Virtual Reality in Education:
A Case Study on Exploring Immersive Learning for Prisoners

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ABSTRACT

Our research presented here tries to bridge the gap between technology-oriented lab work and the praxis of introducing VR technology into difficult to deploy-to contexts—in our case prisoners with high learning needs. We have developed a prototypical immersive VR application designed for delivering low-level literacy and numeracy content to illiterate adults. This development has been taken to the commercial sector and is currently under product development. The target population for the application are those currently held in a correctional facility, but who have the motivation and determination to educate themselves. In this paper we discuss the current lifecycle of this project including the development, initial tests, and an exploratory study we conducted. We conclude with a discussion of logistical issues, potential research opportunities, and current outcomes.

Keywords: VR education, learning, in-the-field

Index Terms: Applied computing~Education~Interactive learning environments; Human-centered computing~Human computer interaction (HCI)~Interaction paradigms~Virtual reality

1 INTRODUCTION

Virtual Reality (VR) technology is widely used in environments like manufacturing plants, design studios, and research laboratories. However, it is less common to apply VR in very constrained environments like prisons. This application context seems to be very promising [10], since real settings often can't practically be applied within the physical, technological, and organizational constraints of a prison. The task of bringing VR to prisoners is much more complex than e.g. implementing it in a rather easily accessible presentation environment.

Some researchers and practitioners went the "extra mile" and for instance used VR for therapeutic purposes (e.g. [6]) or to ease a transition from prison life to real life by exposing prisoners to controlled real world content [7-9]. Of particular interest is the idea to bring pedagogical, interactive content into prisons. Because of the lack of proper education for large proportions of the prison population very basic literacy and numeracy training is often a good starting point to help prisoners to successfully re-integrate into society later [5].

The Methodist Mission Southern (MMS) is a non-governmental organization based in Dunedin, New Zealand, who is involved in community work throughout the region. One of their focuses is the education of prisoners at a regional correctional facility where they help to deliver basic literacy and numeracy classes to high-needs foundation learners. A common issue with delivering educational content to high-needs learners is their lack of confidence, motivation, and engagement with content. To mitigate this issue, the MMS uses a contextualized learning approach in which they wrap the literacy and numeracy content in vocationally-relevant contexts to improve the engagement and motivation levels of their learners. To take contextualized learning one step further, they conceived of the idea to deliver this content using VR technologies. This would further provide an immersive environment capable of captivating learners within their contexts of interest.

The first step in pursuing such a project was to select a context that would be relevant to a large enough subset of the learners attending classes at the correctional facilities. Upon questioning the prisoners, all male, of their interests there were a number of commonalities, although most were unethical in nature such as gambling, tattooing, or drugs. However, one very clear interest among many was automobiles. At this stage of the project the MMS reached out to the HCI laboratory at the University of Otago. In joint initial brainstorming sessions we discussed the potential of the project and its relevance to our research. We committed to the development of an early prototype to demonstrate the idea in practice allowing it to be more easily presented to interested parties, investors, and the New Zealand Department of Corrections whose support was required.

Figure 1: Presenting the immersive Virtual Mechanic application. A virtual car is placed inside a real workshop, which users can look around in (left). Specific car parts can be isolated for inspection where parts can be exploded (brake system). We show the literacy content specific to the car parts with multiple possible functions to help learners (right).

We began the design process with the MMS who provided the pedagogical guidance and contributed to the design of the content delivery mechanisms. After several design and development iterations, we had a functional prototype we call the "Virtual Mechanic" project, which demonstrated the basic concepts of immersive contextualized learning in VR where a mechanics workshop was the primary context (see Figure 1). The prototype was presented to a small number of prisoners from the facility, teaching staff, and other third parties such as investors, and was very well received. This prompted the MMS to take the project to the next step and begin collaboration with a commercial partner who would develop the project into a product. The MMS began a collaboration with Animation Research Limited (ARL) based in Dunedin, New Zealand.

The project development team at ARL has started to build the application from the ground up in a scalable manner with the intention this product will be adopted on a large scale. The project is being developed with an initial goal of 40 hours of educational content. We conducted an evaluation where prison literacy and numeracy learners were exposed to different content delivery mediums, one of which was the immersive VR Virtual Mechanic application. The study is exploratory in nature, and investigates how our methodology and the early stages of our structured analysis process could work in a real-world scenario, and to identify potential issues in measuring different dimensions of data.

In the remainder of this paper, we report on the project development lifecycle to date, and the exploratory study conducted at the Otago Correctional Facility. We conclude with recommendations for analyses, lessons learned, and implications of future real-world immersive VR learning developments. We describe the application prototype, which was developed primarily by the research team from the University of Otago as a proof of concept for the purposes of demonstrating the concepts and ideas to interested parties. A second application is in the early stages of development as a collaboration between ARL and MMS was developed and is used in an exploratory study described in a later section.

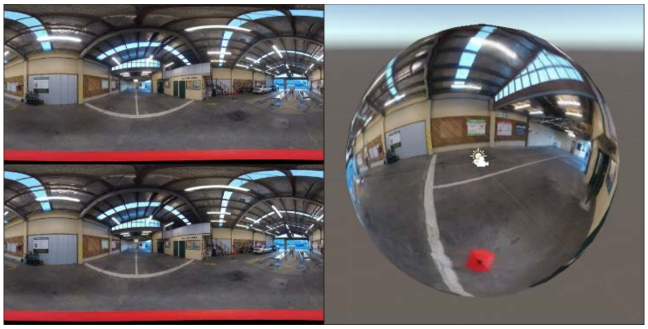

Figure 2: The resulting stereoscopic 360 panorama photograph of the mechanics workshop. The photos and stitching were provided by ARL (left). An example of the image textured to a sphere in the Unity environment (right).

2 PROTOTYPICAL DEVELOPMENT

When considering initial prototypes, one challenge was the specific context of use: a minimum to high security prison, which normally requires specific security-related measures that need to be addressed. E.g. electronic devices of any kind can't normally be brought into the secured zones and, if brought in by special permission, should not allow for communication with external parties or networked computers. Those measures apply in addition to all standard security mechanisms on restricted items, clothing, and permissible behavior. Bringing VR systems to our correction facility and let prisoners interact with them is seen as very critical in relation to those measures and only possible if all parties involved co-operate willingly and constructively.

There were two base requirements for the system: 1) an immersive VR application where the user would wear an Oculus Rift headset for visual immersion, and 2) the scenario context: a mechanics workshop. The Virtual Mechanic prototype went through several design iterations with respect to the environment, interface, and tasks. The prototype is fully developed within the Unity3D engine. This section summarizes the design choices and the development steps for the prototype application.

2.1 Environment

There were two primary options for the design of the environment: 1) an entirely virtual scenario with a surrounding virtual workshop and virtual contents, or 2) a realistic environment generated by mapping photographs to surfaces in the environment to achieve the illusion of a real workshop, and integrating virtual content within. We opted for option (2). The realism of 360 degree panoramic images would provide a convincing experience for prisoners.

We were able to contact staff at a local mechanics workshop and arrange a time to take photos. ARL provided the stereoscopic 360 degree camera rig and joined us to take the photographs. While at the workshop, we took images from four different positions in the environment so we could potentially provide different perspectives in the virtual environment. Figure 2 (left) demonstrates a stereo pair of one of the stitched images where the left and right eye were mapped to the top and bottom halves of the image respectively. Figure 2 (right) shows one of the images mapped to a sphere. We implemented two different methods: 1) a monoscopic implementation where just one image of the stereo pair would be mapped to one sphere that the user would see with both eyes, or 2) a naive stereoscopic implementation where the left and right eye halves of the image were mapped to separate spheres, and the two virtual cameras representing the users' eyes were set to cull the sphere representing the opposite eye. Spheres were displaced the same distance apart as the stereo panoramic camera rig (66mm).

2.2 Virtual Content Integration

We decided to insert a basic car model in our environment as a placeholder for what would eventually be more complex and detailed car models (see Figure 3). Because the surrounding environment was mapped to a sphere, there was no ground plane, which meant the model car would cast no shadow. This resulted in a break of the visual coherence of the scene [1]. To remedy this, we inserted a ground plane and applied a modified custom shader, which would render all pixels of the ground plane invisible except pixels that received shadows. The resulting shadows are demonstrated in Figure 3.

Figure 3: The figures above demonstrate the virtual car inserted into the environment surrounded by the panoramic workshop. Each figure is taken from a different position in the workshop. A basic model car is used as a placeholder for demonstration purposes. We perform shadow rendering onto an invisible plane to achieve visual coherence of the scene and provide depth cues.

2.3 Navigation and Interaction

A project like ours is a complex, long-term endeavor. Our prototype started before Oculus touch controllers were readily available. At the time, two devices were considered for navigation and interaction. Firstly, we discussed the use of a 3D mouse such as a space mouse by 3Dconnexion. Using this device for navigation did not make sense after our selected environment within which we can only place users at specified positions. Therefore, we went with an XBOX controller given that they are a prolific device, and we expected our target users to be familiar with them.

Figure 4: The virtual car presents a display guiding the user to which controls can be used to navigate (left). The small black gaze dot is always centered within the users' view frustum. When the user gazes at an object that is interactive, the gaze dot turns

into a picture of the ‘A’ button of the XBOX controller, prompting the user to press the button.

There were four positions a user could be placed in to view the virtual car in the scene. We implemented navigation about these four positions on the two shoulder buttons of the XBOX controller (commonly known as L2 and R2). Figure 4 (left) shows the display above the main car model prompting the user with possible actions.

For interactions, we implemented a center gaze indicator. The main interaction metaphor required users to place the gaze marker over the object they wish to interact with, and if an interaction is available, a prompt will appear telling users to press the ‘A’ button on the XBOX controller (for example, see Figure 4, right).

Figure 5: The figures above demonstrate the virtual brake assembly (left) with an accompanying display presenting the assembly name and a picture of the interaction device (XBOX controller) identifying possible controls. The brake assembly can be separated into its main components (middle and right).

2.4 Additional Virtual Content

The environment developed so far had provided the overall context for the educational content to be integrated with. We decided that the educational content would need to be based on potential real-world tasks. We decided that literacy content would be our main focus for the prototype. We would present a further scenario where a user would focus on a specific car part as an exemplar method of delivering literacy content. The car part we selected was the brake assembly (see Figure 5 (left)).

The wheel of the virtual car model was programmed to pulse indicating that an action was possible. When the user gazed at the wheel of the virtual car with their gaze dot, they would be prompted to press the ‘”A’ button (see Figure 4 (right)). When they did, the scene would smoothly fade away, and then back into view, the virtual car would be gone, and the brake assembly would remain in a close up state as in Figure 5 (left). We also applied a Gaussian blur to the background environment to direct the focus of the user towards the brake assembly.

We programmed the brake assembly to allow the user to perform a simple two-level explode function which separated the brake assembly into three primary sub-components (see Figure 5 (middle and right)). We experimented with different controls for this interaction, but we settled on using the upper shoulder buttons of the Xbox controller (often referred to as L1 and R1) to disassemble and reassemble the sub-components.

Figure 6: The passive task in which users click ‘A’ when prompted on a sub-component (left), can see what the sub-component part name is called (middle), and can click on the speaker symbol to have a voice over say the name of the part first normally, and then by syllables (right).

3 EDUCATIONAL CONTENT

We ran through several scenarios in a storyboarding session to design the educational content that would be integrated with the current environment. We conceived of one passive, and one interactive activity. For the passive activity, users were provided a prompt when gazing at specific brake assembly parts (Figure 6 (left)). We presented the names of specific brake assembly parts upon the users prompt (e.g. Figure 6 (middle)). By gazing at the speaker symbol on the display and actioning the prompt, users trigger a voice over which demonstrates the pronunciation of the part name, and would break the word down into its syllables (Figure 6 (right)). This was implemented for all three sub-components of the brake assembly.

The active task was implemented based on a rhyming task. This task was only implemented based on the “brake pad” sub component of the brake assembly, which users could activate by hovering their gaze dot over the controller symbol on the brake pad display and pressing the ‘A’ button (Figure 7 (left)). Upon activating the rhyming task, a voice over provides instructions for the user stating they must select the first letter of a word ending in ‘ad’ from the set provided which makes a word that rhymes with ‘Pad’ (Figure 7 (middle)). Users hover over letters with their gaze control as usual and press ‘A’ when they wish to select a word. If the word is correct, it is said aloud by the voice over, and is added to the list of correct words on the left of the display (Figure 7 (right)). If an incorrect word is selected, it appears but flashes red and is not added to the list of correct words.

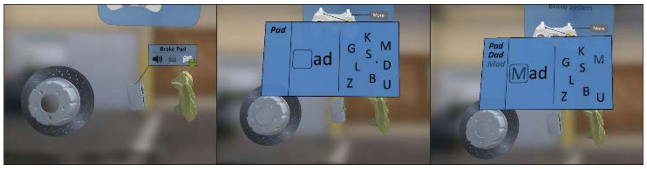

Figure 7: The active task in which users click ‘A’ when prompted while hovering over the controller symbol of the brake pad sub-component display (left). A rhyming task is activated in which users must select the first letter from a set of letters to make words that rhyme with ‘pad’ (middle). When words are correct, the voice over says the word, and adds it to the list of correct words (right). If an incorrect word is selected, it appears but flashes red and is not added to the list of correct words.

With the environment implemented and the exemplary educational tasks integrated with the context, the prototype was ready for presentation to various parties. This was a successful undertaking and facilitated the project’s progress by gaining the support of entities such as the Department of Corrections and further investment from other third parties. A collaboration was formed between the MMS and ARL to further develop a commercial product based on this idea. This led to an early stage development, which we could use in an exploratory study. With this, we had the opportunity to test aspects of our previous investigations in a real world scenario implementing an immersive educational VR application.

4 EXPLORATORY STUDY

The nature of the environment our evaluation takes place in comes with inherent complexities, more so than arguably most other learning environments. When plans are made with the correctional facility to conduct certain lessons, there can often be changes due to events external to the classroom. They cannot be certain which prisoners will be showing up to classes. Our study was planned to be conducted with three separate groups of learners, each group having six learners. In total, we were able to evaluate three groups with six, five, and four learners in each, giving us a total of 15.

Each of the three class sessions were run the same way where the learners would, at any given time, be in one of three conditions: 1) immersive Virtual Mechanic application, 2) tablet-based activities, or 3) taking a break, talking, or giving feedback. Due to the environment, tight regulations, and consequential protocols, we are only able at this stage of the project to take a certain amount of equipment into specific designated areas of the correctional facility. In total, we had two Virtual Mechanic systems and two tablets for each session. Therefore, if there were more than four learners, they were either passively observing, or interacting with the staff from the MMS, ARL, or ourselves.

The general aim for each session was to have two learners in the Virtual Mechanic application, two learners on the tablets, and two learners observing. The longer the exposure the better, but due to time and content constraints, we settled on approximately 15 minute segments after which time the learners would rotate their activities. Once again, due to the environment, and somewhat chaotic nature of each session, it was difficult to maintain each session in this manner, though they did approximate this flow of execution.

4.1 Study Design

One of the more specific goals of our work is to investigate the value of emotional engagement with Immersive Virtual Reality Learning (IVRL) environments, and what that engagement means in the context of learning processes. We take this opportunity to test our previous findings [2] in a real-world learning environment. In this exploratory study, we utilize the physiological measure of emotional response through electrodermal activity (EDA) and heart rate (HR) data, and we observe users achievements and environmental behavior. The measures we used and the procedure we followed are described in the proceeding sections. As previously described, our participants are prisoners at the Otago Correctional Facility who voluntarily commit to classes held at the facility.

4.2 Apparatus and Measures

We utilize three different methods of measurement within this exploratory study: 1) we sense EDA and HR data using an Empatica E4 wristband, 2) we record participants' achievements using the immersive Virtual Mechanic system, and 3) two investigators observe the sessions and record events as they are observed.

Physiological Data. As in our previous investigation [2], we employ the Empatica E4 wristband (Figure 8) for measuring EDA, HR, accelerometer, and skin temperature. It also contains an internal clock storing unix-based UTC timestamps.

Achievements. Participants are given at least one exposure session to the immersive Virtual Mechanic VR system. The implementation of the tasks were described earlier. When a participant completes a part of a task, or a whole task, the system is programmed to store the timestamp of the achievement, and which achievement was completed.

Observations. This measurement is complex but is a requirement due to the nature of the study. We need to know which participants are currently active in which tasks. Two investigators have notebooks and pens with which they record environmental events throughout the session. For instance, the times in which participants would begin the VR tasks, tablet tasks, or if they were just sitting around observing, are recorded by the observers. It is imperative that it is clear and known which participants are performing which tasks at any given time, especially because they are wearing physiological devices. It would be ideal to have a video camera set up for the duration of this study so observations could be recorded retrospectively, but ethical considerations and correctional regulations prevented us from doing so.

Figure 8: Empatica E4 wristband to measure electro-dermal activity heart rate, acceleration, and skin temperature before, during, and after VR exposure. Unfortunately, it is very difficult to get reliable data in non-laboratory conditions.

4.3 Procedure

At the beginning of each session, we introduced ourselves to the participants and described our investigation. We expressed our interests in exploring how VR technology can improve learning engagement and potentially learning outcomes. In total, there were five people running the session including two people from ARL, one person from MMS, and two researchers from the University of Otago. The two ARL representatives present were guiding the users of the Virtual Mechanic application if they needed help and taking notes on user interactions and feedback. The MMS representative was guiding the overall operation and was the primary contact for the visit. And, the two researchers (first and last author) were conducting the exploratory study.

We described the details of the Empatica wristbands explaining what they measure, and why we use them. We firmly attached the bracelets onto participants' wrists so they could not move around much. This way all participants would wear a bracelet for the entire duration of the class session.

Upon commencement of the session, participants split off into an activity. Two would use the immersive Virtual Mechanic application, two would use the tablets, and the remaining participants observed, or engaged in conversation with others. Participants were expected to spend approximately 15 minutes in the VR environment, though this varied depending on how long it took participants to complete the content, and how long they wanted to spend exploring the VR environment. After approximately 15 minutes, participants were rotated so the VR participants would move to the tablets, the tablet participants would observe, and those observing would move to the VR activity. This part of the procedure was flexible, and did not always execute this way. It was heavily dependent on the participants, and how many participants were in each session. These rotations happened however until all participants had attempted all activities. In some cases, some participants attempted certain activities more than once. Upon completion of each session, we removed the bracelets and turned them off which stores the data on the bracelet as a separate session. Participants were thanked, and were escorted away.

5 DISCUSSION

VR shows promise as an engaging method of educational content delivery, although some issues came to light throughout our investigation highlighting the difficulty of conducting robust and thorough educational VR research. All participants to attend the class attempted the Virtual Mechanic application with our desired time of exposure meeting our expectations with a mean overall time of 14.13 minutes. There were some differences however between the three groups using the application.

Of the three groups, one group had previous exposure to an earlier version of the Virtual Mechanic application. Furthermore, the groups had different abilities and were sitting on different levels of education. The content currently integrated into the VR application consisted of literacy and numeracy tasks at a level similar to that of the third group's education level. While this exposure was not designed to evaluate for learning outcomes, the participants' level of education was reflected in the time they spent completing the tasks. The first group of six had no previous experience, but were at a higher level of education already, and they had a mean exposure time of 13.16 minutes. The second group of five had previous experience with the system and were of a high level of education. They spent a mean time of 11.2 minutes in the system. The third group consisted of only four participants, and they had a lower level of literacy and numeracy education, and no previous experience with the system. Their mean exposure time was 19.25 minutes. Additional exposures were allowed although the majority of participants only had one exposure with only two participants, both from the first group, having an additional two exposure times each.

The tasks within the Virtual Mechanic application were designed to gauge how target users generally interact with the environment. Therefore, our analyses is not to be conducted in the context of learning gains, but rather in terms of general engagement with the environment. From here, we will discuss the potential analyses that can be conducted from this exploratory study. We also give an overview of issues with the study conduct and the implications of these on future immersive educational studies.

5.1 Physiological Analyses

In our previous investigation [2], we used our physiological measures of EDA and HR to successfully predict moments of insight and cognitive load. Given the exploratory nature of this evaluation, we were not measuring for moments of insight, and the conditions are arguably not conducive to insight learning. Cognitive load analysis however could be possible.

In our own work, we were able to fully control the content, which users were exposed to, i.e. four-dimensional spatial constructs, and we had total control of the tasks we presented participants with. In the case of the Virtual Mechanic application, at the time of this evaluation, it is only in the early stages of development and consists of a small number of simple tasks. Both literacy and numeracy tasks were all of approximately the same difficulty. With respect to our evaluation of cognitive load, the current state of the system does not facilitate the same analyses from our previous investigation.

The cognitive load analyses we conducted previously was based on three categories of task difficulty, i.e. easy, medium, and hard. Therefore, we could use a multi-class classifier to determine degrees of cognitive load through heart activity analyses. In the current approach, with only several tasks of similar difficulty, the analysis would have to be based on a binary classifier, which gives less information about the current state of the participant in the environment, but would still tell us, perhaps, whether the participant has surpassed a particular level of cognitive load. Furthermore, the small number of tasks currently implemented would not provide enough achievement data for such a classification. Consequently, a comprehensive numerical analysis of the physiological data is not possible.

5.2 Observations

Several observations were made throughout the study. We required observation to ensure we knew which participants were active in which activities, but in particular, it was important we knew when they were active in the immersive VR application. In addition to our main observations, we noticed several issues with the study conduct that affect robust analyses.

Of the outside personnel present, two were involved with the system development. They were tending to the two VR applications to guide the users should any issues or questions arise. A lot of the time, however they would provide more instruction than was required, rather than letting the participants attempt to complete the tasks themselves. One consequence of this is the participants' break in focus. Often they might ask a question about the interface and the helpers would answer the question but then continue to tell them what to do next. This prevents the participant from becoming engaged with the task at hand.

Furthermore, throughout most of the sessions, the ambient noise in the classroom was quite high and distracting. The participants would often be prompted by other classmates in the room resulting in a break in focus. This is exemplary of a typical classroom environment, and presents a further issue with such studies.

Anecdotally, we noticed that prisoners had to learn to develop a minimum amount of trust when wearing head-mounted displays in a room where other prisoners are present, since they don't see the real world any longer. Also, that it requires prisoners' trust in us visitors when e.g. equipping them with our electronic monitoring devices (Empatica wristbands).

5.3 Implications on Future Educational VR Studies

The first key lesson learned is with respect to the tasks that system users are expected to complete. These should be well structured against a known hierarchy of expected difficulty. In the context of immersive VR systems, tasks should also be self-directed, and self-explanatory as much as possible. If a user constantly requires help from an external source, the effectiveness of the virtual environment will be hindered.

We were able to collect physiological data in the correct manner however there were many sources of external stimuli participants were exposed to. Measurements of EDA and HR are highly responsive to the sympathetic nervous system (SNS) and the more variables present in an environment means more possible effects on the SNS. This in turn means less reliance on the effects of stimuli from the virtual environment. Therefore, it is important to try and maintain a controlled environment for the duration of a given exposure to allow users to achieve a focused state. This issue is highly relevant for the users' sense of presence as it is well established that external stimuli of a distracting nature causes a decrease in the users' sense of presence [3, 4]. We established in our previous work that reported presence approximated emotional engagement and correlated highly with achievement levels.

An issue related to users' engagement factor and sense of presence is exposure time. Once again, the stage of development limited the exposure time we could provide participants with. It was sufficient for the purposes of exploring potential class session structures and, for our purposes, whether or not our methodology holds real-world validity. Longer exposure times are however desirable for maximizing engagement with material. Users should be allowed to gain momentum in their learning experiences so they can develop strategies and construct their knowledge accordingly. If they are interrupted, their momentum can be broken as in any environment. A further reason for longer exposure times is to allow for more robust physiological analyses. Particularly in the context of system evaluation, it can be difficult to establish patterns in users' physiological states with short exposure times.

A qualitative dimension of measurement will be highly beneficial in future evaluations of educational VR systems. One of the natural outcomes of the learning process is that learners will ask questions. Any feedback that is given at a point in time should be noted and ideally integrated into any analyses. This requires a more complex qualitative analysis, though it could provide important insights, particularly on individual learning efforts.

5.4 Insights for the Classroom

The various insights we attained from conducting this study are relevant not only for the highly regulated prison environment, but also for the more general educational classroom environment. However, applying these insights in evaluations and immersive VR learning (IVRL) environments varies between these two scenarios.

A distraction-free environment is desirable to help attain reliable physiological measures and also to facilitate a user's presence and engagement. In the context of the prison, it is a highly controlled but unpredictable environment with multiple distractions. Apart from noise from other learners in the space, the users' trust in their environment arose as an internal stimuli which could constantly distract one from their task. These issues can be addressed with smaller classroom sizes and potentially more isolated immersive learning spaces. Collaboration is a beneficial strategy in learning environments, however this should be implemented through telepresence systems, or in other elements of the classroom. In a more general classroom context with younger children, it is more likely that there will be noise from other students and potentially performance anxieties that will detriment genuine engagement and presence attributes in IVRL environments. Smaller classroom sizes are not as common in regular schools, though an effort should be made to isolate the immersive learning space to facilitate students' presence and engagement, and if sensed measures are applied, to help with targeted physiological readings.

Controlled and isolated immersive environments are highly applicable for the prison learning environment. As VR systems and applications improve and become more portable (such as wireless technologies), more portable and even mobile solutions will be possible. The interactive element of IVRL systems will also have users holding controllers, which means there is potential for abrupt and unexpected actions such as swinging controllers. These aspects are also applicable for student classrooms as children are also prone to such impulses, however in the volatile prison environment, avoiding any unnecessary incidence is a high priority.

If one is conducting an evaluation of an IVRL application, and they plan to incorporate physiological measures, then longer exposure times are desirable. There are multiple benefits to increased exposure time including an improved sense of engagement and presence. A drawback of long exposure to current immersive technologies is the potential for simulator sickness symptoms to emerge. If these are addressed, longer exposure times will be possible. In terms of prison environments, system designers should use a targeted persona to create content and develop the system. Frustration and boredom can begin to detriment the user experience and consequently, the learning outcomes. This is true of a classroom environment, however student users are more generally tolerant of a typical class length experience and can have their limit pushed at a greater rate.

Qualitative data is important in any evaluation. If a system is being evaluated on learners at a prison, it is likely evaluators are dealing with a smaller sample size than normal. This makes qualitative data collection and analysis more appropriate. It could also be beneficial to tailor an experience to prison learners' individual needs. Tailoring individual experiences is desirable in any case, however given the type of learner often found in the prison learning environment, short term benefits may be achieved by employing such an approach.

6 CONCLUSION

From the outcomes of this exploratory study, we have drawn up preliminary guidelines for robust evaluations of educational virtual environments. As a community that focuses on user experiences in VR systems, it is desirable to see their success not only in the education domain, but throughout multiple domains. It has been shown here that VR applications can be delivered even in logistically difficult classroom environments surrounded with ethical and regulatory constraints. Our methodologies have demonstrated potential to help with the success of these applications, and it is our hope they will be adopted in the further development as immersive VR proliferates.

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REFERENCES

[1] Collins, J., Regenbrecht, H., and Langlotz, T. (2017). Visual coherence in mixed real- ity: A systematic enquiry. Presence: Teleoperators and Virtual Environments, 26(1):16– 41.

[2] Collins, J., Regenbrecht, H., Langlotz, T., Can, Y. S., Ersoy, C., & Butson, R. (2019, October). Measuring cognitive load and insight: A methodology exemplified in a virtual reality learning context. In 2019 IEEE International Symposium on Mixed and Augmented Reality (ISMAR) (pp. 351-362). IEEE.

[3] Liebold, B., Brill, M., Pietschmann, D., Schwab, F., and Ohler, P. (2017). Continuous Measurement of Breaks in Presence: Psychophysiology and Orienting Responses. Media Psychology, 20(3):477–501.

[4] Slater, M. and Steed, A. (2000). A Virtual Presence Counter. Presence: Teleoperators and Virtual Environments, 9(5):413–434.

[5] McLauchlan, J., & Farley, H. (2019). Fast Cars and Fast Learning: Using Virtual Reality to Learn Literacy and Numeracy in Prison. Journal for Virtual Worlds Research, 12(3).

[6] van Rijn, B., Cooper, M., Jackson, A., & Wild, C. (2017). Avatar-based Therapy within Prison Settings: Pilot Evaluation. British Journal of Guidance & Counselling, 45(3), 268-283.

[7] Teng, M. Q., Hodge, J., & Gordon, E. (2019, May). Participatory Design of a Virtual Reality-Based Reentry Training with a Women's Prison. In Extended Abstracts of the 2019 CHI Conference on Human Factors in Computing Systems (pp. 1-8).

[8] Dolven, T., & Fidel, E. (2017). This prison is using VR to teach inmates how to live on the outside. Retrieved from https://news.vice.com/en_us/article/bjym3w/this-prison-isusing-vr-to-teachinmates-how-to-live-on-the-outside. 27 Dec 2017.

[9] Knowles, K. (2017). Prison inmates are using virtual reality to visit home. Retrieved from https://www.thememo.com/2017/10/25/catalina-alarcon-san-joaquin-prison-vr-film-backhomevirtual-reality-volver-a-casa-chile/

[10] Zoukis, C. (2016). Virtual reality behind bars could change the game for prisoners. Huff Post. Retrieved from https://www.huffingtonpost.com/christopher-zoukis/virtual-realitybehindba_b_12791456.html