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Feasibility and Potential Benefits of Immersive Virtual Reality in the Intensive Care Unit

Virtual reality (VR) is a developing technology with much current interest in its potential to improve patient outcome in a variety of clinical settings. Critically ill patients, their relatives and intensive care unit (ICU) staff are all at high risk of stress and anxiety and patients often experience pain. This study explores the potential benefits of virtual reality for stress, anxiety and pain management in the ICU.

Background

Patients in Intensive Care Units (ICU) often experience low mood, anxiety and fear (Choi et al. 2016). Stress factors include sensory overload and deprivation, isolation, temporal disorientation and a feeling of lack of control (Gerber et al. 2019). These symptoms are often a result of feeling vulnerable, lacking in stimulation and/or from an inability to relax and sleep (Ding et al. 2017). Anxiety also detrimentally affects perceived levels of pain and motivation for physical rehabilitation (Dubb et al. 2016).

Family members also experience depression, anxiety and fatigue during a relative's ICU admission (Day et al. 2013; Bolosi et al. 2018), and ICU staff report anxiety, stress and burnout (Colville et al. 2017).

Immersive virtual reality is well established in the gaming industry and is starting to be used more widely in education. There is now a lot of interest in its potential to improve patient outcomes in a variety of clinical settings. It is increasingly being used in rehabilitation (Llorens et al. 2015) and in the assessment, understanding and treatment of mental health disorders (Freeman et al. 2017).

Given that our critical care patients, their relatives and staff are all at high risk of stress, anxiety and depression and the patients often experience pain, we were particularly interested in exploring the potential benefits of virtual reality for stress, anxiety and pain management.

This pilot study aimed to assess the feasibility and potential effectiveness of virtual reality distraction therapy in the critical care environment for patients, staff and patient relatives.

Inclusion criteria	Exclusion criteria
Patient, relative or member of critical care staff Ability to provide informed consent	Inability to provide informed consent Major visual or hearing impairment rendering use of the VR equipment futile Head or facial injury or abnormality such that the VR goggles and earphones are unable to fit properly or safely Epilepsy History of motion sickness

Table 1. Inclusion and exclusion criteria for virtual reality study.

Method

Ethical approval for the study was given by the West of Scotland Research Ethics Service (19/WS/0102) on 2nd August 2019 and by HRA and Health and Care Research Wales on 14th August 2019 (IRAS ID 264717). Critical care patients, their relatives and staff members were approached by a member of the research team and invited to participate in the study. They were shown the equipment, given a detailed information sheet explaining the study, time to think about it and the opportunity to ask questions. See **Table 1** for list of inclusion and exclusion criteria.

After informed consent, participants were asked to complete a brief questionnaire about their mood, anxiety levels and pain score using visual analogue scales (VAS) **(Figure 1)**. They then chose their virtual reality experience from a selection of documentary-style or guided relaxation-

VR experiences offered
Wildlife
Around the World
Cities
Underwater
Relaxation
Space
Guided breathing exercises in a variety of different peaceful surroundings.

Table 2. List of virtual reality experiences offered.

	Whole Cohort			
	Pre-VR	Post-VR	Mean change	P value
Mood	6.3	8.68	2.38	<0.0001
Anxiety	4.27	2.2	-2.07	<0.0001
Pain	2.84	1.99	-0.85	<0.0001

Table 3.1 Summary of VAS results pre- and post-VR intervention.

BEFORE THE VIRTUAL REALITY EXPERIENCE

Question 1

Draw a circle around the face and number that best describes how you feel at the moment. 1 means very bad and 10 means fantastic.

1 2 3 4 5 6 7 8 9 10

Question 2

Draw a circle around the face and number that best describes how worried/anxious you feel at the moment. 1 means not worried/anxious at all and 10 means extremely worried/anxious.

1 2 3 4 5 6 7 8 9 10

Question 3

Draw a circle around the face and number that best describes how much pain you have at the moment? 1 means you have no pain at all and 10 means you have the worse pain ever.

1 2 3 4 5 6 7 8 9 10

Figure 1. Pre-VR experience Questionnaire

Figure 2. Examples of virtual reality scenes

experiences. See **Table 2** for list of experiences offered and **Figure 2** for examples of patient view during experiences.

We used the DR.VR™ system; a PICO VR headset and noise cancelling headphones. This is operated using DR.VR™ closed system which allows a Samsung tablet to control the VR. The system was designed and provided by Rescape Innovation **(Figure 3)**. The headset is made of hard plastic, which can be wiped clean with sporicidal wipes used to clean equipment in intensive care, and a soft cushioned part in contact with the user's face. Disposable sanitary masks were worn to prevent skin contact with this soft material during each use. The programmed experiences were created to appeal to a wide demographic and were produced in 4K with a static 3600 camera to reduce the risk of motion sickness. All experiences were between 7 and 10 minutes in duration. If the participant enjoyed the experience and requested further uses, this was permitted.

After the VR experience(s), the participant was asked to complete a further brief questionnaire to assess their mood, anxiety

	Staff				Patients				Relatives			
	Pre-VR	Post-VR	Mean change	P value	Pre-VR	Post-VR	Mean change	P value	Pre-VR	Post-VR	Mean change	P value
Mood	7.19	9.16	1.97	<0.0001	5.97	8.46	2.09	<0.0001	5.07	8.14	3.86	<0.0001
Anxiety	3	1.5	-1.5	<0.0001	4.91	2.83	-1.87	<0.0001	5.57	2.21	-3.43	<0.0001
Pain	1.4	1.19	-0.22	0.02	4.23	2.91	-1.48	0.001	2.64	1.5	-0.71	0.27

Table 3.2. More detailed summary of VAS results pre- and post-VR intervention.

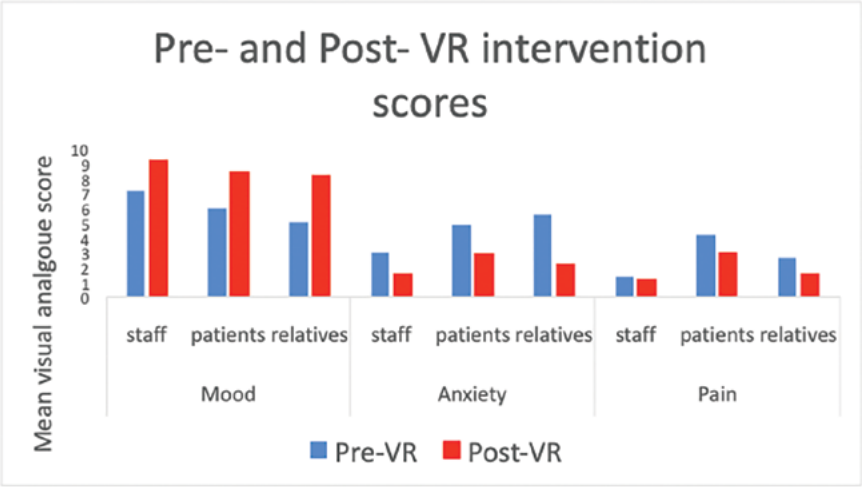

Figure 4. Graphical representation of VAS results pre- and post-VR intervention.

Figure 3. Virtual reality equipment used.

and pain scores again. On this questionnaire there was the opportunity to write free-text feedback if desired.

Mood, anxiety and pain scores were put into Microsoft Excel and SPSS and free-text feedback was transcribed into a Microsoft Word document and then analysed by both authors for emerging themes.

Results

In total we had 80 separate uses of VR from 72 participants. Usage by cohort: 32 staff members; 34 patient uses and 14 patient relatives. More than one VR experience on the same occasion was counted as one use. VR experiences on different occasions were regarded as separate uses. Seven patients chose to use the VR on more than one occasion. One patient felt nauseated before starting his VR experience, felt worse on application of the headset (within the first few seconds of use) so abandoned the experience and did not complete the post-experience questionnaire. Therefore we analysed data from 79 VR uses. There were two further reports of mild motion sickness, not sufficient to want to stop the VR experience. No other negative effects were reported and all other users completed one or more VR experience. There were no issues with fitting the headset on patients receiving oxygen via facemask, nasal cannulae, or with an endotracheal tube or tracheostomy tube. There was no interference between the VR kit and any other electrical equipment surrounding the patient. The compact case containing the VR equipment was placed on a chair or table at the bedside. See **Table 3** and **Figure 4** for summary of VAS results pre- and post-VR intervention.

Most of the differences in VAS scores pre- and post-VR intervention were normally distributed and were analysed using paired t-tests. Only change in pain scores for staff and relatives were non-normally distributed and were analysed using Wilcoxon signed-rank test. For the whole cohort of users mean improvement in mood score was 2.38 points; anxiety score 2.07 and pain score 0.85. All three parameters had p values <0.0001. The change in VAS scores pre- and post-VR intervention was statistically significant ($p<0.05$) for all

Theme	Example Statements	User
Positivity	"The virtual reality made me feel as if I didn't have a care in the world."	Member of staff
	"Wow I have never in my life seen anything like this. I was bored and down a little but when I went on this I have never in my life seen anything like it. Fantastic is too small a word."	Patient
	"I'd like to get one for myself! Fun and educational."	Patient
	"That was fab, Took me away from my stress for 10 minutes. Want to do it again please."	Patient
	"I really enjoyed finding out about the animals and getting up close and personal with the elephant, lion and polar bear. It definitely distracted me from the world outside for the duration of the experience."	Patient
Relaxation	"I have thoroughly enjoyed my virtual reality experience. After using it I now feel calm, peaceful and grounded."	Staff member
	"I felt relaxation flowing all around me. Any problems I currently face did not surface."	Patient
	"I feel that it helps take away the tension and stress."	Relative
	"It was very relaxing. The pictures were lovely and made you feel as though you were there."	Staff member
	"A wonderful experience, very calming."	Patient
Escape	"Just for 5 minutes it took me away from the ward environment and made me smile and forget my problems."	Patient
	"I think it takes you out from what is going on around you. It gives you that break from hospital and the ward."	Relative
	"Helped me to forget distressing memories."	Staff member
	"I felt transported away from the hospital environment for 8 minutes and re-energised to start work."	Staff member
Would recommend for others	"I can see how this would improve the patient experience in critical care by transporting them out of a distressing reality."	Staff member
	"An essential piece of kit for ICU."	Patient
	"Very beneficial considering how intense the ICU can be. This tool would most definitely benefit both patients and the family/friends."	Relative
	"Would highly recommend."	Patient
	"I believe it will help a patient a lot, for a few minutes it can take them away from reality being on the ward. It can take their mind away on holiday exploring for a few minutes some different worlds."	Patient

Table 4. Examples of user feedback themes after VR experience

Negative Statements	User
"Felt like the mask pressed down on my nose. Good experience, Relaxing."	Member of staff.
"Cities experience, needed to be stood to gain full experience. Gave the impression of being there." Smiley face drawn on feedback form.	Member of staff.
"Very enjoyable experience however nausea after a while (usually suffer with motion sickness)."	Member of staff.
"Thoroughly enjoyed. Pain increased when looking directly down but if lying or standing, I think this would be fine – stomach surgery. Great tool."	Patient

Table 5. Negative feedback after VR experience.

parameters except pain scores in patient relatives (p 0.27).

Perhaps unsurprisingly, patients had higher pain scores than staff or relatives, and also had the biggest improvement in pain scores (mean change of 1.48 points on a 10-point scale versus 0.22 and 0.71 points respectively for staff and relatives). Interestingly, of the 12 patients with higher pain scores (6 out of 10 or greater), all but one (92%) reported an improvement in pain score after VR, and the mean change was 3.41 points. Patient relatives had the lowest mood scores and the highest anxiety, higher than the critically ill patients themselves. This group also reported the biggest improvements in mood and anxiety scores after VR.

Qualitative Feedback

The majority of users (86%) took the opportunity to give extra feedback and this was overwhelmingly positive. 28/32 staff, 31/33 patients and 9/14 relatives chose to give additional feedback. Feedback was transcribed verbatim and analysed for common themes by highlighting frequently used words and sentences and classifying them into groups. Four main themes emerged:

1. Positive experience (48 statements). Assigned when there was a sentence stating that the user enjoyed the experience, or words such as "great" "fantastic" or fabulous" were used.

2. Relaxation (30 statements). When words such as "calm" "relaxed" were used, or sentences mentioning reduction of stress or tension.

3. Escape (18 statements). When users reported feeling like they had left the room and gone elsewhere or forgotten their worries.

4. Recommendation (13 statements). When comments were made suggesting the VR would be useful for others.

Some feedback fitted into two themes, for example:

- **Positivity/relaxation:** "I really enjoy the VR. It put me at ease and made me feel relaxed." (Patient)
- **Recommendation/escape:** "I would recommend the VR experience as it can transport you from your surroundings and distract patients from their situations allowing medical staff opportunities to carry out procedures." (Patient)
- **Relaxation/recommendation:** "I feel completely relaxed and wish I was still 'there.' As a member of staff I can definitely see the advantage of using this technology to calm patients and distract them. It's amazing!" (Staff member).

Of 113 total statements, 4 (3.5%) were coded as negative. These comments were usually written along with positive comments **(Table 5)**.

Discussion

There is increasing interest in using virtual reality for a variety of medical conditions, but so far, very limited experience with hospital inpatients and even less in the intensive care setting. We wanted to explore the safety, feasibility and acceptability of using this technology in the intensive care unit, and whether it may have any benefits for three groups of users: critical care staff; patients and relatives.

We found that VR is safe, feasible and acceptable to all of these three groups, and visual analogue scales demonstrated mean improvements in all three parameters measured.

Mosadeghi et al. (2016) explored the feasibility of immersive virtual reality in 28 hospitalised patients and found that 86% reported a positive experience, 7% neutral and 7% negative. Only 50% found the device comfortable to use, with complaints including that it was too heavy, hard to fit, uncomfortable and difficult to focus. The headset used in this study was a Samsung Gear VR which is an older version. Pain and anxiety were not measured but on questioning, 75% of patients believed VR could improve pain by means of distraction and 43% thought it could change anxiety level. This is in contrast to our study where only one person (a staff member) found the facemask uncomfortable. However, we had similarly positive feedback rates (96.5%).

Gerber et al. (2019) performed a feasibility study to investigate the acceptability, comfort and recollection of immersive nature-related VR stimulation for 33 cardiac surgery patients prior their ICU admission, during their stay and 3 months after discharge. They found that VR stimulation

was considered pleasant, immersive and easy to use. They noted a reduction in respiratory rate during the VR session which was interpreted as a sign of relaxation, which again fits with our self-reported effect of relaxation and reduced anxiety in our ITU patients.

Mood and Anxiety

Our findings showed a measurable improvement in self-reported mood scores in all three groups. The biggest change in score of 3.86 out of 10 was seen in patient relatives, who reported the lowest pre-intervention mood rating, although all changes in mood with VR were statistically significant.

Patient relatives were also the most anxious of the three groups, followed by patients, then staff. This was interesting, as we all assume critically ill patients to be highly anxious about their condition, ongoing treatment and prognosis. However, their families are going through the experience as well, with the fear and frustration of not being able to do much to help. This group reported the greatest change in anxiety level (mean score of 5.57 to 2.21 out of 10) with VR. This is important, as post traumatic stress disorder, complicated grief, anxiety and depression are well recognised in family members of critically ill patients with reported rates of between 14 and 82% depending on the diagnostic tool used and the timing of assessment (Petinec et al. 2016).

If there is a simple intervention such as VR, that could potentially ameiliorate these feelings of anxiety, low mood and helplessness, it could make a significant difference to the quality of life of these families. It would be easy to have a couple of VR headsets, along with instructions for their use, available in the relatives' waiting room for use at their own discretion.

Equally, the patients themselves reported improvements in mood and anxiety after using VR. As we already know patients are at high risk of anxiety, depression and PTSD after critical illness (Burki 2019), this simple, non-pharmacological intervention is worth offering if there is a chance it may improve psychological outcomes.

Staff members had the highest mean mood scores and lowest anxiety scores. However, some staff members reported high anxiety and low mood. In the nine staff members reporting anxiety scores of 5 out of 10 or higher, the mean improvement in anxiety score was 3.3 points out of 10. Staff members also frequently commented on feelings of escape, relaxation and forgetting their worries. Intensive care is well known to be a specialty with a high risk of burnout (Brindley 2017) and anything that could help reduce this risk is worth exploring, for the benefit of staff and patients.

> **virtual reality has the potential to reduce the risk of long term psychological sequelae of critical illness in patients and their relatives and reduce the risk of stress and burnout in ICU staff**

The effect of VR on mood and anxiety may partly be explained by the feeling of being removed from an unpleasant and overwhelming reality and immersed in a "soothing, comforting environment" (Beaucote et al. 2019). All the VR experiences in our study were set outside and it has been suggested that being outside in nature has a restorative effect (Berto 2014). It may be that this effect also holds true for exploring nature in VR.

Pain

The improvement in patients' reported pain after VR, particularly for those patients with higher pain scores (3.41 points of out 10) was remarkable and is comparable with opioid analgesics. This has been noted in other studies in different patient cohorts including hospitalised patients with pain scores >3/10 from any cause (Tashijian 2017), during repeated burns dressing changes (Faber et al. 2010; Hoffman et al. 2019) and during dental procedures (Wiederhold et al. 2014).

It is well-recognised that psychological factors, including fear, anxiety or depression can amplify the subjective experience of pain (Hoffman et al. 2019). Hoffman et al. (1998) proposed that VR is "attention grabbing," reducing the amount of attentional resources the brain has available for pain perception. Hoffman et al. (2007) used functional magnetic resonance imaging to demonstrate that VR reduced pain-related brain activity. The degree of pain reduction from VR was comparable to that from a moderate dose of hydromorphone, and when VR was combined with opioids, larger reductions in pain were seen.

This study has some important limitations. As it was a pilot feasibility trial we were unable to perform an initial power calculation to ensure an appropriate sample size and there was no randomisation and no control group for comparison. Our study findings can now be used as a basis for future randomised controlled studies exploring the use of VR for specific purposes such as pain relief and anxiety management. All outcomes were user-reported and therefore subjective and there were no objective measurements. However, several nursing staff anecdotally reported observing reductions in patients' heart rates and respiratory rates whilst using the VR. Additionally, mood, anxiety and pain measurements are usually subjective ("pain is what the patient says it is") and the pain visual analogue scale is widely used throughout hospitals to assess pain and the effect of analgesics.

Another limitation is that because this was a clinical trial requiring informed consent to participate, it excluded patients with delirium. It would be interesting to

explore the use of virtual reality in this population who have significantly increased mortality with no treatment yet shown to be truly effective.

Conclusion

We have shown that immersive virtual reality is safe, acceptable and feasible to use in the critical care unit with significant benefits to patients, their relatives and staff members in terms of mood, anxiety and pain management. Feedback was overwhelmingly positive with 100% of users reporting an improvement in at least one of the modalities measured and every free-text feedback containing at least one positive statement. Future randomised trials should focus on timing and frequency of virtual reality sessions for specific purposes. For example, physical rehabilitation, weaning from ventilatory support, during procedures such as line insertion and dressing changes and prevention and management of anxiety, PTSD and burnout. Objective measurements such as heart rate variability and skin conductance could be incorporated into some of these studies to observe whether there is correlation with the self-reported data. ■

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Conflicts of Interest

None to declare.

Key Points

- A study explored the potential benefits of virtual reality for stress, anxiety and pain management in the ICU.
- Critical care unit patients, staff and relatives were asked to complete a visual analogue scale (VAS) questionnaire on mood, anxiety and pain before and after a virtual reality experience.
- 100% of users reported an improvement in at least one of the modalities measured and every free-text feedback contained at least one positive statement.
- 92% of patients with higher pain scores reported improvement in pain after VR.
- Changes in mood, anxiety and pain with VR were statistically significant for all groups except pain scores in patient relatives.
- Four main themes emerged in qualitative assessment: positive experience; relaxation; escape and recommendation for others.

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