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Abstract: Resilient healthcare emphasises the importance of adaptive capacity for the quality of healthcare. It has had extensive theoretical development, but comparatively limited translation for clinicians in practice. This study was the first in the world to present resilient healthcare principles in a serious video game. Serious games are an effective tool for engaging users, sharing ideas and eliciting reflections. The purpose of this study was to communicate principles from resilient healthcare to clinicians through a serious video game, and to evaluate the game's feasibility as a prompt to reflect on practice. The game, Resilience Challenge, is scenario-based and requires players to resolve dilemmas in clinical practice. It was disseminated online, and was played 1,949 times during the four-month study. The game was evaluated using an immediate cross-sectional survey, which included both Likert-style and free text responses (n=141). Participants reported that the game was engaging (93%) and that they would recommend it to others (89%). Fewer participants reported learning about resilient healthcare concepts (64%). Resilience Challenge is a promising way to engage with healthcare professionals and potentially improve safety in healthcare, and warrants further research.

Cover Letter

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February 14, 2019

Dear Dr. Dempsey and Members of the Editorial Board:

Thank you for the opportunity to submit an article, in response to the call for papers for the special issue on Resilience Engineering. Our paper discusses a world-first study, where we operationalized resilience engineering concepts through a serious video game for healthcare professionals.

This paper will be of interest to AE readers as it outlines of how we created the resilience engineering videogame, *Resilience Challenge*. In this game, a player guides a patient's journey through a hospital by making trade-off decisions, and receiving feedback. There has been very limited translation of resilience engineering concepts to healthcare professionals, and our evaluation demonstrates the advantages and challenges in using a medium like a videogame. It is hoped that the information from this research can help clinicians and safety scientists engage with the concepts of resilience engineering, and that other researchers may be inspired to carry this work further.

Please let me know if I can provide any additional information. I appreciate your consideration of this article.

Best Wishes,

Jennifer Jackson PhD(c), RN

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Title Page

Title: Operationalizing resilience engineering concepts through a serious video game for healthcare professionals

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Operationalizing resilience engineering concepts through a serious video game for healthcare professionals

Abstract

Resilient healthcare emphasises the importance of adaptive capacity for the quality of healthcare. It has had extensive theoretical development, but comparatively limited translation for clinicians in practice. This study was the first in the world to present resilient healthcare principles in a serious video game. Serious games are an effective tool for engaging users, sharing ideas and eliciting reflections. The purpose of this study was to communicate principles from resilient healthcare to clinicians through a serious video game, and to evaluate the game's feasibility as a prompt to reflect on practice. The game, *Resilience Challenge*, is scenario-based and requires players to resolve dilemmas in clinical practice. It was disseminated online, and was played 1,949 times during the four-month study. The game was evaluated using an immediate cross-sectional survey, which included both Likert-style and free text responses (n=141). Participants reported that the game was engaging (93%) and that they would recommend it to others (89%). Fewer participants reported learning about resilient healthcare concepts (64%). *Resilience Challenge* is a promising way to engage with healthcare professionals and potentially improve safety in healthcare, and warrants further research.

Keywords: resilience; safety II; serious video game; healthcare; resilience engineering; gamification; resilient healthcare; serious games; safety; feasibility; reflection; survey

Highlights:

- Resilient healthcare was translated into a series of scenarios in a videogame, where players make decisions to guide a patient's journey through the hospital.
- Resilience Challenge was found to be acceptable, feasible, and engaging. Participants reported that the game helped them to reflect on their practice.
- Serious video games can prompt reflection on practice, and start discussions about competing priorities in healthcare

1 Introduction

Error rates in healthcare remain at 10% worldwide, despite concerted efforts to improve safety and quality (World Health Organization, 2014). Current approaches to addressing errors in healthcare, such as root cause analysis, have been criticised for being reactive and focused on individuals, rather than systemic issues (Anderson et al., 2016a; Cook and Nemeth, 2010; Wears et al., 2015). A new safety approach is being developed, which is termed resilient healthcare (Hollnagel, 2014). Resilient healthcare is a coherent set of principles that highlight the complexity of everyday clinical work and propose that clinicians' ability to adapt to pressures is key to safe, high quality care (Wears et al., 2015). Resilient healthcare has the potential to improve the quality of care by focusing on understanding the challenges and problems in clinical work that require constant adjustments and adaptations to ensure safe care. In this paradigm, understanding and increased adaptive capacity is essential for ensuring high quality care. Using these insights to improve quality provides better support for healthcare workers (Anderson et al., 2016a). In contrast, current regulatory and improvement approaches emphasise controlling healthcare work through policies, procedures, and checklists (Hollnagel et al., 2015).

Whilst there has been extensive theoretical development of resilient healthcare, there has been comparatively little translation of this theory to clinicians. There is evidence to suggest that resilient healthcare concepts can positively impact safety in healthcare practice (Back et al., 2017), but for this potential to be realised, there is an urgent need to engage clinicians in debate and discussion around these principles. Therefore, the purpose of this study was to develop a serious video game to communicate principles from resilient healthcare to clinicians, and to evaluate its feasibility as a prompt to reflect on practice.

Serious videogames offer an engaging medium to communicate new concepts, and have been shown to be effective training tools within healthcare in areas such as surgery, emergency

care and nursing (Ricciardi and Paolis, 2014). The serious videogame in this study was designed around a patient's journey through a hospital.

2 Theory

Resilient healthcare is concerned with organisational resilience, which is the ability of a work system to adapt safely to pressures (Ross and Anderson, 2015). An organisation is said to be resilient when its systems perform safely under pressure (Fairbanks et al., 2014). However, these principles are difficult to study in practice. The Concepts for Applying Resilience Engineering (CARE) model (Anderson et al., 2016a), presented in Figure 1, was developed to define and operationalise resilient healthcare principles to enable scientific study. In the CARE model, care outcomes are conceptualised as emerging from the interplay of misalignments between demand and capacity that generate the need for adaptation. Work-As-Imagined, in policies and procedures, does not always fit the reality of the clinical environment. For example, patients can be late, staff can be on leave and not replaced, equipment can be missing and so forth, requiring staff to compensate and adapt their work (Anderson et al., 2016a).

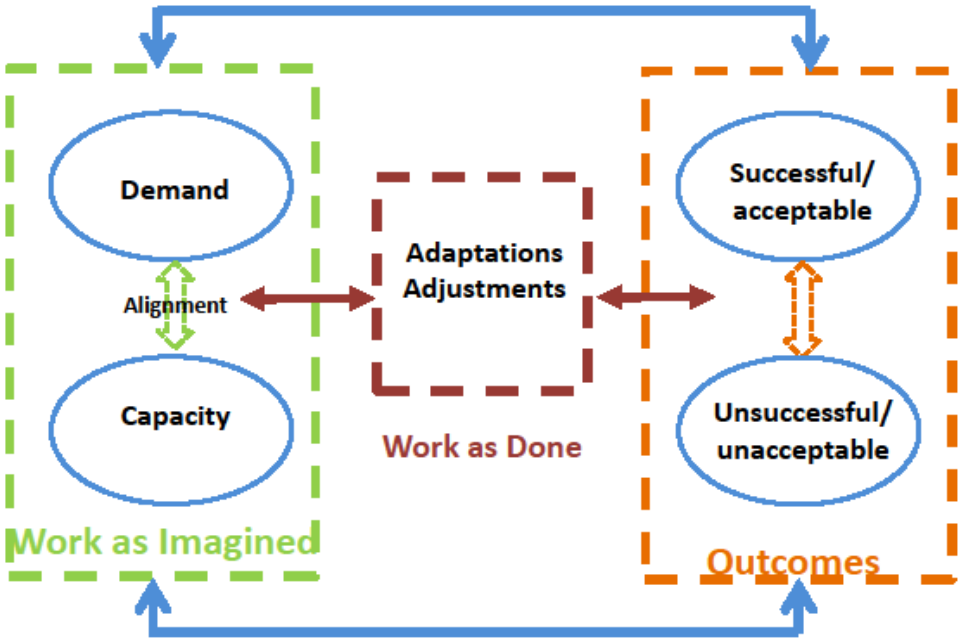

Figure 1: CARE Model of Organisational Resilience (Anderson et al., 2016a)

These adjustments are termed Work-As-Done, reflecting what actually happens in real world operations. Adaptation can lead to either successful or unsuccessful outcomes, based on emergent system conditions. Success is relative in this context; what may be acceptable for a healthcare professional is not necessarily acceptable for a patient, and what works one day may not work the next. The CARE model provides a framework for investigating and understanding how clinicians reconcile such tensions in their work environment, in order for an organisation to respond resiliently to pressures. This is in contrast to the implicit assumption behind many safety and quality improvement projects - that actions will always lead to the specified, planned outputs.

3 Serious Games

The domain of serious games is an academic discipline, which uses gamified tools to support learning and engagement (Iacovides and Cox, 2015; Lu, 2013). This format was chosen specifically because video games are able to promote reflection (Iacovides and Cox, 2015; Khaled, 2018; Mekler et al., 2018) and are known to influence attitudes and behaviours (Connolly et al., 2012). Hart et al. (2017) refer to serious games that are used to support training in domains such as the military, emergency services and healthcare as 'safety-critical games', as errors within these areas are likely to have significant physical and psychological consequences.

In healthcare, serious games have been successfully used with healthcare providers to, for example, support training in surgical procedures, to allow nurses to practice assessment, prevention and treatment related patient skin integrity, to simulate the placing of electrodes, and the recording and reading of electrocardiographs (Ricciardi and Paolis, 2014). Many games have focused on specific skills and activities, but others have broader aims. For instance, Iacovides and colleagues (Iacovides et al., 2019; Iacovides and Cox, 2015) explored

the use of different games to raise awareness of 'blame culture' in healthcare. Moreover, Hannig et al. (2012) describe *eMedOffice*, which introduces medical students work system problems that can affect practice. The findings of these studies indicate that games may serve as powerful tools for engagement, reflection and learning.

4 Methods

4.1 Development of the game

The serious video game *Resilience Challenge* (also referred to as 'the game') was created through a series of stages. This work was completed through collaboration between nurses, safety scientists, a serious games expert, and a digital arts studio. The initial setup, planning, development, launch, and evaluation are summarised in Table 1, and discussed in more detail below.

Table 1: Stages of Video Game Development over 7 months

Initial setup	Apply for and receive funding Attend Serious Games conference Write brief and recruit agency bids, including social media marketing strategy Write and broker contract
Planning	Review best practices/research literature around serious games Host afternoon workshop to develop scenarios, with 2 nurses, a safety scientist, a serious games expert, and a digital arts studio Create storyboard of the game Meet with game developers to outline project Provide developers with contextual information, and images of hospitals
Development	Review resilient healthcare literature and identify key concepts Refine game narrative Design game process and develop pilot Extensive user testing, including a focus group Provide iterative feedback to developers about game design, including accuracy of medical imagery Ensure characters in the game represent healthcare workforce diversity Develop evaluation survey for the game
Launch	Approve final version of game Design social media strategy Write blog and social media posts for target audiences Plan and host launch event

Dissemination	Game publicised on social media Public presentation of game (9 presentations, Feb 2017- Sept 2018) Write and publish blog posts on various websites (9 to date) Email game link to healthcare and safety staff mailing lists Promotional game postcards distributed with QR code
Evaluation	Complete evaluation of game content and process, using survey (Feb-June 2017)

An initial workshop was held to develop the game's narrative, which was refined during further development and testing. At the beginning of the game, a player receives a brief introduction to organisational resilience, then starts the game itself. *Resilience Challenge* presents a series of five scenarios, in which the player guides a patient's journey through the hospital. The player takes on a variety of healthcare roles, and must choose from three options to respond to dilemmas presented during each scenario. The options presented are not ideal; all require an element of adjustment from what would be considered best practice. The player has to decide which option is most acceptable as part of patient care delivery. For example, in the first scenario, a patient needs to be transferred out of the emergency department but there is no bed on the appropriate ward. The player must choose between keeping the patient in the emergency department, moving the patient to a different ward, or moving the patient to a hallway. Figure 2 presents an image from Scenario 1 in *Resilience Challenge*, where the patient is waiting in the emergency department.

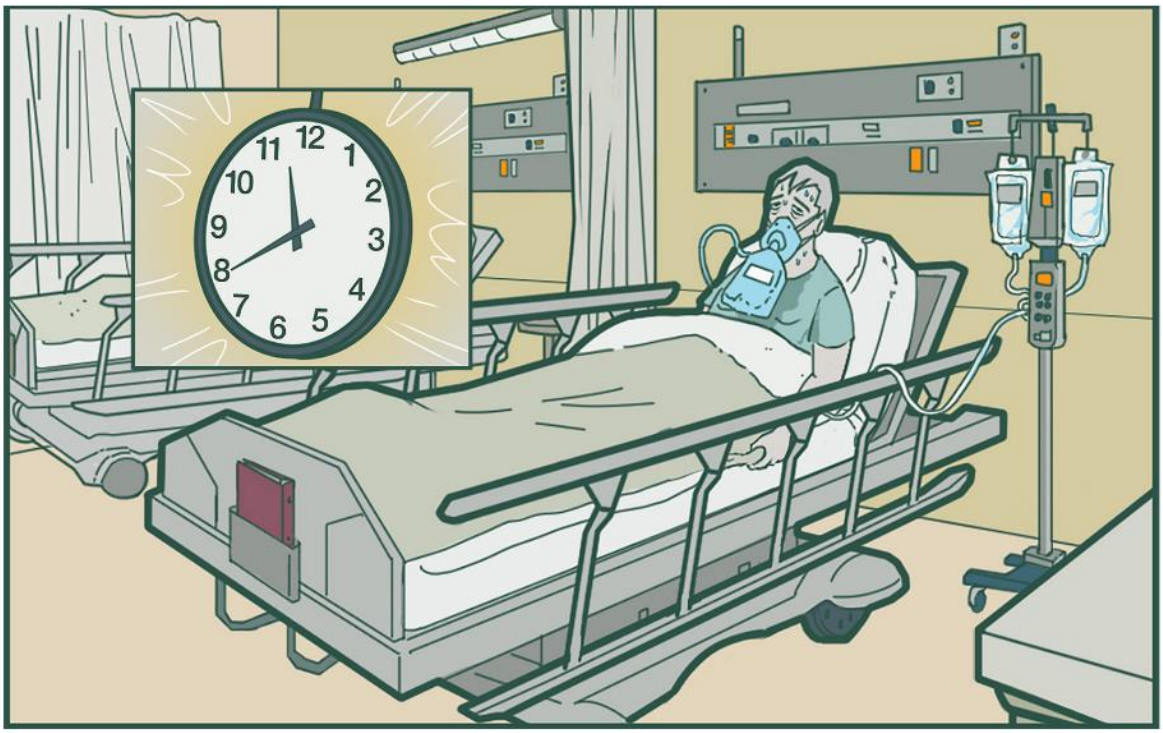

Figure 2: Image from *Resilience Challenge*

There is only one path, or set of responses that allows a player to move through the game. A player could not progress in the game unless they had chosen an 'optimal' response. When a response was chosen, the players received feedback about their answer and why it was or wasn't considered the optimal response. There is an ambient soundtrack that accompanies the game, to simulate a busy clinical environment. At the end of the game, the patient has improved, and thanks the player for their care.

Resilience Challenge was launched online in February 2017. An evaluation survey questionnaire was integrated with the game and players could choose to complete the survey after playing. The purpose of the survey was to evaluate the content of the game and to assess the feasibility of using a video game to convey resilient healthcare principles. The survey was live from February to June 2017 and is described below.

4.1.1 Ethical Considerations

Full ethical approval from the Florence Nightingale Faculty of Nursing, Midwifery & Palliative Care at King's College London was obtained on November 3, 2016, LRS-16/17-3787. There were no known risks to participating in this research. Participants were required to confirm that they had read an informed consent information page before completing the survey.

4.1.2 Data Collection

The original on-line survey developed to evaluate *Resilience Challenge*, contained 12 questions for clinicians. There was also a survey for people who were not clinicians, which will be reported elsewhere. The healthcare professional survey consisted of four demographic questions, followed by six Likert-type questions, asking participants to rank their agreement with statements about the game on a five point scale from Strongly Agree, to Strongly Disagree. Finally, there were two open ended questions: a) Has playing the game caused you to reflect on your own practice? If so, in what ways? and b) Do you have any other comments regarding the game?

4.1.3 Data Analysis

Survey data were automatically generated from the website as descriptive statistics. The surveys yielded quantitative and qualitative data and analytic data in the form of fixed-response survey questions were analysed with descriptive statistics using SPSS v22. Framework Analysis (FA) (Gale et al., 2013; Smith and Firth, 2011) was used to analyse findings from the free-text responses in the survey. FA is well suited to cross-sectional, descriptive data (Ritchie et al., 2003). In contrast with other methods of qualitative data analysis, FA allows for deduction using existing models and theories, and induction for emergent themes (Ward et al., 2013) which is the approach used for this analysis. The CARE Model (Anderson et al., 2016a), shown in Figure 1, was used deductively. Inductive themes

were also created when these data presented concepts outside of the CARE model. The NVivo v12 software management tool was used to organise these data. The following section presents the findings from this evaluation.

5 Results

5.1 Analytic and demographic data

The website hosting the game was designed with automatic analytic capacity to monitor how many times the game was played and where. These data are presented in Table 2: Gameplay analytic dataTable 2. The top five locations accounted for 86% of the total game plays. Please note: the N value varies in the tables, as not all participants answered every question.

Table 2: Gameplay analytic data

Location	Number	Percentage (where applicable)
United Kingdom	1,230	63%
United States	145	7%
Canada	122	6%
Australia	111	6%
Belgium	80	4%
Other	261	14%
Total Game plays	1,949	
Number of Unique users	1,559	

The demographic information for the participants is presented in **Error! Reference source not found.**. Overall, 141 people completed the survey, from the February 2- June 8, 2017. Of these, 107 self-identified as healthcare professionals. The mean age of participants was 40 years (N=103, SD 1.8 years). There were 87 female participants and 20 male participants (N=107) in the study.Table 3 displays the professional role of participants.

Table 3: Professional roles of healthcare participants (n=99)

Role	No of Participants	Percentage
Registered Nurse	54	54.5%
Student	11	11.1%
Physician	13	13.1%
Midwife	4	4.0%
Human Resources	3	3.0%
Occupational /Physiotherapist	3	3.0%
Research Associate	3	3.0%
Dentist	2	2.0%
Physician Assistant	2	2.0%
Psychologist	2	2.0%
Pharmacy Technician	1	1.0%
Therapeutic Radiographer	1	1.0%

5.2 Likert-style questions

There were 107 participants who self-identified as working in healthcare settings. These participants responded to six statements about the game, as reported in Table 4. These statements assessed whether the game translated concepts from resilient healthcare effectively, and if the game was engaging.

Table 4: Survey responses from clinicians

	Disagree		Somewhat Disagree		Neither Agree nor Disagree		Somewhat Agree		Agree	
Item	N	%	N	%	N	%	N	%	N	%
The game is relevant to my work	1	1	6	6	12	11	31	29	57	53
The game is engaging	1	1	1	1	6	6	34	32	65	61
I would recommend the game to others	0	0	2	2	10	9	26	25	68	64
Playing the game increased my awareness of how clinicians adapt safely at work	5	5	9	8	17	16	32	30	44	41
Playing the game helped me think through the impact of my actions on patient safety	1	1	4	4	13	12	33	31	56	52
The game introduced me to the concept of organisational resilience	12	11	8	8	18	17	39	36	30	28

From Table 4, it can be seen that the modal response for items 1-5 was 'Agree', indicating that most participants found the game relevant to their work, and engaging, and would recommend the game to others. Participants found that playing the game increased their awareness of how clinicians need to adapt and the impact of their own actions on patient safety. For the final item, the modal response was 'Somewhat Agree', and responses were more spread across the scale than previous questions. This indicates that participants were less sure that the game introduced them to the concept of organisational resilience.

5.3 Findings: Qualitative Data

Framework analysis was used to analyse 153 free text comments written by participants. These findings are presented in the following section. Section 5.3.1-4 refer to deductive themes generated from the CARE Model (Figure 1) and Section 5.3.5-9 refer to themes that were generated inductively.

5.3.1 Demand

The first deductive theme was demand, which "refers to pressure in the clinical environment and includes requirements for effective care, such as the targets and standards set by regulators and policy makers" (Anderson et al., 2016b, p. x). Participants placed a particular emphasis on the role of daily pressures and challenges in their work. Participants reported that the pressures presented in the game reflected clinical realities. [The game] *highlights day to day issues that are frequently seen in practice (A39)* and *highlights the pressures we all face every day (A35).* Participants highlighted that clinical staff face the brunt of the demands within the healthcare system. However, some participants thought that *Resilience Challenge* did not go far enough to capture reality of their clinical environments. *This was not comparable to the stress and pressure that you can be put under in the clinical environment (A11).* It was notable that participants referred to pressures as a whole, without naming things like staffing as specific examples.

Participants discussed the way that the expectations of senior managers can add to the pressures and demands of their roles.

> *I know I always put patients' safety first. What (the game) gave me was the knowledge that I can make the right decisions but that's not how the NHS works. You have to make the right decisions (based on) your senior management and what they have in their heads as priority (A29).*

Participants also recognised that management staff face their own demands. *It helped see the pressures other staff are under too (A7)* and reported that the different professional roles in the game raised their awareness of the universality of pressures in healthcare.

5.3.2 Capacity

Capacity refers to resources within a system that are available to meet demands. These can include "a range of capacities, including numbers of staff, their skill mix, physical infrastructure and equipment, processes, procedures and protocols" (Anderson et al., 2016b, p. x). A participant identified the organisation as a whole as being the source of organisational capacity. *This is interesting because it's about more than expensive technology- it's about having more strategic approaches and an organization-wide culture of robust systems (C22).* An emphasis on staff adapting to pressures could mask chronic under-resourcing in the system. Conflicting views were reported on how this was represented in the game.

> *I worry that* [Resilience Challenge] *can be seen as passive acceptance of an unsafe situation rather than also talking about how front-line staff can engage in improving the capacity of the system (C52).*

Participants felt they must meet demands, but might not feel empowered to try and increase capacity in the system.

5.3.3 Adaptation

The third deductive theme was adaptation, referring to "mismatches of demand and capacity that require clinicians to work around problems and devise solutions" (Anderson et al., 2016b, p. x). Participants remarked on how the adaptations required in *Resilience Challenge* helped them to recognise the value of adaptation. *Made me reflect on fact that adapting my behaviour and not always giving a " textbook " answer and deviating from protocols may be the correct thing to do (A2).*

Participants discussed at length the nature of decision-making in adapting to pressures, including one free text response of over 300 words, in which the participant described decision-making scenarios in other settings, such as mental healthcare. Participants also identified the limits of adaptation, through decision making.

> *Some decisions has (sic) to be done under pressure and playing the game showed me that sometimes taking a plan B is right but breaking policies is not. Thinking outside (or inside the problem box) can help patients. This is a concept that shows that flexibility is necessary in some scenarios* [sic] *(A5).*

Participants clearly identified the difficulty associated with making decisions. Participants reflected on the potential trajectories that their decisions could create, and how difficult it could be to reconcile these outcomes with their goals for care. The emotional aspects of decision-making was highlighted as being difficult, and a source of stress and anxiety.

> *What the game also did was help me reflect on how frustrated I get with some of the scenarios as I could feel my anxiety increasing with each scenario. I can imagine all of those scenarios happening and how unsupported I feel when they do happen. Each scenario usually involves a conflict with other workers/patients/family members and as an RN how I navigate these stressors is important too. (A20)*

5.3.4 Outcomes

The fourth deductive theme was outcomes, which "are broadly viewed, and include consequences for patients, staff and the organisation" (Anderson et al., 2016a, p. 3). Participants considered the potential outcomes of each scenario, and the consequences for patients. It was the outcomes with which participants most frequently disagreed; for example in Scenario 5:

> *I disagree with one answer, when the man starts talking about going home and it is the drug round I would have spoken to the patient when they ask a question even (for) just a few minutes and it can make the patient feel valued and listened to. By making a promise to go back to him and something happens and you are unable to go back it can muddy the therapeutic relationship (C3).*

This demonstrates how much clinicians prioritise engagement with patients. Others agreed: *Remember to put patient above your own needs (A38).* The emphasis was placed on supporting patients and providing safe care, despite challenging circumstances.

5.3.5 Reactions to the game

Overall, the process and design of *Resilience Challenge* was well received. The process refers to how the game moved from one scenario to another, and how users interacted with the game. Participants generally liked the design, use of sound, and the images in the game, although there was critical feedback as well (Table 5).

Table 5: Participant comments on the design of Resilience Challenge

Technology and Design	*It looks and feels great, is simple, realistic and very interactive. (C12)*
	Well designed and smoothly functioning. Good software. (C35)
	Well constructed learning resource - short and to the point. Well done!! (C32)
Sound	*I like the background distracting sounds, gives an element of realism (C50)*

	I liked the noisy background - felt real (C36)
Images	*The graphics are really good (C30)*
	I didn't find the pictures helped - they weren't easy to interpret. A bit of animation or video would have been better. (C54)

Overall, the game process and design were liked by participants, and were felt to support the content of the game.

5.3.6 Reflecting on Practice

Participants suggested the game helped them reflect on different aspects of their practice. For example, participants responded that playing *Resilience Challenge* highlighted interactions with colleagues. *Made me reflect how my actions can affect other healthcare professionals (A27)*.The game prompted participants to reflect on their decision-making. *I realized I did not always make the best choice the first time, so I need to think more before reacting (A44).* Overall, clinicians felt that the game encouraged them to reflect on their practice.

5.3.7 Safety

The game helped participants to reflect on the connection between their actions and safety. *Playing the game confirmed that I have patient safety at the forefront of all my decision making at work (A20).* Another participant focused on skills depicted in the game.

> *It was actually very helpful. It made me realize that when I'm distracted while giving meds, yes it's annoying to me, but also affects my patients negatively. I started thinking, what habits have I picked up in my practice that are causing me to practice unsafely. (A37).*

This demonstrates the utility of *Resilience Challenge* to start discussions about safety, as clinicians consider the safety implications of their decision-making.

5.3.8 The Correct Answer?

Some participants were adamant that there was a 'correct answer' to the scenarios and approached *Resilience Challenge* as a tool that evaluated whether they were making the 'correct' decisions. *I was relieved to note that most of the decisions I made in the video game were correct and I hope this is reflected in my practice (A28).* Other participants disagreed with the outcome of the scenarios, opining that a different choice should have been labelled 'correct'.

> *Also, in a real scenario, I would not have moved a medical patient to an orthopaedic ward without reassurance that they had medical doctors to cover them. And if that reassurance could not be provided I would not be moving my patient, especially if they were showing signs of sepsis. I would be escalating that case to bed managers. Patient safety first (A32).*

Some participants suggested that the game could serve as a means for an organisation to test its employees about safety, or be used to screen future employees.

> *I think this would be a great tool for hospitals to assess their care givers culture of safety. Especially new caregivers or new hires. As an organization I'm sure hospitals want to know what each individual does in their practice to ensure safety. As well as identify where caregivers need more education and support from the hospital to facilitate safety [sic] (C33).*

Others discussed decision-making in a nuanced way, reflecting the view that there is often no one correct answer to problems in healthcare.

> *Some of the choices given were challenging and my response was not considered to be the best response by the game authors. This allowed me to consider why the game's best choice was selected and whether this sat well with me (A25).*

These differences demonstrate varied perspectives on safety. There is a tension between a clear idea of right and wrong, and the perspective that patient care is complex, and doesn't necessarily have a correct answer and that adaptations are driven by contextual nuance and understanding.

5.3.9 Organisational Resilience

Resilience Challenge aimed to communicate ideas about organisational resilience to clinicians. However, there was a lack of understanding about organisational resilience for most participants. The survey comments suggested that only a few participants connected the principles of organisational resilience to the scenarios in the game. It appears that the principles of organisational resilience were not translated in a way that was accessible to participants. This could have been related to the current trend of the word 'resilience' being synonymous with personal resilience and emotional coping. *I think it would be helpful to include something about how the individual feels/ reacts in these situations when under pressure and what options they would take to maintain their personal resilience (C12).* Other participants referred to ideas from organisational resilience, but using different terms. *We continually risk assess and shift the parameters to maintain a safe functioning unit, by continually stretching the boundaries we have impact on all parts of the pathway (A33).* Some participants expressed confusion about the connection between the game and the concept of resilience. *This feels like a fairly simplistic approach and how does this transfer into an understanding of resilience? (A13).* These findings are discussed in the following section.

6 Discussion

This study has demonstrated that it is feasible to design an authentic serious video game to promote staff engagement with concepts from resilient healthcare. Overall, participants found the game to be relevant, engaging, and said they would recommend to others. Participants

also agreed that the game sparked thinking about adaptation and the impact of their actions on safety, even if they did not always connect these reflections explicitly to the concept of organisational resilience. While some reflected that flexible adaptation is an integral part of their jobs, others were more aligned with the idea that adapting practice to pressures is not always desirable. Debates about the contribution of individual responsibility and system shortcomings to quality and safety problems are highly topical. This can be seen in recent cases like that of Bawa Garba (Nicholl, 2018), a UK physician who was found guilty of manslaughter and gross negligence after a boy died under her care. This legal outcome was disputed by many doctors who stated that a lack of system resources were to blame. Playing *Resilience Challenge* is one way that issues around resources and decision-making may be surfaced and discussed openly.

6.1 Designing the game

Many aspects of the game were effective, such as the creation of a believable storyline and images. Field et al. (2018) found that a lack of realism in a serious game about air ambulances was a hindrance for participants. Great attention was paid to the details of *Resilience Challenge*, and participants reported that it was an accurate portrayal of healthcare and relevant to their work. Hart et al. (2017) described relevance to practice and authenticity as key factors for success in a safety critical game. The current study reinforces the importance of attending to detail and producing believable scenarios and accurate images.

6.1 Elicit reflections

Participants in the current study indicated that the game did help them to reflect on their practice. This supports other studies which have shown that games can elicit reflections, which is deemed worthwhile by players (Mekler et al., 2018), and have the potential to improve patient safety (Aubin et al., 2012). However, Mekler et al. (2018) found that it is rare for participants to experience transformative reflection to enable them to translate ideas from

videos games into their lives. Participants in the current study did experience a measure of critical reflection and some suggested that they were going to change aspects of their clinical practice. This could be followed up further in a future evaluation to see if participants did make changes in their practice, and if so, whether these changes were sustained.

6.2 Translating ideas

An aim of this study was to design a game to translate the concepts of organisational resilience for clinicians. Responses to open ended questions indicated that some participants interpreted the game as a way to test the accuracy of answers, a response that presupposes that correct responses can be easily identified and judged. The aim of the game was to raise awareness of the difficult challenges faced by clinicians that require flexible adaptation, and this concept was not easily grasped by all participants. It does illustrate the need to change conversations about how safe, quality care is achieved in complex healthcare environments, and about the ubiquity of adaptation in healthcare work.

Organisational resilience was not named throughout the game, which may have limited the clinicians' ability to connect the scenario content with the overarching concept of organisational resilience. In a future iteration of the game, the information about organizational resilience could be made more prominent, to enhance the linkages between the concepts and their role clinical practice. In a formal educational context, this could also be achieved through debriefing where the game is used as a tool to facilitate discussion with a facilitator that ties the experience to key learning points.

There is increasing recognition of the educational value of serious games for healthcare professionals (Ricciardi and Paolis, 2014; Sipiyaruk et al., 2018). *Resilience Challenge* has potential uses for healthcare staff education. Serious games can be more cost effective than other educational methods (Field et al., 2018; Ricciardi and Paolis, 2014) and are more engaging than other types of digital education tools, like e-learning modules (Dankbaar et al.,

2017). *Resilience Challenge* could be updated or modified for comparatively low cost, incorporating feedback and improving its effectiveness. The convenience of serious games suggests they could be used as an adjunct to traditional clinical education and to reach staff that do shift work, and may not be able to attend traditional education sessions (Lomas, 2008).

There could be limitations in the extent to which a serious game can teach about new concepts. While it is generally agreed that serious games are more engaging than traditional teaching or e-learning modules (Dankbaar et al., 2017; Field et al., 2018; Sipiyaruk et al., 2018), the evidence around learning outcomes has been mixed (Sipiyaruk et al., 2018). Dankbaar et al. (2017) found that students who had played a serious game had higher scores on a patient safety test than controls, but were not statistically different from participants who used an e-learning module. This may indicate that serious games are effective at engaging clinicians and eliciting reflections, but are not necessarily a superior teaching tool. In contrast, Kow et al. (2016) found that a serious game improved medical students' scores regarding patient safety and surgery. More research is needed to understand how serious games may support patient safety education.

6.3 Limitations

There were several limitations of this study. The scenarios in the game were limited to four different professionals (administrator, physician, x-ray technologist, and nurse), and one setting (a hospital). Resilient healthcare has the potential for system-wide application, which was not represented in the game. Further, the nature of the survey meant that it provided limited insight into how the game facilitated reflection, and how participants reached their conclusions. The survey was conducted using non-validated tools, which were used for the first time. Additionally, the participants were a convenience sample, which may not reflect the breadth of healthcare experiences.

6.4 Future work

There are many opportunities for further development of serious games about resilient healthcare. For example, the game could be expanded to allow for multiple players. Collaborative games with multiple players present an opportunity for students to work together, and are feasible and effective in medical teaching (Hannig et al., 2012). There could be more scenarios created, reflecting different practice settings and different professional groups and there could also be applications of the game in different contexts. The game could be used more formally as a tool to prompt discussion about patient safety for student learning.

7 Conclusions

A serious video game proved to be a feasible way of translating theoretical ideas into healthcare practice. The design of the game emphasised accuracy, and the complexity of everyday clinical work. The game also stimulated reflections on practice by offering players ambiguous choices. Serious games can support healthcare professionals to reflect on their practice, and help them think about how to adapt safely to pressures. *Resilience Challenge* is a promising way to engage with healthcare professionals and potentially improve safety in healthcare, and warrants further research. Future studies with serious games could explore links between reflection and clinical practices, increasing educational impact, and addressing specific safety concerns in healthcare.

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