

Institution: University of Chester		
Unit of Assessment: 11 Computer Science and Informatics		
Title of case study: Using Virtual Reality to Aid Cognitive Rehabilitation of Stroke Survivors		
Period when the underpinning research was undertaken: June 2015 – ongoing		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s): Nigel W. John Serban R. Pop Panagiotis Ritsos Tom Day	Role(s) (e.g. job title): Professor Dr, Senior Lecturer Dr, Senior Lecturer Research Assistant	Period(s) employed by submitting HEI: 2015 – ongoing 2015 – 2019 2015 – 2017 2018 – 2020
Period when the claimed impact occurred: 2018 – ongoing		
Is this case study continued from a case study submitted in 2014? N		

1. Summary of the impact (indicative maximum 100 words)

We have utilised affordable virtual reality (VR) technologies within several novel healthcare applications. In particular we have developed an immersive environment that has been shown to aid in the cognitive rehabilitation of stroke survivors. Previous use of VR in this area has focussed on physical rehabilitation and not addressed those activities of daily living that require cognitive processing. Our system has had particular impact on the cognitive recovery of people with more severe impairments following a stroke. The system has undergone a clinical trial and is being commercialised. The goal is to improve patient treatment and reduce costs to the NHS.

2. Underpinning research (indicative maximum 500 words)

The Medical Graphics Research group at the University of Chester was established in 2015 by John; and Day, Pop and Ritsos have all been members of the group involved in this Impact Case Study. The period concerned has coincided with the availability of new affordable hardware for Virtual Reality (VR), specifically head mounted displays and interaction devices. The group started to exploit this technology and develop the underpinning applied research necessary for applications in healthcare, including training of paramedics and assisting patients and people with disabilities in carrying out activities of daily living. The first project (2015-2017) was to create an immersive driving simulator for users of powered wheelchairs [1]. The validation study produced statistically significant evidence that using VR for training increased the competency of inexperienced powered wheelchair drivers. This positive result was the catalyst for broadening our research efforts into other healthcare areas. We started to use gamification techniques to create serious games for training and rehabilitation and learned how to minimise unwanted side effects from VR such as cybersickness. Projects with paramedics [5], endoscopy surgeons, and stroke specialists [4] have subsequently occurred. The latter is the main focus of this impact case study.

We identified a need, through networking with local clinicians, to provide a new tool to help with the cognitive rehabilitation of stroke patients, starting this activity in 2017 and continuing until the present [2, 4]. Stroke is the second largest cause of death and disability worldwide with 15 million cases occurring each year. This includes over 113,000 strokes every year in the UK and over 950,000 stroke survivors among those aged 45 years and over (source: Stroke Association, <https://www.stroke.org.uk/>). Over two-thirds of stroke survivors suffer from post-stroke cognitive impairments (PSCI), reduced ability to undertake activities of daily living, inability to return to work or participate in social activities, increased caregiver strain, and higher rates of institutionalisation and mortality. This places a huge burden on the healthcare system and many survivors require substantial socio-economic support, sometimes for the rest of their lives. The Stroke Association predicts that the overall cost of stroke in the UK for those aged 45 years and over will rise from £26 billion in 2015 to £43 billion in 2025 and £75 billion in 2035, an increase of 194% over 20 years. PSCI can impair one or several cognitive domains, with varying degrees of severity. Although brain mechanisms of recovery are poorly understood, half of those with PSCI at baseline

Impact case study (REF3)

improve their overall cognitive score over time. If this recovery time can be shortened, then the cost savings can be significant.

The cost benefits of using immersive virtual reality for such projects must be proven in order to achieve the desired impact. John was involved in a theoretical cost benefit analysis of visualization in virtual environments during 2018 [3]. The practical application of the ideas elucidated in this paper have been a part of the underpinning research for designing and evaluating the stroke rehabilitation project.

3. References to the research (indicative maximum of six references)

- [1] John, N. W., Pop, S. R., Day, T. W., Ritsos, P. D., & Headleand, C. J. (2018). The Implementation and Validation of a Virtual Environment for Training Powered Wheelchair Manoeuvres. *IEEE Transactions on Visualization and Computer Graphics*, 24(5), 1867–1878 DOI: [10.1109/TVCG.2017.2700273](https://doi.org/10.1109/TVCG.2017.2700273)

Listed in REF2

- [2] InnovateUK Grant Award, September 2018
 Application number: 11029
 Competition: Digital health technology catalyst round 2
 Project title: VIRTUE - Virtual Reality for Cognitive Stroke Rehabilitation
 Total Project Grant: £451,907
- Cadscan Ltd, £190,886
 - Countess of Chester Foundation Trust, £80,318
 - University of Chester, £180,703
- Project Duration: September 2018 – December 2020

- [3] Chen, M., Gaither, K., John, N. W., & McCann, B. (2019). An Information-Theoretic Approach to the Cost-benefit Analysis of Visualization in Virtual Environments. *IEEE Transactions on Visualization and Computer Graphics*. DOI: [10.1109/TVCG.2018.2865025](https://doi.org/10.1109/TVCG.2018.2865025)

Listed in REF2

- [4] John, N. W., Day, T. W., Pop, S. R., Chatterjee, K., Cottrell, K., Buchanan, A., & Roberts, J. (2019) Virtual Reality Environment for the Cognitive Rehabilitation of Stroke Patients. In *Proc. of 11th International Conference on Virtual Worlds and Games for Serious Applications (VS-Games 2019)*, IEEE. DOI: [10.1109/VS-Games.2019.8864513](https://doi.org/10.1109/VS-Games.2019.8864513)

Available on request.

- [5] Rees, N., Vaughan, N., Day, T.W., Dorrington, K., Rees, L. & John, N.W. (2020) ParaVR: a virtual reality training simulator for paramedic skills maintenance. *Journal of Paramedic Practice Vol. 12 No. 12*, 430-438

Available on request.

4. Details of the impact (indicative maximum 750 words)

Research Process

The track record of the Medical Graphics Group and initial work carried out with the Countess of Chester NHS Trust was instrumental in a successful grant application to Innovate UK, the UK's innovation agency, to fund the research and development of the VR system for cognitive rehabilitation of stroke survivors [2]. This is in collaboration with an SME active in the medical devices industry, called CADscan Ltd.

Impact case study (REF3)

John was the principal researcher at the University supported by Day and Pop, but now with collaboration from a clinical expert in the NHS (Prof K Chatterjee, Consultant Physician in Stroke and Elderly Medicine) and from industry (Dr A Buchanan, Managing Director, CADscan Ltd). Together we have developed a novel immersive software solution that can be deployed in a hospital to enhance the therapy of stroke survivors. It allows them to practice everyday activities around a home, supermarket or a café, with increasing levels of difficulty. For example, the patient can make a slice of toast, wash dishes, select and pay for items in a supermarket, or order a meal from a menu – all in a virtual environment. An occupational therapist can dynamically change a scenario to tailor it to the requirements of an individual patient, adapting to the patient's requirements in real time whilst they are immersed in the software. The University of Chester has jointly designed and implemented the software in collaboration with developers at CADscan Ltd, with the functionality requirements defined by the clinical experts.

Feedback from in-patient volunteers and patient groups was extremely positive with comments that using a VR headset did not feel intimidating, and they felt it was more beneficial than the conventional activities that they had been doing in the hospital. This allayed fears that an older generation that typically do not play computer games would be more reticent to use the technology. This led to a double-blind randomised controlled trial to identify the optimum dosing, to confirm the acceptability of VR-based treatment, and to test the effectiveness of the treatment, commencing in August 2019. Results have indicated that the patient group who started the trial with a more acute PSCI show excellent improvement from using our VR system when compared with patients who have been less effected by the stroke. One 93-year-old participant enjoyed the experience so much that she kept talking to everyone about it. The trial has been run by staff from the Stroke Unit at The Countess of Chester NHS Trust. The University has provided technical support throughout the trial and ensured that the system is working properly in the hospital environment. This has involved exploring various customisations of the VR headsets to enable them to be compliant with infection prevention and control protocols. This in itself is invaluable experience for future exploitation of this system and other uses of VR in the hospital. The University has also taken a lead in the analysis of the trial data. Refer to [5.1] and [5.2] for corroboration.

Beneficiaries

The resulting immersive virtual reality environment has been called VIRTUE [4]. The built-in flexibility of VIRTUE facilitates personalised medicine without any limitation and this unique feature makes it different from other existing solutions in this area.

VIRTUE will transform rehabilitation services. It is more engaging, delivered more often than conventional therapy and can continue at home, leading to greatly improved patient outcomes. Patient recovery will be accelerated through intensive delivery of therapy with minimal supervision, shortening hospital stays and lowering costs. See [5.1] for corroboration. In the UK, there are 171 stroke units that rehabilitate 110,000 patients each year with a direct annual cost of £4.5b. Reducing the length of hospital stays while delivering more effective rehabilitation is of great economic value, with a stroke ward bed costing between £300 - 7000 / day.

For clinicians, VIRTUE frees up time for patients with more complex needs.

Through increased participation in the rehabilitation process and tracking their own improvement, patients are empowered by directing their own recovery, building confidence in their ability to perform everyday tasks, and reducing psychological trauma by addressing their needs earlier (See [5.1] and [5.3]).

Dissemination

The work was first presented and published at the VS-Games 2019 international conference and further publications are in progress. In addition, several invited talks have resulted in John presenting the research and demonstrating the software at the: Assistive Technology in Neurorehabilitation conference, Northampton, July 2019 organised by Elysium Healthcare; and Tech in Medicine (the 9th national student conference) organised by The Royal Medical Society in

Impact case study (REF3)

Edinburgh, March 2019. (Such activities continue and although outside of the qualifying period for this impact case study, further presentations are already confirmed for March 2021 at the Medicine of the Older Person symposium organised by the Royal College of Physicians of Edinburgh; and the 5th Annual Virtual Reality and Healthcare Global Symposium organised by the International Virtual Reality Healthcare Association).

This project, together with the work we are doing with paramedics on VR skills maintenance, was selected by the Made at Uni 'The Nation's Lifesavers' campaign organised by University's UK in May 2019. This highlighted the 100+ ways that Universities are saving lives and keeping us healthy.

The final product will be marketed by Cadscan, including distribution of fliers and demonstrations at trade shows.

Commercialisation

The impact of our work continues into the next stage – a multi-site trial, and then the commercialisation of the software. The IEC 62304 software lifecycle process will be followed for MDR conformance. By 2023 the product will be CE-marked and market-ready, being sold direct and through the NHS Apps Library. We will also apply to the NHS's Innovation and Technology Payment, an initiative to accelerate adoption with a current focus on digital technology. Based on the leasing/supply of equipment, consumables and software licences, Cadscan estimate a total addressable market of £25m/year across the 171 NHS Stroke units in the UK, and forecast annual revenue of £7m (32% penetration) by post-project year 5. This is corroborated in [5.2].

5. Sources to corroborate the impact (indicative maximum of 10 references)

Factual statements have been provided to corroborate specific claims from:

[5.1] Consultant Physician in Stroke and Elderly Medicine

- Corroborates the clinical deployment and novelty of this approach

[5.2] Managing Director, Cadscan Ltd

- Corroborates the development of the VR software for stroke rehabilitation and commercialisation plans

[5.3] Information in the Public Domain:

- Industry Reviews/News
 - <https://www.digitalhealth.net/2018/10/virtual-reality-stroke-funding/>
 - <https://healthcareweekly.com/vr-holds-promise-for-stroke-patients/>
 - <https://internetofbusiness.com/uk-hospital-vr-quality-of-life-stroke-sufferers/>
 - <https://www.cheshire-live.co.uk/news/chester-cheshire-news/chester-project-uses-virtual-reality-15291263>
- Radio interview on Radio Wales Science Café programme “Transforming Healthcare”. Broadcast 12 Feb 2019.
 - <https://www.bbc.co.uk/programmes/m0002h3y>
- Made at Uni campaign: The Nations Lifesavers – the top 100 individuals or groups based in universities whose work is saving lives and making a life-changing difference to our health and wellbeing
 - <https://madeatuni.org.uk/>
 - <https://www1.chester.ac.uk/news/university-chester-research-team-named-among-nation%E2%80%99s-lifesavers>