SEPSIS COLLAB: A Virtual Reality Training Simulation For Sepsis Treatment

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ABSTRACT

Sepsis is a main cause of death, by infection in the world. Despite modern treatments, mortality and morbidity could be reduced by improved training of the clinical teams. SEPSIS COLLAB (developed using Unity game engine and C# programming language for Meta Quest 2) is a unique virtual reality simulation for training both doctors and nurses to treat sepsis. It was evaluated with the help of 110 volunteers, in terms of usability (System Usability Scale) and knowledge acquisition. The latter used pre-/post-tests based on clinical treatment guidelines. Participants were divided into a control group (doctors n:35 and nurses n:20) who did not use SEPSIS COLLAB and a test group (doctors n:35 and nurses n:20) who did. The consensus regarding the usability of SEPSIS COLLAB was rated as excellent. Analysis showed significant improvement in the post-test results of the test group compared to their pre-test. There was no significant difference in the pre- or post-test scores of the control group. The test group performed significantly better in the post-test than the control group. These findings show SEPSIS COLLAB has potential to provide positive educational benefits to medical teams in their treatment of sepsis and act as a complement to traditional in-person training.

Keywords: VR Medical Training Simulation, Sepsis, Sepsis Screening Tool and Sepsis Six Bundle, Collaborative Learning, Instructional Design.

1 INTRODUCTION

Sepsis is a life-threatening response to an infection that can result in organ and tissue damage [1]. It is a leading cause of death worldwide with an estimated 49 million people developing sepsis and 11 million people dying from it around the globe each year. In the United Kingdom, there is an approximated 52,000 annual deaths due to sepsis [2,3]. To reduce the number of fatalities, the standardised 'Sepsis Screening Tool' and 'Sepsis Six Bundle' were developed for the early identification and treatment of sepsis [4]. This flow-chart helps the clinical team identify if there is a high probability a patient has sepsis. If presumed, the Sepsis Six Bundle is conducted. The bundle involves six elements: the provision of oxygen, fluids and antibiotics within one hour and taking blood cultures, blood gas and measuring urine output. Despite these frameworks showing evidence of reducing death, mortality rates remain high which has been attributed to low compliance rates by the clinical team [5].

To address these issues, it was suggested that clinical performance could be improved by collaborative learning between the teams of doctors and nurses [6,7]. This would generate a better appreciation for the different team roles and a clearer understanding of each discipline's responsibilities in caring for the patient. Previous attempts to implement sepsis training through collaborative face-to-face training have resulted in improved transparency and achievement of goals [8,9]. Despite this, low participation in the collaborative learning processes, by the different clinicians, has hampered its success.

An alternative approach to using traditional face-to-face training could be to use computer-based simulations. For example, a recent study developed a PC-based multi-user simulation that was designed for on-line collaborative learning about the treatment of sepsis [10]. The simulation improved the users understanding and of sepsis. To make these types of computer-based simulations more immersive Virtual Reality (VR) could be used. In doing so this approach may further improve the clinicians understanding of how to treat sepsis, leading to improved long-term clinical performance and ultimately better patient care [11]. Existing VR simulations for training in Sepsis have been developed for a single health discipline rather than encouraging collaborative training amongst the different clinical teams [12, 13].

2 THEORY

In this work the authors hypothesise that implementing a collaborative VR-based sepsis training program can lead to improved interdisciplinary clinical knowledge, performance and attitudes towards the roles within the sepsis clinical-care team. SEPSIS COLLAB was developed in collaboration between the Department of Computing and Data Science, Birmingham City University (UK) and Sepsis clinical teams from Sandwell and West Birmingham NHS Trust (UK). It converts the normal written instructions of the Sepsis Screening Tool and Sepsis Six Bundle and recreates the scenarios into an interactive multi-user room-scale VR simulation. The simulation is designed to be used simultaneously by both doctors and nurses working together.

3 SIMULATION DEVELOPMENT

SEPSIS COLLAB (Figure 1) was developed using Unity 2020.3.29f and the C# programming language for the Meta Quest 2. Clinical accuracy was ensured through consultation with clinical specialists from University Hospitals Birmingham NHS Trust (UK), Sandwell and West Birmingham Hospitals NHS (UK) Trust, and the Sepsis Trust UK. The simulation is designed for a maximum of 4 users. Normcore.io was used to implement teamwork in VR. Doing so allows for participants to interact through voice and see each other's simulated avatars including their interactions, movements (such as their hand movements, teleporting and walking). SEPSIS COLLAB requires two users to take on the role of doctors and two more taking on the nurse role.

The users can interact with their environment by selecting buttons (which are highlighted when hovered over with the laser from the handheld controllers) on the user interface in the form of a clinical computer menu and a patient menu. These menus are used

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by the team to decide what to do and conduct clinical examinations, tests, sepsis screening and carrying out the sepsis six bundle to treat the simulated patient. SEPSIS COLLAB is a room-based VR simulation, as such the users can physically walk around the virtual environment within a set boundary. Alternatively, they can choose to move around the environment through teleporting.

Virtual objects such as stethoscopes, thermometer and other clinical equipment can be picked up from the medical trolley. SEPSIS COLLAB also includes sounds expected in a real-world clinical setting such as patient observation machines and patient lung and heart sounds.

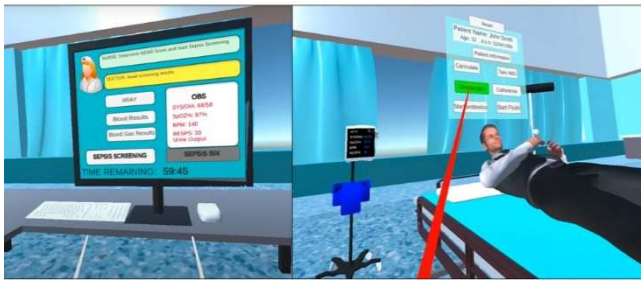

Figure 1: Screenshots of the screening and sepsis six bundle menus and patient in SEPSIS COLLAB

During the initial orientation tutorial, the team work together on one computer simulated patient. They must determine if the patient has sepsis using the Sepsis Screening Tool and Sepsis Six Bundle. Subsequently they provide appropriate treatment for the patient. Whilst using the simulation the users are given guidance in the form of digital menus as well as text and verbal instructions. SEPSIS COLLAB indicates if user interactions are correct via audio (bell dings or buzzer sound effects, a simulated assistant informing the participants if they were correct/incorrect and successful or unsuccessful in treating the patient) and visual cues (ticks and crosses).

The simulation does not allow the team to use the sepsis six bundle until the sepsis screening tool has been correctly completed. The correct outcome to this part of the simulation is if the team determine that there is a high possibility of the patient experiencing sepsis or not. If they do not complete it correctly, they are unable to proceed to the next stage, the sepsis six bundle, and the simulation can be reset to try again. After the tutorial, the team can practice their newly acquired skills on 4 different computer-generated patients in a simulated emergency department. The team are required to determine which patient has sepsis and treat accordingly while acknowledging the priority order of the patients. Throughout SEPSIS COLLAB, the team can track their progress via a feedback checklist within the simulation.

3.1 Simulation Testing

SEPSIS COLLAB was evaluated with 110 student volunteers from nursing (Birmingham City University) and doctors (Sandwell and West Birmingham NHS Trust). Fifty-five students used SEPSIS COLLAB (35 medical F:15, M:20 and 20 nursing, F:11, M:9). A further 35 medical (F:15, M:20) and 20 nursing students (F:12, M:8) formed a control group who did not use the simulation. The volunteers were either fourth or fifth year medical and third year nursing students, as training in sepsis treatment is part of the curriculum at these levels of their study.

Both the control and test group completed a written pre-test and post-test quiz (TABLE I). The questions were written by clinical educators and based on sepsis learning and training objectives. Success was based on undergraduate clinical grading criteria where students require 60% or more to successfully pass. The total marks available in either test was 71 and the tests were graded by clinical educators (see Supplementary Materials – Appendix I).

To gain views on user experience with SEPSIS COLLAB, students completed System Usability Scale (SUS) [14] and a subsequent verbal interview with the students and their teachers. A further follow-up interview was conducted with them five months after initially using the simulation.

TABLE I

QUESTIONS IN THE PRE AND POST TESTS

Pre-test Questions (Maximum mark = 71)	Mark
Name the non-specific sepsis symptoms	8
What are the clinical signs of sepsis?	8
What are the red flag sepsis indicators?	10
What are the yellow flag sepsis indicators?	9
Name the six stages of the sepsis six bundle	6
How quickly should sepsis care be implemented?	2
When should antibiotics be administered?	2
What are the stages of the screening process?	8
Why would you stop antibiotics in a suspected sepsis patient?	2
Why is providing fluids important in treating a sepsis patient?	2
What antibiotics are used to treat the four types of sepsis?	8
Describe the process after applying the elements of sepsis six.	6
Post-Test questions (Maximum mark = 71)	**Mark**
Name the clinical signs that may indicate sepsis	8
What are the sepsis red flag symptoms?	10
What are the six stages of sepsis six?	6
What should be done after the fluid challenge is complete?	6
Why would you stop antibiotics for a suspected sepsis patient?	2
Why would you continue fluids for a suspected sepsis patient?	2
Why would you consider contacting critical care after sepsis six?	4
What would you do if patient stabilises after sepsis six?	3
Describe the process after applying the elements of sepsis six.	6
Describe the sepsis screening process	8
What are the different possible causes of sepsis?	8
What antibiotics are used to treat the four types of sepsis?	8

4 RESULTS

Statistical analysis was conducted using parametric paired t-test to evaluate each group's pre-test and post-test results. Unpaired t-testing was used to analyse the difference between the two groups regarding the pre and post-test. After calculating the SUS score, and the mean rating and standard deviation for each statement, parametric t-tests were used to compare the responses between the positive and negative SUS statements.

4.1 Pre-Test and Post-Test Results

There was no significant difference between the pre-test scores in students who used SEPSIS COLLAB (45±19.6%, n:55) and the control group who did not (32±16.0%, n:55). For those who used the simulation, there was a significant difference ($p<0.05$) in the pre-test (45±20.0%, n:55) and the post-test (95±4.8%, n:55) scores. There was also a significant difference ($p<0.001$) in the post-test

results between the students who used SEPSIS COLLAB (95±4.8%, n:55) and the control group (46±19.3%, n:55). Statistical analysis showed no significant difference between the pre- and post-test scores in the control group.

4.2 Usability Results

SUS consists of 10 statements (TABLE II) rated between 1 (Extremely Unlikely) to 5 (Extremely Likely). The average SUS Score for all users was 88 out of a possible 100. There was a significant difference ($p<0.00$) between the positive leading statements of the survey (4.5±0.12, n:55) and the negative leading statements (0.2±0.91%, n:55).

TABLE II

SYSTEM USABILITY SCALE RESPONSES

Statement	Mean	Std Deviation
I think I would like to use this system frequently	4.71	0.46
I thought that the system was easy to use	4.47	0.58
I found the various functions well integrated	4.54	0.64
I imagine most people would learn to use this very quicl	4.57	0.63
I felt very confident using the system	4.39	0.63
I found the system unnecessarily complex	1.43	0.57
I think I would need technical support to use the systen	1.79	0.69
I thought there was too much inconsistency in the syste	1.36	0.49
I found the system very awkward to use	1.36	0.56
I needed to learn a lot of things before I could get going	1.64	0.83
Average SUS Score = 87.8		

Data presented as mean ± standard deviation from SEPSIS COLLAB participants

4.3 Qualitative Data

The students who used SEPSIS COLLAB praised the "quality of the graphics" within the simulation which aided the "visualisation of the sepsis treatment process." They felt that the simulation allowed for "visual learning" and appreciated the different clinical symptoms and audio (such as lung sounds) depending on the patient(s) presented. Working in a team helped them "appreciate and understand the different roles" of a sepsis clinical team. It also allowed them to "apply paper-based instructions to practice" in a "realistic clinical environment", thus aiding their understanding and application of the Screening Tool and Sepsis Six Bundle. The students also commented on how the simulated environment "realistically responded to treatment and interactions" in terms of their clinical observations (such as oxygen levels, blood pressure, test results, urine output, breathing). They also liked the presence of a tutorial at the beginning to "introduce them to VR" and understand what they are supposed to do. The students found it useful to then move to a simulated "realistic hospital ward" where, as a team, they had the chance to practice what they had learnt in the tutorial. From the students who used the simulation, 89% expressed how they wished they "had more opportunity to experience sepsis training via VR." The ability to reset the screening tool and being prevented from proceeding if a stage was incomplete increased the students' "awareness regarding what was expected" of them and "how to apply the written instructions."

The clinical teachers found after using SEPSIS COLLAB both nursing and medical students were "willing to collaboratively train together where they would normally be reluctant." Both disciplines acting together helped to "increase clinical empathy and encouraged acknowledgement of each other's roles." Collaborative communication also provided "practice for working in an interdisciplinary team" in a safe virtual environment.

The teachers also commented on the process of treating a sepsis patient with the appropriate antibiotics. It is based on the antibiotic micro-guide "which is used by hospitals and graduate clinicians." They expressed how this is a "much-needed aspect in sepsis training" that is not focused on often. Students tend to experience a lack of confidence due to having "limited knowledge and understanding of antibiotic treatment." However, the simulation provides "a good opportunity to practice this fundamental part of sepsis treatment." The teachers thought SEPSIS COLLAB could be applied whether the team of learners consist of students from the same discipline or instead a collaborative team. This is due to how the simulation "is all inclusive of the learning objectives the different disciplines require." The educators could envision repeated use of the simulation for their students and noted how the concept "could be applied to other acute medicine training scenarios."

5 DISCUSSION

After using SEPSIS COLLAB, the results show all users improved their knowledge and understanding of how to treat sepsis when compared to traditional clinical sepsis training. It encourages deliberate practice by consisting of two sections. The first is a tutorial that systematically guides the user in the correct way of treating a patient with suspected sepsis. The second part is a simulated emergency department with four patients. The simulation provides users with different forms of feedback on their progresses towards achieving the learning objectives for sepsis training.

In interviews with students five months after initial user evaluations, they expressed their willingness to use SEPSIS COLLAB again. They stated how their first use of the simulation helped them remember the key components of sepsis treatment. These were particularly the early provision of antibiotics, how to screen for sepsis and the expected process after completing Sepsis Six. A key finding from the interviews was how learners expressed that SEPSIS COLLAB aided their ability to work as a team in a simulated real-world environment and allowed. This developed their appreciation of the different roles within the clinical team when treating a sepsis patient. Learners stated they felt that they had improved confidence due to their better understanding and memory of the Sepsis Screening Tool and Sepsis Six bundle. The students expressed how they now give early consideration to sepsis if their patients present with any of the severe or moderate symptoms that act as indicators to the condition.

From a usability perspective (SUS) all users, from both health disciplines, rated it as excellent and easy to use. The perceived improvement in their confidence in understanding the processes behind the treatment of sepsis, after using the simulation, was supported by the improved knowledge acquisition in their post-test scores.

6 CONCLUSION

Findings from this paper's initial evaluation show SEPSIS COLLAB has the potential to provide VR sepsis training as a complement to in-person collaboration. As a result, the authors propose this simulation could be used in the wider clinical setting to tackle the issues of lack of appropriate sepsis training. To assess this, it is in the intention to explore the impact of SEPSIS COLLAB for further hospital trusts both nationally and internationally.

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