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Can Virtual Reality (VR) enhance students' learning experience?

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ABSTRACT

Immunology is a fascinating yet complex subject area to teach undergraduate students, mostly due to the vast specialised vocabulary and complex processes associated with the topic. One solution to this challenge is to embrace innovative digital technologies such as Virtual Reality (VR), which immerses users in an interactive environment and encourages them to actively participate in their own learning. This alternative teaching model also creates an inclusive learning environment, allowing students to learn at their own pace, aiding their comprehension of the material. Here we describe the development and implementation of a novel VR simulation at the University of Glasgow.

The bespoke 'Battling Infection' VR simulation takes place inside the human body: students visit different anatomical sites in their quest to eradicate an infection caused by the bacterium *Salmonella*, interacting with and choosing the appropriate immune cells to do so. We explored how this innovative resource could support medical and life sciences students with their understanding of immunity to infection. Following the interactive VR session, students completed a voluntary questionnaire to enable us to determine the impact this digital tool had on their learning experience. Most students surveyed agreed the VR simulation enhanced their understanding of the topic and helped them to visualise the complex processes of host immunity. Some participants commented on the discomfort of the headset and others suffered motion sickness, issues commonly reported within VR technology.

Overall, this study found that the VR simulation was an innovative model of educational delivery which enhances the student learning experience and helped students to conceptualise complex information. Future work will focus on student knowledge retention using this method of teaching, in addition to developing further resources to supplement the VR simulation and exploring immune responses to other pathogens.

Keywords: Virtual Reality, digital technology, innovative practice, immersive learning, inclusive teaching

Background

Immunology, the study of the immune system, can be a challenging subject for students to conceptualise and recall (Zhang & Bowman, 2021). Immunology teaching at the University of Glasgow is typically delivered through didactic teaching (lectures), practical laboratories and problem-based learning (PBL).

Virtual Reality (VR) can offer an immersive environment that encourages active participation with the subject matter. This aligns with our institutional strategic goal to redesign teaching to support interactivity and students' independent learning skills (University of Glasgow, n.d.). According to the popular DICE model, by leading VR researcher and head of the Stanford Virtual Human Interaction Lab Jeremy Bailenson, VR learning can offer an alternative to learning that would otherwise be Dangerous, Impossible, Counterproductive or Expensive and rare (Bailenson, 2018). VR experiences can take learners to the edge of a volcano, or condition firefighters' responses to simulated house fires. It can take learners on field trips to distant destinations for a fraction of the cost of airfare. And in the current context, VR can allow learners to do the impossible – to participate in immunological processes within the human body.

Research into the pedagogical efficacy of VR learning is a nascent field, but recent studies find that VR can provide a range of cognitive and motivational benefits over traditional learning (Makransky et al., 2019) as well as leading to higher rates of reported student engagement (Parong & Mayer, 2021). This 'On the Horizon' paper briefly outlines our work creating and implementing a novel VR simulation to supplement the teaching of immunology to undergraduate Medicine (MBChB) and Life Science (BSc) students.

Development of a 'Battling Infection' Virtual Reality simulation

Investment into VR technology at the University of Glasgow was initiated by a 2017 'VR Teaching Ideas' internal competition, to which a 'Battling Infection' simulation was pitched by authors Gillian Douce, Robert Nibbs, Simon Milling and Neil McDonnell. The bespoke simulation was developed as part of Project Mobius, an Innovate UK-funded project, in collaboration with industry partner Sublime Digital (now Edify, https://www.edify.ac). The aim of Project Mobius was to research the pedagogical benefits of VR and provide a data-driven approach to developing pedagogical content for immersive technology.

Students enter the VR simulation in the human intestine, whereupon they discover an infection caused by the bacterium *Salmonella*. Their task is to identify the appropriate protective immunological response by answering questions and interacting with immune cells to eliminate the infection, visiting various anatomical sites (intestine, lymph nodes, bloodstream) as they do so (Figure 1). The Battling Infection simulation was designed to offer students an alternative method for learning an overview of how the innate and adaptive immune systems interact in a successful response to an infection.

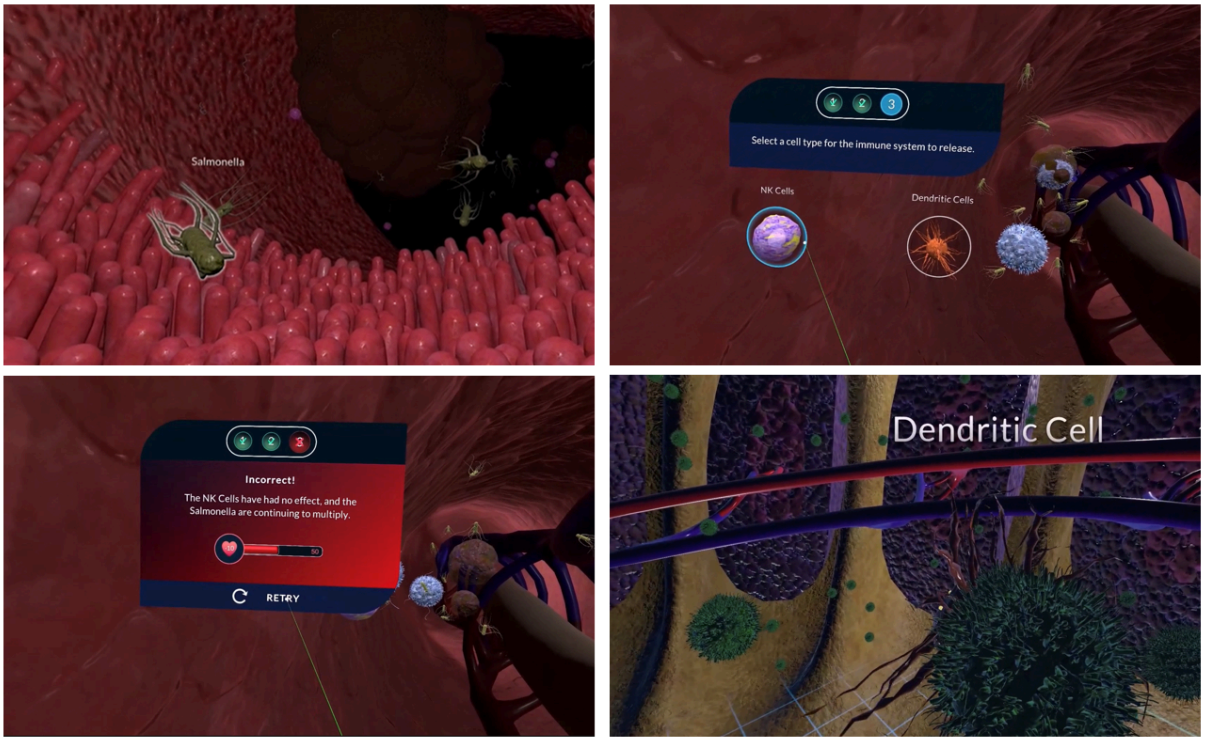

Figure 1: Screenshots from the Battling Infection Virtual Reality (VR) simulation. Students enter the VR simulation in the small intestine, where they encounter a *Salmonella* infection. They must then travel through the body, interacting with immune cells and selecting the appropriate immune response to combat the infection.

Implementation

The Battling Infection VR simulation was offered to year 1 undergraduate Medicine (MBChB) students (n = 330) and year 2 undergraduate Life Science (BSc) students (n = 278) in academic year 2022-23. The VR application was described to students as a lab, placing emphasis on the active role they would play while attending the session. MBChB students were also given access to an online pre-lab activity hosted on the Lt online physiology software (https://www.adinstruments.com/lt) to familiarise them with the subject matter and prepare them for the in-person VR lab. The pre-lab activity contained short questions and information about general concepts related to *Salmonella* infection.

All students attended the VR lab in small groups of up to 30 and were split into pairs. The custom Battling Infection simulation was delivered using head-mounted displays and hand controls. The simulation was also visible on a computer screen, giving the pairs of students the option to work together to navigate the environment and answer questions, and giving teaching staff the opportunity to provide help if required.

Following the completion of the VR lab, student experiences were evaluated using a voluntary subjective learning experience survey, administered via a QR code. All students were told verbally that their participation in the survey was entirely voluntary. A comprehensive Participant Information Sheet was the first page of the online questionnaire; students had to indicate that they had read the Participant Information Sheet and agreed to be involved in the study before completing the survey. Ethical approval was granted by the College of Medical, Veterinary and Life Sciences, University of Glasgow (200220012).

Findings

The online pre-lab was accessed by 92% (304/330) of MBChB students, with an average of 7/9 questions attempted. For the practical VR simulation, 96% (317/330) of MBChB students and 29% (81/278) of BSc students attended the laboratory, with most students completing the online survey (233 MBChB [74% of attendees] and 77 BSc [95% of attendees]: 310 undergraduate students total). For our analysis, results from both student cohorts were collated because responses between the two teaching groups were not dissimilar.

Of the 310 students surveyed, 57% (131, 56% MBChB; 45, 58% BSc) had never experienced VR before so this lab offered not only a new teaching method, but also a new technological experience. Participants were asked for their thoughts on the use of the VR simulation as a learning tool, and specifically if it enhanced their understanding of the subject and their enjoyment of the platform (Figure 2).

The survey data indicate that students enjoyed the Battling Infection VR simulation, and that it enabled them to visualise the immune system in space and time.

Most students rejected statements related to the VR being 'gimmicky' or too simplistic.

Students were also asked for their comments on what was the most and least enjoyable part of the VR simulation. The use of the VR as an alternative learning method was very well received by both student cohorts, with key highlights being the ability to visualise the complexity of the host immune response clearing a bacterial infection and the ability to interact with the animations, such as choosing a T cell with receptors that recognise the antigen on the dendritic cell. Furthermore, students felt their understanding of the topic increased which was partly due to the multiple-choice questions throughout the simulation, as illustrated in the comments below:

"Deciding which cytokines the T-cells should release and seeing if we were correct" BSc student.

"Being able to "see" the intestine and the immune cells and controlling which immune cells to use" MBChB student.

"I really really enjoyed it. It was interactive, I liked working in pairs and I liked how it was multiple choice to make things a bit easier. I took my time in looking around and processing the information/my surroundings. I really hope we get to do more of this in the future." MBChB student.

"the interactivity engaged me more than usual lectures … also feel it was able to condense hours of time that I'd have to spend learning lecture slides into a comprehensive 15-20 minutes." BSc student.

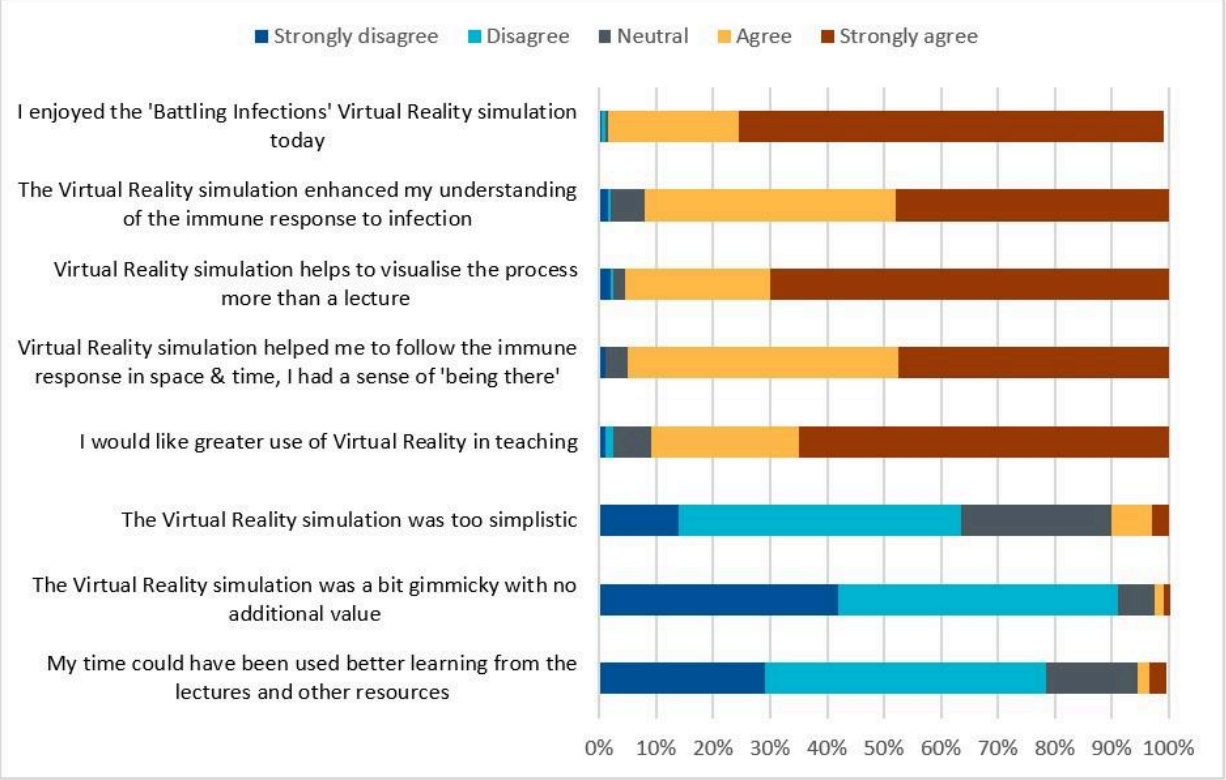

Figure 2: Student responses to questions exploring their experiences of using the Battling Infection VR simulation. Data are presented as collated responses from MBChB and BSc undergraduate students. Questions are presented in a different order to that in the online survey for ease of interpretation.

In line with previous studies (e.g. Marks & Thomas, 2022), some students said that they found the headset uncomfortable or had motion sickness during the simulation. The VR simulation was short – most students were able to complete it in ~20 minutes – and feedback suggests that some students would enjoy a longer experience:

"I get nauseous using VR :(" BSc student.

"It makes me feel weird/off balance" MBChB student.

"It was too short, would have liked a full hour it was so good" BSc student.

"I wanted to have the headset on for longer because it was so fun!! 😊 maybe even a game of attacking the pathogens or a group task." MBChB student.

Some students suggested using the same approach in different subject areas, such as anatomy, or to demonstrate the immune response to other pathogens, such as viruses, fungi and parasites:

"I think VR would be very useful for learning the body systems and their anatomy. I think it would be very useful for learning the circulatory system and the digestive system for example but I enjoyed the session just wish it was longer and more in depth" MBChB student

"Would be really cool to have the same game but with lots of different pathogens to respond to although I'm sure that takes a long time to develop" BSc student.

Building on our findings

Looking forward, we plan to implement a 'post-lab' activity on the Lt online physiology software to bookend the in-person VR lab. The post-lab will include a video recording of the VR simulation, with interactive short answer questions to encourage revision of the topics covered in the in-person lab. We hope that this will help consolidate learning and provide additional context to the VR lab.

Although this VR simulation was developed via a specific Innovate UK funding collaboration with Edify, we continue to explore alternative routes for building on this work and developing additional content to demonstrate the immune response to other pathogens, as recommended by students. One route currently being explored is working with colleagues in the Glasgow School of Art as part of the MSc in Medical Visualisation and Human Anatomy, whereby we aim to develop an environment that integrates 3D animation (potentially Augmented Reality) of a virus, fungus and/or parasite into our undergraduate courses. Such resources would not only prove valuable from a learning and teaching perspective but can also be used as an outreach tool to enable a wider audience to engage with and understand the processes by which the immune system responds to various pathogens (Slater et al., 2022).

Conclusions

Initial findings suggest that students find the VR lab to be immersive, fun, and engaging. Students said they had an 'active' role in their learning and that the VR simulation offered an alternative teaching style that helped to "put [the] learning in context" (Fabris et al., 2019; Marks & Thomas, 2022). Student feedback highlighted some pragmatic considerations for the future use of this digital technology, such as scheduling and providing reinforcement of the topics covered in the simulation. Future work should explore whether, and how effectively, this innovative learning experience helps develop student competency and understanding of the subject matter.

Biographies

Kirsty McIntyre is a Lecturer in the School of Medicine, Dentistry & Nursing, University of Glasgow. Her current scholarly research explores support of student transition into higher education and patient involvement in medical research and practice.

Leighann Sherry is a lecturer in Microbiology in the School of Infection & Immunity at the University of Glasgow. Her research background is in medical mycology and scholarship work focuses on embedding inclusive learning practices into the curriculum.

Genevieve Stapleton is a senior lecturer in the undergraduate medical school at the University of Glasgow. Her scholarship interests include academic development and student-centred learning.

Imants Latkovskis manages the University of Glasgow's extended reality research lab at the University's Advanced Research Centre.

Neil McDonnell is Professor of Philosophy and XR Technology at the University of Glasgow and was Co-Investigator on Project Mobius. He is responsible for the running of the University's XR research and teaching facilities.

Robert Nibbs is Professor of Chemokine Biology in the School of Infection & Immunity at the University of Glasgow. He coordinates the several undergraduate Immunology courses and has research interests in chemokines, immune cell migration and cancer.

Gillian Douce is a Senior Lecturer in Microbiology in the School of Infection & Immunity at the University of Glasgow. Her research is based on the study of intestinal bacterial pathogens and the design of new treatments to reduce disease.

Simon Milling is Professor of Immunology at Glasgow University, and Course Director for the Immunology Undergraduate Degree. He runs a research laboratory investigating the immunology of the intestine.

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