

Impact case study (REF3)

Institution: Sheffield Hallam University		
Unit of Assessment: UOA34 - Communication, Cultural and Media Studies, Library and Information Management		
Title of case study: Using Virtual Reality for the Benefit of Patients and Medical Practitioners		
Period when the underpinning research was undertaken: January 2014 - February 2019		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s): Ivan Phelan	Role(s) (e.g. job title): Senior Research Fellow	Period(s) employed by submitting HEI: Feb 2013 – Present
Period when the claimed impact occurred: July 2016 - present		
Is this case study continued from a case study submitted in 2014? No		

1. Summary of the impact

The *Impact VR* team at Sheffield Hallam University (SHU) has developed a suite of immersive, interactive Virtual Reality (VR) rehabilitation systems for paediatric and adult patients with neurological and musculoskeletal conditions, orthopaedic trauma, and chronic pain. Immersive VR can be defined as an artificial environment where the user feels just as immersed as they usually feel in everyday life. The impact achieved by these innovations has been fourfold: (i) physically and/or psychologically enhanced the health, lifestyles and wellbeing of patients; (ii) promoted more effective practitioner standards and services; (iii) increased public awareness and improved understanding of such technology and entering a related debate on social policy; and (iv) established commercial and medical collaborations to further improve healthcare and cost-effectiveness in the NHS.

2. Underpinning research

SHU's *Impact VR* research group (led by Ivan Phelan) has been working with VR applications in the healthcare sector since 2013. Its first project developed a high-fidelity VR training system for military surgical staff in a simulated field hospital environment, incorporating novel haptic feedback mechanisms within the VR scenario. This was a MOD-funded project from January 2014 to March 2015.

Exploring VR Prosthetics Training

This project received internal funding for a proof-of-concept project from January to June 2014. This preliminary research gave upper limb amputees a simulated virtual interactive experience of what it would be like to use a prosthetic limb. It became the basis of a 'VR Prosthetics Training System' grant from the NIHR i4i, running from August 2017 to Present [R1].

In collaboration with the Department of Physical Medicine/ Rehabilitation at the Loma Linda University Medical Center in California, *Impact VR* repurposed the prosthetics interactive virtual environment to be used in a study as a method of relieving phantom limb pain. Analysis of pain scales showed statistically significant decreases per session and on follow up at six weeks [R2].



Further to this collaboration, a pilot study was conducted to explore the effects of therapeutic immersive VR on pain in upper-limb complex regional pain syndrome (CRPS). Results indicate

Impact case study (REF3)

that four of the six participants reported a subjective improvement in their pain and daily function [R3].

VR distraction from pain during burns dressings at Sheffield Teaching Hospital (STH)

This MRC-funded project ran from August 2016 to December 2017. It sought to investigate possible ways of reducing the pain and anxiety experienced by burns victims by using immersive VR distraction techniques. This involved engaging patients in 'passive' or 'active' VR scenarios (the latter requiring the individual to actively participate rather than passively observe). In keeping with *Impact VR*'s customary modus operandi, these scenarios were developed following a consultative workshop which included two burn survivors, games designer, a clinical psychologist and a SHU psychologist with prior experience as a burns nurse. Immersive distraction techniques were tested out in trials involving 15 university students (10 men and five women) [R4], before being reapplied to burns victims in a hospital setting [R5].



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A clinical trial conducted with 5 in-patients (with a mean age of 48.2) at the Burns Unit showed how, during the VR exposure, the burn-injured patients experienced considerably less pain and/or anxiety (according to score-ratings of 0 to 100), compared to conventional dressings sessions, which are typically extremely painful. It was those immersive scenarios that possessed high degrees of patient presence and engagement which proved the most effective. This suggests that 'as well as reducing the negative impacts of dressing change on pain, anxiety, and distress, immersive VR can create positive experiences of fun, challenge, and laughter, 'lightening' the experience for all parties.' [R5]. A post-study staff focus group highlighted their enthusiasm for, and eagerness to utilise such an innovation in their practice [R5].

VR upper limb rehabilitation with Sheffield Children's Hospital (SCH)



This MRC-funded project ran from August 2017 to February 2019, the principal aim of which was to develop immersive VR scenarios for children with upper limb injuries, to facilitate a less painful and more effective recovery of limb movement. Playtests were carried out at Sheffield schools with physiotherapists to identify potential issues and steer the design of the system before the clinical trials.

3. References to the research

- R1. Phelan, I., Arden, M., Garcia, C. & Roast, C. (2015). Exploring virtual reality and prosthetic training. In: T. Hollerer., V. Interrante., A. Lecuyer & J.E. Swan (eds.) *Proceedings 2015 IEEE Virtual Reality Conference (VR)*. Arles, France, 23-27 March, 2015. Piscataway, NJ, IEEE, 353-354. <https://doi.org/10.1109/VR.2015.7223441>
- R2. Chau, B., Phelan, I., Ta, P., Humbert, S., Hata, J., & Tran, D. (2017). Immersive virtual reality therapy with myoelectric control for treatment-resistant phantom limb pain: Case report. *Innovations in Clinical Neuroscience*, 14(7-8), 3. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5880370/>

Impact case study (REF3)

- R3.** Chau, B., Phelan, I., Ta, P., Chi, B., Loyola, K., Yeo, E., & McCowan, B. (2020). Immersive virtual reality for pain relief in Upper Limb Complex Regional Pain Syndrome: A Pilot Study. *Innovations in Clinical Neuroscience*, 17(4-6), 47
<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7413329/>
- R4.** Phelan, I., Furness, P., Fehily, O., Thompson, A., Barker, N., Lamb, M. & Lindley, S. (2019). A mixed-methods investigation into the acceptability, usability and perceived effectiveness of active and passive virtual reality scenarios in managing pain under experimental conditions. *Journal of Burn Care & Research*, 40(1), 85-90.
<https://doi.org/10.1093/jbcr/iry052>
- R5.** Furness, P., Phelan, I., Babiker, N., Fehily, O., Thompson, A. & Lindley, S. (2019). Reducing pain during wound dressings in burn care using virtual reality: a study of perceived impact and usability with patients and nurses. *Journal of Burn Care & Research*, 40(6), 878-885. <https://doi.org/10.1093/jbcr/irz106>

All articles were rigorously peer-reviewed prior to publication.

4. Details of the impact

(i) Improving Patient Healthcare, Lifestyle and Well-Being

The suite of projects has succeeded in developing a set of immersive, interactive VR techniques which have considerably improved the health, well-being and lifestyles of children and adults affected by neurological and musculoskeletal conditions, orthopaedic trauma, and chronic pain. The perceived benefits of the interventions are reflected in the testimonials of patients and their relatives, which show enhanced satisfaction and greater freedom from pain [E1].

'It [VR intervention] was like I was picking up things with my own arm'; 'I enjoyed using a hand for the first time in my life!' (Trans-radial amputee)

'It [VR intervention] took my mind off from pain and made me concentrate in the VR, this is a good fall-back'; 'I would like to always have this even if I had to pay for it' (adult burns patients)

'I was doing something I enjoy'; 'It [rehabilitation exercise] was much easier to do'; 'I didn't notice any pain' (upper limb rehabilitation paediatric patients)

'She [patient] didn't look as though she was in pain at all. She looked as though she could've done a lot more [movements] than she realises possible' (family member)

A clinical trial of 10 children aged 9-16, who were receiving rehabilitation after burn injuries (n = 6) or bone fractures (n = 4) showed a reduction in the experience of pain and difficulty rated overall as lower than usual, both with median scores of 3 (pain range 0-6.5; difficulty range 0-7). Enjoyment was rated as much higher than usual, with a median rating of 10 (range 8-10). Physiotherapists use a goniometer to record patients' range of movement (ROM), which showed a marked improvement [E1].

The upper limb rehab system was repurposed as part of a chronic pain management program for InHealth Pain Management Solutions. Tom Sheldon (Physiotherapist Specialist at InHealth) has reported that *'the use of VR transitioned well to this community setting and encouraged people to move in ways that they have not done for some time. Patients received VR headsets to take home, and the feedback was entirely positive once people had become accustomed to using the technology. We found that individuals who were quite severely socially isolated found that they were able to engage with new experiences and new ways of exploring their world.'* [E2].

(ii) Enhancing Medical Practice

The testimonials of NHS practitioners in Yorkshire and Lancashire also reflect the advancements made by *Impact VR*. Burns unit staff were able to spend more time on changing dressings and removing more surgical staples, all of which helps speed up the healing process: *'She [patient] was not in need of any extra analgesia during, before or after the dressing changes. Normally she would have asked for some'; 'Normally he [patient] does not allow the staff to do what we want to do because of the pain, whereas with the VR he allowed me to do that.'* [E1].

Impact case study (REF3)

The physiotherapists who participated in the VR rehabilitation study thought that VR techniques of this nature (active immersive VR) would form the cornerstone of future rehabilitation, treatment and therapy: *'I would feel very positive if VR technology were gradually to come into the clinical areas and be used more widely and routinely in the care of children in the future.'* [E1].

A direct Twitter message from a staff member who participated in the VR study for burns patients stated how it changed the way they approached their role. *'I was the Student Nurse on placement in the burns unit when you were testing your VR therapy [...]. It [VR intervention] was the inspiration for my last assignment which I did on pain management in burns and managed to incorporate what I learned from you within it. So thank you.'* [E2].

Professor Paul Dimitri (Director of Research & Innovation at SCH) writes, *'We received very positive feedback about this novel rehabilitation method from health rehabilitation staff, patients and parents. It was clear that children who needed to undergo painful rehabilitation procedures, rapidly overcame their pain to participate in the exercises to facilitate their recovery.'* As Professor Dimitri further explains, these procedures are now being introduced in various clinical settings, since *'We were keen to integrate VR into regular clinic use as soon as we could, and potentially in patients' homes where it could have even greater benefits, improving the delivery of rehabilitation in an effective way to benefit patients and staff'*. The success of the upper limb rehabilitation trial led to additional funding to create a refined and portable version of the system to be trialled in the homes of SCH patients to reduce the strain on the clinics and improve adherence to physiotherapy. SCH has approved a large scale, pilot trial for 18 months for upper limb rehabilitation (currently paused due to COVID-19) [E2].

(iii) Contributing to Public Understanding and Policy Debate

A Wellcome Trust-funded project has been exhibited in local museums, the National Museum of Scotland and the World Para Athletics Championships in London in July 2017. A range of interactive activities and exhibits were developed that focused on joint physiology, prosthetics, and the lived experience of people with limb loss. The combined visitor count from all events was 12,236. Questionnaire and poster evaluation demonstrated increased knowledge in all areas of the exhibition by the majority of attendees, was enjoyed by visitors who evaluated the exhibits favourably: *'Overall, the exhibition was an engaging and interesting experience for visitors and offered something for adults and family groups alike. Visitors left the exhibition having learnt about the challenges of living with limb loss and how technologies can help to overcome some of these difficulties'*. In terms of overall enjoyment and value of the exhibitions, visitors gave an average rating of 4.5/5, and visitors left the exhibition feeling considerable better informed about all of the areas that were covered [E3].

One of the visitors, an amputee himself, learnt about modern prosthetics as a result of attending the exhibition at Weston Park, and met Kevin (the amputee demonstrating the use of his advanced prosthetic arm). Despite being in his 70s he decided that he wanted a new prosthetic and has now been fitted with a modern myoelectric prosthetic arm [E3].

Upper limb rehab was shown on BBC Click, BBC Breakfast and YouTube - 06/02/19 - 5,498,021 views. An email was received from a member of the public asking if similar techniques could help with conditions like Functional Neurological Disorder which manifests as a motor dysfunction/gait disorder. *'On seeing the programme I had a feeling of hope that maybe a VR experience such as the children were having could be developed to immerse someone who needs to use diversion in such a way that the brain could be fooled, and normal function restored. I am retired now but once was a nurse. I can see how research such as yours will continue to have momentum and impact'* [E4, E5].

VR Prosthetics was demonstrated during the visit of the Duke of Sussex to SHU, was featured on regional and national television news and the use of VR was tweeted by the Royal Family – 25/07/19 with 2.6K 'likes' from the public [E6].

Impact VR contributed to the Digital Healthcare and Healthy Living Task Force workshops for the National Centre for Universities and Business held on 05/12/2016 and 21/03/2017 [E7]. This also formed part of the Evidencing Digital Health Tools workshop working group led by NHS England on 18/07/2018 and the National Institute for Health and Care Excellence (NICE), Public Health England, MedCity and Digital Health. This fed into the initial NICE evidence standards framework

Impact case study (REF3)

for Digital Health Technologies (DHT) released in December 2018 (updated in March 2019 after open consultation). The framework describes standards for the evidence that should be available or developed, for DHTs to demonstrate their value (technologically and economically) in the UK health and care system and to help enable them to identify the most effective, valuable technologies and help speed their take-up and adoption [E8].

(iv) Establishing Commercial and Medical Collaborations

The Director of the Unreal Engine Enterprise team at Epic Games (the makers of Fortnite and the industry-standard game development engine 'Unreal') has provided *Impact VR* with a Technical Account Manager and the premium support version of the Unreal game engine on a pro bono basis due to their interest in the application of their software in novel ways [E9].

Further collaboration with SCH has taken the form of joint grant applications for an MRC Confidence in Concept grant to provide rehabilitation for children after lower limb surgery. Dimitri explains, '*We are forging a longer-term strategic partnership with SHU to explore our shared vision of SCH becoming a National Centre for VR therapy in children*'. [E2].

During July and November 2016, VR prosthetics was shown on BBC's Look North and Channel 4 News (online 7,337 views, live views N/A). This exposure led to Loma Linda University Medical Centre in California to contact the team to collaborate on research around complex regional pain syndrome (CRPS) and VR. The results of this research have been published as a pilot study indexed in PubMed, showing satisfactory results in pain reduction [E4, R3].

The pain reduction project was in 79 pieces of coverage on BBC national and regional television, radio and online channels - 18/04/2018 - 40,848,326 views. InHealth contacted *Impact VR* to repurpose the VR systems for chronic pain after viewing this footage, which led on to developing a bespoke VR system based on their needs around chronic pain [E2, E10].

5. Sources to corroborate the impact

- E1. Data from Clinical Trials – testimonials and goniometer records
- E2. Testimonials from healthcare workers, including physiotherapist, student nurse and Clinical Director, NIHR Children and Young People MedTech Cooperative
- E3. Wellcome Trust award, end of grant report
- E4. Corroboration of increasing public understanding and collaborations via media engagements: https://youtu.be/Hp_KKhPMXJE; <https://youtu.be/vSF9Z1BLnQA>; <https://youtu.be/sDc5llj1VbY>
- E5. Audience response / feedback from the BBC Click
- E6. Public prosthetics demonstration to the Duke of Sussex: <https://www.bbc.co.uk/news/uk-england-south-yorkshire-49116831>;
- E7. Correspondence corroboration invitation to join Digital Healthcare and Healthy Living Task Force correspondence
- E8. NICE guidelines: Evidence Standards Framework for Digital Health Technologies, March 2019. <https://www.nice.org.uk/Media/Default/About/what-we-do/our-programmes/evidence-standards-framework/digital-evidence-standards-framework.pdf>
- E9. Correspondence with Epic Games corroborating collaboration.
- E10. Media coverage report - April 2018