3D Virtual Eye Clinic: a proof of concept project

End of project report

November 2020

Summary

3D virtual worlds (3D VWs) are innovative environments with the potential to support immersive and interactive learning.

The aim of this project was to develop a 3D virtual optometry clinic and evaluate the use for clinical decision making and patient management. Secondly, to determine the potential for future development and use of 3D optometry clinics in the sector.

We built an interactive 3D virtual world with avatars, patients and optometric equipment.

We developed 3 cases and held 4 case discussion sessions with students. Interaction levels were measured by the word count from the transcribed audio recordings of the discussions. The knowledge levels and learning outcomes were assessed using pre- and post-quizzes. We also conducted short focus groups to hear what students thought of the experience.

Following the sessions there was an increase in the knowledge levels overall with the 3D virtual eye clinic (3D VEC). The 3D VEC was found to be equally as good as the 2D face-to-face discussion environment and encouraged both individually directed and group learning.

Further study with more students and cases would be required to fully understand the implications of the observed behaviours within the 3D WV. However, these findings suggest that the VEC has potential within optometry education. When considering the potential for future development and use of 3D VEC in the sector we considered it had several strengths:

- Evidence-based learning platform
- Immersive, interactive & collaborative
- Social networking element adds fun dynamic
- Scalable platform with many applications
- Remote delivery of education
- Closely replicates and emulates a real-world eye clinic
- Pseudo-identity avatars may encourage trainee participation
- Safe environment for optometry trainees to practice
- Particularly well suited to cognitive learning and OSCE style testing

There were also key weaknesses:

- Interactivity currently limited to basic gestures and textual communication
- VR world may be distracting or dissociative (Vs Real world)
- Lack of gamification and extrinsic reward/feedback systems
- Lack of data collection for post-hoc analysis and improvement metrics
- No MacOS, Web or Mobile platforms (May limit future traction)
- Not easy to upload cases in the present format

We concluded that the 3D VEC has the potential to revolutionise optometry training. The scalability of the platform coupled with the wide range of applications make it an exciting prospect. It is well placed to exploit emerging trends in digital education. Further funding will be necessary to develop the platform so that it is futureproof.

Introduction

Virtual clinics could have far reaching applications as they provide a risk free immersive and social environment in which to learn and share best practice. The aims of this project were firstly to develop a 3D virtual optometry clinic and evaluate the use for clinical decision making and patient management. Secondly, to determine the potential for future development and use of 3D optometry clinics in the sector. The LOC Central fund kindly funded the project. This report outlines what we did and what we have learnt.

Literature search

A literature search about the use of virtual worlds for clinical simulation in work-based learning was conducted by Jane Gray (optometrist). This guided many of the decisions we made about the development and the design of the clinic and the evaluation.

In summary, there is a significant body of evidence supporting the use of virtual reality technology in medical and optometry education. However, lots of people seem to have got to the prototype and proof of concept phase and not beyond. It was not clear from the published literature why other projects have stalled.

We hope to publish the literature review shortly.

The 3D Eye Clinic build

- ### Advisory Board

An advisory board was established to give guidance and feedback on the development of the 3D Virtual Eye Clinic. This included undergraduate and postgraduate optometry teachers/ academics, an e-learning technologist, the lead for e-learning technology for Cardiff University and a Social Scientise who is Professor of Medical and Dental Education at Cardiff University.

- ### The 3D virtual optometry clinic

A 3 D virtual optometry clinic was created by the Resound team with input from Jane Gray and Barbara Ryan (optometrists) and the Advisory Board (Figure 1).

Figure 1. The 3D virtual eye clinic viewed from outside

- Avatars

Computer avatars were developed. These were graphical representations of participants, designed to be in their likeness, as an alter ego or as a character. Figure 1 Examples of avatars within the 3D eye clinicshows examples of the avatar personas that people entering the 3D Virtual Eye Clinic (3D VEC) people participants select and assume a pseudo-identity avatar which enables them to participate and interact in a 3D virtual environment. The purpose of the pseudo-identity is to afford anonymity to the participant so they can engage more 'freely' and without prejudice within the environment.

Figure 1 Examples of avatars within the 3D eye clinic

The avatars used are able to move around within the virtual space, manipulate objects and change things which remain in their new state even when the participants via their avatars leaves the space. The viewing perspective of avatars can be altered from third person (watching the avatar in action) to first person (looking through the eyes of the avatar) or to a birds-eye view (flying drone mode), as shown in Figure 2 The different viewing perspective of an avatar outside the 3DVW Virtual Eye Clinic: a) 3rd person, b) 1st person and c) birds-eye view.

Figure 2 The different viewing perspective of an avatar outside the 3DVW Virtual Eye Clinic: a) 3rd person, b) 1st person and c) birds-eye view.

The avatars are not restricted by the physical laws of the real-world or the physical abilities of the participants and as such they are able to perform fun activities such as flying and breakdancing (Figure 3 An avatar enjoying breakdancing, one of the gesture actions in 3DVW.).

Figure 3 An avatar enjoying breakdancing, one of the gesture actions in 3DVW.

- Equipment

For the initial design phase of the project the equipment construction was prioritised. The choice was primarily based on clinical examination requirements; therefore, refraction equipment was not included. Clinical examination equipment was selected to provide the test results relevant to the clinical cases to be explored within the pilot study (Figure 5).

Figure 5 The equipment and the layout of it within the 3D VEC

The position of the equipment within the Virtual Eye was agreed by the project team and advisory group, this was further adjusted after the team were able to enter the 3D virtual world to include the addition of an optometrist's chair to sit opposite the patient, the test chart behind and the slit lamp adjacent to be moved across when external and internal examinations were performed (Figure 6).

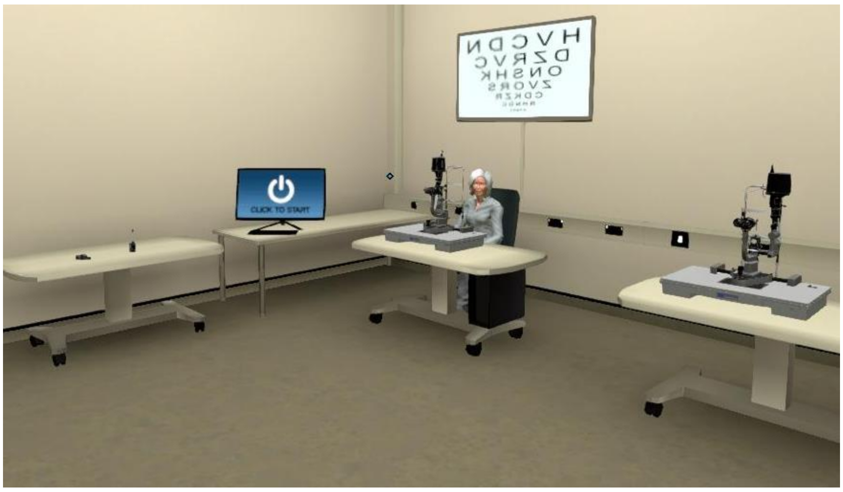

Figure 6 The slit lamp moves across to examine the patient.

Feedback from the Advisory Group identified that the level of fidelity within the design was a priority. So, the equipment was arranged to ensure the space had credibility and enabled the visitors to the VEC to accept the space as having validity with a sense of function and professional relevance giving a more realistic representation of what would happen in real-world optometric practice.

- Clinical Case Scenario Design

The learning objectives set for the project e-learning sessions were taken to be in alignment with the General Optical Council (GOC) stage 2 core competencies for UK optometry section on ocular abnormalities.

The virtual clinic was built with the capacity to contain 99 patient cases, but building case studies was time intensive, therefore, only 3 were developed for the prototype. The case series constructed included three patient clinical scenarios; cataract, glaucoma, and age-related macular degeneration (wet). The case scenarios were developed by Jane Gray an optometrist. The cases were reviewed by optometrists involved in UG and PG optometry education, to ensure they were at the appropriate level.

Patients were created for each of the three cases (Figure 7).

Each case included a full patient history and symptoms. Details of their general health, current medications, previous ocular history and family health history (general and ocular) were included. Life-style stories detailing employment and hobbies were created to satisfy the best practice guidance on taking full patient.

Figure 7 A practitioner avatar with a patient.

Voices of 3 people were recorded giving the history and symptoms for the three different cases and written text was also made available to view Figure 8.

For each of the cases, one student had to take the lead and be the practitioner. When this happened, they would get the crown (Figure 9).

Other students could listen and watch the case history (Figure 10).

Before examining a patient, everyone had to wash their hands (Figure 11).

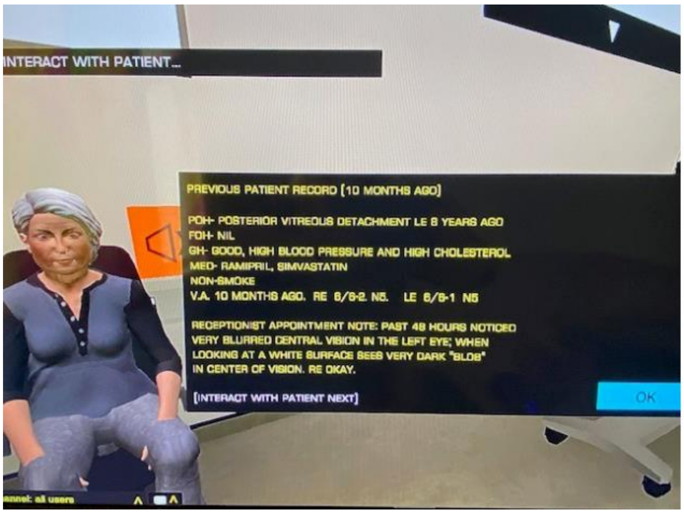

Figure 8 A patient history.

Figure 9 The optometrist wears the crown.

Figure 10 A group of students listening to a patient history and symptoms.

Figure 11 Washing hands at a sink before examining patients was a requirement.

All the students, via their avatars, were able to move around the space and locate the pieces of equipment and gain access to the result information by clicking on each instrument, either at the same time as a group or individually. As the participants hovered the cursor over the equipment it highlighted in pink and could then be clicked to access the information, which could be enlarged to review fine details (Figure 12).

Equipment included	images
Vision/Visual Acuity	
Current spectacle prescription	
External examination description. Anterior segment and media description and image (if pertinent)	
Fundus images and mydriatic drops information	
Image of the mires, intraocular pressures (IOP) and anaesthetic drops information	
Visual field plots	
OCT images including videos	

Figure 12 The equipment within the 3D VEC and the results displayed

A post-it type tool enables students to write up their diagnosis and treatment plan for each patient case, the space is voice enabled and has text chat, providing 3 communication channels for students when discussing cases (Figure 13).

Figure 13: Students using Post-it note tool to write up diagnosis and treatment plans

Evaluation

- Quantitative with students

A pilot study used opportunity sampling to recruit third year (Y3) undergraduate (n = 11) and first year (Y1) postgraduate optometry students (n = 8). During four study sessions, participants discussed three case scenarios. Interaction levels were measured by the word count from the transcribed audio recordings of the discussions. The knowledge levels and learning outcomes were assessed using pre- and post-quizzes. The quizzes comprised of 20 multiple choice and matching questions.

The results were quantitatively analysed using SPSS statistical software.

The word count demonstrated that both e-learning platforms were suitable environments for peer discussions. There was a statistically significant increase in the knowledge levels overall (n = 19) as p = 0.045. No statistically significance difference was found between the 3D (n = 9) and the 2D (n = 10) e-learning platforms in the pre-quiz scores (p = 0.394), post-quiz scores (p = 0.188) or the learning difference (p = 0.662). Group C (3D) had the lowest recorded word count (3312) but the second largest knowledge improvement (+1.59± 1.55). This group was observed to individually explore the learning objects, as opposed to operating as a group. This self-directed student-centred learning and decision making was not possible within the 2D platform.

The 3D VEC was found to be equally as good as the 2D face-to-face discussion environment and encouraged both individually directed and group learning. Further study xiii would be required to fully understand the implications of the observed behaviours within the 3D WV. These findings suggest that the VEC has potential within optometry education.

- Qualitative with students

Group discussions

Following their completion of the cases the students participated in a short group discussion (via voice and text chat) with Gill Brabner about the virtual clinic and its potential to support clinical education. 8 questions were used. Thematic analysis to identify and interpret key themes within the data.

In the facilitated discussions students from both groups referred to the space as being cool and fun and a fun way of going through patient cases. They used their current experience of clinical lectures with larger numbers of students as a point of reference and comparison when describing their experience in the 3D virtual eye clinic with the words engaging, fun, cool, emerging as a dominant theme to explain the 3D experience: 'more engaging' 'more engaged in this space that in a lecture but less than in a [physical] clinic' 'there was higher engagement and participation' 'with a group of 4 or 5 you have to be on the ball and engage and participate' 'more interesting' 'more fun…..lectures are not helping that much' 'similar to lectures…but a lot more visual' Further evidence of immersion, in both groups, is to be found in students' comments about their professional identity and the activity of being an optometrist in the 3D space: 'I feel more like a practitioner [in the 3D clinic]' ‘you’re physically doing it’ ‘feels more like a practitioner than just going through it in a lecture and they [tutors] are like; oh this is what it is’ ‘it’s more realistic’.

Students liked the hand-washing requirement, the black-box protocol that the clinical steering group added to the design, and referenced it as supporting their learning and practice. The students identified that having record cards in the 3D virtual clinic would support their skills development and importantly, accurately reflect the real-world work of an optometrist. Alongside the need for record cards all students’ voiced their disapproval of the post-it notes tool that they were asked to use to display their clinical decisions and treatment plans, instead they wanted more realistic tools that replicated the real-world clinic materials. This demonstrates the tension between play and fun and high fidelity, because the students had no difficulty in being represented by a gaming avatar in the clinic, or wearing a crown when they became the optometrist leading the case, but were unhappy about using a post-it note tool as this was not realistic.

Observation

‘Reactive’ observation is a category within naturalistic observation, which means that groups were aware that Gill Brabner was observing them in the 3D clinic and these observations were being used for a research study. When the students had finished working through the cases and reached agreement. Responses from group discussions were cross-checked against the video analysis and researcher observations.

Analysing the video recordings of the in-world sessions with students it is evident that the environment provoked a ‘felt-response’ and encouraged play. There is also a sense of excitement and anticipation discernible in the student voices as they grappled with their avatars and navigating the space. Physically the students were distributed across a university building, located in separate rooms, to test whether they experienced the 3Dworld as immersive. The lively discussions and the amount of laughter between students suggest that their embodiment in the 3D space enabled them to experience co-presence. Two voices dominated the first session, with other students preferring to use the text chat tool to discuss their clinical diagnosis and treatment recommendations, creating a lively channel of multiple communications and responses. The group managed to communicate together, simultaneously, over the different channels and appeared to derive enjoyment from working together. ‘was too big’ and another thought it was: ‘a bit daunting to have a group discussion.’

In contrast the second group were more reserved and initially wanted to work through the cases individually, and eventually they were encouraged to work as a group, Interestingly this second group became playful once the serious business of working through the patient cases and reaching agreement on diagnosis and treatments plans was done. At this point one of the students discovered the avatar movement and expressions tab and soon all the group were dancing and jumping around the clinic.

Video Analysis

Video recordings of the sessions were conducted by the learning technologist in-world. This means that the video recordings are viewed through the lens of his avatar, providing a very useful but incomplete data set in terms of perspective. The audio track from the videos were transcribed by the researcher and themes developed for analysis and the student interaction and playfulness from the video footage was recorded.

- ## Qualitative with tutors

In-world session would be made available for a small number of tutors and short semi-structured interviews would be offered to follow up on the in-world session should be added to the data collection. The in-world session for tutors followed a similar but abbreviated agenda to the students, as they were not there to learn about the cases but to experience the site as a potential environment for teaching. This session was videoed by the learning technologist and uploaded to a secure area within the department. 3 tutors attended the in-world session

The semi-structured telephone interview provided the tutors an opportunity to discuss their current digital teaching approaches and expand on their initial responses to the 3D clinic as a teaching space. Five interview questions were crafted to encourage interviewees to talk in depth about their teaching approaches and explore their thoughts about the virtual clinic.

In the tutor in-world session there was clear evidence of a playful approach being taken, despite the session being beset with usability issues including bandwidth issues, continual lag and a problem with audibility for one tutor. Even with the frustrations they had to contend with there was a lot of laughter especially about choices of avatars: 'Ohh! I wanted to be the dog!' [followed by laughter] 'This is the only reason I'm doing it: to walk around as an elephant' [followed by laughter 'Why is she dressed as….' [laughter] Two of the three tutors who attended the in-world session linked the fun and play elements to student engagement but the third tutor raised concerns during the interview about the space being 'gimmicky' and the risk that students would learn more about the game features in the space rather than achieve the clinical learning objectives. However, the students felt it was a valid clinical space and the majority of students found the play elements either supported the learning and were interesting, fun and more visual than other learning approaches, or at least did not detract them from learning.

Despite enjoying the opportunity to be in the 3D clinic represented by a girl-gamer, dog or elephant, realism was important to the tutors. In their 3D session, the group quickly moved to an in-depth discussion about patient interactivity including patient responses and cited this as the biggest potential for the space in terms of future teaching. They wanted patient avatars to have the types of eye conditions that their students would routinely encounter and for these to be visible on the avatar and affecting their posture. One tutor went further in the interview suggesting that the patient avatars should provide physical feedback with the example of a student optometrist selecting the incorrect instrument resulting in a scar on the patient avatar's eye.

Whilst the students did not experience usability issues and quickly acclimatised to the environment, despite most not having prior gaming experience, it was a serious issue in the tutor session during which bandwidth, lag and audibility problems were experienced causing frustration for the tutors and a focus on technical issues for a significant period of the session. With the tutors needing to log in and out of the session to combat the lag issues, a technical fault was uncovered; namely when an individual logged back in to the group session they were not able to view the session taking place but were taken back to the start of the process, causing confusion and disruption.

- ## Summary of findings of qualitative evaluation with students and tutors.

Students and tutors were positive about the future potential for the 3D virtual eye clinic. All agreed that addressing the technical problems, such as participants not being able to re-join a session when logging back in, was important. Enabling the system to provide real-time feedback for students was deemed a priority by both students and tutors.

Students in the second group expressed interest in the 3D eye clinic being used as a pre-cursor to patient work, a revision tool, providing an opportunity to work through patient cases. All tutors could see future potential for the 3D virtual clinic to be used with optometry students, especially time-poor distance learning students as it would provide a clinic environment without the need for travel.

The tutors who attended the in-world session were keen for future iterations to develop the communication requirements between optometrist and patient, meaning that the student optometrist would have to ask the appropriate questions in order to elicit the information they needed from the patient avatar. One tutor discussed the need to develop a bank of patient cases for use in the 3D clinic, which would benefit the whole department and encourage tutors to use case-based learning in their teaching.

There is clear evidence for what students need to have a meaningful learning experience in the 3D clinic and barriers to this have been identified. The data generated by the additional in-world session for tutors added weight to the changes that need to be made in the space to support teaching and learning and they identified how the 3D virtual clinic might be used in the future. However, this is a small study using a single case study approach. It is highly contextualised and therefore provides low generalisability. Therefore, the transferability of findings from this study are limited but nonetheless will be of specific interest to optometry educators and potentially educators with an interest in student experience of 3D virtual clinical simulations.

The potential for future development and use of 3D optometry clinics in the sector.

Positive findings

The immersive, interactive and collaborative nature of 3DVEC affords it a substantial advantage over traditional learning methods. The platform particularly excels in co-creative learning experiences where teamwork plays more of an essential role. This also includes but is not limited to mentorship and coaching scenarios. The avatars and social networking dynamic add a fun element and thus may improve comradery between trainees while enhancing peer support. It may also encourage platform adherence via online rapport building and via gamification. The pseudo-identity avatars help preserve privacy while encouraging trainees who may be of a shy or introverted disposition to participate more freely without fear of public reprimand. They also help ensure that all trainees are on a 'level playing field' and treated fairly. The large number of potential teaching applications and high-fidelity simulated training scenarios (not limited to optometry) makes the platform highly scalable highly scalable. 3DVEC offers trainee optometrists a safe environment to practice cognitive skills without fear of embarrassment or patient harm.

1. Evidence-based learning platform
2. Immersive, interactive & collaborative
3. Social networking element adds fun dynamic
4. Scalable platform with many applications
5. Remote delivery of education (Increased cost effectiveness)
6. Closely replicates and emulates a real-world eye clinic
7. Pseudo-identity avatars may encourage trainee participation
8. Safe environment for optometry trainees to practice
9. Particularly well suited to cognitive learning and OSCE style testing

Key Weaknesses

Notwithstanding the fact that 3DVEC is a 'proof of concept' prototype, one of the potential weaknesses of the platform in its current build state is the fact that it is a Windows only desktop application that requires a substantially large (1gb+) download. This might limit future traction and dissuade some users. As such it could become a barrier to entry. Excluding a small (Approximately 10%) but sizeable chunk of the desktop user market who use Mac OS and an upwardly mobile generation Z who have become increasingly reliant on mobile applications for daily living, it would be prudent to develop a responsive web (Cloud based/ OS independent) or mobile platform in the future.

3DVEC may be vulnerable to technical problems such as server overloads, low internet speeds and internet connectivity issues (Includes institutional firewall issues) which might result in a suboptimal user experience. There might also be user technical difficulties relating to the accessibility and utility of the platform. There is a need for a dedicated 'facilitator' who can troubleshoot user technical problems and guide participants through.

While 3DVEC is highly suited to learning cognitive or critical thinking skills, it is suboptimal for learning 'hands on' or practical skills. This includes 'bed side manner' or non-verbal communication between trainee and virtual patient. There is also a high degree of technical utility associated with the use of complex eye equipment which cannot be adequately assessed in a VR environment. Interactivity between participants is currently limited to basic gesturing and textual communication.

The fidelity of 3DVEC closely emulates a real-world eye clinic, however, the virtual world is far from being photo-realistic and has more the appearance of a computer game. Avatar animations are also non-fluid or robotic. This is a problem with VR technology in it's current form and it can actually be a distraction or dissociative for some participants. Some VR companies are addressing these concerns by integrating augmented reality (AR) technologies with virtual reality (VR) technologies.

The lack of gamification and positive reinforcement via reward/feedback systems in the current build of 3DVEC may inhibit trainee adherence or 'stickiness'. Procedures and protocols need to be reinforced for participants to internalise the mental schemas and motor skills required for real life optometry scenarios. The use of real time feedback to relate clinical knowledge and skill execution to performance via measurable outcomes as well as collected data for post-hoc

1. Technical and practical difficulties for optimal functioning
2. Interactivity currently limited to basic gestures and textual communication
3. VR world may be distracting or dissociative (Vs Real world)
4. Lack of gamification and extrinsic reward/feedback systems
5. Lack of data collection for post-hoc analysis and improvement metrics
6. No MacOS, Web or Mobile platforms (May limit future traction)

Conclusion

The 3DVEC is a novel and innovative product that has the potential to revolutionise optometry training. The scalability of the platform coupled with the wide range of applications make it an exciting prospect. It is well placed to exploit emerging trends in digital education. Further funding will be necessary to develop the platform so that it is futureproof and can maintain it's economic moat. Whether or not it can be a commercial success will largely depend on it's acceptance, utility and future adoption.

Next steps: Future Funding, Partnerships and Commercialisation

COVID-19 has had a huge impact on education and business and has highlighted the urgent need for well-designed virtual spaces that are suitable for clinical education and assessment. We believe the 3D VEC has a role to play in offering interactive, immersive digital optometry education and assessment and could provide an opportunity for partnership working across the Higher Ed sector and business (not limited to the UK).

Since the summer (and the completion of the research and MSc projects) Barbara Ryan and Gill Brabner have held discussions with several people who have expressed interest in supporting the team to:

1. Develop the 3DVEC, addressing the issues encountered and developing assessment capability and capacity within the space.

2. To secure a commercial partner.

These include Professor Paul O' Brien, Chief Executive Officer at ELAROS, a health-tech company based at Sheffield University and Mr Eugene Ng, Ophthalmologist, and his team. Critically these contacts have all been successful in bringing health tech products to market and working at scale.

Our priority is to secure the next stage of funding. We require £200,000 to deliver on the works described.