



The promise of immersive healthcare

How the UK can reap
the benefits of the latest
healthcare innovations that
use immersive technology.



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About this report

This Institution of Engineering and Technology (The IET) insight, introduces immersive healthcare technology in the UK and has been written for all those academic, industry and policy stakeholders that are interested in the subject of immersive healthcare.

Immersive healthcare continues to advance but there are still many challenges and concerns that need to be addressed.

This IET document seeks to provide insight into key issues, views and recommendations given at the *Think Big: Future Health and Life Sciences Unconference*, jointly hosted by the IET, Immerse UK and Hatsumi VR in November 2019. It contains a summary of key recommendations from participants, data and ethical challenges and case studies.

The author of the report is Liz Heron. This document was reviewed by the members of the IET's Healthcare Sector and immersive healthcare technology participants in the *Think Big: Future Health and Life Science Unconference*:

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Please note that the views expressed in this publication are not necessarily those of the IET. It is not intended to be a guidance note with a specified set of recommendations or actions but rather seeks to add understanding and debate around the topic.

The IET Healthcare Panel would welcome any comments you may have on the contents / your ideas for future healthcare publications. Please send these to healthcare@theiet.org



Recommendations



Immersive technology has provided new and enhanced healthcare solutions and treatments over recent decades. As the technology matures, there are great expectations of its potential to further promote the advancement of medicine through a wide range of new and enhanced devices and treatments. With that said, innovators and researchers at the cutting edge of this novel field face structural, financial, and regulatory challenges as they seek to achieve medical benefits. The conference concluded that action is needed to address these issues and release the potential of virtual reality (VR) and augmented reality (AR) to help provide enhanced healthcare services. Participants proposed a range of measures that would help to address problems in the field, which form the basis for the recommendations of this report.

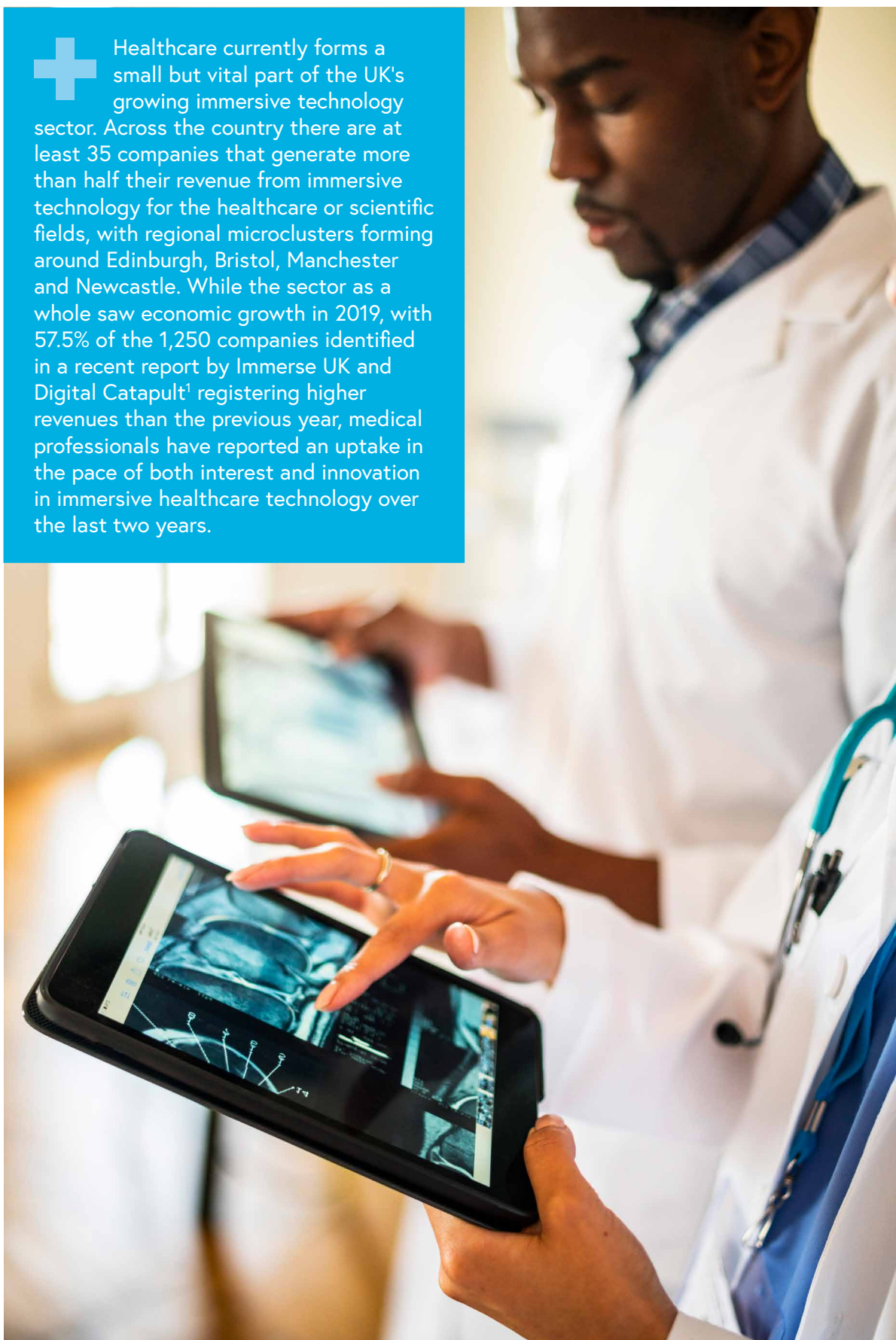
Recommendations:

1. Immerse UK should set up extended reality (XR) in healthcare working groups that bring together key players to identify opportunities, barriers and future trends in the sector. Data, case studies and examples of XR in healthcare are needed to understand its value and impact in the UK market.
2. Industry leaders should prepare a joint report calling on NHSx to develop a strategy for immersive technology in healthcare, prepare a business case for its adoption by healthcare providers and provide support, as it is an emerging healthcare industry.
3. A simpler, quicker and more affordable process for conducting clinical trials of VR products and services should be developed by the National Institute for Clinical Excellence in conjunction with relevant industry bodies.
4. The government should be encouraged to ensure that medical device licensing regulations remain in line with the regulatory regime of the European Union in order to maximise export potential and maintain the UK's attractiveness to overseas suppliers as a market for medical products and services.
5. An online platform for immersive medtech products should be set up in consultation with the trade bodies techUK, the Association of British HealthTech Industries (ABHI) and the Digital Health and Care Alliance (DHACA). The platform should provide a set of minimum digital standards for the products it displays and a quick, simple and transparent assessment process for meeting those standards.
6. Industry leaders should call on the government to designate a public body to spearhead the UK's participation in the XR Safety Initiative and its global drive to tackle cyber-security risks in immersive technology.

Introduction and methodology



Healthcare currently forms a small but vital part of the UK's growing immersive technology sector. Across the country there are at least 35 companies that generate more than half their revenue from immersive technology for the healthcare or scientific fields, with regional microclusters forming around Edinburgh, Bristol, Manchester and Newcastle. While the sector as a whole saw economic growth in 2019, with 57.5% of the 1,250 companies identified in a recent report by Immerse UK and Digital Catapult¹ registering higher revenues than the previous year, medical professionals have reported an uptake in the pace of both interest and innovation in immersive healthcare technology over the last two years.



Viewed from the global stage, the UK's immersive technology sector is certainly punching above its weight. A recent report by PricewaterhouseCoopers (PwC) found that the UK has the largest immersive technology industry in the world, contributing £1.8 billion to national GDP in 2019². PwC predicts that, across all countries, the industry's contribution to global GDP, which stood at £41.9 billion in 2019, will soar to £429.6 billion by 2025 and £1.39 trillion by 2030. Immersive healthcare technology is predicted to add £316.6 billion to global GDP in 2030, accounting for more than 22% of the industry's total contribution.

It is not only such eye-watering global economic predictions that underline the growth potential of the UK's nascent immersive medtech sector. Innovative solutions that improve patient outcomes are in demand from a healthcare system under pressure from an ageing population and demands to reduce costs and boost efficiency. With a long pedigree in surgical training and tools, immersive technology has proven successful in rehabilitation, pain reduction and treatment of trauma, phobias and anxiety. Applications of these gains to other conditions and new contexts are now being developed, while major nationwide studies into using VR to treat psychosis and diagnose Alzheimer's disease are in progress³.

The introduction of 5G mobile networks across the country, which began in May 2019, is expected to enhance the user experience in immersive technology and bring down headset costs, by moving storage and processing to the cloud. Such developments along with rapid advances in VR and AR hardware, such as haptics and omni-directional treadmills, are expected to open up further opportunities for research and development in healthcare. Meanwhile, suppliers such as Samsung are developing dedicated healthcare applications for their headsets.

Institutional support and public funding, which are crucial to successful innovation, have also been strengthened over recent years. Innovate UK, the national innovation agency, has invested £2.5 billion in innovative businesses since 2007 under a matched funding scheme⁴, while The Knowledge Transfer Network (KTN) works to promote research and development (R and D), knowledge transfer and business innovation in healthcare amongst other fields.

Across England, regional Academic Health Science Networks run medtech incubators, accelerators, skills labs and innovation exchanges that put innovators in contact with researchers, engineers and investors. In October 2019, the KTN ran a series of labs aimed at developing new immersive medtech products with the InGAME research and design centre in Dundee that is dedicated to applied games innovation. The lab set a healthcare challenge to game-making firms in the Dundee cluster, which then presented their proposed solutions to a review panel, who decided what follow-up action to take.

Immerse UK, which was set up in 2016 to spearhead development of the immersive technology industry, has worked to foster a joined-up approach among the diverse players within the segment. *The Think Big: Future Health and Life Sciences Unconference*, which was jointly hosted by the Institution of Engineering and Technology, Immerse UK and VR studio Hatsumi in November 2019, is one instance of such work. The conference brought together 159 innovators and experts from across the UK – as well as Europe and the US – to discuss key advances, challenges and opportunities in medtech, with a special stream dedicated to immersive technology in healthcare. This report presents information, issues, views and recommendations given at the conference as a contribution to the ongoing effort to advance immersive healthcare in the UK.



¹ *The immersive economy in the UK 2019*, Immerse UK and Digital Catapult, November 2019.

² *Seeing is Believing: How VR and AR will transform business and the economy*, PwC, November 2019.

³ <https://oxfordhealthbrc.nihr.ac.uk/wp-content/uploads/2019/06/PR-46.19-gameChange-VR-Therapy-Trial-OXHFT-2696.pdf>; <https://cambridgebrc.nihr.ac.uk/expandables/could-virtual-reality-help-detect-the-earliest-stages-of-alzheimers-disease/>

⁴ <https://www.gov.uk/government/organisations/innovate-uk/about#who-we-are>

Designing with data and ethics in mind



Failure to understand the regulation of data is one of the main reasons that funding pitches by medtech start-ups are rejected, Charles Lowe, chief executive of the Digital Health and Care Alliance, told the conference.

"There are some brilliant ideas out there but if you don't understand the really basic aspects of data privacy, then you will never succeed," said Lowe, who also is an assessor for various government funding initiatives. "You also need to specifically build it into your proposal."

"To say that you have developed your super whizzo that will do something wonderful in the digital health space, and then say, 'Oh by the way, we are going to employ somebody to make sure that we are GDPR compliant,' – doesn't work, because there are aspects of data privacy you need to build in right from the start, according to the legislation."

"You need to build in the fact that you are going to minimise the amount of data you collect. You need to build in data protection by default. And you also need to understand the difference between a data-processor and a data-controller, because if you write a proposal that says 'I'm only a data-processor', when actually you are a data-controller, the rest of the proposal is just completely wasted."

Innovators working on immersive technology for healthcare face a special set of data regulations - and ethical considerations - that are unique to the sector. While personal health data is treated as sensitive personal information – requiring greater protection - under the General Data Protection Regulation (GDPR), which came into force in 2018, the new regulatory regime also makes exceptions for the use of such data in the National Health Service (NHS) on public interest grounds.

"Consent is still implied for the NHS in terms of using personal health data," said David Calder, knowledge transfer manager for health and care at the Knowledge Transfer Network. "We can't protect your health without being able to access your information. So you can't stop people from accessing your health data. That is one thing that is different from other industries. But you still have to think about the secondary use of data, particularly for research purposes and so on."

However, tech companies wishing to access and use personal health information must also comply with seven principles that were established by Dame Fiona Caldicott and form part of the NHS confidentiality code of practice. These are:



You must justify the purpose for using confidential, personal information.



Don't use confidential, personal information unless it is necessary.



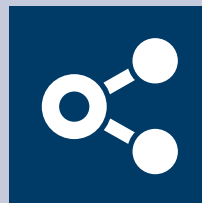
Everyone with access to confidential personal information should be aware of their responsibilities.



Access to confidential, personal information should be on a strict need-to-know basis.



Use the minimum necessary confidential, personal information.



The duty to share information can be as important as the duty to protect patient confidentiality.



You must understand and comply with the law – in a firm, someone must be responsible for ensuring this is the case.



"If you are using AR and VR technology and you are going to be accessing and using personal information at any time, then these principles apply – that is the law," said Calder.

Another upcoming regulatory issue that innovators in medtech need to be aware of is the Medical Devices Regulation (MDR), which comes fully into force on 26 May 2020. Currently, most VR headsets do not need to be registered as a medical device. However, their increasing diagnostic capability combined with the strictures of the MDR is likely to change that. Under the MDR, almost all medical software is upgraded from Class I, which can be self-certified by the developer, to Class IIa or Class IIb, which require certification from a "Notified Body" to ensure the safety and efficacy of the device.

In addition, the MDR expands the definition of a medical device beyond the previous Medical Devices Directive including the words "predict" and "prognosis" for the first time, alongside keywords such as "treat" and "diagnose". Thus, apps that predict mortality rates for procedures or anticipate how a medical condition will develop, for example, are now likely to be covered by the regulations, where previously they were not. Returning to the issue of VR headsets, given the wide impact of the MDR, regulatory agencies are likely to prioritise regulatory adherence to high risk devices.

Lowe also stressed that he is merely raising awareness: as he is not a practising lawyer, all developers of digital health software need to consult their legal advisers on questions that are important to the success of their companies.

The challenges of immersive healthcare



Two ethical dilemmas lie at the heart of the data regulations for digital healthcare. Firstly, how do you make health data available for essential research and development into new treatments, while protecting individual patients' sensitive personal information? Secondly, in what circumstances should a physician proceed to treat a patient who will not give consent to access their medical records, in order to save their life? Both issues – of anonymity and consent – loom large for innovators in immersive healthcare.

Advances in mapping the human genome have made it possible for physicians to obtain the entire genome sequence for an individual patient. While this enables better health outcomes, an individual's entire genome sequence is unique and cannot be anonymised, adding to confidentiality issues in the use of health data. Moreover, recent studies have shown that health data such as medical records and DNA sequences, which has been stripped of names and identifying information in an attempt to make it anonymous, can be traced back to identified individuals, if it is combined with other publicly available information⁵.

The huge capacity of XR for collecting personal information about users amplifies the issues of anonymity and consent. In a 20-minute VR experience, 2 million data points are collected from the user, according to Jeremy Bailenson, director of Stanford University's Virtual Human Interaction Lab⁶. Leading VR headset suppliers are developing biofeedback sensors

for a new generation of headsets that will take intimate data such as heart rates and sweat production levels from users.

Andreea Ion Cojocaru, co-founder of the Berlin-based VR studio Numena, said: *"We are already at the point where all the big players have eye-tracking and they are working on having ways of collecting information about visual expression and brain activity and so on. So, in this context, of course, consent becomes a very big deal."*

Add to this the fact that technology is advancing so fast that things are likely to be possible in a few years' times that were not possible at the time when a user gave their consent, and the scale of the challenge becomes clear. Information about users' brain activity collected through VR that cannot be traced to an individual today, could potentially be used to identify individuals in five to 10 years' time, Cojocaru said.

⁵ <https://about.unimelb.edu.au/newsroom/news/2017/december/research-reveals-de-identified-patient-data-can-be-re-identified>; Melissa Gymrek, Amy L. McGuire, David Golan, Eran Halperin and Yaniv Erlich, Identifying Personal Genomes by Surname Inference, *Science*, 18 Jan 2013, Vol 339, Issue 6117, pp 321-32

⁶ <https://vhil.stanford.edu/mm/2018/08/bailenson-jamap-protecting-nonverbal.pdf>

The wide exposure of the NHS to the global WannaCry ransomware attack of 2017 highlighted another challenge that is faced by medtech innovators: the severe risks posed by cyber-security breaches. Kavya Pearlman, founder of the US-based XR Safety Initiative, which aims to boost cyber-security in the burgeoning XR industry, said its researchers had discovered five forms of cyber-attack that are specific to immersive technology from which users need to be protected. These are:



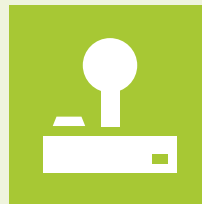
Camera Attack, in which the attacker hijacks the VR camera and looks inside the virtual environment without the user's knowledge.



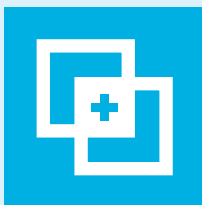
Tracker Attack, where the attacker can track what the user is looking at and see what is going on around them, leading to privacy issues.



Chaperone Attack, in which the attacker is able to remove the safety boundaries that limit the movements of a VR headset user, potentially causing them physical harm.



Human Joystick Attack, where the attacker can actually move the user within the VR environment without their knowledge.



Overlay Attack, in which the entire virtual environment seen by the user is taken over by the attacker.

Lack of regulation in immersive technology and its content also poses a challenge to innovators, the conference heard. *"The worrying factor at the moment is that it is totally unregulated,"* said Glen Hapgood, co-founder and commercial director of VR healthcare application provider ReScape. *"That first experience needs to be: 'Oh my God, this is it!' As soon as that experience is bad or low quality or you haven't focused it right, or they haven't enjoyed that experience, they will never use it again. At the moment, outside of this room, there are a lot of little players who are creating a bad name for the industry."*

The restriction on the use of headsets to people aged 13 and over, enables VR content providers to create horror games of any kind and freely place them in online stores, Hapgood said. *"I think it's going to be really hard to regulate that content because it is 360°, so you could look in one direction and have a different experience to looking in the other direction,"* he said.

A lack of collaboration and replication of effort in a fragmented and undeveloped market is a further issue, as tech firms seek to keep new products under wraps in the early stages of development, said Hapgood. *"We are all wasting so much money, doing something that someone else is doing,"* he said.

Conference participants pointed to the difficulties of getting products licensed as a contributory factor in the fragmentation of the market, with the clinical trials process also being too complicated and convoluted. *"Everyone is duplicating what they are doing because there is not one space where you go through a process and then publish it with a digital set of standards,"* said one.

"The National Institute for Clinical Excellence (NICE) won't assess any digital product and give it the NICE stamp of approval that you would get in the medication world. To get a medical device licence from the Medicines and Healthcare products Regulatory Agency (MRHA) is an 18-month process and there are 6,000 different companies applying for 300 spaces to go through that process."

The cost of clinical trials is also an issue, Hapgood said, *"We are on clinical trial number five now, but we have funded them all ourselves. There is more involvement now with universities, and there are funding options available for us, which is great, but we need to make sure that the path is right for us."*

Rescape had not involved universities or other public bodies in trials to date because it needed to move at pace, and they tended to require companies to amend projects to fit funding requirements. While there are more funding options available today, these tend to be on a matched basis, with companies required to put up 50% of the money themselves.



Immersion for mental health



Growing interest among researchers in the use of immersive technology as a tool for treating psychological disorders has triggered a new wave of spin-off products. Virtual reality has been used to treat Post Traumatic Stress Disorder (PTSD) among military veterans since the 1990s, and a range of VR applications that deploy exposure therapy is available to treat phobias and anxiety disorders following successful trials.

Now, the technology is being investigated for its effectiveness in treating patients with psychosis, addictions to drink and drugs, depression and eating disorders, amongst other conditions. Recognition of VR's potential as a diagnostic tool is also growing. Cambridge University is leading a three-year study on the use of VR to detect early signs of Alzheimer's disease, following preliminary results indicating that it was more accurate than traditional "gold-standard" cognitive tests⁷.

Extraordinary success in the use of VR as an engagement tool to widen access to psychological services has been registered by the mental health team tasked with spearheading the response to the 2017 Grenfell Tower fire, in which 72 people died. The team were on the spot from day one, with a desk in the relief centre set up for survivors, handing out leaflets and seeking to engage people in support services.

"It boggled our minds when people didn't talk to us about trauma and bereavement," said Ross O'Brien, who was then service manager of West London Primary Care Mental Health Service. "But we realised on the first day that it was completely the wrong approach. People didn't trust anybody unless they knew you were somebody who was there before the fire. They didn't trust the NHS, they didn't trust the Red Cross, they didn't trust any voluntary sector organisation."

Instead, the team decided to go into the busy Portobello Market, in sight of Grenfell Tower, and demonstrate Oculus Rift headsets showing games such as a rollercoaster ride or a tour of The International Space Station to passers-by. They would then engage the person in conversation and, if appropriate, offer them outreach support or psychological services and take their details for follow up. The sessions were held weekly for six months.

⁷ <https://cambridgebrc.nihr.ac.uk/expandables/could-virtual-reality-help-detect-the-earliest-stages-of-alzheimers-disease>

"We were flooded with people who then not only wanted to talk to us but started to really talk about all the trauma in the community," said O'Brien. "You instantly build trust, engage and make an impact. There is a release of endorphins and you have a shared experience. And because you have facilitated this, people trust you and they want to talk to you."

The novel approach combined with further work taking survivors back to their flats in the burnt-out tower rebuilt the community's trust in the mental health service and 10,335 people have now been screened for psychological support – close to the service's target of 11,000. *"We think it is the biggest trauma service that has ever been established,"* said O'Brien.

The team also created a series of short VR pieces on mindfulness presented by celebrities including Les Ferdinand, coach at West London football team Queen's Park Rangers, and actor Jason Isaacs, who played Lucius Malfoy in the Harry Potter films, in an attempt to make the practice accessible to the Grenfell community.

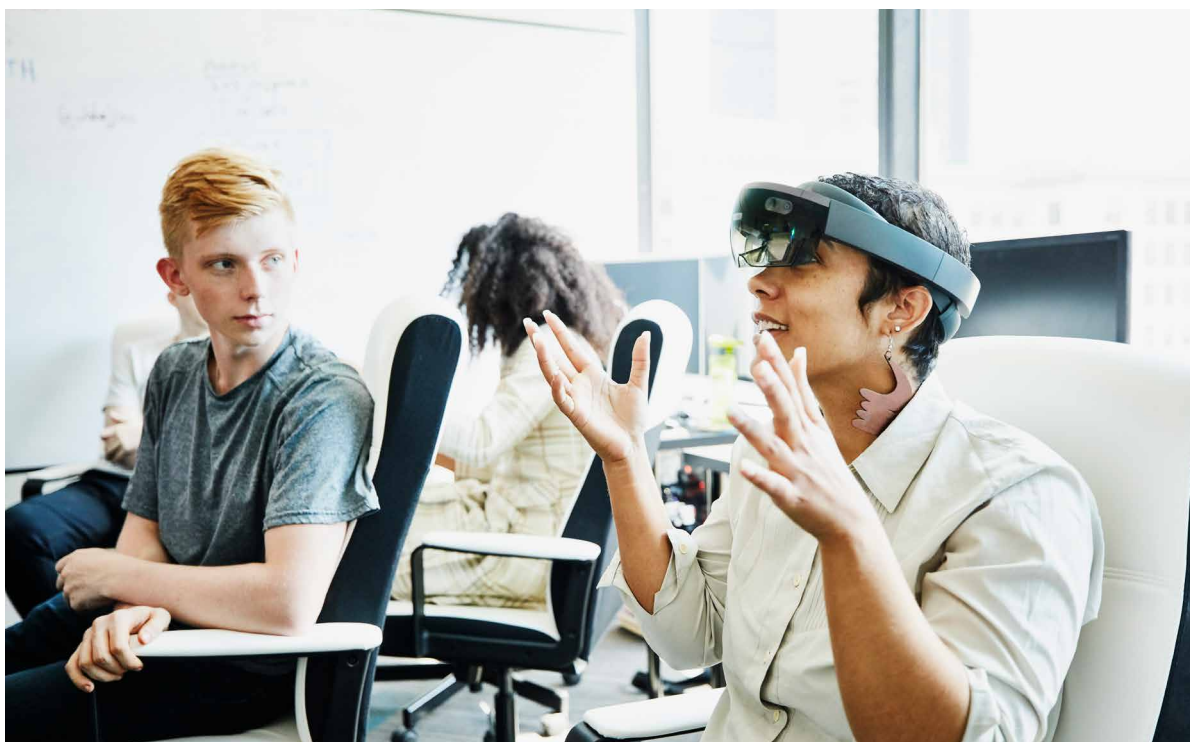
Mindfulness, which draws on both Western psychology and Oriental Buddhist tradition, has gained considerable traction within health and care services over recent years as a method of reducing anxiety and promoting well-being, and VR apps seeking to make its techniques accessible to a wider public have proliferated.

In the Netherlands, DEEP VR has produced a meditative virtual reality experience controlled by breathing, using a custom biofeedback breath belt. Trials have shown that it is effective in reducing anxiety among emotionally and behaviourally disturbed children.

The Mindfulness Centre of Excellence in London, which aims to provide an information hub for innovation promoting the practice, offers an audit called Mindful 360 for medtech firms producing mindfulness apps to ensure that the design process reaps maximum benefits for users.

Co-director Tony Langford said that he is also taking part in a VR arts project in London and Birmingham that aims to provide "self-dosing" relief for people with addiction cravings and anxiety disorders and is developing a new VR imaging system that includes the viewer's body in the virtual environment to mirror the way we actually see things.

The new imaging system aims to increase awareness of sensations in the body, first-person perspective and empathy, as a way of supporting resilience and healing trauma. The centre is exploring such creative and technological interventions with the aim of making mindfulness more accessible.



Case Study: Explore Deep



A visitor to **NEMO Science Museum** in the Netherlands can experience at first hand the way interactive experiences are being harnessed to reduce anxiety. Developed by the team behind Explore Deep, a non-VR translation of the experience is available on permanent display in the museum. Entering an installation that opened in November 2019, you strap on a seat-belt and sit on a chair facing a large screen.

The belt measures your breathing and an interactive game instructs you to breathe deeply from the stomach. As you breathe in, the entire installation lights up, and as you breathe out, the chair vibrates and resonates down your back, creating a multi-sensory feedback loop.



"DEEP is a meditative VR game controlled by deep-belly breathing," explained Niki Smit, co-founder of Dutch design studio Monobanda, who co-created DEEP with Toronto-based game designer Owen Harris. "This method of deep-belly breathing is so natural for us that even new-born babies breathe like this."

The seat-belt is a game controller that was devised by Harris, which links signals from the user's breath to the lighting and image outputs of a VR headset, providing a feedback loop that encourages slower, deeper breathing and, with it, relaxation and calmness. The aim is to provide easier access to meditation as a method of reducing anxiety.

Smit and Harris have teamed up with Dr Isabela Granic, professor of developmental psychopathology at Radboud University in Nijmegen, The Netherlands, to develop DEEP as an anxiety reduction tool for children and young adults.

Radboud is testing the effectiveness of DEEP in reducing anxiety and has published two papers to date, with five more in the pipeline. Researchers held random-controlled trials with pupils at a school for children with severe behavioural problems over several months. Half the class were told to play the game before going into class and half were not.

"One of the things the teacher reported is that, in these very hyper and sometimes even aggressive children, the effects of playing DEEP for a class were measurable for up to two hours after playing, which is hugely useful because for two hours they have an emotionally receptive student," said Smit.

exploreddeep.com

Roads to recovery

A key area for the application of immersive technology in healthcare is in the fields of rehabilitation and pain reduction. The quest to find new and enhanced solutions for rehabilitation using virtual reality got underway after the millennium and research and development efforts have spanned stroke recovery, motor disorders, Parkinson's disease, brain damage, and phantom limb pain. One recent study has found that VR therapy significantly improves balance and mobility outcomes for children with cerebral palsy⁸, while another reported promising results for the use of VR technology with myoelectric and motion-tracking controls in tackling treatment-resistant phantom limb pain⁹.

Rehabilitation for stroke victims has been a major focus of activity over the past decade, following promising results in early trials. A 2012 Cochrane Review found VR therapy was significantly more effective than conventional methods in improving upper limb function and daily activities among stroke patients, although not in increasing grip strength and walking speed¹⁰. Research and development in both upper and lower limb rehabilitation have continued to build since, given their importance to patients recovering from a wide range of conditions and injuries as well as people with physical disabilities.

Sheffield Hallam University (SHU) is developing VR applications in three major areas: upper arm rehabilitation, prosthetics training for amputees, and pain relief for severe burns patients, associate game developer Ivan Phelan told the conference. Phelan and his colleagues at SHU's Culture, Communication and Computing Research Institute (CCCRI) have developed VR applications to boost children's engagement in upper arm rehabilitation, which tends to be lengthy and repetitive.

Working with Sheffield Children's Hospital, the multi-disciplinary team designed VR scenarios for archery and rock climbing to encourage movements used in rehabilitation exercise programmes that many children failed to complete. When physiotherapists pointed out how children avoided stretching movements that they found uncomfortable, researchers were able to use VR to adjust the height of the quiver or increase the size of the bow in the archery game to encourage full participation in therapy.

Physiotherapists reported dramatic improvement in performance using the VR archery application and recorded children's movements on a goniometer, which measures the range of motion in joints. Phelan said they found an increase in all movements, while hospital staff had since reported that children's progress had been sustained over time. *"We have just got some Grow MedTech funding to go further with this and get it to the next stage because SCH are very happy with it and they want to get it into clinics as soon as possible,"* he said.

The team have also had success developing engaging programmes to train amputees in the use of state-of-the-art prosthetic arms, for which rejection rates are high. They developed life-like VR training scenarios linked to a myoelectric armband, which conveys muscle signals, and the latest artificial hand from leading German prosthetics manufacturer Ottobock, to replace existing training software, which is some 30 years old and tends to be very abstract.



⁸ Nadieh Warnier, Effect of virtual reality therapy on balance and walking in children with cerebral palsy: A systematic review, *Pediatric Health*, November 2019.

⁹ Brian Chau, Immersive virtual reality therapy with myoelectric control for treatment-resistant phantom limb pain: Case report. *Psychiatry*, August 2017.

¹⁰ Laver K, George S, Deutsch JE, Crotty M, Cochrane review: virtual reality for stroke rehabilitation, *European Journal of Physical and Rehabilitation Medicine*, 20 June 2012, 48 (3), pp523-530.

When presented with an image of an apple and a prosthetic arm on a VR headset, the first patient to take part in trials immediately grabbed it, despite having had no previous exposure to myoelectric prosthesis and before any training began. The application was developed into a three-day "try-before-you-buy" programme for artificial limbs.

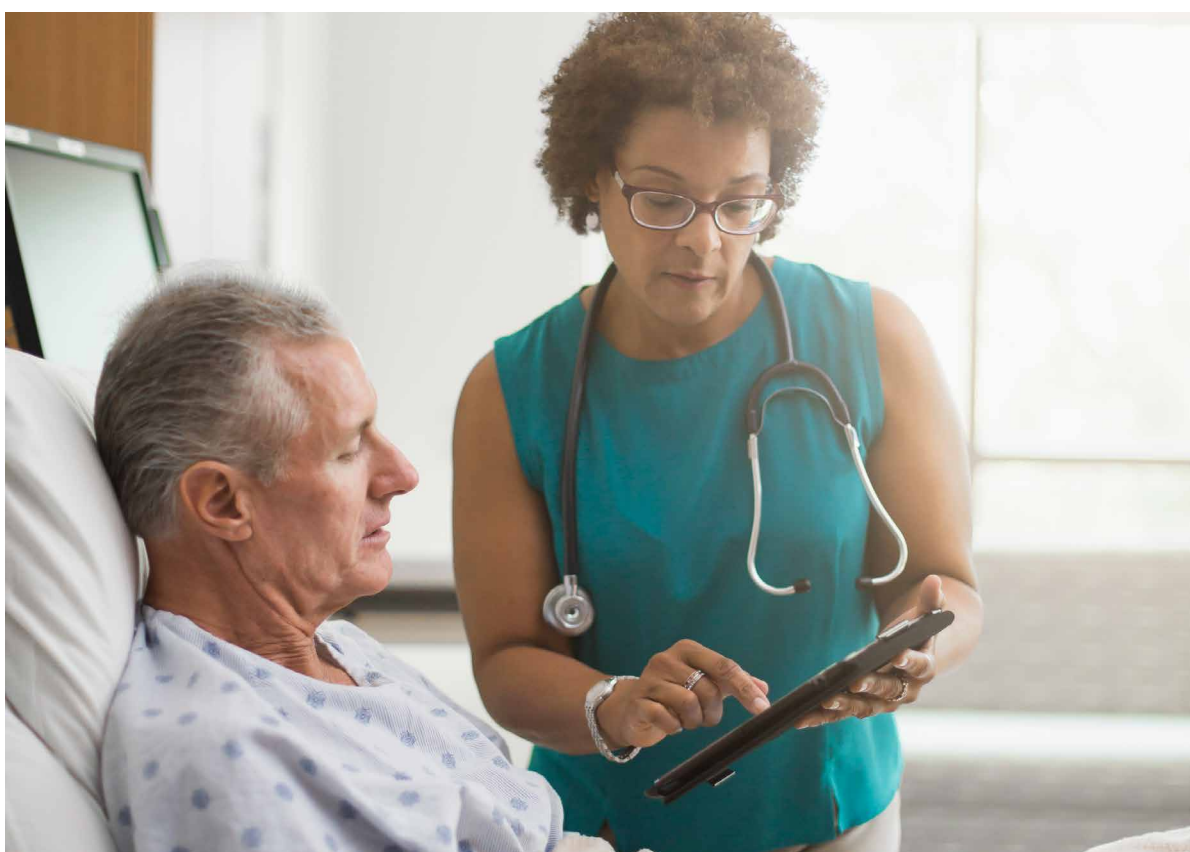
The CCCRI has secured funding from the National Institute for Health Research for refinements to the programme including more gradual opening and closing of the hand and a weighted sleeve to prepare patients for the heaviness of an artificial arm. It is also being trialled for home use to help bridge the gap between training and delivery of a prosthetic arm, which can amount to some four weeks.

The third project, which builds on extensive research into pain distraction and VR, examined the impact of VR on pain distraction for severe burns. Neuroscientists theorise that VR is effective in distracting patients from pain because it competes for their attention, taking away from the resources in the brain that are involved in processing pain and diverting them towards processing information in the virtual environment. While the pain does not go away, the patient is more in control and less overwhelmed by it.

Researchers assessed how VR was impacting a patient's tolerance and threshold for pain using a cold pressor test, in which a subject's blood pressure and heart rate are measured when they place their hand in ice-cold water. Active VR games such as playing basketball and herding sheep were found to increase patients' pain tolerance by 500% to 900%, thereby helping to distract them from a painful injury or illness.

Clinical trials at a Sheffield teaching hospital, which were funded by the MRC, proved equally successful. A car-crash victim, who had over 100 staples in his body and was not responding to any medication or treatment, was put forward for the VR trials because staff were unable to change his dressings. While the patient was absorbed in VR, medics were able to remove all the staples, to the surprise of both staff and researchers, Phelan said.

The BBC filmed the response to the VR trials of one 19-year-old patient, who suffered severe burns to her legs when a bowl of boiling water fell in her lap. Megan Moxon said: "Without the VR, I would be virtually in tears, because it's that painful. But with the VR, [the nurse] would be able to prod it, poke it, put a bit of pressure on it and I wouldn't feel a thing."



Case Study: Nature Treks VR



There is nothing virtual about the success of **Nature Treks VR**, the non-competitive, ambient relaxation game that takes users swimming with dolphins and transports them to south sea islands, desert oases or outer space.

The game, which is available on all major headsets, has sold more than 150,000 units online since May 2017, was one of only 50 titles selected to take part in the launch of Oculus Quest, and boasts ratings of 4.4/5 on Oculus Go and 87% on Steam.



However, commercial success was not the primary aim of John and Ria Carline, co-founders of GreenerGames, when they created Nature Treks, which emphasises positive and calming experiences in contrast to the violence and speed that characterise many VR games. Instead, they wanted to draw on their parallel careers in the games industry and the care sector to create something that would help people.

"At that point, there was nothing like Nature Treks and it had an enormous amount of downloads," said Ria Carline. "One morning we got up to be told that we had broken the App Store."

The first Nature Treks video game, Healing with Colour, was for sale on the App Store, when Swedish game developer Markus Persson, who created Minecraft, mentioned it in his blog. The same night there were 30,000 downloads in just one hour. Universities and healthcare settings then began to get in touch with GreenerGames, reporting positive outcomes from using Nature Treks, and some 100,000 apps have now been supplied to such settings.

The couple went on to actively develop Nature Treks as a VR tool for managing pain and coping with symptoms and anxieties through trials at Severn Hospice in Shropshire. Nurse Rebecca Farmer, who mounted the



trials, developed a screening tool to assess whether it was safe to use VR with a patient. She identified symptoms with which it might be unsuitable, such as dizziness, nausea and infection.

Farmer said none of the symptoms caused problems while patients were using Nature Treks in the trials, while it proved good for reminiscence, which helped them to relax, with reduced heart rates recorded. *"Patients definitely felt calmer after the experience," she said. "We have no negative experiences from patients."*

naturetreksvr.com

Steps to an immersive future



Early in 2019, the UK government launched two major initiatives aimed at boosting the adoption of digital technology within the National Health Service. The NHS Long Term Plan placed digital health services squarely in the mainstream of healthcare provision¹¹, while NHSx, the new body to be set up jointly with industry, was tasked with setting standards and national policy for "technology, digital and data" in the service¹².

Thanks to such efforts the NHS is "starting to become an environment in which innovators and new technologies such as AR and VR can find a home", said David Calder, knowledge transfer manager for life sciences (health) at the Knowledge Transfer Network. "Before it was really, really difficult, now it's just really difficult to innovate in the NHS," he said.

"There is an Academic Health and Science Network (AHSN) in every region of England to help innovators who are targeting the healthcare sector and they all have strong networks of expertise – clinical, technological and academic - to draw on", said Neil Mortimer, head of digital health at the West Midlands AHSN.

"We in the West Midlands have got a digital incubator and accelerator, a digital health and skills lab, and a regional health innovation exchange that allows people with problems to publicise them to the innovation

community," he said. "We are not cash-rich, but we are really good at finding money, whether it's research [grants], venture capital or angel investment."

Aquarius Population Health (APH) is an independent health economics consultancy that advises entrepreneurs on how to prepare the sort of evidence-based case for adoption of their product that is expected by healthcare bodies. Associate Georgie Weston told the conference that five areas of evidence are used to build up such a case: insight; pathway mapping and micro-costing; health economics; interactive decision tools; and communication.

The first stage, insight, is "a whole set of questions that need to be addressed before you progress into the technical end of things, such as who is making the decision to adopt your product and what outcomes are likely to change their decision in your direction", she said.

¹¹ <https://www.gov.uk/government/news/nhs-long-term-plan-launched>

¹² <https://www.gov.uk/government/news/nhsx-new-joint-organisation-for-digital-data-and-technology>

"Is it solely cost, which at the moment in the NHS is so important," Weston said. "Is it clinical outcomes; unnecessary treatments avoided; staff time decreased or decrease in consumables? And then we need to think about the structure of care: is it primary care using the product or intervention and, then, is it secondary care funding it? How does that funding mechanism work? Or it could be a more strategic decision."

The second stage, pathway mapping, involves plotting out what is currently going on in the healthcare segment that is being targeted on a granular level. The enterprise will be asked to look at the activities involved, the staff used, the consumables and the costs and should then be able to identify the unmet need that the product is addressing.

"Then you will do the same for a hypothetical pathway for your product," said Weston. "In this sector, there are lots of innovative and transformative interventions being designed. These can really disrupt and change the delivery of healthcare and health services. So, it is not only the impact of the product itself that you are looking for, it is [also] the additional benefit of changing that pathway. This is a key step."

Next comes the substantial economic evaluation, which should draw on the insights and pathway mapping. *"There are lots of different approaches that can be used," she said. "You might do a theoretical model, which you don't need very much data for. You can also do more of a data analysis, if you have already got a pilot study or a clinical trial. The results of the model can be fed into publications or business case studies."*

"Use of interactive decision tools – the fourth stage – is a good way to engage decision-makers because medtech products are adopted at a regional level, not a national one", said Weston. "It will be a robust health economic model, which might have been published, so the methodology is peer-reviewed and out there," she said. "The key is that it is really flexible, so the regional manager can change the population, the cost or the pathway for patient management within the model to reflect what they see [on the ground in their region]."

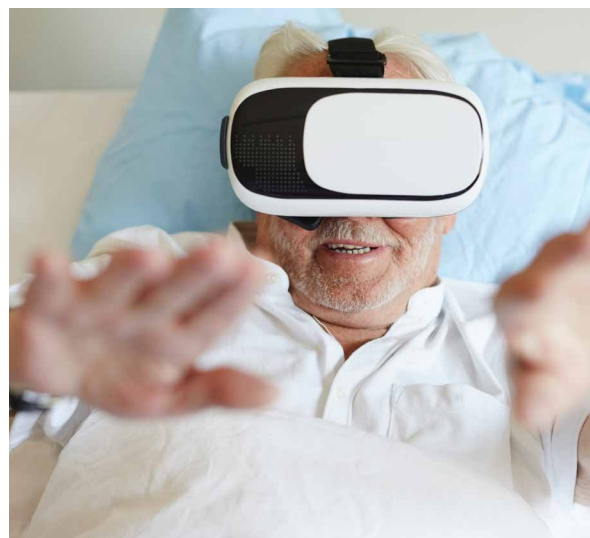
"Finally, written publications – especially peer-reviewed ones – are helpful in influencing clinicians and policymakers. Here it is important to think about your intended audience and key message, which should be the value of your product and what action you want people to take", Weston said.

As well as adapting to the structures and requirements of Britain's health system, innovators in immersive healthcare technology need to consider the issue of cyber-security in relation to their products and to the research and development process. The XR Safety Initiative (XRSI), which is based in California, is spearheading the development of global cyber-security standards for the immersive technology industry, which faces high levels of risk because it is developing so fast.

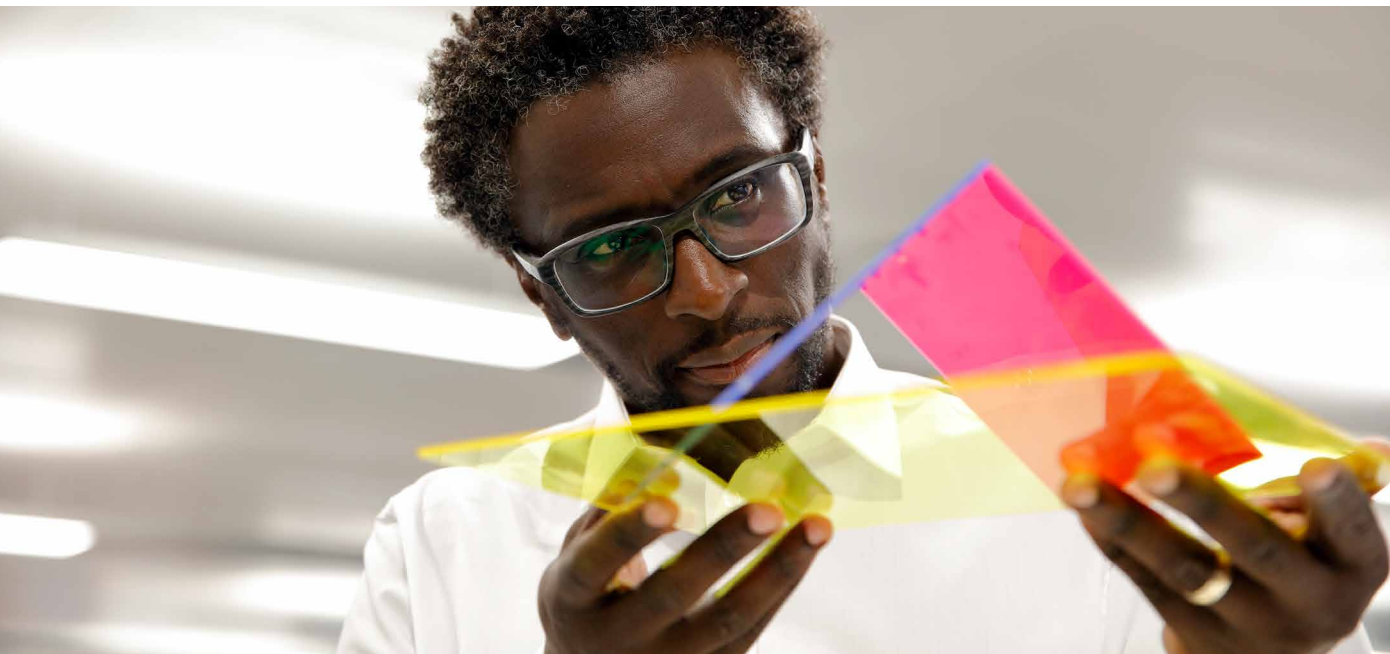
"XRSI is working with the online safety awareness agency Stop, Think, Connect, on an information campaign about cyber-security risks specific to immersive technology that will target 22 governments and 2,200 organisations around the world", founder Kavya Pearlman said via teleconferencing.

In June 2019, it set up an XR Data Classification Framework to classify the data used in immersive technology according to how sensitive it is and launched a public working group for industry stakeholders to take part in the exercise. XRSI went on to establish a 3C Information Security Framework for XR Enterprises that will consider ethical risks such as harassment and misinformation that were previously ignored by big tech firms.

At the conference, Pearlman announced a new XR Healthcare Advisory Group, which XRSI is due to set up by April 2020, and she urged participants to join it – and the XR Data Classification Framework working group – in support of the fight against cyber-crime.



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