying out the experiment was more complex when compared to six other participants who took part in the experiment individually and on separate days. The remaining eight participants of the comic book cohort also took part in the experiment together as a group, but, when compared to the large lecture theatre scenario, it was a simpler and more manageable session. This was due to the overall smaller environment and a denser seating arrangement.

6.10 Post-Use Questionnaire Results

The questionnaire opened with a simple retention test, requesting participants to list items and characters they interacted with in the scenarios. In addition, participants were asked to remember elements concerning the patient, such as his name, age and medical history.

6.10.1 Situational Awareness Assessment

6.10.1.1 What characters do you remember being present in the environment?

A total of 185 references to characters were made for this question. All character references and similar responses were placed into categories based on the responses given, such as 'Consultant', 'Nurse', 'Patient' and 'Doctor', including extra categories for each gender of the nurse and consultant characters. 80 references to characters were made in the simulator experiment and 105 in the comic book component of the study. Interestingly, nine participants (three from the simulator group and six from the comic book) identified themselves as a character in the environment and noted this down in their questionnaire, which was not anticipated.

The results revealed that the most common character identified, after engagement with both the simulator and the comic book applications, by 51 participants (88%; 28% of total responses) was the consultant. This was then followed by 49 (84%) and 47 (81%) participants who

identified the nurse and patient characters respectively. When combining the 'Doctor' and 'Consultant' categories, a total of 61 (33% of 186) references were made. The remaining totals are displayed below in Table 6.18. As shown in Table 6.19, 19 (33%) participants referenced the nurse character in the simulator experiment, the highest overall followed by the consultant with 18 (31%). However, the consultant character was most referenced in the comic book experiments, with 33 (57%) participants stating this in the questionnaire followed by 30 (52%) who referenced the nurse.

Table 6.18 - Total Character References Sorted by Percentage of Responses

Characters Identified	**Count**	**% of cohort (n=58)**	**% of responses**
Consultant	51	88	28
Nurse	49	84	26
Patient	47	81	25
Themselves / "Me"	9	16	5
Doctor	10	17	5
Consultant – Identified as Male	3	5	2
Consultant – Identified as Female	3	5	2
Nurse – Stated Male	3	5	2
Nurse – Stated Female	3	5	2
Vague Character Description	3	5	2
Background Nurse	2	3	1
Surgeon	1	2	1
Miscellaneous Medical Staff	1	2	1
Total	**185**		

With respect to the gender aspect, only six participants who took part in the simulator experiment specified the gender of the consultant character, including six who also noted the genders of the nurse. In contrast, not one participant from the comic book experiment specified

any character gender. However, this could be attributed to the comic book presentation, in which only a female nurse and male consultant were presented, and no gender switches were used.

Table 6.19 – Characters Identified Across Each Experiment Group

Character Identified	Simulator n=24 (% of group)	Comic n=34 (% of group)
Consultant	18 (23)	33 (31)
Nurse	19 (24)	30 (29)
Patient	17 (21)	30 (29)
Themselves / "Me"	3 (4)	6 (6)
Doctor	6 (8)	4 (4)
Vague Character Description	1 (1)	2 (2)
Consultant – Stated Male	3 (4)	0 (0)
Consultant – Stated Female	3 (4)	0 (0)
Nurse – Stated Male	3 (4)	0 (0)
Nurse – Stated Female	3 (4)	0 (0)
Background Nurse	2 (3)	0 (0)
Surgeon	1 (1)	0 (0)
Miscellaneous Medical Staff	1 (1)	0 (0)
Totals	**80**	**105**

6.10.1.2 What examinable items do you remember being present in the environment?

A total of 209 references were made to items that participants perceived to be 'examinable.' 122 (58%) references to items were made in the simulator experiment, and 87 (42%) in the comic book. In the simulator, eight items could be picked up and examined but references were made to other items that were not, such as the ECG monitor.

All objects presented in both the simulator and comic book experiments were referenced at least once. As there were less items present in the comic book, when compared to the simulator, a lower number of references was expected. All responses are listed below in Table 6.20. The item most frequently referenced by participants, with a combined total of 47 (81% of cohort) counts, across both experiments, was the blood bag. This could be due to the scenario's primary focus of approving a blood transfusion. In the simulator experiment, reference to the blood bag was followed by 23 and 20 participants identifying the Obs Chart and Patient Notes items (96% and 83% of simulator participants respectively). In the comic book experiment, the Blood Bag was followed by 17 and 16 references to the Ward List and JW Note items (50% and 47% of comic book participants respectively).

Table 6.20 - Examinable Items Identified by Participants Sorted by Total Percentage of Cohort

Examinable Item	**Simulator n=24 (% of group)**	**Comic n=34 (% of group)**	**Total (% of cohort)**
Blood bag	23 (96)	24 (71)	47 (81)
Patient Notes	20 (83)	12 (35)	32 (55)
Ward List	12 (50)	17 (50)	29 (50)
Patient	15 (63)	11 (32)	26 (45)
Obs Chart	23 (96)	0 (0)	23 (40)
JW Note/Bag	4 (17)	16 (47)	20 (34)
Bed Number	9 (38)	4 (12)	13 (22)
JW Wristband	12 (50)	0 (0)	12 (21)
ECG Monitor	4 (17)	0 (0)	4 (7)
No response	0 (0)	3 (9)	3 (5)
Totals	**122**	**87**	**209**

6.10.1.3 Do you remember if it was day or night, and what the weather conditions were outside?

The purpose of this element of the questionnaire was to evaluate how much the participants would explore the environment and identify which areas they focused on most (discussed in Section 6.9.1.3). Across both experiments, a total of 85 references were made to the time of day and weather conditions presented outside of the simulated windows included within the scenario environment (Table 6.21). 38 (45%) references to the outside setting were given in the simulator experiment and 47 (55%) in the comic book. 21 (36% of cohort) participants were not sure of the outside setting, which represented the highest overall response, eight of which were participants of the simulator and 13 the comic book.

It is worth noting that there was no cell within the comic that clarified the time of day or weather conditions. However, interestingly, more references to the outside scene were made within the comic book experiment than the simulator experiment. The highest response (after 'Unsure') for the time of day across both experiments was 'Day', with 20 (34%) references made by participants. Of these 20 references, seven (29% of group) were from the simulator group and 13 (38% of group) from the comic. The simulated outside conditions took the form of a night-time and snowy setting. Of the 58 participants who took part, only seven (12%) gave the correct response (i.e. those who stated both "Night" and "Snowing"), all of whom were from the simulator group. Those who did state night as the time of day also stated snowing. However,

three (5% of cohort) participants from the comic book group correctly stated that there were no weather conditions present in the media.

Table 6.21 - References to The Day Time and Weather Conditions Outside of the Simulator Environment Sorted by Total Percentage of Cohort

Response	Sim n=24 (% of group)	Comic n=34 (% of group)	Total (% of cohort)
Unsure/Unknown	8 (33)	13 (38)	21 (36)
Day	7 (29)	13 (38)	20 (34)
Night	7 (29)	4 (12)	11 (19)
Sunny	3 (13)	8 (24)	11 (19)
Snowing	9 (38)	0 (0)	9 (16)
No weather conditions / N/A	1 (4)	3 (9)	4 (7)
Raining	0 (0)	3 (9)	3 (5)
No time	2 (8)	1 (3)	3 (5)
Cloudy	1 (4)	1 (3)	2 (3)
Morning	0 (0)	1 (3)	1 (2)
Totals	**38**	**47**	**85**

6.10.1.4 Do you remember what the patient's name, age and gender was?

Table 6.22 lists all the unique responses given concerning the patient's details such as name, gender and age. A total of 192 references were made to the patient's details across both groups. Of the 192 references, 83 (43%) were given in the simulator group and 109 (57%) in the comic book group. Only five (9% of cohort) participants correctly specified all details for the patient, by providing his name, initial, surname, age and gender, four (7% of cohort) of which were from the simulator group. Of the 192 number of references made, 138 (72%) included correct

elements of the details whilst the remaining 54 (28%) provided incorrect elements. Incorrect details included any combination of wrong forenames, surnames, initials, ages, gender or empty responses. Interestingly, three (5% of cohort) participants provided the name of the other patient, James A. Walton, whose name was displayed on the ward list. The number of references made in the comic book experiment were higher when compared to the simulator due to the larger cohort in that group.

Table 6.22 - Responses Given for The Patient's Details Sorted by Total Percentage of Cohort

Details Given	**Sim n=24 (% of group)**	**Comic n=34 (% of group)**	**Total (% of cohort)**
Male	24 (100)	28 (82)	52 (90)
James	10 (42)	16 (47)	26 (45)
Walton	11 (46)	15 (44)	26 (45)
Wrong Forename	5 (21)	13 (38)	18 (31)
P. / Patrick	8 (33)	9 (26)	17 (29)
32	11 (46)	6 (18)	17 (29)
Wrong Surname	5 (21)	11 (32)	16 (28)
Wrong Age	6 (25)	7 (21)	13 (22)
Wrong Initial	1 (4)	2 (6)	3 (5)
James A. Walton	2 (8)	1 (3)	3 (5)
No response given	0 (0)	1 (3)	1 (2)
Totals	**83**	**109**	**192**

6.10.1.5 Do you remember what different issues there were with the patient in the scenarios?

A total of 167 references were made to the patient's issues. As stated in Chapter 5, the issues of the patient included his JW status, the wrong patient name on the blood bag and a missing wristband. However, a total of 14 unique responses were given by both groups of participants, who had, in addition to identifying the three primary issues, given details of his medical history. This included being hypotensive, tachycardic and confused. The highest response given was that of the patient being a JW with 31 (53% of cohort), and this was followed by 21 (36%) references being made to the wrong blood bag given. As illustrated below in Table 6.23, the missing patient wristband was one of the lowest references made, with only five (9% of cohort) participants from the simulator group stating this.

Table 6.23 - Responses Given for the Patient's Issues Sorted by Total Percentage of Cohort

Issue with patient	Sim n=24 (% of group)	Comic n=34 (% of group)	Total (% of cohort)
Jehovah's Witness / Religion	16 (67)	15 (44)	31 (53)
Wrong Blood Bag / Blood Type	10 (42)	11 (32)	21 (36)
GI Bleed	5 (21)	11 (32)	16 (28)
Low Hb Level / Needs Transfusion	6 (25)	9 (26)	15 (26)
Vomit Blood / Haematemesis	6 (25)	8 (24)	14 (24)
Patient with Same Name	6 (25)	8 (24)	14 (24)
Hypotensive	3 (13)	9 (26)	12 (21)
High Heart Rate / Tach	5 (21)	5 (15)	10 (17)
Confused / Dazed	6 (25)	4 (12)	10 (17)
Aggressive / Pushy Consultant	3 (13)	3 (9)	6 (10)
Deteriorating	1 (4)	5 (15)	6 (10)
Patient Wristband/ID not present	5 (21)	0 (0)	5 (9)
Unwell / Pale / Sick	0 (0)	4 (12)	4 (7)
Consciousness	3 (13)	0 (0)	3 (5)
Totals	**75**	**92**	**167**

6.10.1.6 Do you remember any of the patient's medical history?

Ten unique responses were given for this question (listed in Table 6.24), including similar responses for the previous issue (such as the JW status). The highest response given, with a total of 21 (36% of cohort) references, was the gastro-intestinal bleed. This could be because it was the first condition each participant was made aware of in the scenario, and was first introduced by the nurse once the scenario had commenced.

Table 6.24 - Responses Given for the Patient's Medical History Sorted by Total Percentage of Cohort

Patient Medical History	Sim n=24 (% of group)	Comic n=34 (% of group)	Total (% of cohort)
GI Bleed	8 (33)	13 (38)	21 (36)
Vomit Blood / Haematemesis	8 (33)	10 (29)	18 (31)
No / No response	5 (21)	7 (21)	12 (21)
Hypotensive	3 (13)	6 (18)	9 (16)
High Heart Rate / Tach	3 (13)	5 (15)	8 (14)
Jehovah's Witness / Religion	3 (13)	5 (15)	8 (14)
Low Hb Level / Needs Transfusion	3 (13)	5 (15)	8 (14)
Confused / Dazed	1 (4)	1 (3)	2 (3)
Unwell / Sick / Nausea	0 (0)	2 (6)	2 (3)
Blood in Stool	1 (4)	0 (0)	1 (2)
Totals	**35**	**54**	**89**

6.10.1.7 Do you remember what bed number the patient was in?

Examining the sign above the door or the ward list on the wall in either the simulator or comic revealed that the patient was in Bed Number 4. With a total of 36 (62% of cohort), a response of '4' was the highest received, with 17 (71%) from the simulator group and 19 (56%) from the comic book. This was followed by 12 (21% of cohort) participants, six from each group, who stated 'No' or provided no response. The remaining 9 references (10% of cohort), also listed below in Table 6.25, were incorrect answers.

Table 6.25 - Responses Given for The Patient's Bed Number Sorted by Total Percentage of Cohort

Response	Count n=24 (% of group)	Comic n=34 (% of group)	Total (% of cohort)
4	17 (71)	19 (56)	36 (62)
No / No Response	6 (25)	6 (18)	12 (21)
9	2 (8)	2 (6)	4 (7)
7	0 (0)	2 (6)	2 (3)
21	0 (0)	1 (3)	1 (2)
6	0 (0)	1 (3)	1 (2)
5	0 (0)	1 (3)	1 (2)
Totals	**25**	**32**	**57**

6.10.1.8 Anything else in particular you noticed about the environment?

36 (62%) participants provided a response to this question, of which 17 (29%) were from the simulator group and 19 (33%) from the comic book group. Many of the responses consisted of simple references to other items in the environment, such as a wheelchair, working clock and walking frame. Adjectives used to describe the environment were also given, including "noisy", "clean" and "cluttered".

6.10.2 Questions 1 to 6

The first six questions of the post-use questionnaire, following the simplified situational awareness exercise, consisted of a series of Likert Scale responses related to each participant's sense of "immersion" into the media and "realism" of the content. The following table, Table

6.26, lists the averages and frequency distribution analyses of each participant's response to these questions across both groups, along with a combined total.

The results revealed that the simulator group rated the questions higher overall when compared to the comic group, the only exception being questions 4 and 5 (the realism of the consultant and nurse characters respectively). Frequency distribution analysis demonstrated that the participants found both media to be immersive, with most of the simulator group (16) rating their immersion as 'High' (mean immersion rating = 3.50, SD of 0.83) and 14 participants within the comic book group also rating their immersion as "High" (mean immersion rating = 3.39, SD of 0.70). However, the comic book format also received 15 counts of 'Somewhat' which represented the highest rating from that group.

Questions related to the realism of the scenario, consultant and nurse elicited a mixed response. For example, a further frequency distribution analysis of these questions revealed that most participants within both groups (11 from simulator and 20 from comic) rated the realism of the scenario as 'Somewhat', followed by 9 and 8 ratings of 'High' (simulator mean realism rating = 3.46, SD of 0.78; comic mean realism rating = 3.18, SD of 0.68).

Table 6.26 - Average Response Values and Frequency Distributions for Questions 1 To 6 Of the Post-Use Questionnaire Separated into Simulator (n=24), Comic (n=34) and Combined Groups

Q1) How would you rate your immersion into the media?							
Group	**V. Low (1)**	**Low (2)**	**Somewhat (3)**	**High (4)**	**V. High (5)**	**Mean**	**SD**
Sim	1	2	5	16	0	3.50	0.83
Comic	0	3	15	14	1	3.39	0.70
Total	**1**	**5**	**20**	**30**	**1**	**3.44**	**0.75**

Q2) How would you rate the room conditions surrounding the experiment?							
Group	**V. Low (1)**	**Low (2)**	**Somewhat (3)**	**High (4)**	**V. High (5)**	**Mean**	**SD**
Sim	0	0	3	13	8	4.21	0.66
Comic	0	3	15	9	3	3.40	0.81
Total	**0**	**3**	**18**	**22**	**11**	**3.76**	**0.84**

Q3) How would you rate the realism of the (base content) scenarios and their outcomes?							
Group	**V. Low (1)**	**Low (2)**	**Somewhat (3)**	**High (4)**	**V. High (5)**	**Mean**	**SD**
Sim	0	2	11	9	2	3.46	0.78
Comic	0	4	20	8	1	3.18	0.68
Total	**0**	**6**	**31**	**17**	**3**	**3.30**	**0.72**

Q4) How would you rate the realism of the consultant character?							
Group	**V. Low (1)**	**Low (2)**	**Somewhat (3)**	**High (4)**	**V. High (5)**	**Mean**	**SD**
Sim	1	3	18	2	0	2.88	0.61
Comic	1	12	9	11	1	2.97	0.97
Total	**2**	**15**	**27**	**13**	**1**	**2.93**	**0.83**

Q5) How would you rate the realism of the nurse character?							
Group	**V. Low (1)**	**Low (2)**	**Somewhat (3)**	**High (4)**	**V. High (5)**	**Mean**	**SD**
Sim	1	1	8	13	1	3.50	0.83
Comic	0	1	16	11	3	3.52	0.72
Total	**1**	**2**	**24**	**24**	**4**	**3.51**	**0.76**

Q6) How would you rate the visual quality/fidelity of the media?							
Group	**V. Low (1)**	**Low (2)**	**Somewhat (3)**	**High (4)**	**V. High (5)**	**Mean**	**SD**
Sim	0	0	1	18	3	4.09	0.43
Comic	0	2	6	19	7	3.91	0.79
Total	**0**	**2**	**7**	**37**	**10**	**3.98**	**0.67**

6.10.3 Questions 7 and 8

Consisting of Yes/No responses, Questions 7 and 8 requested participants to state if they had encountered a scenario like the one presented in both applications, along with identifying anything they felt was 'out of place' or unrealistic. The responses for these questions are listed below in Table 6.27.

With a total of 14 (24% of cohort), more elements were labelled as unrealistic in the simulator than with the comic book. The highest identified issue across both groups concerned the ward list being inside the patient's room. Whilst the simulator was still being developed, the ward list item was located outside of the room. However, the item was in view of the participant when interacting with the other characters or looking around the immediate bed area. This, therefore, caused the system software to register that the item had been 'looked at', albeit unintentionally, and this prompted the appearance of the user interface dialogue window to appear on the screen, subsequently blocking the participant's view. The consequence of this design choice was, therefore, reflected in the results.

Other comments for Question 7 included:

- Patient was not connected to any lines or intravenous drips
- Very clean (i.e. environment not cluttered or messy)
- No pillow or bed cover for patient
- Room too large
- Walking/Zimmer frame
- Blood bag left on side table.

Table 6.27 - Participants Who Stated 'Yes' For Questions 7 And 8 Of the Post-Use Questionnaire Separated into Simulator, Comic and Combined Groups

Responses ▸ Question ▾		**Sim n=24 (% of group)**	**Comic n=34 (% of group)**	**Total (% of cohort)**
7	Did you notice anything in the environment that seemed out of place or unrealistic?	14 (58)	13 (38)	27 (47)
8	Have you ever encountered this scenario (or something very similar) before?	13 (54)	11 (32)	24 (41)

As Table 6.27 illustrates, a combined total of 24 (41% of cohort) participants claimed to have experienced a scenario like the one presented in both applications. The highest response for this question came from nine (16%) participants who provided a brief description of a scenario that involved either a giving an inappropriate transfusion, or an issue concerning blood. Of relevance to the scenario, some examples of this are (as written):

- Often consultants want to transfuse inappropriately
- Have been asked to give an inappropriate blood transfusion - challenged it
- Been asked to give blood to a patient with a GIB where blood had been out too long
- Wrong blood arrived for a patient - near miss.

6.10.4 Questions 9 and 10

Data for Questions 9 and 10 of the questionnaire took the form of a further set of Likert Scale responses. Firstly, Question 9 aimed to evaluate the rarity of the scenario, as discussed earlier in this thesis (Experiment Aim M; Table 6.1). This was an intentional design choice, based on

research summarised earlier in this thesis concerning the use of training simulation to assist in practicing, and therefore preparing trainees to be more prepared for rare events (Wright *et al.*, 2004; Byrne, 2012). The results have supported this choice, with a combined mean response of 3.12 (the 'Rare' Likert category). The comic book group rated the scenario as "rare" more so than the simulator group, with a mean of 2.79 and 3.58 respectively, although both means are within the 'Rare' Likert categories. A total of three participants across both groups stated that they had not experienced any form of similar scenario.

Table 6.28 - Mean Responses and Frequency Distributions for Questions 9 And 10 Of the Post-Use Questionnaire Separated into Simulator, Comic and Combined Groups

Q9) How rare would you say this scenario is in real life?							
Group	**Not Encountered (1)**	**V. Rare (2)**	**Rare (3)**	**Common (4)**	**V. Common (5)**	**Mean**	**SD**
Sim	1	0	11	8	4	3.58	0.93
Comic	2	8	19	5	0	2.79	0.77
Total	**3**	**8**	**30**	**13**	**4**	**3.12**	**0.91**

Q10) Do you feel the media has had an immediate effect on your ability to challenge clinical decisions?							
Group	**Not at All (1)**	**Not V. Much (2)**	**Somewhat (3)**	**Much (4)**	**V. Much (5)**	**Mean**	**SD**
Sim	2	12	5	2	2	2.57	1.08
Comic	6	15	9	2	1	2.30	0.95
Total	**8**	**27**	**14**	**4**	**3**	**2.41**	**1.00**

Data for Question 10, which set out to directly support Research Question 4 (*Can VR-based training simulation aid in developing the ability to challenge clinical decisions?*), provided some important results. The data revealed a combined mean of 2.41. This indicated that the consensus was that the project did not affect participants' ability to challenge by very much. However, when comparing each group, the mean result for the simulator, 2.57, could be placed in the 'Somewhat' Likert category, albeit on the borderline. The mean result of the comic group was slightly lower at 2.30, therefore placed in the 'Not Very Much' Likert category.

6.10.5 Question 11

"How do you think the media could be improved to develop your ability to challenge clinical decisions?"

A total of 47 items of feedback were provided by participants across both groups, 25 (53%) from the simulator group and 22 (47%) from the comic book group. Due to the wide variety of answers, responses that contained similar topics were grouped together for easier analysis, providing 21 unique forms of feedback, listed below in Table 6.29. For example, two participants stated that the ability to "ask questions" and "interact more with the characters" would improve the experience. Therefore, each of these responses were placed into the 'Interact more with the characters' category.

The highest-scoring topic raised, with seven (12% of cohort) references, related to the provision of more interaction with the virtual characters. These responses mainly consisted of more options to choose from when challenging, such as being able to discuss the situation further or ask questions. Six (10%) participants requested that the simulator should be designed around other professions or specialities. However, this result was also matched with another six participants who were critical of the events in the scenario and questioned the realism of elements, mainly the attitude and behaviour of the consultant.

Table 6.29 - Feedback Given for Question 11 of the Post-Use Questionnaire Sorted by Total Percentage of Cohort

Response ▼	**Sim n=24 (% of group)**	**Comic n=34 (% of group)**	**Total (% of cohort)**
Be able to interact more with the characters	4 (17)	3 (9)	7 (12)
Tailored to different professions/specialities	5 (21)	1 (3)	6 (10)
Scenario may not be realistic	1 (4)	5 (15)	6 (10)
Longer scenario	2 (8)	2 (6)	4 (7)
Prior information on aims / tutorial / practice	3 (13)	0 (0)	3 (5)
More interactable elements	3 (13)	0 (0)	3 (5)
More information available	0 (0)	2 (6)	2 (3)
Cartoon style may not convey right message	0 (0)	2 (6)	2 (3)
More video game/VR simulator elements	0 (0)	2 (6)	2 (3)
Be able to clarify reasons behind challenge	1 (4)	0 (0)	1 (2)
Scenario too simplistic	1 (4)	0 (0)	1 (2)
More time to interact with elements	1 (4)	0 (0)	1 (2)
More noises / sound effects	1 (4)	0 (0)	1 (2)
More scenarios to engage with	1 (4)	0 (0)	1 (2)
Be able to confirm patient identity (no wristband)	1 (4)	0 (0)	1 (2)
Increase chance of consultant acquiescing - i.e. consider challenge	1 (4)	0 (0)	1 (2)
More visual detail / information / design	0 (0)	1 (3)	1 (2)
See outcome of scenario	0 (0)	1 (3)	1 (2)
More outcomes based on challenge	0 (0)	1 (3)	1 (2)
More immersion required	0 (0)	1 (3)	1 (2)
Consider personality traits	0 (0)	1 (3)	1 (2)
Totals	**25**	**22**	**47**

6.10.6 Question 12

"Do you have any other comments or feedback for the media regarding its design, usability, or visual quality?"

Across both groups, a total of 39 responses were given concerning the overall experience of each participant (Table 6.30). 28 (72%) responses were provided from the simulator group and 11 (28%) from the comic book group. The simulator group provided more varied feedback, spreading over different topics. In comparison, the comic book group provided less varied feedback. The highest overall response for this question consisted of 21 (36% of cohort) participants who stated that they enjoyed their experience, praising the visual design, application engaged with and the project's topic. This was followed by five (9%) participants who requested a much clearer presentation be considered, such as easier controls and simpler interface.

Table 6.30 - Responses Given for Question 12 of the Post-Use Questionnaire Sorted by Total Percentage of Cohort

Response ▼	**Sim n=24 (% of group)**	**Comic n=34 (% of group)**	**Total (% of cohort)**
Good project / Enjoyable / Good Design / Useful experience/system	12 (50)	9 (26)	21 (36)
Consider clearer overall presentation e.g. menus/UI and controls	4 (17)	1 (3)	5 (9)
Simple and/or easy to use	2 (8)	1 (3)	3 (5)
Perception separate from real life	2 (8)	0 (0)	2 (3)
Good subject teaching area/aid	2 (8)	0 (0)	2 (3)
Consider tutorial or practice sequence	2 (8)	0 (0)	2 (3)
As with response given for Question 11	1 (4)	0 (0)	1 (2)
Beneficial project for junior staff	1 (4)	0 (0)	1 (2)
Lack of gaming experience difficult	1 (4)	0 (0)	1 (2)
Scenario realistic	1 (4)	0 (0)	1 (2)
Totals	**28**	**11**	**39**

6.10.7 VR Simulator and Comic Book Post-Use Results Analysis

Mean Likert scale responses provided by both groups for questions one to six of the post-use questionnaire suggested that engagement with the VR simulator was the most immersive experience of the two media. In addition, the simulator represented the higher visual quality. Despite this, the characters featured in the scenario (especially the consultant and nurse) were rated as more realistic in comic book form when compared to the simulator.

The results suggest that efficacy of both tools may be equal, as illustrated by the near similar mean Likert scale responses and their respective SDs. This finding is consistent with the responses to all other questions concerning the effect on challenge ability and overall feedback.

Therefore, there was no demonstrable evidence that suggested either media significantly outperformed the other.

A frequency distribution analysis of all responses to the Likert scale questions, that compared positive ratings to negative ratings in the post-use questionnaire, demonstrated an overall positive response to both applications concerning immersion, scenario realism and the effect on challenge ability. This analysis is listed in Table 6.31 below and illustrated in Figure 6.10, where 180 positive ratings ('4' and above) were provided compared to 72 negative ratings ('2' or below). 141 ratings of '3' (i.e. "neutral", neither positive nor negative) were given. The combined mean Likert scale response to questions 1 to 6 and question 10 of both groups was 3.33 with an SD of 0.94 (simulator mean = 3.45, SD of 0.93; comic mean = 3.24, SD of 0.93).

Table 6.31 – Frequency Distribution of Likert Scale Responses to Questions 1-6 and Question 10 of the Post-Use Questionnaire Including Overall Averages and SDs

Group	V. Negative (1)	Negative (2)	Neutral (3)	Positive (4)	V. Positive (5)	Mean	SD
Sim	5	20	51	73	16	3.45	0.93
Comic	7	40	90	74	17	3.24	0.93
Total	**12**	**60**	**141**	**147**	**33**	**3.33**	**0.94**
Total P/N	**72**			**180**			

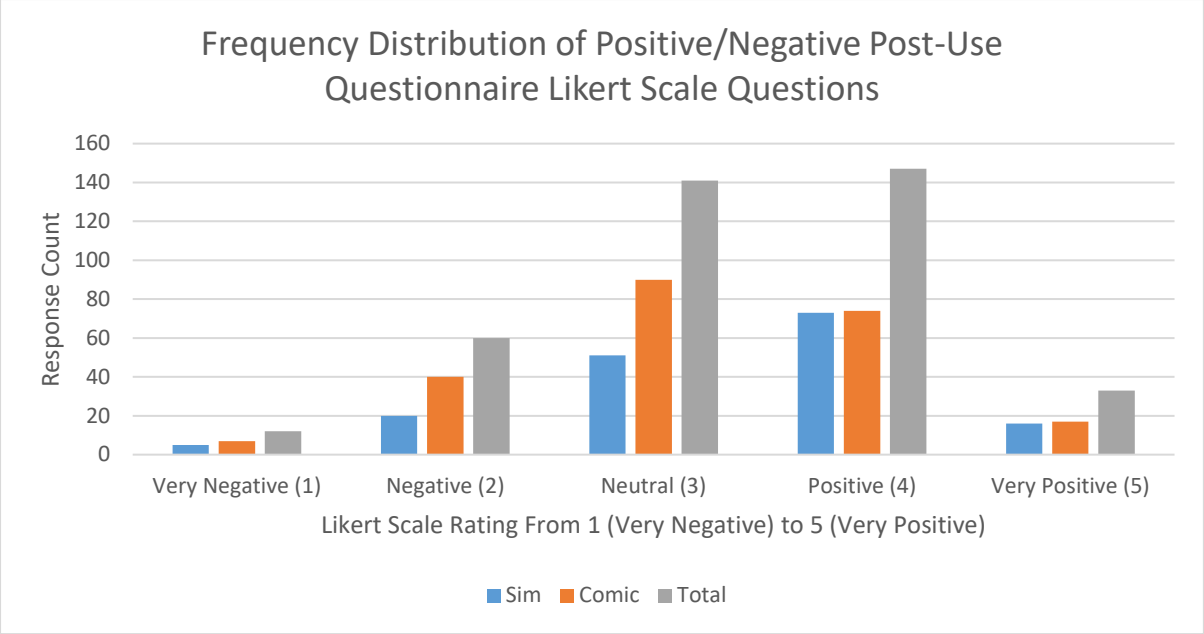

Figure 6.10 - Histogram That Illustrates the Frequency Distribution of Positive and Negative Responses to Likert Scale Questions 1-6 and Question 10 of the Post-Use Questionnaire

Listed in Appendix M, each of the responses given as part of the situation awareness assessment (discussed in section 6.10.1) element of the post-use questionnaire were tallied and the results were placed into a table. For example, each participant who identified the patient as a character in the environment were given a point and if the blood bag was identified as an examinable item they were also given a point, and so on. Only content shared across both the simulator and comic were tallied (e.g. as there was no Jehovah's Witness wristband featured in the comic this item was not tallied and compared). In total, there were 24 shared elements that were scored. The established elements were distributed across the identifiable characters, examinable items, patient information, patient issues, patient's medical history and bed number. The results of

this analysis revealed that the comic book cohort scored the highest number of points in 15 categories (303 points total), compared to the simulator's 8 (258 points total). The remaining case, where the nurse stated in the scenario that the patient was confused, was tied at a single point each.

This analysis suggested that the comic book was the more engaging tool despite contradicting evidence, as previously highlighted, that suggested the simulator was the more immersive experience. There were several other findings that were consistent with those discussed in, for example, 6.9.1.3. The participants were predominantly focused on the patient's bed within the simulator, which resulted in a low number of references to the patient's bag when compared to the comic book group (as it was situated behind the virtual participant's position).

However, these results are most likely attributed to, and therefore potentially skewed by, the group size difference (24 for simulator and 34 for comic). Despite this finding, a further analysis, that compared the tallies for each category between both groups, revealed that categories 1, 2, 4, 11 and 14 are all among the six highest scores for both groups and are, arguably, both the focal points and most memorable aspects/theme of the entire scenario. These categories are:

- (1) Identified the patient
- (2) Identified the consultant
- (4) Identified the nurse
- (11) Listed the blood bag as examinable
- (14) Correctly stated the patient's gender

6.11 Follow-up Questionnaire Results

The follow-up questionnaire was distributed approximately six months following the conclusion of the experiment. Submissions were open for five months, with a monetary voucher given to two participants, chosen at random after two months, as a form of encouragement for participants to re-engage with the project. Email invitations were distributed to 57 of the participants who willingly provided contact information in the earlier investigations, and additional emails were sent out at the start of each week for the first two months. Invitations emailed to nine participants were rejected by the email domain, seven from the comic group and two from the simulator group, as the email addresses were invalid. The invalid email addresses were a combination of illegible handwriting and personal addresses that were not related to the QEHB or NHS. A total of 22 submissions were received and verified, 11 from each of the simulator and comic book cohort, providing a response rate of 38%.

Due to the QEHB's website filtering system, survey websites, including the online-based Google Forms survey system, were banned from the network. Therefore, of the 22 submissions received, only 12 were submitted through Google Forms. It was predicted that some responses were not received or even attempted because of this. As an alternative form of submission, a word document version of the questionnaire was created and attached to an additional invitation email that was sent out shortly after the first. The word document version was submitted by ten participants.

The following sections outline the results of this follow-up. It starts with Section 2, where the survey data begins; Section 1 was only used as an introduction.

6.11.1 Section 2 of the Follow-up Questionnaire

The series of questions for this section required the participant to state whether they had to challenge the decision of a colleague since taking part in the experiment. As with the first investigation, they were asked to specify the grade or role of the person they challenged (Table 6.32), why they issued a challenge and how their challenge was received.

Of the 22 participants who submitted this questionnaire, 20 (91%) stated that they had been involved in a scenario after participation in the earlier experiments where they found themselves challenging a decision. The grade of the staff member challenged was identified in 16 (73%) cases. When asked to specify the grade or role of the person challenged, the most frequently-challenged grade, with a total of six (38% of all identified grades challenged), was a consultant. This was followed by three instances where a CT 1-2 and AHP were challenged.

Table 6.32 - Grade Categories Challenged After Taking Part in The Experiment Sorted by Percentage of Total Identified Grades

Grade Category ▾	Count	% of total grades identified
Consultant	6	38
Core Trainee 1-2	3	19
Allied Health Professional	3	19
FY2	2	13
FY1	1	6
Nurse - 6+	1	6
Totals	**16**	

Table 6.33 below highlights the reasons each participant challenged their colleague. As with some of the questions in this chapter, this question gathered a wide variety of responses and, therefore, similar answers were grouped together in a category. The highest response was that from five participants, who challenged because of poor or unsafe medical practice being performed. This was matched by another five participants who challenged because of a disagreement. The final question in this section asked participants to rate, on a Likert Scale of 1-5, with 1 representing ‘Very Negatively’ and 5 ‘Very Positively’, how their challenge was received. The results for this question were mixed, with a mean of 3.16 (somewhat positive) and an SD of 1.18.

Table 6.33 - Reasons for Challenging Responses Sorted by Percentage of Total Identified Reasons

Reason for challenging ▼	**Count**	**% of total identified reasons**
Poor/Unsafe Medical Practice	5	23
Disagreement over decision	5	23
Clinical issues with patient	3	14
Attitude	1	5
Inappropriate presence	1	5
Misuse of equipment	1	5
No research/investigation	1	5
Clarification of decision/investigation	1	5
Scenario where more time was needed	1	5
Issues with handover	1	5
Issues with location/department	1	5
Giving factually incorrect information	1	5
Total	**22**	

6.11.2 Section 3

This section consisted of seven questions concerning how well each participant recalled their experience in the experiment. This was then followed by questions that asked whether each participant had experienced a scenario like the one encountered in either the simulator or comic book application. Finally, it set out to establish whether their interest in the project would see them engage with the other form of media they had not yet experienced (i.e. those who were in the simulator group engaging with the comic book, and vice-versa).

The first question asked each participant to rate, on a Likert Scale of 1 to 5, with 1 representing 'Not at All' and 5 'Very Much', how well they remembered the scenario that was presented. The results for this question were mixed, with a mean of 3.32 ('Somewhat') and an SD of 1.43. The responses given from the simulator group produced a slightly higher mean than the comic book, with 3.36 and 3.27 respectively. The SD of the simulator group was also slightly higher at 1.5, with the comic book at 1.49.

The second question asked participants to provide a brief description of the scenario content with which they engaged. The responses given, 47 in total, varied across many topics, with similar answers grouped together. This included multiple references to the incorrect blood bag, vomiting blood, the consultant's negative attitude and how the scenario was presented. Table 6.34 below lists all the responses given for this question, sorted in order of percentage of participants.

Table 6.34 - Responses Given When Asked to Provide a Description of the Scenario Participants Engaged with Sorted by Total Percentage of Follow-up Responses

Unique Responses ▼	**Count**	**% of total follow-up responses**
Asked to administer blood	5	23
Incorrect blood for patient	5	23
Patient needed blood transfusion	4	18
Inappropriate Procedure	3	14
Patient was Jehovah's Witness	3	14
Consultant gave inappropriate order	3	14
Stated only that there was a blood bag present	3	14
Explored environment	3	14
Patient had Haematemesis	2	9
Generic overview on experience/scenario	2	9
Consultant's negative attitude	2	9
Gave incorrect information	2	9
Cannot remember anything to do with scenario	2	9
Stated why blood couldn't be given	1	5
The consultant asked you to do something	1	5
GIB	1	5
Wrong patient information	1	5
Rejected instructions	1	5
Stated that they were on a ward round	1	5
Multiple scenarios/replays	1	5
Able to examine items	1	5
Total	**47**	

The third question asked participants to rate on a Likert Scale of 1 to 5, with 1 being 'nothing similar at all' and 5 'something very similar'. Across both groups, the mean rating was 1.55 (borderline between nothing similar at all and not very similar) with an SD of 0.94. When both groups were compared, the mean response was 1.27 with an SD of 0.47 and 1.82 with an SD of 1.25 for the simulator and comic book groups respectively.

The next part of this question asked participants, if they had encountered a similar incident, to provide a brief description of that incident. Only four scenarios were provided for this part of the question, and are listed below in Table 6.35.

Table 6.35 - Similar Scenarios Provided as Part of the Follow-Up Questionnaire

Likert Value	Participant Grade	Scenario Description
2 / No, Nothing Similar	Consultant	I have stuff like this happen 3-4 times a year, I don't let it bother me. I report it and escalate it. If I am being "fobbed off," I will keep going until people get the message.
2 / No, Nothing Similar	Nurse – Band 6+	A patient had a documented allergy to a medication and, even though it was in the notes and the patient was wearing a red wristband, the doctor insisted that the drug be given. I refused to administer the drug and was "verbally hauled over the coals" for the refusal.
5 / Yes, something very similar	CT 1-2	Unwell patient with prescribing errors leading up to his illness. They hadn't been prescribed steroids, went into adrenal crisis and had a myocardial infarction (blocking of arteries in the heart). ECG showed new changes, I tried to get registrar to help me actively manage the patient with medication and cardiology review. They thought the patient was dying and planned for no treatment. I asked consultant for help who spotted the steroid prescription error and actively treated the patient, who recovered.
1 / No, nothing similar at all	FY2	Nothing that extreme.

The final two questions of this section required participants to state if they would be interested in taking part in the study again, either to interact with an improved version of the media they had originally engaged with, or to try the other form of the application. Firstly, they were asked to rate, on a Likert Scale of 1 to 5, with 1 being 'very unlikely' and 'very likely', their likeliness of taking part in the study again. The mean response for this part, across both groups, was 4.14 (likely) with an SD of 1.06. The mean response from those who took part in the simulator experiment was 3.91 (somewhat likely) with an SD of 1.38. In comparison, the comic group response was higher, with a mean response of 4.36 and an SD of 0.67.

The second part of this question asked participants to clarify why they gave their rating and clarification was given in 30 cases. As with all other questions, similar responses were grouped together. The highest response given by four (18%) participants consisted of 'enjoyed' and/or 'useful experience'. This was matched by 'happy to help out' and issues with time, both stated by four participants. All other responses given are listed below in Table 6.36, sorted in descending order of percentage of participants.

Table 6.36 - Responses Given as to Why Participants Rated Their Likeliness to Take Part in the Study Again as Part of the Follow-Up Questionnaire Sorted by Total Percentage of Follow-up Responses

Response ▼	**Count**	**% of total follow-up responses**
Enjoyed/useful experience	4	18
Happy to help	4	18
Time is an issue	4	18
Improving learning/training/confidence	3	14
Influence medical practice	2	9
Alternative method of training	2	9
Useful in training junior staff	1	5
Simplicity	1	5
Important area for research	1	5
Found subject interesting	1	5
Makes you think about decision making	1	5
Helpful in some way	1	5
Improving patient safety	1	5
Interest in Simulation/Human Factors	1	5
Sympathetic to the difficulty in recruiting study participants	1	5
Did not find the simulator reflected real-life	1	5
Useful for / encourages reflection	1	5
Total	**30**	

6.11.3 Section 4

The penultimate section of the questionnaire set out to obtain current opinions on the technology the participants had engaged with, and if they felt it would be a beneficial resource to the medical sector or education in general. In the middle of this section, more importantly, were questions designed to establish whether either technology had had a longer-term impact on each participant's ability to challenge.

Table 6.37 lists the means and SDs for the response to two questions that asked each participant to rate, on a Likert Scale of 1 to 5 (with 1 representing 'Not at All' and 5 'Very Much'), how beneficial either technology – simulator or comic book – would be as a potential training resource. The VR question included examples of specific technologies, such as VR headsets (i.e. head-mounted displays) and various other gaming devices. The comic book question also listed examples of applications, such as graphic novels. As Table 6.37 below illustrates, the use of VR technologies was rated higher when compared to printed media across both groups.

Following on from the questions listed in Table 6.37, the questionnaire asked participants to list examples of applications that could benefit from the adoption of either VR or comic book technologies as a training tool. A total of 46 references were made across both groups, with 32 (70%) made in the simulator group and 14 (30%) from the comic book group. As Table 6.38 and Table 6.39 indicate, a wide variety of responses were provided for these questions and matching recommendations were very low across the population.

Table 6.37 - Means and SDs Representing How Beneficial VR And Comic Technologies Could Be as A Training Resource to Hospitals

Question ▼	**VR Tech Mean / Likert (SD)**	**Comic Mean / Likert (SD)**	**Combined Mean / Likert (SD)**
Do you think virtual reality technologies (such as headsets or 3D-based gaming technologies) integrated into healthcare training could provide a beneficial future training resource to the NHS?	4.09 / Yes, much (1.22)	4.00 / Yes, much (0.77)	4.05 / Yes, much (0.98)
Do you think printed media (such as comic books or graphic novels) integrated into healthcare training could be a beneficial resource?	3.64 / Somewhat (1.21)	2.91 / Not much (0.83)	3.27 / Somewhat (1.05)

Table 6.38 - Applications That VR Technologies Could Potentially Benefit Sorted by Total Percentage of Follow-up Responses

Response ▼	**Count**	**% of total follow-up responses**
Observing/practising difficult situations or scenarios	3	14
Uncertainty due to realism	2	9
Benefit younger generation	2	9
Emergency Resus training	2	9
Student Nurses	1	5
HCAs	1	5
No applications	1	5
Participant not suited to presentation	1	5
Military presence	1	5
Reflection	1	5
Breaching Protocols	1	5
Planning interventions	1	5
Challenging behaviour	1	5
Gaming allows acting out real scenarios	1	5
No access to live patients may not benefit	1	5
Drug examination	1	5
Observations	1	5
Disability	1	5
Noise	1	5
Various versions of environment	1	5
Training scenarios	1	5
Emergency Scenarios	1	5
Clinical examination	1	5
Communication Skills	1	5
Beneficial for those who learn best through visual means	1	5
Can benefit all/most areas	1	5
Existing simulation courses (e.g. SIM MAN)	1	5
Total	**32**	

Table 6.39 - Applications That Printed Media Technologies Could Potentially Benefit Sorted by Total Percentage of Follow-up Responses

Response ▼	Count	% of total follow-up responses
Unsure	2	9
Nothing	1	5
Visual messages more memorable	1	5
All avenues of training assessed	1	5
Presentation used to explain things	1	5
General Skills Training	1	5
No Interaction	1	5
All applications	1	5
Associated with entertainment	1	5
Comparisons to real-life experience	1	5
Helpful as secondary source	1	5
Not suitable as a main source	1	5
Emergency scenarios	1	5
Total	**14**	

The final part of this section consisted of a series of Likert Scale questions, scaled from 1 to 5. The questions asked each participant to rate how much they felt the study had affected their ability to challenge and their current confidence level in issuing a challenge. Then, it concluded with two questions that asked participants to rate their interest in attending any form of simulation course dedicated to developing assertiveness, and how beneficial such a course would be to NHS Trusts.

Table 6.40 lists the responses for these questions. The results from the simulator group revealed a mean of 2.45 (‘Not Very Much’), with an SD of 1.37, for the question concerning how the study affected their ability to challenge. The comic group mean response was slightly lower,

with 2.36 (‘Not Very Much’) and an SD of 1.03. Current confidence to challenge was also higher overall in the simulator group than the comic, with a mean response of 4.27 (‘confident’) and an SD of 1.01 compared to 3.91 with an SD of 0.94 respectively.

The response to the questions concerning the development of a simulation course dedicated to challenging decisions was quite positive. The mean response to the first question of this set, asking participants to rate how beneficial such a course would be to NHS trusts, was 4.23 (‘beneficial’) with an SD of 1.00. When asked if they would be interested in taking part in such a course, the overall mean response was 4.09 (‘interested’) with an SD of 1.00.

Table 6.40 - Likert Scale Responses for Section 4 Of the Follow-Up Questionnaire

Question ▼	**Simulator Mean / Likert (SD)**	**Comic Mean / Likert (SD)**	**Combined Mean / Likert (SD)**
Since finishing the study, do you feel the media you interacted with has had any long-term effect on your ability to challenge clinical decisions?	2.45 / Not very much (1.37)	2.36 / Not very much (1.03)	2.41 / Not very much (1.15)
How would you currently rate your overall confidence to challenge a clinical decision?	4.27 / Confident (1.01)	3.91 / Somewhat confident (0.94)	4.09 / Confident (0.95)
Do you think a simulation-based training course or workshop dedicated entirely to assertiveness or how to successfully challenge a decision would be a beneficial resource to NHS Trusts?	4.18 / Beneficial (1.17)	4.27 / Beneficial (0.90)	4.23 / Beneficial (1.00)
Would you be interested in taking part in such a course?	4.18 / Interested (1.25)	4.00 / Interested (0.77)	4.09 / Interested (1.00)

Regarding the question that asked participants to rate how much the study had affected their ability to challenge, a text box was included that requested participants to clarify why they gave their rating. As with other text-based questions, similar responses were grouped together. Eight (36%) participants stated that they already possessed an extensive level of experience in challenging, representing the highest response given. This was followed by four participants who stated that the project "encouraged reflection". All other responses, listed below in Table 6.41, varied on topic, but these were referenced by a smaller number of participants.

Table 6.41 - Responses to Question Concerning Whether Either Technology Has Had Any Long-Term Effect on Each Participant Sorted by Total Percentage of Follow-up Responses

Response ▾	**Count**	**% of total follow-up responses**
Already have confidence in challenging	8	36
Encouraged reflection/thinking	4	18
Senior member of staff	3	14
Follow up session would benefit	2	9
Grade affected participation	1	5
Concerns with scenario	1	5
Juniors/inexperienced would benefit	1	5
Military background	1	5
Would need more than one application	1	5
Simulator too game-like	1	5
Opportunity to discuss with peers	1	5
Comic book scenario not realistic	1	5
Depends on individual	1	5
Challenge only for learning	1	5
Don't doubt a senior's decision	1	5
Total	**28**	

6.12 Discussion

6.12.1 Overall response to the applications and the scenario

Overall, participant responses to both projects were positive, albeit with many implications that assisted in the formation of design considerations for future research and training system modifications (detailed in Chapter 7). The purpose of the investigations and experiments was to evaluate whether either the VR or the printed media/comic book application could be potentially used as a training tool to assist in the development of decision-making abilities of clinical trainees, specifically preparing them to be able to cope with the act of challenging decisions.

Whilst the results of the experiment suggest that the effectiveness of the two media are questionable, the widespread adoption of such technologies throughout the healthcare domain specifically and related training contexts generally to complement traditional forms of simulation is most definitely promising. For the healthcare domain, confidence in this assessment is based on the responses from the participants in the post-use and follow-up questionnaires and their respective analyses (e.g. positive frequency distribution reported in Table 6.31 and Figure 6.10). As a further example, Table 6.42 and Figure 6.11 below illustrate a frequency distribution analysis of both positive and negative Likert scale questions within the follow-up questionnaire. This analysis revealed that, despite low evidence of efficacy (mean

response to effectiveness question = 2.41, SD of 1.15), responses to both media related to interest in taking part in a further study, impact to healthcare domain and how well each participant recalled their experience in the experiment are positive (98 ratings of '4' or above compared to 30 ratings of '2' or below and 26 neutral ratings of '3').

Table 6.42 - Frequency Distribution of Positive/Negative Likert Scale Responses of the Follow-Up Questionnaire Including Overall Averages and SDs

Group	V. Negative (1)	Negative (2)	Neutral (3)	Positive (4)	V. Positive (5)	Mean	SD
Sim	11	4	10	25	27	3.69	1.38
Comic	4	11	16	27	19	3.60	1.16
Total	**15**	**15**	**26**	**52**	**46**	**3.64**	**1.27**
Total P/N	**30**			**98**			

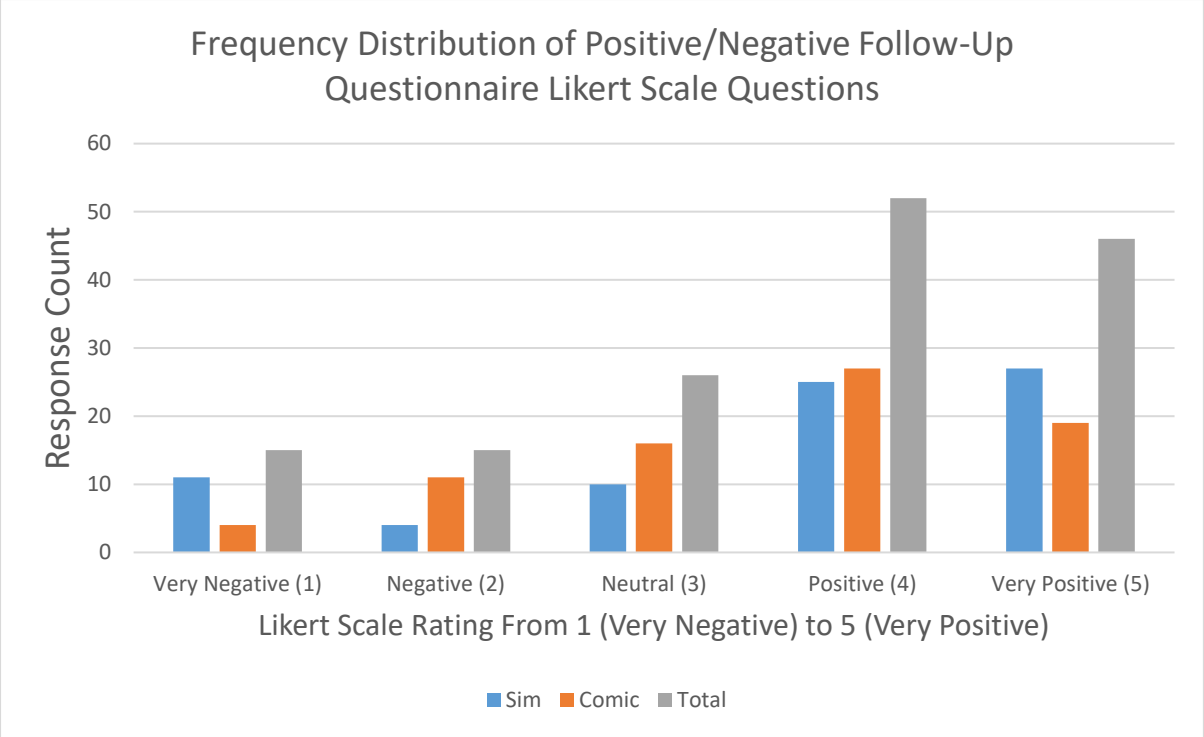

Figure 6.11 - Histogram That Illustrates the Frequency Distribution of Positive and Negative Responses to Likert Scale Questions of the Follow-Up Questionnaire

Despite providing widely mixed responses to the effectiveness of the tools, most of the participants cited their participation in the study – with respect to the subject matter and use of gaming technologies – as an enjoyable and useful experience. Furthermore, a total of 40 different subjects were discussed in the follow-up questionnaire (including criticisms and areas of improvement) concerning other applications that could benefit from both the VR-based technologies and the comic book style of presentation. This included, as stated by some participants, "observing" or "practising difficult scenarios", as an adjunct to existing simulation

courses such as SimMan, emergency scenarios and intervention planning.

However, there were two recurring criticisms which, more so than the simulator and comic applications themselves, focused on aspects of the scenario presented. The first criticism concerned the mixed responses aimed at the consultant character, questioning the realism of their presentation and attitude. These responses resulted in a low mean realism rating of the scenario (combined group mean ratings of 2.93 and 3.3, respectively; 'Somewhat' Likert category). Comments provided by participants on this topic included statements that consultants would normally invite feedback and that the anger of the consultant (especially in the comic book version) was an emotion that was "not welcome in the NHS." Other examples of comments included a CT 1-2 who stated: "I do not think the portrayal of the consultant is realistic - I have never encountered this sort of consultant" and an FY1 who recommended that a "more realistic consultant and scenario" be implemented. As a further example, a comment provided by a consultant from the simulator group stated: "Change response of consultant when challenged. Consider them reviewing decision to transfuse rather than proceeding."

The second criticism was based on several mixed reactions that also questioned the realism of outcomes that saw, in some instances, participants' challenges being overruled. This was despite the existence (and sometimes obvious existence on occasions) of incorrect information (e.g. blood bag not matched to patient identification). A total of six participants (i.e. 10% of the whole cohort) suggested that a more realistic consultant, or scenario, be implemented in future

versions of the media to increase the real-world fidelity and relevance of the scenario and, in doing so, this would help to increase the potential effectiveness of the applications (Question 11 of the post-use questionnaire).

Both criticisms discussed above were evident despite contradictory findings (detailed below) in the earlier project research (e.g. participant interviews in section 4.5.2, for example) and from the results of both the post-use and follow-up questionnaires. For example, earlier findings revealed that staff in clinical environments had experienced conflicts with consultants who expressed an overly negative attitude and, in some instances, saw their challenges needlessly overruled (see Table 4.21 and Table 6.35 for examples). As a second example, of the 26 consultants who were challenged in the scenarios provided in the interviews conducted in the earlier part of the present investigation, 13 (50%) outcomes were not altered because of the challenge. Furthermore, of these 13 instances, four (31%; 15% of total) participants experienced a negative response to their challenge. A third example was that, despite the mixed realism rating of both the consultant and the scenario, some participants stated in their responses that these experiences are, in fact, possible in real-world settings. Responses included: "Some doctors are like that but most are good", "Have seen this, though mostly consultants have listened to concerns" and "A bit dramatic (and somewhat clichéd) but possible."

As a final example, the consultant in the scenario presented could retract their decision upon a successful second challenge attempt. However, this process occurred only six times (i.e. 5% of

total scenario runs) out of the 13 (11%) instances where a second challenge was issued. The retraction process was also limited to the simulator conditions, as no cells in the comic book illustrated such an outcome. This was, therefore, a rare outcome. Further analysis into this topic produced an interesting finding. The six participants who experienced the consultant accepting their challenge were placed into a sample group and the mean realism ratings were recalculated based on their responses. This analysis revealed that the mean scenario and consultant realism ratings increased from 3.46 and 2.88 (i.e. in the 'Somewhat' Likert category) to 4.17 ('Good') and 3.33 (slightly below 'Good' but still 'Somewhat'). This finding suggests that the mean realism rating of both the consultant and scenario content may have been higher overall if the consultant was more likely to retract their decision.

Furthermore, this finding coincides with comments provided by participants who did not receive this scenario outcome, such as:

- "I don't think a doctor would administer the blood himself."
- "Outcome low re. consultant decision being unrealistic relative to consultants I have worked with."
- "Change response of consultant when challenged."
- "Consider them reviewing decision to transfuse rather than proceeding."

In existing literature, this finding supports the design methodology of Calhoun and colleagues' (2013) scenario content, where a second challenge *always* resulted in the confederate retracting their decision.

Regarding the post-use questionnaire, when comparing the mean Likert scale responses of the simulator group to the comic book group, analysis revealed no significant different in ratings. However, the simulator group produced slightly higher responses overall (as illustrated below in Figure 6.12). For example, the participants were asked to rate their sense of immersion within the media, the environmental conditions, the realism of the scenario and the visual quality. The simulator (using a Likert Scale from 1 to 5) was rated higher overall. The exception to this is Question 9, which asked participants to rate how rare this scenario is real-life, where the comic book group was rated much lower (i.e. rarer) than the simulator group. Whilst comparisons between both media is limited, the results suggest that the simulator is slightly more effective in terms of immersion and visual quality, whereas the comic book's portrayal of the characters were more realistic than their VR counterparts. However, more importantly, the final question of the post-use questionnaire asked participants to clarify if the study had produced any immediate effect on their ability to challenge. The simulator group also rated this question slightly higher than the comic group, suggesting that the VR technique, despite the limitations with realism discussed previously, is a more effective method to help develop the ability to challenge and despite the smaller cohort.

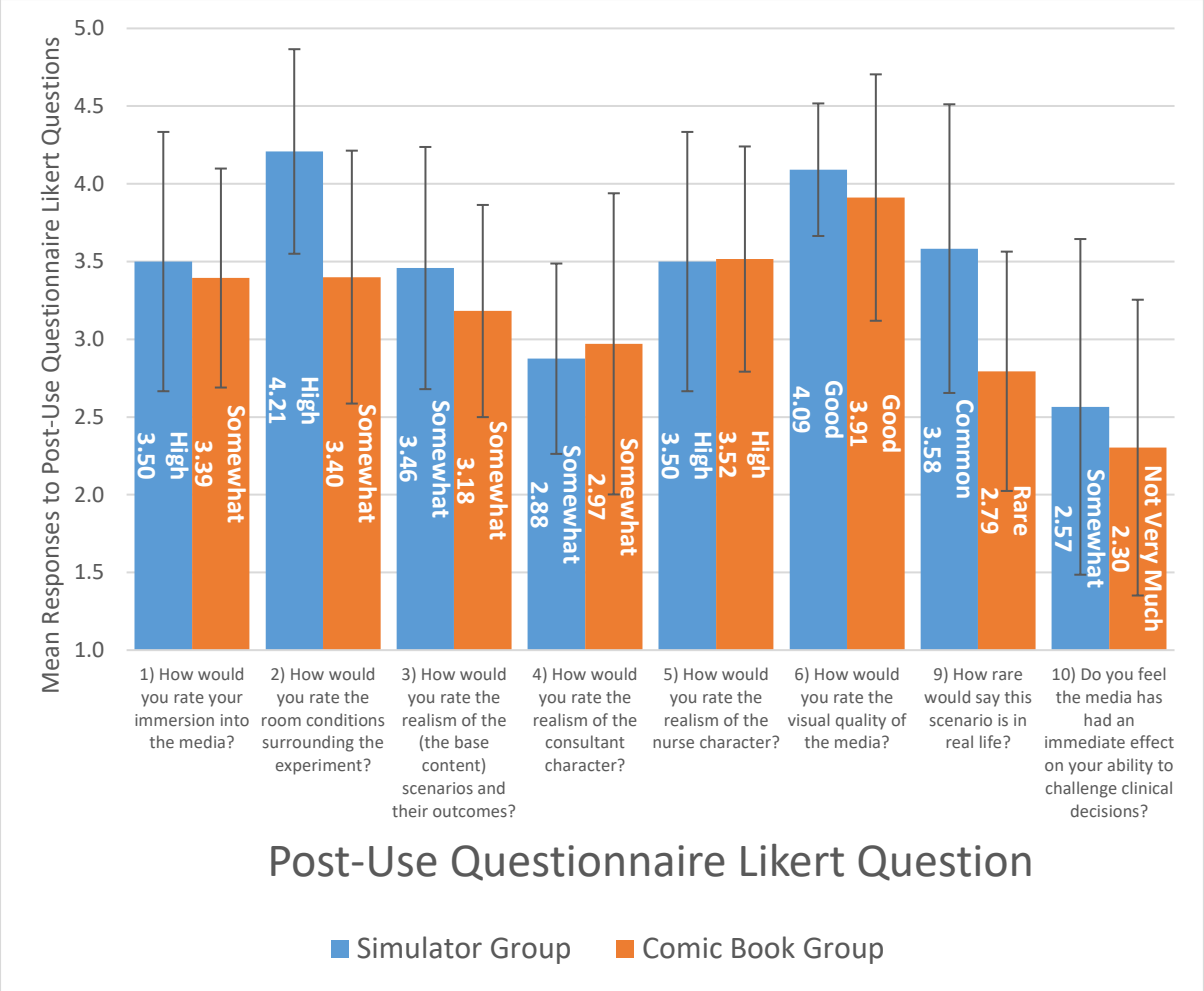

Figure 6.12 – Histogram Comparing Mean Likert Scale Values of Post-Use Questionnaire Responses Between Simulator and Comic Book Groups

6.12.2 Scenario Presentation and Participant Control

With respect to the simulator, the responses and feedback elicited from the experimental cohort raised significant design concerns. Firstly, the amount of 'gaming experience' had not been determined prior to the commencement of the experiment. As the results of the experiment had shown, gaming experience among the cohort was low (mean 2.29; 'Low') despite an overall high level of computer experience (mean 4.07; 'Good') and time spent interacting with the technology (mean 4.66; '8+hours'). Computer experience and competence could be attributed to how often computers are now used in the clinical environment (for example, the computer running the drug software that accompanied the ward round), as studies have shown (Gerrish *et al.*, 2006; Whittaker *et al.*, 2009; Gürdaş Topkaya & Kaya, 2015).

Because of this finding, the overall presentation of the simulator had seemingly overwhelmed those with limited experience in gaming technology. For example, despite each participant receiving a demonstration on how to handle the Xbox controller from the author, one participant began to the use the controller upside-down as the experiment session started. However, in this case, the participant had realised shortly thereafter (as the camera controls were, therefore, inverted) and corrected the controller's orientation. As a second example, analysis of the recorded footage revealed one case where a participant was moving the camera around the environment, seemingly confused as to the aims despite clarification from the author beforehand. As a third example, despite demonstrating that only a single button on the

controller is required to operate the simulator (except for the joy-stick for camera movement), six participants frequently examined the controller upon being presented with the button prompt to respond to the consultant. It was assumed that this behaviour was to clarify where this button was located and to ensure they pressed the right button. As a fourth example, four participants stared at the screen idly when the on-screen prompt to respond to the consultant appeared, suggesting that they were unsure of how to proceed.

As a final example, this analysis was reflected in the participant's feedback, including:

- "Felt a bit stressed with the noise."
- "Difficulty using controls."
- "I do not play computer games so this was an additional challenge."
- "Very useful system for people confident with game controllers."
- "The joystick took a lot of getting used to."

In contrast, another participant, a medical student, stated that they interacted with video games between one and four hours a week and rated their experience as 4 ('Good'). In this instance, the participant's experience in gaming was evident during the recording of the experimental session, which showed that they had recognised the structure/flow of the scenario by the second run-through (as illustrated in Figure 5.1). For example, by the time the character had reached the bedside of the patient in scenario runs three to five, the participant had quickly and efficiently navigated the environment, examined the items and had identified the issue with the patient. Then, they rotated the camera to face the position where the consultant would stand when they arrived and simply waited for the random event to occur during the simulation that

progressed to the decision for treatment.

Furthermore, and leading on from the above, there is an association between those with more gaming experience and performance within the simulator. Table 6.43 demonstrates this, where an increase in gaming experience ratings led to an accompanying increase in the mean number of items looked at and examined, an association that was higher than those who rated their experience with computers as 4 and above (see Table 6.44). However, the percentage of items looked at and *then* examined decreased slightly as the gaming experience rating increased, from 36% to 32%. Although this apparent reduction is small, an explanation of this finding could be that those with high gaming experience did not need to examine the items as much as participants with lower gaming experience. Further analysis of this finding revealed that the mean number of items examined in each single run of the scenario is 4.52. When taking the gaming experience rating into account (ratings of 4+), the mean number of items examined almost doubles to 7.55, suggesting that for each single item examined, those with gaming experience examined two. Therefore, participants with gaming experience have interacted with the simulator more so than those with no gaming experience.

Table 6.43 - Gaming Experience Compared with The Number of Items Looked at And Examined

Gaming Experience Rating	Mean items looked at	Mean items examined	% from look to examine
1+	80.38	22.58	36
2+	85.19	23.94	36
3+	97.75	29.50	33
4+	121.50	37.75	32

Table 6.44 - Computer Experience Compared with The Number of Items Looked at And Examined

Computer Experience Rating	Mean items looked at	Mean items examined	% from look to examine
3+	80.38	22.58	36
4+	86.13	22.63	38
5+	82.33	20.33	40

Further to this finding, the simulator group cohort was split into two groups, one consisting of those who rated their gaming experience as 3 or above (the ‘gaming group’) and another comprising those who rated their gaming experience as less than or equal to 2 (the ‘non-gaming group’). The mean items looked at was higher in the gaming group than the non-gaming group, at 97.75 and 71.69 respectively. The mean number of items examined was also higher in the gaming group in comparison to the non-gaming group – 29.5 and 19.13 respectively.

The amount of challenges and agreements to transfuse the patient were higher in the non-gaming group in comparison to the gaming group, with 36 (69% of total challenges) and 25 (21% of total agreements) compared with the gaming group's 16 (31%) and two (2%). There were also more refusals to treat the patient in the gaming group, with 13 (65% of total refusals) against the non-gaming group's seven (35%). This analysis suggested that those with more gaming experience were more likely to identify the issues with the patient, and act accordingly (e.g. more likely to refuse treatment or never resorting to administer the blood), than those with less gaming experience.

Overall, and as demonstrated below in Figure 6.13, the performance of all participants within the simulator, with respect to items looked at and examined, gradually improved (albeit by a small amount) as the participants progressed through their session. However, as suggested by the comments and five (9%) participants in the simulator group, a tutorial, practice session or a more detailed introduction screen to clarify the control functions and demonstrate the in-simulation process of examining items and responding to characters may have produced better results.

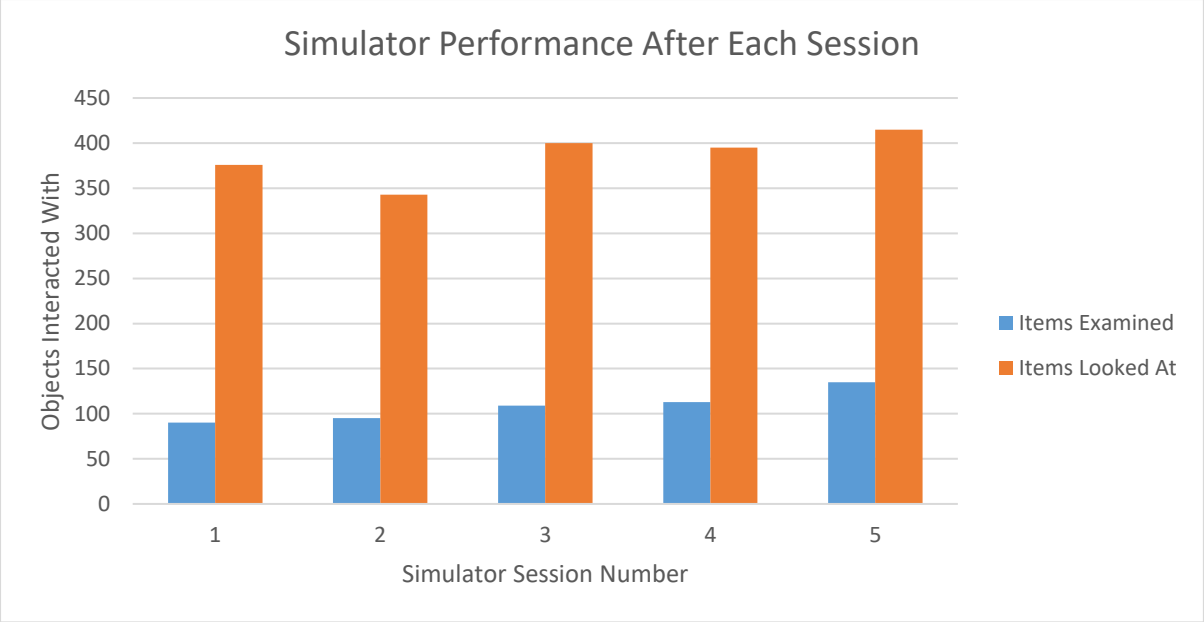

Figure 6.13 - Line Graph Illustrating the Number of Items Looked at Examined Over the Course Of 5 Engagements with The Scenario

6.12.3 Further analysis into the challenge ability and clinical experience association

The results of the investigation conducted and detailed in Chapter 4 indicated that the ability to challenge successfully improved as staff became more experienced in a medical profession (Research Question 3). This was demonstrated in the decision challenge confidence matrix (Table 4.12), where the mean confidence to challenge increases when descending along the medical hierarchy (as also illustrated in Figure 4.1). Comments provided by participants in the senior grade categories for the follow-up questionnaire further supported this hypothesis. Examples of comments included: “Already have extensive experience”, “I am quite a senior

member of staff now, recently appointed as a consultant" and "I am already very senior and felt empowered to challenge anyway". The participants who gave these responses each provided a '1' rating for the question that asked them if the study had produced any effect on their ability to challenge since originally taking part.

However, despite the low ratings for the effectiveness of both the VR/simulator and the comic book applications in helping to develop the ability to challenge, further analysis into this topic revealed an interesting finding. The simulator and comic book groups were split into two groups consisting of 'senior' and 'non-senior' participants. The senior group contained a sample of the cohort whose grade categories were 'Nurse 6+' and 'Consultant'. All other grade category participants were placed into the non-senior group, and average responses for the first six questions of the post-use questionnaire were then re-calculated. This analysis revealed that the senior group found the scenario and the consultant to be more realistic compared to the non-senior group. Therefore, and as illustrated in Figure 6.14, each mean response for these questions was higher than the responses given by the non-senior group. The exception to this was the question concerning the environmental conditions of the experiment. The non-senior group's responses were also lower than the combined averages of both groups.

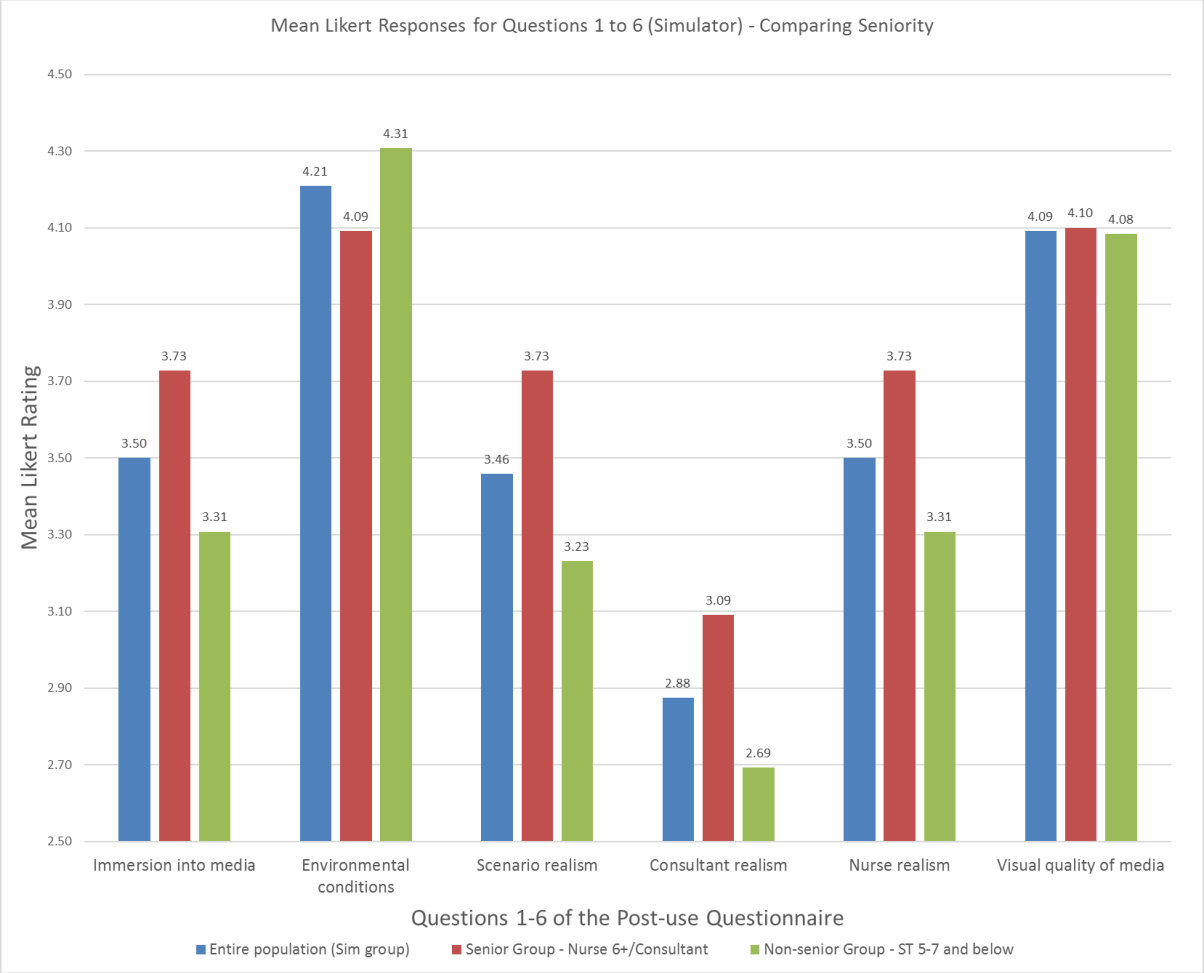

Figure 6.14 - A Graph to Show the Differences of Responses When Comparing Those in The Senior Grade Categories and Non-Senior Categories

6.13 Conclusion

The main criticisms that were frequently identified in the results centred on the validity of the consultant's portrayal in the scenario and their persistence to deliver the blood transfusion to the patient. This was despite accounts of real-world instances, provided by participants throughout the investigation and experimental phases of the project, which included descriptions of similar events involving consultants with overly negative attitudes (as demonstrated in Table 4.22). It was also despite some feedback from participants who stated that the chance of experiencing such a scenario was not impossible, and from those more senior in the cohort who rated the realism of the scenario more highly than those with less experience. The scenario and its contents were also repeatedly verified by clinical stakeholders supporting the project, who assisted in removing unnecessary and unrealistic elements previously implemented.

However, conversely, it was evident that most the negative comments regarding the consultant's realism were provided by participants in the lower region of the grade categories. For example, when providing feedback to assist in further developing the projects, an FY1 stated: "More realistic with regards to consultant attitude" and a CT 1-2 stated: "I have never encountered this sort of consultant." Therefore, it was apparent that these scenarios, although possible, are a rare, perhaps isolated, situation to encounter. However, it is possible that clinical staff will encounter a similar scenario later in their careers. It was also likely that participants

in the experiment who were inexperienced had yet to encounter a negative scenario, and would, thus, perceive anything related to the content in this experiment to be unrealistic. This hypothesis could also be associated with the high realism ratings of the senior group of participants, who may have experienced many negative outcomes prior to their participation.

Chapter 7 Conclusions

7.1 Project Aims

The PhD project outlined in this thesis set out to evaluate a series of research questions. These research questions were:

1. Is the ability to challenge clinical decisions an essential skill to develop?
2. Is challenging a decision an indicator of situational awareness?
3. Is the ability to successfully challenge a decision associated with clinical experience?
4. Can VR-based simulation techniques help develop an ability to challenge clinical decisions?
5. When is the optimal time of exposure to VR-based training simulation?

All questions were developed based on anecdotal evidence and reports provided by early briefings, observational research and meetings with clinical and military SMEs associated with the project. The message from the early briefings was that challenging decisions is an essential skill to develop to maintain, and demonstrate, a high level of SA. Championed by medical education organisations such as the HSC team and QEHB's CSS team, SA was described as a fundamental principle in minimising the chance of medical error and, ultimately, maintaining patient safety. It was also a topic discussed in Chapter 2, which comprised a body of literature that supported the claims made by both organisations.

7.1.1 First Investigation

The first investigation conducted as part of the project set out to obtain both quantitative and qualitative data to build a body of evidence to support research question 1. The methodology in which to acquire this evidence consisted of inviting an opportunistic population of medical staff to complete a preliminary questionnaire and take part in a short-recorded interview. The sessions explored multiple levels of the healthcare employee hierarchy, ranging from medical student through to consultant level. The overall aim of the investigation was split into a series of objectives (defined in chapter 3), but set out to, more importantly, obtain both quantitative and qualitative data that formed the considerations for the next project phase as per the requirements of the third research objective defined in chapter 1.

The results of this investigation had suggested that it is important to challenge decisions to maintain the safety and wellbeing of the patient. This result was also indirectly supported by the literature, as many authors and studies that were discussed conducted their research, ultimately, for the well-being of patients in their care. The life and recovery of a patient is entrusted to the staff who are assigned to act as their 'advocate', a term which was frequently mentioned in the results. However, a breakdown of the 'non-technical' skills within human factors that are associated with optimal healthcare can have severe consequences. These skills included – identified both within research of various literature and observations and frequently referred to in the results – communication, assertiveness, leadership and teamwork. The

consequences of such breakdowns were evidenced by the Francis Enquiry publication (Francis, 2013), which was the result of an extensive investigation into increased patient deaths that occurred at Mid-Staffordshire trust. The investigation revealed that the deaths of up to 1200 patients across the years examined were caused by a very low standard of care.

The results of the investigation also revealed that the ability or confidence to challenge effectively is associated with experience. Figure 4.1 and Figure 4.2 illustrated this link, where the confidence value for each grade category to challenge increased as the grade in the hierarchy increased. This was further illustrated by Figure 4.4, which illustrated an overall positive correlation between challenge confidence and the number of years qualified.

Based on these findings, an outcome of the investigation stated that providing trainees (who represented the least confident to challenge) with more opportunities to become assertive may produce more positive results than the findings of the investigation. This could be achieved by attending ward rounds, that have shown to be a welcoming opportunity for trainees.

7.1.2 Use of Simulation

The second phase of this project consisted of gathering data to support the second research question. It proposed the use of VR and comic book-style applications as a possible future training solution, allowing users of either system to practice opportunities to challenge, whilst raising awareness to the issues and importance of challenging. The applications required

participants to engage with characters representing fictional clinical colleagues within a 3D virtual and hand drawn environment using traditional gaming and simulation development technologies. The objective of the participant was to examine their environment and respond to a confederate's decision for treatment of their patient.

The simulator and comic were developed with a first-person perspective in mind, requiring users of either system to assume their own role in the scenario, where the characters within communicated directly to them from the page or screen. The interviews conducted as part of the first investigation required participants to provide an example of a situation where they were prompted to challenge the decision of a colleague to prevent, what they perceived to be, a negative outcome. A selection of these accounts was then combined, then further developed by clinical SMEs, that provided the simulator with a unique scenario that was considered a rare, but realistic event.

Organisations such as the HSC and CSS at the QEHB championed the widespread adoption of mannequin-based simulation training technologies, focusing primarily on enhancing the non-technical skills. Research into human factors and observations of simulated scenarios at both the HSC and CSS had demonstrated that the non-technical skills (including the ability to challenge) are essential in providing optimal healthcare. Observations of simulated scenarios and research into the relevant literature had shown that the use of simulation to address hierarchical related conflicts are not uncommon and effective. The simulation methods and

objectives in these cases had revealed from their relevant documentation that they follow a set path, consisting of participants diagnosing a patient in their care and responding to an event (such as a cardiac arrest) that prevents them from further deteriorating. The scenario presented in the simulator and comic essentially deviated from this tradition, instead focusing on the issue of challenging decisions whilst common elements such as diagnosing the patient were already carried out.

An experiment was conducted at the QEHB that saw another population of clinical staff engage with both applications. Presented using a high definition projector, participants who interacted with the simulator drove the scenario with an Xbox One controller. The projector, meanwhile, rendered the environment onto a 100-inch projector screen. The environmental conditions of the comic book experiment varied, with participants engaging with the comic in small offices, large recreation rooms and lecture theatres.

The results of experimental and subsequent follow-up phase suggested that both the VR simulator and comic book prototype are viable tools in the delivery of decision-making training and could potentially deliver impact into other applications within the healthcare environment, such as emergency resuscitation scenarios or drug examination. However, feedback from the participants on both forms of media suggested that there are many areas in the presentation of the simulated content that would benefit from future improvement, including (a) presenting the applications in a format appropriate for those with limited ‘gaming’ experience and (b)

allowing a more dynamic, and credible level of interaction and engagement (with respect to the environment and virtual characters), in order to increase the overall realism or fidelity of the training material and, therefore, maximise the effectiveness of both tools.

7.2 Implications of the Francis Report

The Francis Report (Francis, 2013; FR) was published because of a public inquiry investigating a series of claims of poor healthcare and medical professionalism and negligence at the Mid Staffordshire National Health Service Foundation Trust between January 2005 and March 2009. The aim of the investigation was to identify the causes behind inflated mortality rates, low standards of treatment and poor patient care (Francis, *op cit.*, p19) which were reported as being a result of a large-scale breakdown of communication and incident reporting.

As part of an extensive list of recommendations, the FR stated that the reporting of incidents be, not only encouraged, but, "insisted upon". This is especially so when the reports concern the safety of patients. Further from this, staff are entitled to give feedback regarding any report they submit which should include explanations for any further action taken (or not taken). Finally, it was recommended that reports of all adverse events, that result in harm or injury to patients, be mandatory.

The repercussions, if relevant training in this area is not adequate, could be disastrous for patients, and so is important to maximise safety. Research in this thesis had shown that medical errors and patient harm affects those who inflict them. Examples included loss of confidence, guilt and anxiety (Mira *et al.*, 2015). The emotional distress can also last a long time, become a traumatising experience and elicit various negative responses, such as fear, anger and embarrassment (Christenson *et al.* 1992; Scott *et al.*, *op cit.*).

The aim of this thesis was to evaluate the use of 2D and 3D simulation techniques, such as VR and comic book technologies, to not only help develop the ability to challenge, but to raise awareness to the importance of challenging and incident reporting. A preliminary investigation conducted in the QEHB revealed that publications such as the FR were common knowledge within the medical community. Although most participants were not affected by the publication (e.g. because they already felt that they offered optimal healthcare), others had admitted that the publication had affected their clinical practice. Common responses included reflecting on their own clinical practice; that the outcomes of the report had inspired them to become more vigilant; seeking relevant training to develop their clinical skills further; and raising awareness of incident reporting.

7.3 Recommendations

Based on the outcomes and research findings of each phase of research, such as the first investigation (0) and the experiment (Chapter 6), a series of recommendations were developed. The recommendations, listed below, relate to future developments of both the simulator and comic book concepts and what the research and results reported in this thesis can recommend to the healthcare community.

7.3.1 Healthcare community recommendations

- Courses dedicated to developing the ability to challenge inappropriate decisions or events could be beneficial to clinical personnel. This was widely supported by both sets of participants who took part in the investigation and experiment phases, who expressed an interest in attending such a course (simulation or otherwise).

- 'Challenge scenarios' provided by participants demonstrated that conflict, although widely associated with seniority, affects anyone within the team.

- The challenge scenarios also demonstrated that conflict with seniority was frequently referred to (see Table 4.20 to Table 4.23 for examples), with Consultants representing the highest profession involved with challenging, despite also representing the grade least confident to challenge which could be due to uncertainty surrounding the response.

7.3.2 Simulator and comic book recommendations

1. Gaming experience was low among the cohort. This was reflected in the experiment results, where those with low gaming experience interacted with the environment less than those with high gaming experience. Future work in this area should consider a simplistic approach to avoid overwhelming those with limited gaming experience.

2. Further to the above, participants from the experiment simulator cohort suggested that a tutorial or 'practice round' be implemented to allow potential users of the system become accustomed to the control scheme.

3. The results of the experiment revealed that participants may have rated the consultant's realism higher if they were more willing to discuss or consider a participant's challenge. Though this outcome was possible in the simulator (those who experienced this outcome rated the realism higher than those who did not), it was a rare occurrence, and there was no cell present in the comic book to illustrate this outcome. Although this outcome is possible in real life (as participant scenario examples have demonstrated), the chance of this outcome occurring should be much higher.

4. A more dynamic level of interaction may have resulted in increased scenario realism ratings (and may have complimented the character realism rating as described above). For example, when challenging the decision of the consultant, the user could explain

the reason behind their challenge.

5. The simulator targeted a medium-level of visual fidelity and was rated highly by the participants in both the simulator and comic book groups. This finding supports Maran & Galvin's (2003) research concerning engineering fidelity, where a significant increase in fidelity beyond certain levels does not produce a large improvement in performance when compared to simpler device designs.

6. Participants who responded to the follow-up questionnaire listed examples of other application areas that VR simulation and comic book technologies could stretch into, including drug examination and emergency resuscitation scenarios. Future work that builds on this research could evaluate the use of the technologies explored in this thesis in other areas.

7.3.3 Future Work

Whilst the results of the experiment suggest that the effectiveness of the two media are, in their current form, limited, the widespread adoption of such technologies throughout the healthcare domain to complement traditional forms of simulation is most promising. However, the limitations of the comic book experiment previously discussed, coupled with the low to moderate ratings of realism and effectiveness, impose a challenge. Therefore, the potential to become a beneficial training resource of educational value, supporting junior clinical staff as

they are trained the non-technical skills, is uncertain.

Despite positive feedback from the experiment cohort, future research in this area is needed to ascertain the impact and benefits comic books could potentially bring to medical education. This is especially so, as other research that sets out to specifically evaluate the use of comics where the focus is to raise awareness of the non-technical skills is lacking. Furthermore, future research should consider presenting the comic digitally rather than physically, as it may produce more reliable data which can be used to better compare the performance of participants or other simulation formats such as VR (a limitation discussed further below). For example, a digitally presented comic book displayed within a pre-programmed application could monitor the reader as they viewed the comic, granting researchers the ability to track and record useful information such as time spent between pages or counting the number of times a page is turned.

Future research in this area should also consider prior experience of simulation and comics, as it may be unlikely that participants will perceive comic books or VR as something of educational value. This theory is based on the results of the experiment, where feedback concerning the radical, "game-like" feel of the VR simulator and comic book are amongst the frequently referenced criticisms. The results may have been negatively impacted by the low gaming (and comic) experience among the cohort. Therefore, researching concerning accessibility or presentation of VR-based simulations should aim to address this issue. For example, a finding from the experiment demonstrated that a modern game controller may not

be the most appropriate peripheral to drive the scenario presented. In the literature, studies related to the accessibility of "VR toolkits" have faced significant difficulty in determining the most appropriate control scheme for different use cases (Stone *et al.*, 2014).

7.4 Limitations

Despite representing the highest group sample (n=34), the comic book experiment methodology was vulnerable to noise, distractions or other external interruptions which may have skewed or impacted the results given. Due to the portability of the equipment required to carry out a comic book experiment, when compared to the more constrained simulator procedure, the methodology permitted any session to be carried out at the location of the participant in the Trust. However, the methodology did not initially account for sessions involving more than one participant taking part simultaneously, and it was not possible to predict the level of noise or source of distractions each environment would contain. For example, one (individual) participant of the comic book cohort was required to temporarily leave the area (presumably to speak with the operating team), therefore disrupting the experiment, due to an upcoming surgery they were scheduled to perform. In this case, clinical staff were setting up the theatre to commence the surgery, and the participant was forced to hurry the experiment upon returning as the surgery was imminent.

Furthermore, although every session was pre-arranged, both sessions that involved groups were opportunistic. In that, a participant within the comic book cohort (a senior consultant) invited the author to take part as a guest lecturer (on both group occasions) and facilitate the experiment as part of audience activities. In one of two group-based scenarios, 20 members of the audience took part in the experiment. Participants could communicate amongst each other throughout the experiment process which created a relatively elevated level of noise and a possible constant source of distraction. Because of this, it is very likely that, though not verifiable, responses given to the questionnaires were susceptible to suggestion bias or influenced by neighbouring participants.

It was also not possible to clearly determine which version of the scenario performed better, as the difference in sample sizes made some analyses difficult to carry out. For example, the tallies discussed in 6.10.7 portrayed the comic book version to be the more engaging experience as the score was, overall, significantly higher than the simulator group. However, the differences in sample size resulted in inflated tallies in favour of the comic book group, despite consistency within the spread of the scoring between both groups. Furthermore, except for recording the outcome of each comic book scenario, the inability to record data as participants read the media made comparisons of environment focus or engagement difficult. The digital format of the VR simulator allowed for any number of data (e.g. counting the number of times an item was "looked at" or "picked up") be tracked as the scenario was in motion.

The follow-up questionnaire was conducted approximately six months after the conclusion of the experiment, which may have contributed to the low response rate (38%). The maximum possible response rate (84%) was also initially limited due to invalid contact details. In chapter 4, it was also discovered that clinical staff regularly move on to different hospitals throughout their careers, as evidenced by the varying numerical responses given in the questionnaire regarding the amount of years spent at their post at the QEHB (mean response = 3.2 years). Therefore, it may be possible that many participants who were contacted to take part had left the QEHB by the time the first email was issued.

This limitation is also evident in some of the responses provided by participants, which suggested that recollection of the events that occurred during their participation degraded rapidly over time (mean recollection of events = 3.32, 'Somewhat' on Likert scale, and an SD of 1.43). Indeed, authors of studies in a similar setting that provided training of non-technical skills observed a rapid fall-off in effect once the training had ceased (e.g. Morgan *et al.*, 2015).

7.5 Conclusion

Differences in opinions for patient treatment during the ward round can trigger a negative situation that can negatively affect everyone in the team, including the patient. However, the research conducted for this thesis has demonstrated that the ability to successfully challenge a decision can resolve conflicts and is likely to potentially alter scenario outcomes in favour of the challenger. The act of challenging is an important aspect of ensuring optimal healthcare is given to patients, and research into similar studies has also shown that it can save lives. However, an important finding from the investigation and experiment phases had revealed that the ability to challenge is strongly associated with clinical experience. Further to this, participants who lack clinical experience (e.g. trainees and students) are likely to have never encountered negative scenarios that have seen their challenges needlessly overruled and dismissed by clinical staff with an overly aggressive attitude – evidence of this was the feedback on the simulator's consultant character. Fortunately, these situations are seemingly rare, isolated cases and, therefore, as some participants in the study have stated, are a scenario not welcome in UK hospitals. However, as some have also stated, it is still a realistic possibility.

Therefore, appropriate training in this area can assist with providing opportunities to obtain experience in challenging and conflict management. This thesis proposed the implementation of both a VR and comic book-based simulated scenario as a method to develop the ability to confidently challenge decisions. Literature concerning the use of VR in clinical settings is

prevalent, and such literature has also produced positive findings. However, much of the studies that evaluated such technologies discussed in this thesis primarily targeted the relevant technical skills associated with surgery training. In addition, at the time of writing, there is a dearth of literature related to experience with comic books in clinical settings and very limited evidence of research that evaluates the media to raise awareness, or assist in the development, of the non-technical skills associated with human factors. In this study, experience with comic books was very low coming the experiment cohort. Indeed, whether comic books can produce positive evidence of efficacy in this area requires further research.

In this study, a simple prototype of a simulated scenario, crafted from a series of example challenge scenarios provided by clinical staff, presented in both VR and comic book form was developed and tested by a series of personnel at the QEHB. Though the responses were mixed, and data surrounding the efficacy of the project were questionable, the participants responded positively, were helpful in identifying a series of design considerations based on their feedback for future work and listed other areas these technologies can benefit. Suggestions of improvement to maximise any positive effect these technologies can produce included:

- Increased levels of interaction
- Simplified presentation
- Tutorial sequences to assist those with limited ‘gaming experience’
- Further interaction with the characters to increase the realism of the scenario
- Whilst it was important to emphasise the ‘realistic’ nature of senior attitude, ensuring challenges are responded to in a more appropriate manner, with a higher chance of success.

To conclude, the ability to successfully and confidently issue challenge is an important skill for healthcare staff to possess to maximise the safety of patients in their care. Therefore, as one participant stated in their experiment feedback, it is important that any avenue and resource for training be explored and assessed.

7.5.1 Conferences

SCATA Annual Scientific Meeting (2015) - The Royal College of Anaesthetists (ROCA)

Then-current research presented that showcased the first finished prototype of the VR simulator project.

ASME Annual Scientific Meeting Edinburgh (2015) - Associate for the Study of Medical Education

Then-current research presented that showcased the first finished prototype of the VR simulator project, including full overview of the investigation phase.

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Appendix A: QEHB Observation Report

The Handover Protocol

The ward rounds began with an initial 'handover' process. In both sessions observed, the handover process was delivered early in the morning (approximately 8:00am) by the staff from the previous night shift and took place in a separate "break-out" room, away from the actual ICU Ward. Generally, the ICU Department would carry out two handovers, one early in the morning and the other late in the afternoon (daytime shift and night-time shift, respectively). The arriving team on both rounds included a leading consultant, Speciality Trainees and Nurses of various grades. No junior trainees were in attendance. They were given a thorough overview of the previous shift's events, including any new patients admitted, any surgeries/procedures carried out during the shift and the brief medical history of all patients on the ward. Some examples of patient histories recorded included: patients with tumours, heart transplants, respiratory failure, heart disease, heart attacks, lung transplants, aneurysms, mantle cell lymphoma (a rare cancer of the lymphatic system) and endotracheal tube cuff leak (which may result in ventilator failure). This process was essential for new staff to familiarise themselves with each patient, new and current, and would ultimately contribute to making the ward round process more efficient.

The Ward Round Process - Overview

The ward round process commenced immediately following the handover and involved visiting each patient in their beds, in ascending order of bed number, initiated with a pleasant greeting to help put the patient at ease. A computer-hosted drug prescription software system also accompanied the group.

Patient Greeting

Before commencing each bedside visit, permission for the observation team (including the author) to observe a patient and conduct associated clinical activities was requested. If granted, observation continued as the medical and nursing staff commenced their discussions to review the patient's condition and his or her ongoing treatment régime. If denied, the staff would draw the bedside curtains to ensure privacy until the treatment/clinical assessment process was completed and the observing team would remain outside. Only one instance of this occurred during the author's participation in a ward round.

Direct communication with the patient would ensue if he/she was awake, and conversations would usually revolve around how they were feeling and requests that they inform the staff of any pain present and the location of that pain. Sometimes, but not every time, disposable aprons and gloves were worn before direct communication with a patient. This was to minimise the potential spread of bacteria between beds.

Bed Space Layout (Figure A.1)

Figure A.1 - ICU Ward and Bed Space

The bounds of each bed space were delineated with red tape that was fixed to the floor. In some areas, especially so in the corners of the building, bed space was limited due to the amount of equipment in place. Equipment in these spaces typically included a large sized ward bed, waste

disposal bin, a standard vital life signs monitor that hung from the ceiling providing heart rate, blood pressure and Oxygen Saturation (SATS/SPO2), a desk for food and drink, a larger desk containing the patient's notes (see section 'Patient Evaluation' below) and a syringe disposal bin.

Patient Evaluation

Following the greeting, the group commenced the evaluation of the patient. This began with a quick examination of the patient's observation (or 'obs') chart located at the foot of the bed. The staff examined the observation chart (an example of which is shown in Figure A.2) coupled with any relevant attached documentation (e.g. X-rays), if available. This information provided timestamps of various readings and was used to indicate trends in either patient recovery or deterioration. The amount of content evident on each observation chart varied considerably. According to one nurse allocated to a patient, different staff have "their own style of recording data." Because of this, the content available can either be very little or very detailed. However, due to assorted styles of handwriting, there can be difficulty with reading notes. The nurse then provided an example sheet of paper containing a table that comprised a series of time-stamped notes. The handwriting styles of staff members who had added to the content over time varied dramatically and, therefore, some of the content was illegible.

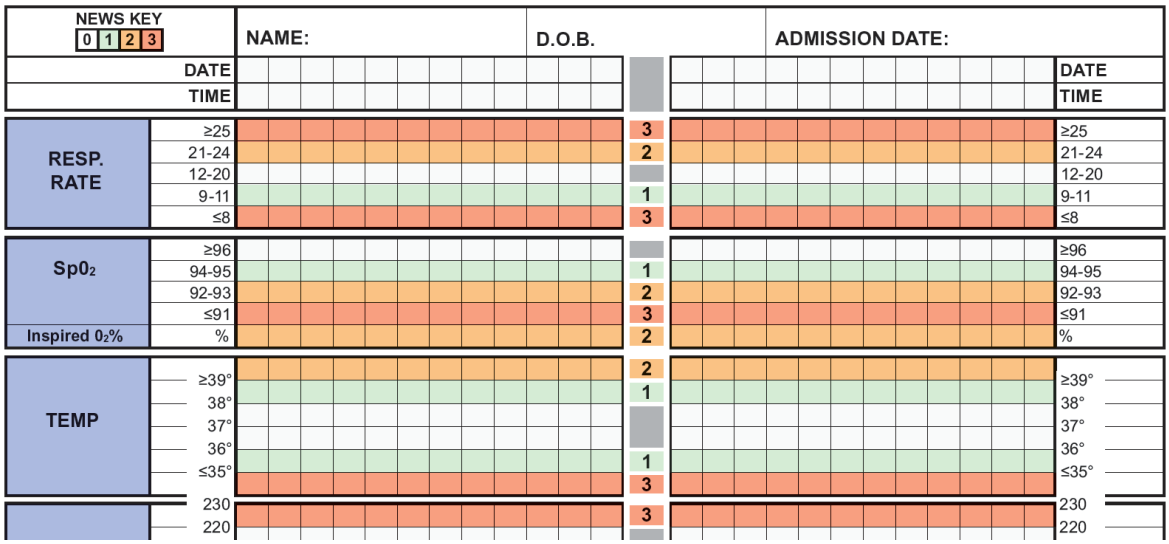


Figure A.2 - Patient Observation Chart Template

Having read all necessary documentation and the notes provided from the handover, the staff then discussed the patient's status, and this formed the basis of any underlying diagnosis, culminating with a discussion on further treatment. Representing the lengthiest process of the observation, the staff gathered, either in the walkway/corridor of the ward or at the foot of the bed, and initiated a debate on further treatment. This sometimes led to heated moments, such as disagreements or queries (see 'Group Conflict' below). If relevant, this also involved examining the patient's drug prescriptions, eating and drinking behaviours, urination frequency, and so on. The team were informed that patients can decline any drugs, even if strongly recommended. Compromises or other suggestions could, of course, be made. Finally, the staff would thank the patient for their time and proceed to the next bed. The process was repeated

for each patient and, upon finishing the round, the staff gathered and discussed any closing statements before departing. Although post-ward round meetings were described during the introductory meeting, none were conducted during the author's periods of observation.

In addition to the observations described above, several miscellaneous issues were also recorded that were deemed relevant to the aims of the present research. These findings resulted during ad hoc queries or requests for clarification directed towards specific members of the ward round team by the author (or other medical personnel associated with specific patients). These are summarised below.

Nurse Allocation

According to a senior nurse accompanying one ward round, nurse allocation was dependent upon a patient's status. For example, if a patient was recovering but did not require constant observation, the allocated nurse could also observe an additional bed. However, should that patient be in ill-health, a dedicated nurse would be allocated until their health improved. In more severe circumstances, a patient could be allocated up to two nurses. They would regularly communicate with the patient, if awake, to maintain that patient's ease and comfort, whilst taking frequent notes and adding to the observation chart. The senior nurse providing these comments then explained that an allocated nurse should never leave a patient's bed area under any circumstances without informing others. Should a nurse request to leave the bed area of their patient(s), they would remain with them until a suitable staff member could be put in place

until they return.

Distractions

Various forms of distractions and interruptions were frequent throughout the round. This included communication via short-wave radio, bleepers and interruptions from non-ward round staff. Although most interruptions witnessed did not interfere with the round's progress, two scenarios occurred where the round was suspended due to the leading consultant leaving the group. However, the suspensions were short (lasting approximately three to five minutes) and the round immediately resumed upon their return.

Cluttered Environment

In addition to being a generally noisy (acoustic) environment, the ward was typically cluttered with various items of equipment, staff and non-medical personnel (including patients' relatives). In some cases, these acted as obstructions to manoeuvre around. Examples of obstructions noted included various chairs and cabinets containing clinical equipment (e.g. empty intravenous drip bags, gloves, cannulas, syringes and drugs), a floor cleaning unit, crowds of staff or visitors. One scenario occurred in the second observation session where a group of staff not involved in the ward round temporarily merged with the main group, creating a large crowd of people that, essentially, divided the ward into two areas, hindering access between the two.

Group Conflict

The leading consultant from the first ward round stated that he encourages his team, especially juniors, to 'challenge' or 'question' his decisions. The reason for this is to avoid treatment errors, such as prescribing too much or too little medication. This, in his view, ultimately, ensures that the best treatment and care is given to the patient as well as minimising the chance of error. If the consultant was not satisfied that his decision was questioned appropriately, he would ask each member of the team if they concurred with his approach to the treatment. When asked if he had been involved in a recent conflict or disagreement over a patient's treatment, he stated that they occur frequently. However, an 'extreme' conflict, though possible, was rare.

A scenario occurred during the second observation session where the group's discussion of a patient's observation chart became confrontational. This conflict concerned an apparent mismanagement of drug prescriptions. Historical records displayed on the accompanying computer stated that a patient had repeatedly refused medication on several occasions. However, this was denied by the patient, who claimed that they did in fact receive, and take, the prescribed medication. The leading consultant, whilst not acting aggressively, became visibly irritated as neither the software nor the patient could confirm what drugs were or were not taken. According to the leading consultant, this scenario could have led to serious consequences, such as an accidental overdose, as it was uncertain how much, and what type of, medication was given and taken.

Finally, another observation was made concerning the group occasionally breaking up. Although the nature of this behaviour was not clarified, members of the cohort broke off and formed a smaller group comprising two or more individuals, presumably to conduct specific discussions relating to the patient.

Appendix B: HSC Observation Report

Introductory Presentation

A typical HSC training day normally accommodated ten pre-enrolled trainee participants. If more trainees were in attendance, the cohort was split into two teams, each subsequently receiving training from separate members of the HSC. Most participants observed were new to the subject of simulation-based training, and travelled to the centre from different UK medical trusts. Others declared that they had some experience with simulation training technologies and courses, either as part of their education or during postgraduate training. Each of the HSC training staff championed a series of key learning points, and the structure of their lectures typically revolved around these. Each of the key learning points were individually elaborated alongside an introductory presentation before the simulated scenarios commenced. Table B.1 lists these key learning points with a short description based on the notes accompanying their delivery during lectures and simulation sessions.

Table B.1 - HSC Key Learning Points

Learning point	**Description**
Leadership	Maintain professional standards of team organisation, leadership skills and demonstrating assertiveness Workload management.
Situational Awareness (SA)	The relationship between one's mental model of what is going on and what is really going on Steps to improve situation awareness include multiple briefings and meetings, maintaining involvement of the whole team and keeping records such as checklists System and environment awareness and anticipation.
Mutual Support	Monitoring each cohort's performance and offering support Conflict resolution.
Teamwork	Two or more individuals who interact dynamically, interdependently and adaptively Shares, and works closely together to fulfil, a common goal. A team's primary goal is the safety, wellbeing and, ultimately, the recovery of the patient Team members possess their own specific role, or function that contributes to the goal.
Communication	Contributes to team organisation Increases the comfort and personal safety of the patient Can help reduce errors.

As the key learning points were discussed during introductory sessions for the trainees, considerable emphasis was placed on the issues surrounding mistakes and distractions. An interesting observation was the repeated reference to the Francis Report (see also Chapter 2 2.2.1 Public Healthcare Enquir; FR). The HOF regularly stated that each member of the clinical community is "only human" and, thus, he believed that mistakes were inevitable. His discussions also described personal factors that could negatively impact clinical decision making, such as stress and fatigue. However, as mentioned and referred to in the FR publication,

it was stressed that all incidents witnessed should be immediately reported. If this was not possible, it was recommended to the cohort that they seek assistance from other colleagues, preferably those more senior, in private, more formal, settings if desired.

It was claimed that distractions during procedures constitute some of the primary causes of serious errors. For example, physicians are interrupted on average every ten minutes, and nurses are administering medication approximately every two minutes. Therefore, there exists a high risk of medication error for every individual interruption. According to the accompanying HSC presentation material on this matter, "the risk of any medication error increases 12.7% with each interruption." In some of the sessions attended, participants described their own experiences of committing errors due to distractions or interruptions whilst working on the ward. Although no specific examples were provided, one of the trainees admitted to causing injury to a patient. Training to manage interruptions and distractions is something that the Centre provides within their scenarios.

The HOF also provided a brief example scenario concerning distractions and multitasking:

"A nurse who had just measured a dose of liquid chloral hydrate [a sedative] into a cup was interrupted by a pharmacist on her way to the patient's room. The conversation was social, and the nurse - who often had a cup of coffee in her hand - absentmindedly drank the medication, as if taking a sip of coffee! The nurse had to be driven home."

The HOF concluded the introductory presentation by clarifying the process of commencing a scenario session. They were encouraged to speak to the Centre's resident nurse during a session should they become anxious or unsure on how to proceed. If necessary, participants could contact the Centre staff via a telephone connected to a simulated switchboard located within the simulation room. Whilst responding to simulated telephone calls, the Centre staff would continue to play out their role within the scenario to maintain the illusion of a genuine medical scenario, and they would attempt to direct the participant towards the correct course of action by direct questioning.

HSC Specific Training Session Observation Overview

Observations of participant activities took place in the Centre's main Simulation Room, a dedicated facility set up to resemble a typical hospital bed space, as illustrated in Figure B.3, with a single mannequin and associated cubicle equipment (intravenous drips, vital life sign monitor, medical cabinets and various items of furniture). The Simulation Room was reconfigurable and could be changed to represent other hospital facilities, including an ICU and Accident and Emergency cubicles. A live defibrillator was also present which, should its use become necessary, was included to ensure trainees' vigilance and attention to important health and safety concerns. A telephone was also evident, and this was connected to another handset located in an anteroom, from which HSC personnel could observe participant activities via a one-way mirror and could, at any time during the simulated scenario, place telephone

calls to mimic those from other hospital departments, consultants or anxious relatives. From this anteroom, various functions of the mannequin could be controlled (including voice) by the simulation coordinator and participants' activities could be recorded via multiple CCTV cameras. The HSC's resident nurse was also involved in the simulation sessions.

Figure B.3 - HSC Simulation Room

The mannequin utilised by the HSC is a Laerdal SimMan (Figure B.4; see Chapter 2 for further

information on simulation technologies), a computerised human form with anatomically accurate features. The SimMan mannequin is fitted with electronic subsystems capable of mimicking drug reactions and features micro-tubing which enables blood and other bodily fluids to be exuded if appropriate (which for the training sessions observed by the author, it was not). The SimMan also possesses speakers capable of relaying a voice or sounds of discomfort and pain from the supervisors or simulation coordinator located within the adjacent simulator control room. The sound system can also imitate a patient's lung, bowel and heart sounds. The simulator's technical coordinator informed the author of the system's key features and limitations and these are listed in Table B.2 and Table B.3.

Figure B.4 - HSC SimMan Technology

Table B.2 - HSC Mannequin Functionality List

Function	Description
Gender	The mannequin was unisex and came with interchangeable body parts to identify as either male or female.
Expulsion	The mannequin could secrete sweat to mimic a high body temperature, and could bleed to simulate a serious wound.
Breathing	The mannequin could display a rising and falling chest to simulate breathing. In addition to this, it could simulate various breathing difficulties such as wheezing or various breath speeds.
Eyes	The eyes could react to light, and could be used in conjunction with pocket pen torches.
Interaction	The system was also capable of presenting functional heartbeats, with variable heart rate, that could be listened to via stethoscopes. Participants could also check the mannequin's wrist or neck pulses, and initiate Cardiopulmonary Resuscitation (CPR). The mannequin could also be connected to, and shocked with, a defibrillator.
Speaking	Members of staff could communicate with the participants during scenarios via the mannequin's mouth, the inside of which contained a speaker.
Monitoring	The mannequin's software allowed participants to monitor its status via a connected electrocardiogram (ECG). The ECG provided common useful information, heart rate, oxygen levels, etc., and reacted accordingly when the patient began to deteriorate.

Table B.3 - HSC Mannequin System Limitations

Limitation	**Description**
Unintended sounds	Various sounds emitted from the mannequin's underlying mechanisms (Figure B.5), both loud and quiet, frequently interfered with the scenarios. The simulation coordinator stated these noises were normal sounds of the machine "working" and should be ignored.
Audio sync	Throughout the scenarios, at times, the sound effects were slightly off sync. For example, the visual feedback depicting various breathing problems did not always match the sound effects outputted.
Interaction limitations	Although participants could interact with the system for various clinical procedures, they were not able to obtain a temperature reading. To overcome this, the trainee participants were informed that they should speak to the in-scenario nurse who could provide this reading, plus any others, if required.
Static	The mannequin was unable to provide visual or emotional responses (via the use of facial expressions, for example). This was due to the face of the system not containing the necessary moving parts. In addition, it could not display accurate scenarios of convulsion; for example, muscle or limb spasms.

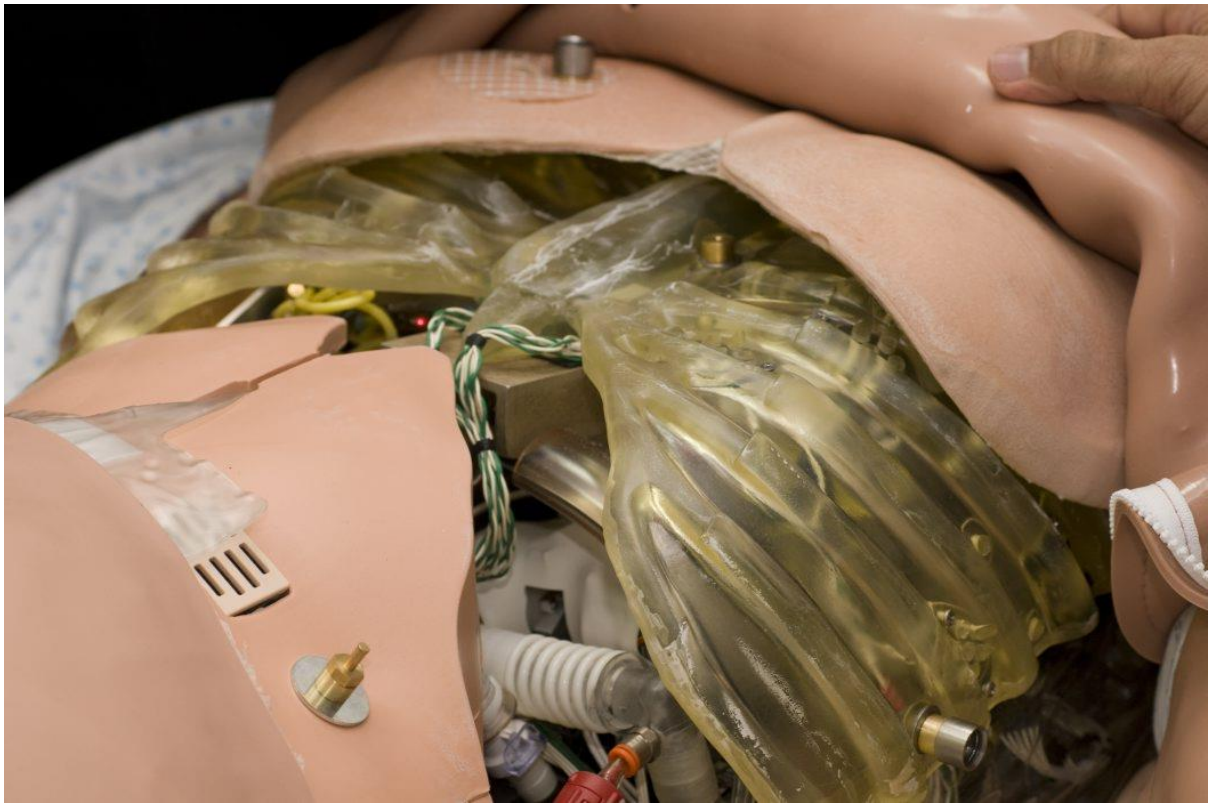


Figure B.5 - HSC SimMan Machinery

Detailed Training Scenario Observations

The following sections highlight the events that occurred within a specific simulated scenario that took place during the author's observational periods at the HSC. Two of the participants were selected at random to take part in the scenario, with others engaging later in the day. Further attempts of this scenario with different course participants were recorded and their analyses have been described in section HSC Video Footage. CCTV footage of these later

sessions was obtained and presented to the author, with permission to use the data for later analysis and future simulator design purposes.

Scenario Observation: Initial Briefing

The scenario commenced following an initial briefing. Two members of the group were selected at random to take part. The introductory briefing notes to the scenario were read out to all participants. Prior to commencing the scenario in the HSC simulation room, the selected participants were provided with basic equipment to assist them during the session, such as a functional pager, pen torch and stethoscope. For the scenario observed, they were informed that the mannequin was set up to represent a young female adult who was suffering from minor breathing difficulties. The full introduction was delivered as follows:

"Lisa Snow is a 24-year-old woman who is 24 weeks pregnant. She has been non-specifically unwell with a dry cough for a few days and been in bed. She started to feel short of breath yesterday and this morning she became more breathless and noticed pain on taking a deep breath in. She also coughed up some clear sputum flecked with blood. She self-presented to A&E this morning."

All scenarios were accompanied with documentation that provided an overview of the scenario content, aims, scripts and instructions for all centre staff involved, including objectives for the participants which are outlined further below. The documentation also included the instructions

for the simulator technician who assumed the role of the patient (communicating via the speaker located inside the mannequin's mouth). The technician was instructed to follow a script that clarified how (and when) communication with the participants should occur, what responses to provide when asked questions, and various dialogue and sounds that should be made. The technician was also instructed to improvise, where necessary, in the event of questions or queries not listed in the documentation. The patient introductory brief was delivered as follows:

"*You will be short of breath and very anxious, your partner isn't present and you are concerned at being on your own and are extremely anxious with regard to your baby. Keep seeking reassurance that the baby is ok. When big PE (pulmonary embolism) is scripted you need to shout/scream because you have suddenly developed severe central chest pain. Do not use the term 'crushing'. There is no radiation. You are also acutely breathless but can speak clearly. The 'Big PE' is a stable condition i.e. if the candidates do nothing the patient doesn't deteriorate any further.*"

Roles for the participants were established before commencing the scenario. The first participant selected to take part in the scenario was assigned as the "primary consultant" (referred to hereafter as PC). The second participant was referred to as the Assisting Doctor (referred to hereafter as AD). They were briefly introduced to the Centre's nurse and were informed that the telephone was connected to a simulated switchboard, enabling them to

contact either an obstetric or clinical specialist registrar (SpR). When the scenario commenced, the PC was instructed to enter the room first and the AD follow shortly thereafter. The reason for this, as clarified by the HOF, was that the PC would provide a summary patient assessment to the AD before working together to formulate a plan to evaluate the patient.

The primary outcome of the scenario required the PC and AD to generate an underlying diagnosis and suggest a course of treatment for the patient. If any events were set to occur throughout the scenario, the PC would have to respond accordingly. For example, in this scenario, the patient was set to suffer a cardiac arrest at a randomly specified time, but only after any kind of diagnosis, irrespective of certainty or accuracy, was made. However, if the scenario progressed slowly, then the arrest event would be triggered in any event. This scenario was set to have a maximum duration of approximately 15 minutes.

According to the documentation provided with the scenario, a thorough investigation into the visual symptoms, patient notes and family medical history were necessary to generate a diagnosis. If the PC or AD were struggling at any point, they could contact the SpR to assist in confirming the illness. For this scenario, the simulated cause of illness was a Pulmonary Embolism (PE), a blood clot in the arteries of the lungs. Finally, the documentation for this scenario defined a list of secondary objectives against which the PC and AD were scored. These secondary aims are highlighted in Table B.4 and are the same for all scenarios. For example, every participant in each scenario should exercise a structured approach and should consider

alternative diagnoses. However, alternative diagnoses may vary across all scenarios based on the primary illness the patient is scripted to be suffering from – see Table B.4 for an example.

Table B.4 - HSC PE Scenario Secondary Aims

Aim	**Description**
Structured approach	Participants must utilise the ABCDE system. This structured technique is a series of guidelines medical staff should follow when examining a patient. Each letter corresponds to a specific action and aids to generate a diagnosis. The letters were defined in the introductory presentation and are as follows: • Airways; signs of airway obstruction • Breathing; signs of respiratory distress • Circulation; signs of a cardiac issue • Disability; drug-induced causes of limited consciousness • Exposure or Examination; full body examination to ensure no detail is missed.
Signs	Elicit diagnostic signs and symptoms, including indicative monitoring, test results and assessing the patient's responses.
History	Examine patient and family medical history for issues related to blood clots. This includes low platelet counts and damaged red blood cells.
Diagnoses	Consider the differential diagnoses of: Chest infection Pneumothorax; the presence of air or gas in the cavity between the lungs and the chest wall Myocardial infarction/angina; severe pain in the chest due to an inadequate blood supply to the heart Asthma; attacks of spasm in the bronchi of the lungs Amniotic fluid embolism; amniotic fluid, hair or other debris enters the maternal circulation.
Management	Instigate immediate management whilst formulating a further plan.
Teamwork	Understand all team members' limitations and, when appropriate, call for more senior/specialist help. Summarise and effectively communicate the patient history and current clinical problems. Understand the impact of non-technical skills and system issues on patient care, as well as their core knowledge and technical skills.

Scenario Events and Observations

As the scenario was carried out, several observational notes were recorded. As previously highlighted, an investigation into various relevant information, including visual symptoms, patient notes and family medical history, is essential to generating a diagnosis. Interestingly, on this occasion, the PC had come to an early conclusion that the patient was suffering from a PE before consulting any of this relevant information.

As the patient script had specified, the simulation coordinator, who assumed the 'role' of the patient from the simulation control room, demonstrated continuous concern for the baby's safety, but, during the scenario, a lengthy period occurred in which no reassurance of the baby's safety was given by either the PC or AD. This was despite continuous, and anxious requests from the patient. In one instance, the nurse enquired as to the status of the patient and baby to the PC. In some circumstances, this situation occurred in conjunction with the patient being ignored. For example, there were several moments where the patient had requested painkillers. Although this was initially acknowledged the first time they were requested, subsequent requests went seemingly unnoticed.

To assist with the patient's breathing difficulties, the PC had placed an oxygen mask onto her face. The PC had enquired about the length of time the patient had suffered from her breathing difficulty. The patient stated that the breathing difficulties started a few hours prior to arriving at the hospital. Further questions were asked by the PC to discover the cause of the breathing

issue. However, as the scenario developed, the answers became vague and difficult to interpret.

To elicit further realism of a real-life ward, the simulation coordinator contacted the pager worn by the PC. Each recurring ‘bleep’ saw the PC stop their current task - artificially creating a distraction - to check it. In most cases, the bleeper message requested the PC to contact the Obstetric SpR via the telephone. Initially, the PC requested that the AD contact the SpR, but they were unavailable at the time. This was to demonstrate that wards are typically very busy. Following this, and to assist with confirming their diagnosis of PE, the AD, as instructed by the PC, contacted the Obstetric SpR via the telephone in response to the bleep. Despite several conversations taking place, and despite describing the patient’s breathing difficulties, the AD was unable to determine a plausible explanation. This was despite the PC maintaining that PE was the cause, and despite the questions being asked by the obstetric SpR.

After finishing on the telephone, the patient’s breathing came to an abrupt halt and the simulator initiated a cardiac arrest. A standard CPR procedure was commenced by the PC in response. However, this started after a short delay as both participants did not acknowledge the events occurring immediately. Fortunately, the patient recovered successfully and the scenario concluded shortly after.

Scenario After Action Review

Following the conclusion of the scenario, the participants were invited back to the debriefing room for the After-Action Review (AAR) Session. The purpose of the AAR was to debrief the participants who took part and discuss the events that occurred throughout the scenario. The method used to carry out the AAR primarily involved viewing the video recordings of the session, skipping through unnecessary parts and pausing at key points to relay positive or negative feedback to the participants and to elicit discussion amongst those who were not directly involved in the scenario (Figure B.6). The main points discussed were the circumstances surrounding the diagnosis, communication breakdowns and the utilisation of the nurse.

Figure B.6 - HSC Scenario Debrief Room

The first, and the most important, discussion point questioned the participants' overall communication and teamwork skills. One negative feedback item raised on this occasion was the fact that the PC did not inform the AD, after arrival, of the patient's status. These events are also referred to as 'handovers'. A handover was not carried out by the PC, nor did the AD request one. Therefore, the AD was forced to consult the notes provided, already setting a communication breakdown in motion shortly after the scenario commenced. Furthermore, as demonstrated in the footage presented, there were frequent moments where both participants

maintained a considerable distance between each other. The footage revealed a moment where the PC was situated close to the bed reading the patient notes whilst, at the same time, and located at the opposite end of the room, the AD was on the telephone to the obstetric SpR. Both participants proceeded to communicate loudly with each other across the room. This situation could have unintentionally affected others, such as disrupting other nearby patient inspections or, worse still, the comfort, well-being and sense of personal safety for the patient under assessment.

A further example of communication breakdown was illustrated during the telephone conversation between the AD and obstetric SpR. Diagnosis issues aside, the AD was unsure of the patient's status and medical history. Therefore, there was some confusion as to why the AD was instructed to contact the SpR by the PC. This resulted in a seemingly awkward conversation between the AD and SpR. To resolve the situation, the SpR attempted to assist the AD themselves by providing their own set of questions. This was to encourage the AD to seek further information related to the patient directly to confirm a diagnosis. It was further pointed out that the AD, due to their inability to update the Obstetric SpR directly, could have challenged the PC for a lack of information provided, as the PC was responsible for handing over this information the moment the AD arrived.

The second major discussion point regarded the nurse. It became apparent that the nurse, whose training role in the scenario was to undertake activities that would test the participants' situation

awareness, frequently wandered outside of the confines of the bed area. Moreover, she began leaving the bed area for increasingly large periods of time. This recurring theme remained unnoticed for the scenario's entirety and was widely discussed during the AAR. Furthermore, the participants were criticised for their frequent instructions issued to the nurse, as this was deemed to represent arrogant behaviour in the medical community. To alleviate this, it was recommended that they demonstrate a more open and equal approach by willingly conducting some of the smaller and simpler tasks that nurses are usually instructed to carry out. This, it was emphasised, would both fulfil the effective teamwork learning requirements and help the participants to come across as more helpful, friendly colleagues.

A further major discussion point focused on the suspicion that had arisen surrounding the diagnosis. As highlighted in the scenario observation notes, the PC had made an immediate diagnosis of PE. The diagnosis was made without consulting any information regarding the patient's medical background, from available visual symptoms, or from seeking third-party assistance. As emphasised by the Centre staff, PE is not an illness that can be diagnosed immediately without the possession of plausible evidence or information. The participant cited no information that justified their response, claiming that PE immediately came to mind when they discovered that the patient was suffering from breathing difficulties. The importance of reviewing patients' medical histories and undertaking timely examinations was re-emphasised, as a misdiagnosis (although PE was correct in this case) could have escalated to become a serious medical error.

The final, although minor, issue highlighted during the AAR was the participants' inability to react within a sufficient timeframe during a crisis. Both participants were considered to have been too 'casual' for a patient entering a state of cardiac arrest. Therefore, they were encouraged to demonstrate further vigilance when in the presence of a patient.

HSC Video Footage

The footage captured during the scenario described above was recorded using a handheld video camera manually positioned in the simulation room. However, a sample of footage recorded by the Centre's CCTV system was also obtained for further analysis at a subsequent date. Using the CCTV footage, it was possible to review events that occurred within two additional 'pregnant PE' scenario sessions. Although the scenario content was identical, there were several differences between these two additional sessions and the earlier scenario detailed above. The two additional scenarios were captured during a separate training day to that described earlier and were therefore carried out by different trainee participants. In addition, and again compared to the previous session, on this day the cohort was split into two smaller groups, with scenario sessions being carried out by one individual rather than two at once. Finally, there were several differences in performance between each participant.

The first session (Session A, Figure B.7), commenced immediately after the introductory greetings, with the second session (Session B, Figure B.8) following after the preliminary lectures (as detailed in Appendix B Introductory Presentation). The video footage analysed

after the sessions illustrated several differences in scenario performance between the two participants observed. Mainly, Session A's participant was seemingly nervous, hesitant when reacting to events and, overall, unsure of how to progress. In comparison, Session B's participant demonstrated a more confident and affable approach and was seemingly more knowledgeable. Both provided a diagnosis after consulting all the available information in appropriate time. Full details of the differences are highlighted in Table B.5.

Figure B.7 - HSC Pregnant PE Scenario Footage Session A

Table B.5 - Participant Scenario Performance Overview

Event/Topic	**Session A**	**Session B**
Confidence	Participant was seemingly nervous throughout scenario and delayed responses to events were evident.	Participant maintained confidence for the entire session, responding promptly where necessary.
Diagnosis	Very delayed process of forming a diagnosis. Requested unnecessary procedures such as a series of X-Rays.	Produced a quick diagnosis after consulting all relevant information.
Nurse	Participant was distant from the nurse, only communicating when necessary.	Utilised the nurse very well, keeping them involved closely, and maintained communication.
Patient	Did not actively reassure the patient of her baby's safety.	Affable with approach, very comforting and assuring. Ensured the safety and well-being of the patient's baby.
Information	Participant consulted most of the available information. The nurse eventually informed them that the patient's personal bag, located on the bed, contained a pregnancy notebook they should observe.	Participant consulted all available information to form diagnosis before contacting the obstetric SpR.
Overall	Participant was evidently nervous, with respect to their reactions, communication and responses. Their overall performance improved as the scenario continued.	Participant was very quick to respond to events and was evidently knowledgeable in their approach.

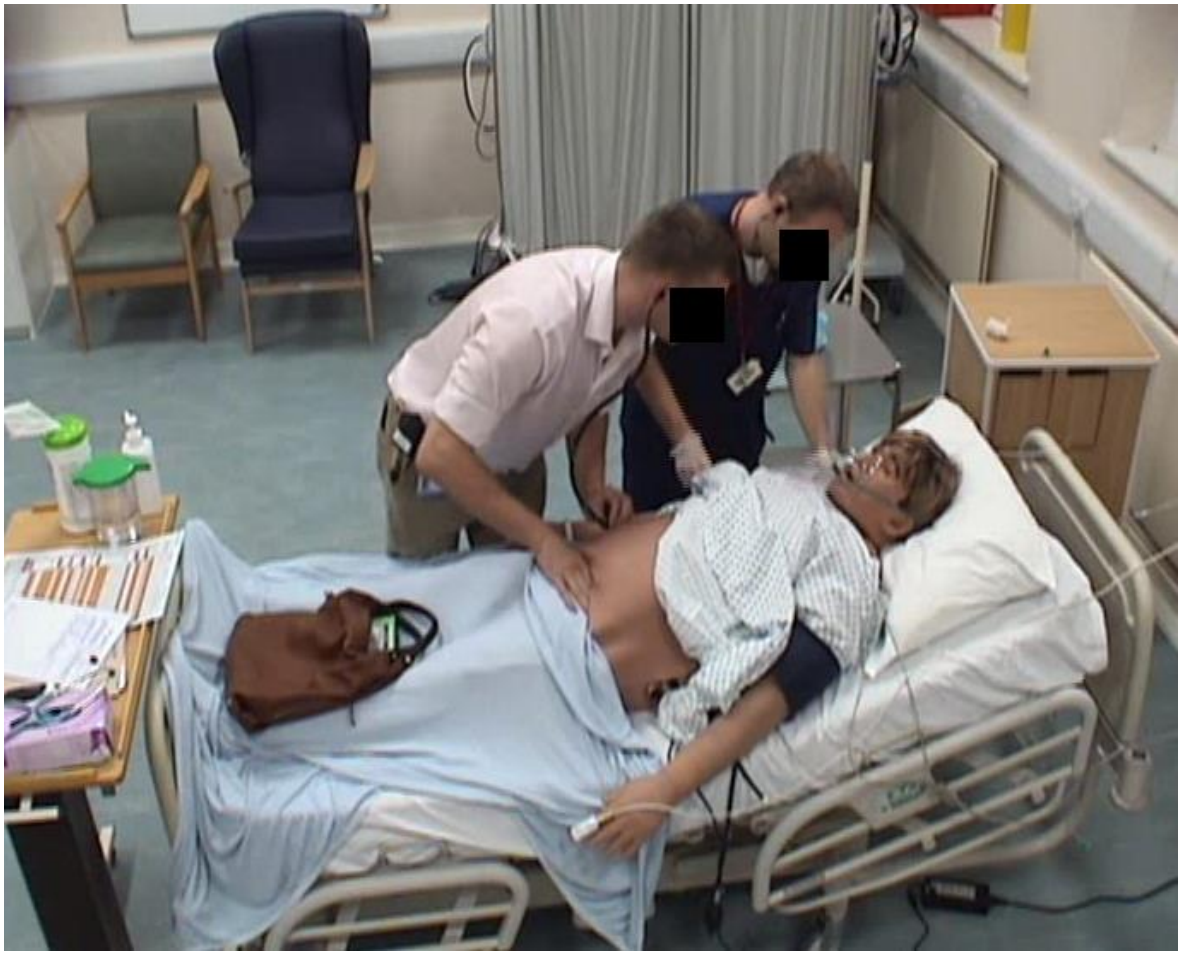


Figure B.8 - HSC Pregnant PE Scenario Footage Session B

Appendix C: Investigation Participant Information and Consent Form

PARTICIPANT INFORMATION SHEET

Simulation-Based Team Training: An investigation into the challenging of clinical decisions using virtual simulated hospital scenarios

This project forms part of a course of study for the ward of a PhD in the School of Electronic, Electrical and Computer Engineering at the University Of Birmingham. The study sets out to establish whether or not virtual simulation techniques can aid in the development of enhanced decision-making training practices for clinical and nursing personnel at UK hospitals (within surgical or ward round team settings). The research includes a consideration of the issue of challenging the decisions made by staff of various roles and positions.

You are invited to participate in this study on a voluntary basis and you may withdraw at any time. You have been selected because your role within the hospital meets the requirement of the study.

The study will require you to complete a preliminary questionnaire on the subject of challenging clinical decisions and then take part in a recorded interview. Participation should require no more than approximately 30 minutes of your time.

Reward/reimbursement/expenses

Your participation in this study is voluntary. Light refreshments will be offered during the period of your participation.

Confidentiality/anonymity and data security

Your data will be treated as confidential and your personal identity will not be included within the study. You will be issued a unique identifying code which will be used to preserve your anonymity and to help the researchers identify and process your data.

Only the researchers Jamie White and project supervisor Professor Robert Stone will have access directly to the data which will be used to analyse the results and answers given. The data will be transferred from paper and stored electronically in a secure location within the University of Birmingham and all paper copies will be destroyed upon transfer. The data will be kept until the conclusion of the project and for up to 10 years under the discretion of Professor Robert Stone, should a publication of any sort result from the project.

Results of the study

The results of the project will be analysed and will contribute to a PhD project report which may also result in a publication of the findings which could appear within various journal portals such as British medical Journal. Participants can find out about the outcome of the project by contacting the researcher and their supervisors whose details are given below.

Contact details

Researcher		Supervisor	
Jamie White	jaw269@bham.ac.uk	Prof. Robert Stone	r.j.stone@bham.ac.uk

CONSENT FORM

Simulation-Based Team Training: An investigation into the challenging of clinical decisions using virtual simulated hospital scenarios

Fair Processing Statement

This information is being collected as part of a research project concerned with assessing whether or not the use of virtual simulation techniques can aid in the development of enhanced decision-making training practices for clinical and nursing personnel at UK hospitals. The research is conducted for the School of Electronic, Electrical and Computer Engineering in the University of Birmingham as part of a PhD project.

The information you supply as part of this research project will be entered into a filing system or database and will only be accessed by authorised personnel involved in the project. The information will be retained by the University of Birmingham and will only be used for the purpose of research and development purposes. It may form part of a publication in an academic journal or other forum. All participants in the research will be anonymised and identified only by means of a unique identifying number for the purposes of post-questionnaire and interview data analysis.

By supplying this information you are consenting to the University storing your information for the purposes stated above. The information will be processed by the University of Birmingham in accordance with the provisions of the Data Protection Act 1998. No identifiable personal data will be published.

Statements of understanding/consent

- I confirm that I have read and understand the participant information leaflet for this study. I have had the opportunity to ask questions if necessary and have had these answered satisfactorily.
- I understand that my participation is voluntary and that I am free to withdraw at any time up to 30/09/2013 without giving any reason. If I withdraw, my data will be removed from the study and will be immediately destroyed.
- I understand that my personal data will be processed for the purposes detailed above, in accordance with the Data Protection Act 1998.
- Based upon the above, I agree to take part in this study.

Name, signature and date

Name of Participant	Date	Signature

Name of Researcher	Date	Signature

Appendix D: Investigation Questionnaire

Questionnaire – Challenging decisions

Please state your profession:		
Grade:		
Speciality:		
How many years have you been qualified?		
How many years have you been at your current post?		
Country of training:		
Military:	Yes	No
Gender:	Male	Female

1. Do you think it is important to challenge decisions being made by your team members?	Yes	No
Why?		

2. How confident are you now in challenging the decisions and actions of staff in the following positions:
   - 1 – Not very confident (NVC), 2 – Not confident, 3 – Neither confident or not confident, 4 – Confident, 5 – Very confident (VC)

Position:	NVC				VC	Any Exceptions?
Consultant	1	2	3	4	5	
Speciality Trainee 5-7	1	2	3	4	5	
Speciality Trainee 3-4	1	2	3	4	5	
Core Trainee 1-2	1	2	3	4	5	
Foundation Year 2	1	2	3	4	5	
Foundation Year 1	1	2	3	4	5	
Medical/nursing Student	1	2	3	4	5	
Nurse – Band 6 and above	1	2	3	4	5	
Nurse Band 4-5	1	2	3	4	5	
Clinical support worker	1	2	3	4	5	
Allied Health Professional	1	2	3	4	5	

3. How confident were you to challenge any decision throughout your previous grade/tier?
   - 1 – Not very confident (NVC), 2 – Not confident, 3 – Neither confident or not confident, 4 – Confident, 5 – Very confident (VC)

	NVC				VC		
Circle answer:	1	2	3	4	5	Comments:	

4. How do you rate the following opportunities to challenge a decision? (1 – 5, Not Very Important to Very Important)	NVI				VI
Immediately, and overtly in front of others who are present at the time	1	2	3	4	5
By attracting attention discretely	1	2	3	4	5
By attempting to engage in a private discussion	1	2	3	4	5
By seeking assistance from a staff member outside of the group	1	2	3	4	5
By forming a huddle to ensure everyone in the team are involved in the challenge	1	2	3	4	5

5. What would you do if you did not receive a satisfactory response to your challenge?

6. Have you received any training in assertiveness or how to challenge the decisions of team members?	Yes	No
If so, how did you receive this training?		

7. What might stop you challenging a member of a team?

8. What factors do you feel affect your ability to make a challenge?

Appendix E: Investigation Interview Document

Section 2: Interview

Do you recall a recent scenario that has prompted you to challenge the decision or event?

Can you provide a description?
What was the role of this particular staff member? (Do not request names).
Was the outcome of your challenge positive or negative?
Was the outcome altered based on your challenge?
Were you satisfied with the eventual outcome?
Did you receive any feedback from the staff member challenged?
Was further action taken as a result of your challenge (i.e. disciplinary or perhaps personal disagreements between you and said staff member)?
Do you consider challenging decisions to be difficult?
Are you familiar with the scope and conclusions of the Francis Report?
Has it affected your clinical practice?
Have you ever been exposed to any form of simulation training?
What are your opinions of simulation based training (Ask both physical and virtual based).
Any other comments?

Appendix F: Engine Technology and Gameplay Elements

The simulator was developed using the Unity3D game engine software (Unity Technologies, 2015). As highlighted in Chapter 2, Unity3D is a cross-platform game engine that deploys applications compatible with the latest gaming technologies, including computers (Microsoft Windows, Apple MAC and Linux), game consoles, mobile smart phones and tablets. Therefore, coupled with experience with the software, and support through third party plugins that extended the functionality of the tool, Unity was an ideal candidate to drive the simulator project. Several Unity 'plugins' (modular components used to extend software functionality) were exploited that extended the features of the engine, providing extra functionality to assist with the simulator's development. This included audio management, scenery design and navigation within the environment.

Various scripts attached to 'Game Objects' (an object within the scene that has functionality) coded using C# (c-sharp) provided them with functionality so they could be interacted with. For example, the examinable items defined earlier in the chapter could be picked up by focusing on the item in the environment and pressing a button on the controller to bring it closer to the screen for the user to look at. A further example was that the user could respond to the consultant's decision for treatment via a simple choice menu that appeared on the screen. Further examples of gameplay elements are detailed below.

Participant Character Control

The simulator was designed to function seamlessly using a mouse or game controller. The Unity engine also featured native game controller support, permitting the immediate use of such controllers the moment they are plugged in via Universal Serial Bus (USB). The implementation of a game controller within the experiment was a result of the adoption of a high-definition projector screen to present the scenario within the eventual experiment (detailed in Chapter 6). Using a combination of mouse and keyboard when placed directly in front of the screen was inappropriate, and limited the user's view of the environment. Therefore, an alternative, more suitable, control scheme, such as a game controller, was required that would support larger distance viewing.

The game controller used for the simulator was a standard Xbox One (Microsoft, 2013) game controller (Figure F.9), which allowed users of the system to look around freely and interact with the environment. This was achieved by simply moving the game controller's left 'thumbstick' (as illustrated in Figure F.9).

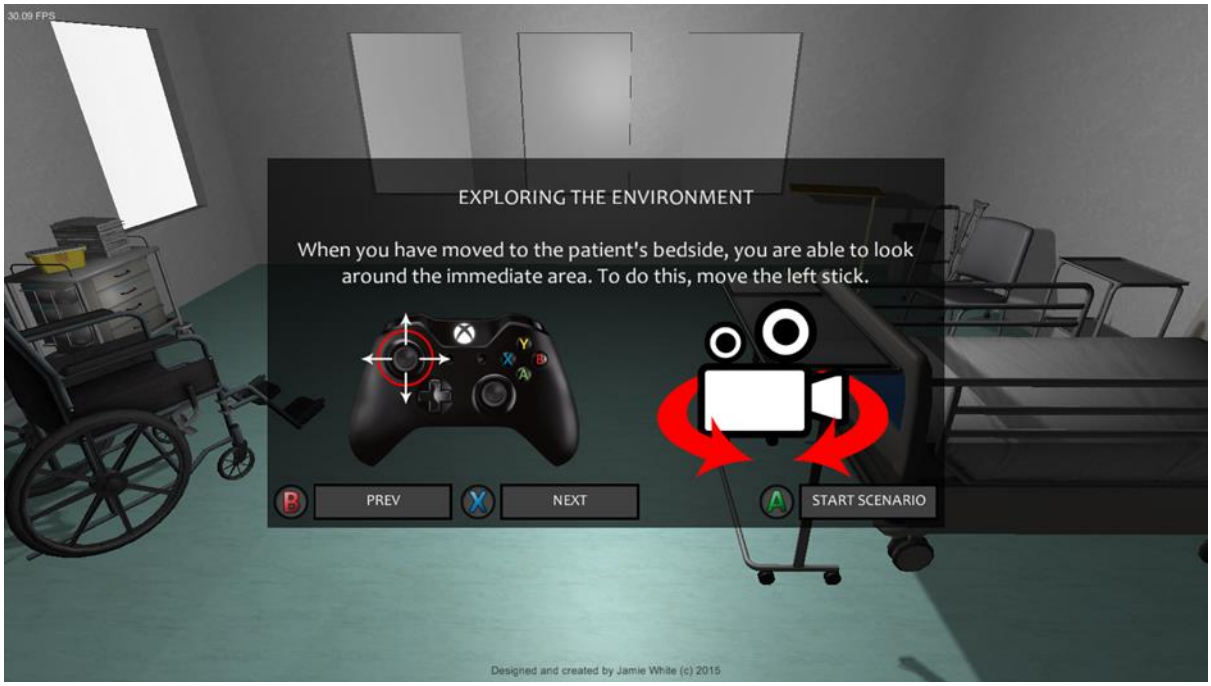


Figure F.9 - Control Scheme Tutorial Information

However, translational movement within the scenario was restricted and was limited to the spline (a form of 'invisible track') that their character was attached to. Therefore, free movement was not possible. This design choice set out to make the overall control scheme easily accessible for those not familiar, or possessing limited experience, with 'gaming technologies', whilst remaining comfortable for those more familiar with gaming.

Examinable Items

To discover the issues concerning their patient, staff would examine various items in the environment such as notes and obs charts. A system was created that permitted participants to ‘pick up’ these items for a closer look. This process was achieved by enlarging items (defined in Table 5.1) when they were in the centre region of the participant’s viewpoint, accompanied by a user interface (UI) window object. When an item was in view, the item was attached and moved closer to the camera using only a single button press. Whilst in this mode, any movement of the camera would be accompanied by the item following the user’s view, and pressing the same button placed the item back down. This process is demonstrated below in Figure F.10.

Figure F.10 - All examinable items implemented into the simulator

Dialogue System

Five drama students based at the University of Birmingham were recruited to record dialogue for the script created for the scenario (see Appendix F for a sample of the script). Dialogue was recorded using a laptop connected to a microphone inside a sound-proof booth. Regarding the different attitudes of the consultant character, two sets of dialogue were required. For the 'calm' version, the actors were requested to emphasise a soft and welcoming tone, whereas the 'angry' version required a more aggressive and more negative tone. The output of both sets of recorded dialogue demonstrated a discernible difference in attitude and tone, and, as such, were both suitable for the simulator.

Session Data Recorder

The simulator was designed to log all events that occurred in the scenario, along with time stamped data and the state of variables used to track the status of objects contained within. The purpose of this system was to be able to analyse each participant's performance within every scenario session. Examples of logs that occur include items that are looked at (when the object enlargement is triggered), when an item is picked up, when an item is put down and whether the participant challenged, agreed or refused treatment. All records were saved to a text file once the scenario session ended with easy to read descriptions for easy analysis. The simulator also records the current camera direction every second. The purpose of this process was to visually analyse the area most viewed in the simulator.

Mixamo Fuse - Character Creation Software

The virtual actors, or 'avatars', were created using the then-latest version of the 3D character creation tool, Fuse (Mixamo, 2014). The software consisted of a simple set of male or female limbs that users could pick from which then formed a nude human 3D 'base mesh.' After the base mesh was created, the program contained a library of clothing items that could be attached to the character, including various t-shirts, trousers, shoes, hats and glasses. A clothing set that contained appropriate uniform for nurses, doctors and patients was used for all characters present in the simulator.

Once a character was complete, it could be uploaded to Mixamo's website where it was automatically rigged and made ready for animating. For the simulator, various walking, talking and gesture animations were used. Each clip was then customised to adjust the amount of emphasis on actions (Figure F.11), such as a shouting animation clip that was used when the consultants were programmed to use the aggressive dialogue set. For this example, the extent to which the avatar's arms could stretch out when speaking aggressively could be simplified, as the default setting was excessive.

Figure F.11 - Editing a talking animation clip for the male consultant model in the Mixamo Animation Clip Editor

A total of six 3D animated characters were used for the simulator (illustrated in Figure F.12 to Figure F.14): a male consultant, female consultant, male nurse, female nurse, male patient and male background nurse. As Mixamo's character rig system was universal, the male consultant

character was used with the animation library tool and finished clips were assigned to all characters. No models presented any visual artefacts or mesh deformation. As the rigging system also supported the implementation of a facial rig, each character's mouth was animated when voice dialogue was played (Figure 5.5).

Figure F.12 - Final male/female Doctor and Nurse character variations

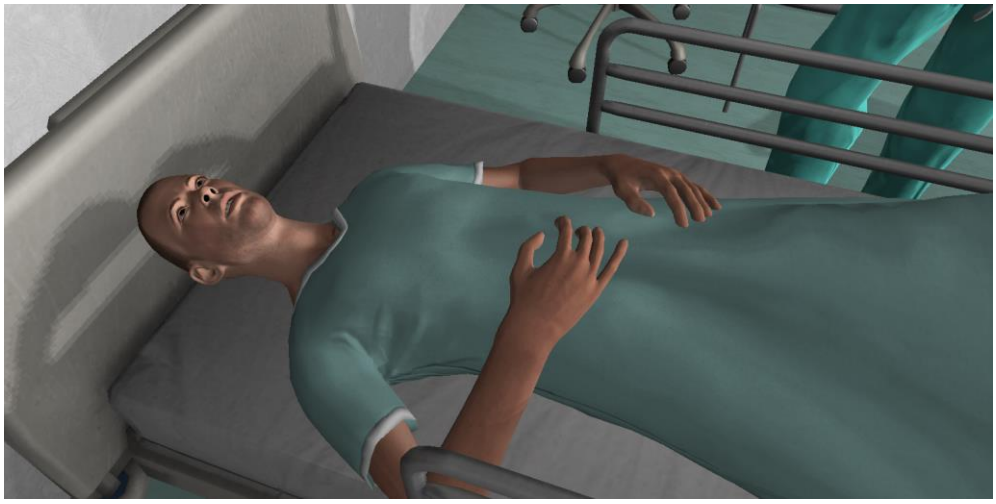


Figure F.13 - Final male patient character

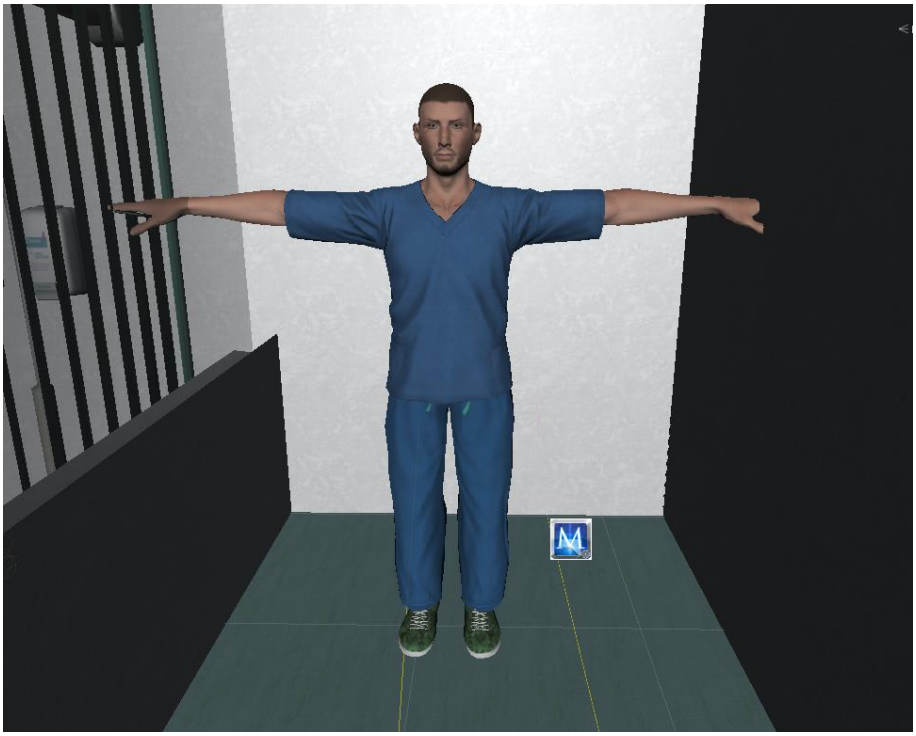


Figure F.14 - Final background male nurse character (scene editing mode)

Appendix G: Simulator Scenario Script Sample

Event	Character	Dialogue
The consultant enters the room	Consultant	[CALM] Hi everyone, apologies I'm late. Can you bring me up to speed? [ANGRY] OK, I'm running late for theatre and so I do not have much time. Tell me what you know about the patient.
	Nurse	We have a 32-year-old male with a suspected gastrointestinal bleed. He's tachycardiac, hypotensive and a little confused, despite fluid resuscitation with 2 litres of Hartmann's solution. His haemoglobin level is 70g.
	Consultant	[CALM] If you have tried fluid resuscitation then he should have a blood transfusion. We should do this as soon as possible. [ANGRY] Well, he needs a blood transfusion. It needs to be given right away.
If the participant challenges twice and consultant acquiesces.	Consultant	[CALM] OK. Let me know how you want to proceed. [ANGRY] You know, I've always been told to never speak back to anyone if a decision is made by a senior. Well then, what do you think we should do?
When the patient begins to deteriorate	Nurse	I think we need to do something soon as it's clear he's deteriorating.
	Consultant	[CALM] The nurse is right; we need to act soon. If the blood is ready do you want to give it to the patient now? [ANGRY] Well? What is the delay? He needs the blood transfusion now so are you going to give administer it?

Appendix H: Comic Book Sample Page (Calm Consultant)

Appendix I: Comic Book Sample Page (Angry Consultant)

Appendix J: Experiment Pre-Use Questionnaire Document

Pre-use questionnaire

What is your profession?	
What is your current grade?	
What is your speciality?	
How many years have you been qualified?	
How many years have your been at your current post?	
What is your gender?	
Are you a member of the Armed Forces?	
Have you taken part in a study like this before?	
If so, can you provide a description?	
Have you received any training that involves challenging decisions/being assertive?	
If so, can you provide a basic description?	

Question 1 – How many hours a week do you usually interact with:

	0 hours	< 1	1-4	4-8	8+
Computers					
Printed media					

Question 2 – What is your current experience with:

	None	Low	Moderate	Good	Excellent
Computers					
Printed media					

Question 3 – How many hours a week do you normally interact with:

	0 hours	< 1 hour	1-4	4-8	8+
Video games					
Comic books					

Question 4 – What is your current experience with:

	None	Low	Moderate	Good	Excellent
Video games					
Comic books					

Question 5 – What is your current experience with virtual reality simulation training technologies?

None	Low	Moderate	Good	Excellent

Question 6 – What is your current experience with mannequin-based simulation training technologies?

None	Low	Moderate	Good	Excellent

Question 7 – In general, what is your opinion on simulation training in healthcare?

Very poor	Poor	OK	Good	Very good

Question 8 – How confident are you in taking part in a study that makes use of gaming technology?

No confidence	Low	Somewhat	Good	Excellent

Question 9 – How would you rate your overall confidence to challenge a clinical decision?

No confidence	Low	Somewhat	Good	Excellent

Any comments:

Appendix K: Experiment Post-Use Questionnaire Document

Post-Simulation use questionnaire

Section 1

Which characters do you remember being present in the environment?	
What examinable items do you remember being present in the environment?	
Do you remember if it was day or night, and what the weather conditions were outside?	
Do you remember what the patient's name, age and gender was?	
Do you remember what different issues there were with the patient in the scenarios?	
Do you remember any of the patient's medical history?	
Do you remember what bed number the patient was in?	
Anything else in particular you noticed about the environment?	

Section 2

Question 1 – How would you rate your immersion into the media?

Very low	Low	Somewhat	High	Very high
Any comments?				

Question 2 – How would you rate the room conditions surrounding the experiment with regards to the room spacing, lighting, projector screen or other environmental conditions?

Very low	Low	Somewhat	High	Very high
Any comments?				

Question 3 – How would you rate the realism of the (the base content) scenarios and their outcomes?

Very low	Low	Somewhat	High	Very high
Any comments?				

Question 4 – How would you rate the realism of the consultant character?

Very low	Low	Somewhat	High	Very high
Any comments?				

Question 5 – How would you rate the realism of the nurse character?

Very low	Low	Somewhat	High	Very high
Any comments?				

Question 6 – How would you rate the visual quality/fidelity of the media?

Very poor	Poor	Somewhat	Good	Very good
Any comments?				

Question 7 – Did you notice anything in the environment that seemed out of place or unrealistic?

Yes	No
If so, please provide a brief description:	

Question 8 – Have you ever encountered this particular scenario (or something very similar) before?

Yes	No
If so, can you provide a brief description?	

Question 9 – How rare would say this scenario is in real life?

Never encountered/not sure	Very rare	Rare	Common	Very common

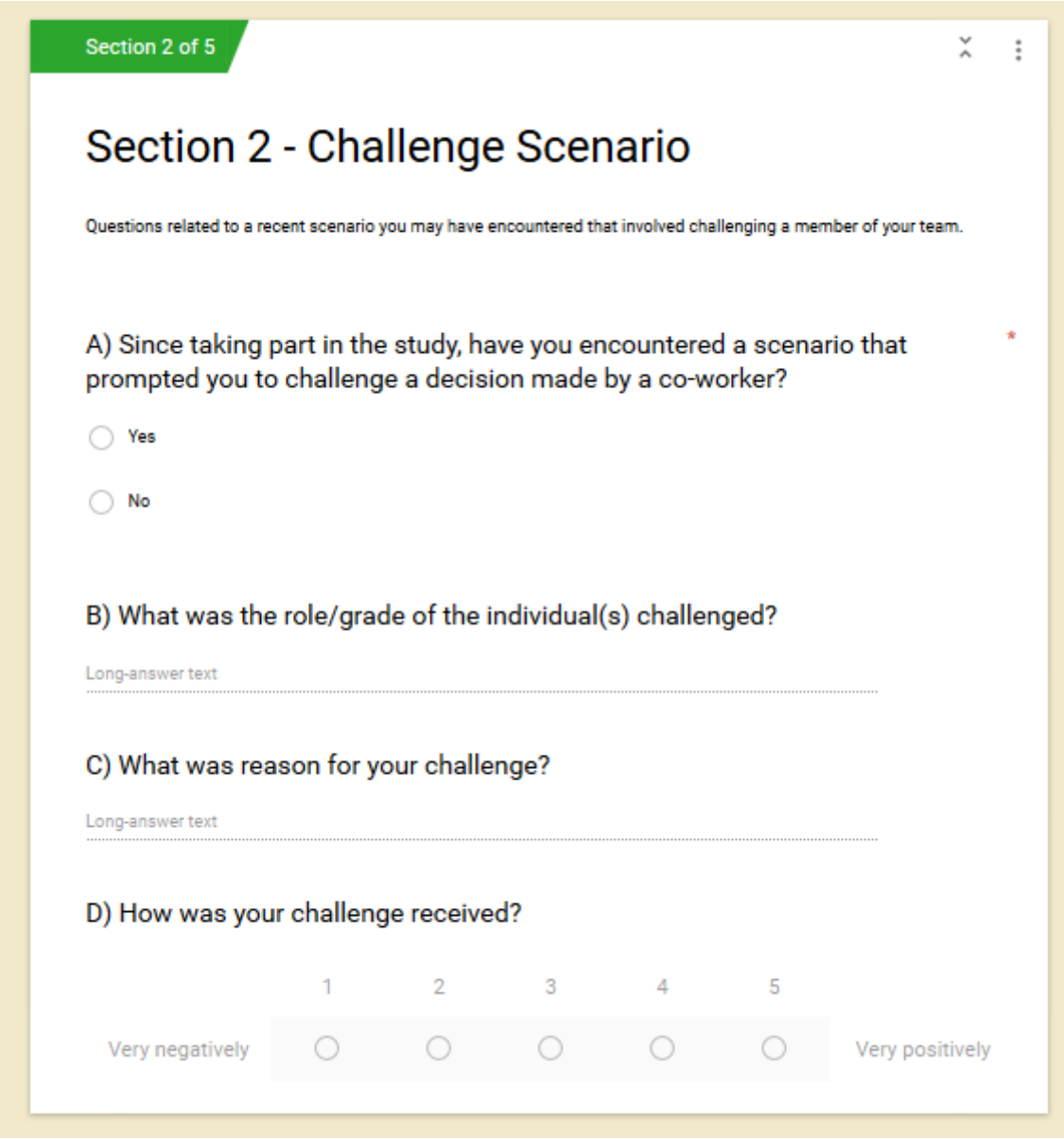
Question 10 – Do you feel the media has had an immediate effect on your ability to challenge clinical decisions?

Not at all	Not very much	Somewhat	Much	Very much

Question 11 – How do you think the media could be improved in order to develop your ability to challenge clinical decisions?

Question 12 – Do you have any other comments or feedback for the media regarding its design, usability, or visual quality?

Appendix L: Experiment Follow-Up Questionnaire Sample (Google Forms)



Appendix M: Post-Use Questionnaire Situation Awareness Assessment List

#	Element	Simulator	Comic	Greatest
1	Identified the patient	17	30	Comic
2	Identified the consultant	18	33	Comic
3	Stated the consultant's gender (M or F)	3	0	Simulator
4	Identified the nurse	19	30	Comic
5	Stated the nurse's gender (M or F)	3	0	Simulator
6	Listed the patient as examinable	15	11	Simulator
7	Listed the notes as examinable	20	12	Simulator
8	Listed the patient's bag (JW note) as examinable	4	16	Comic
9	Listed the ward list as examinable	12	17	Comic
10	Listed the bed number sign as examinable	9	4	Simulator
11	Listed the blood bag as examinable	23	24	Comic
12	Correctly stated the patient's full name	6	7	Comic
13	Correctly stated the patient's age	11	6	Simulator
14	Correctly stated the patient's gender	24	28	Comic
15	Stated that the patient was a Jehovah's Witness	16	15	Simulator
16	Identified the wrong blood bag	10	11	Comic
17	Stated that the patient's wristband was missing	5	0	Simulator
18	Stated that the patient was hypotensive	3	6	Comic
19	Stated that the patient was Confused/Dazed	1	1	Equal
20	Stated that the patient was suffering from Tachycardia	3	5	Comic
21	Stated that the patient was suffering from GI Bleed	8	13	Comic
22	Stated patient was suffering from Haematemesis	8	10	Comic
23	Stated that the patient's Hb was low	3	5	Comic
24	Correctly stated the bed number	17	19	Comic
	Totals	**258**	**303**	
		561		

Appendix N: Simulator Experiment Procedure Checklist

#	Item	Description
1	Explain the simulator	Provide a description of the simulator, clarifying its purpose in the experiment. Invite any questions from participants on technology used how the scenario will run.
2	Scenario completion	Explain that they will be asked to carry out a short medical scenario, which they will repeat a further four times (five in total).
3	Scenario duration	Explain that the scenario will last between 2-3 minutes per run, approximately 10 minutes in total. Clarify that once the scenario has started, including all subsequent repeats, it could not be stopped until completed.
4	Simulator purpose	Clarify that the simulator is not designed to test clinical/medical knowledge, so no judgements will be made on decisions made whilst the simulator is in motion.
5	Xbox controller	Explain the Xbox controller to the participant and how it will be used with the simulator. If a participant asks, allow them to hold the controller to test it first.
6	Button layout	Clarify the buttons that will be used. Explain the three buttons for UI navigation and clarify that only one button will be used throughout the scenario itself. If they are unable to locate the buttons without looking first, tell them to lightly hold their thumb over the 'A' button ready for when it is needed.
7	Camera controls	Explain how the camera controls work and demonstrate use of the thumb stick. Clarify that movement of the character is not possible and that they are welcome to look freely around the environment in all directions.
8	Video camera	Clarify use of the video camera for the experiment. Explain that, whilst they are not being directly recorded, their voices will be captured if they talk throughout the scenario.
9	Final check	Ask participants to commence the scenario when they are ready do so. As per checklist item 3, they were invited to ask any other question they may have concerning the study or simulator.