Institution: Liverpool John Moores University (LJMU)		
Unit of Assessment: UOA4		
Title of case study: Immersive Technology: Using research from Human-Computer Interaction to support business		
Period when the underpinning research was undertaken: 2003-2018		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	**Role(s) (e.g. job title):**	**Period(s) employed by submitting HEI:**
Stephen Fairclough	Professor	2000-present
Andrew Tattersall	Professor	1998-present
Chelsea Dobbins	Lecturer	2014-2018
Christopher Burns	Research Assistant	2012-2014
Kiel Gilleade	Research Assistant	2011-2014
Period when the claimed impact occurred: 2015-2020		
Is this case study continued from a case study submitted in 2014? N		

1. Summary of the impact

Immersive technology covers a range of available products, from virtual reality to high-resolution television. This impact case study describes how expertise from the university has been transferred to a number of industrial partners in the UK who are developing these technologies. Expertise in psychophysiology and human-computer interaction has informed the development of software and hardware products designed to improve safety, health and to promote emotional engagement with digital content. This impact case study primarily focuses on transferring expertise from university to SMEs in order to develop products, enhance income generation and create jobs. This transfer of knowledge has been funded directly by SMEs and consolidated by the UK government.

2. Underpinning research

The impact case study is underpinned by three strands of research. The first concerns the measurement of driving performance in simulated environments and on the real road. This work stems from an attempt to operationalise the concept of driver impairment (i.e. when driver performance is compromised by anxiety, fatigue, alcohol, drugs etc.) with respect to parameters associated with driver performance (e.g. lane-keeping, longitudinal control, hazard detection) complimented by measurement of neurophysiology and psychophysiology [1,2]. This work was funded by the EU under the auspices of the REFLECT project (2008-2011) and via a 12-month project funded by EPSRC (EP/M029484/1) in 2015. The EU-funded project allowed us to explore how mental workload affected driving performance. The EPSRC project focused on the use of wearable sensors to assess the level of anxiety experienced on the real road based on cardiovascular monitoring. There were two key insights from this strand of research: (1) development of objective measures to characterise impaired/unsafe patterns of driving behaviour, and (2) development of signal processing methods to accurately capture psychophysiological data in the real-world using wearable sensors [3].

The second strand of research concerns the use of neurophysiological and psychophysiological methods to measure immersive experiences when interacting with digital content. When a user is immersed in a digital task (e.g. virtual world, game activity, task simulation), assessing the quality of immersive experience can be problematic because the act of measurement (via questionnaire) can 'break' experience. Neurophysiological (e.g. electroencephalograph or EEG) and psychophysiological (cardiovascular) offer a number of advantages in this area being: unobtrusive, quantitative and not requiring any action on the part of the user. Our work on the REFLECT project

plus two additional projects both funded by the BIAL Foundation (2011-12, 2014-15) have allowed us to develop techniques to assess: (1) the degree of immersion in digital content (via neurophysiology) [4], and (2) task engagement and motivation (via functional near-infrared spectroscopy and cardiovascular psychophysiology) [3]. The application of these techniques allows us to quantify those psychological aspects of immersive experience related to attention and motivation.

The third and final strand of research concerns the measurement of emotional experience in response to immersive content. Psychologists have deployed a range of techniques to capture both the type and magnitude of emotional experience. These techniques include self-reported measures and the use of cameras to classify types of facial expression. Our research focused on psychophysiological measures of activation (e.g. heart rate, skin conductance level) and valence using facial electromyography (fEMG), i.e. where electrodes are attached to the face. Work on this topic was funded by the EU via the ARTSENSE project (2011-14) where we utilised a number of wearable sensors to assess emotional responses in the context of cultural heritage [5]. In other words, psychophysiological responses from museum/gallery visitors to specific exhibits or information were collected in order to: (1) assess emotional responses, and (2) 'tag' exhibits with emotional responses that were specific to each visitor.

3. References to the research

All outputs were submitted to rigorous peer-review process prior to publication, including the conference paper, e.g., 4 reviewers, 21-24% acceptance rate for CHI conference. These outputs were funded by the European Union, EPSRC and the BIAL Foundation.

1. Brookhuis, K. A., **Fairclough, S. H.** & De Waard, D. (2003). Criteria for driver impairment. Ergonomics, 46(5), 433-445.
2. **Fairclough, S. H.**, **Tattersall A.** & Houston, K. (2006). Anxiety and performance in the British Driving Test. Transportation Research Part F: Traffic Psychology & Behaviour, 9(1), 43-52.
3. Ewing, K., **Fairclough, S.H.** & Gilleade, K. 2016. Evaluation of an adaptive game that uses EEG measures validated during the design process as inputs to a biocybernetic loop. Frontiers in Human Neuroscience, 10:223.
4. Burns, C.G. & **Fairclough, S.H.** (2015). Use of auditory event-related potentials to measure immersion during a computer game. International Journal of Human-Computer Studies, 73, 107-114.
5. **Fairclough, S.H.**, Karran, A.J. & Gilleade, K. (2015). Classification Accuracy from the Perspective of the User: Real-Time Interaction with Physiological Computing. CHI '15: Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems, 3029-3038.
6. Dobbins, C. & **Fairclough, S.H.** 2018. Signal Processing of Multimodal Mobile Lifelogging Data towards Detecting Stress in Real-World Driving. IEEE Transactions on Mobile Computing, 18(3), 632-644

4. Details of the impact

The research conducted on measurement of driving behaviour was translated into a collaboration with CGA Simulation (http://www.cgasimulation.com) funded by the Department of Transport. The goal of this project, which ran from 2017 to 2019 and generated £117,378 for the company, was to translate the hazard perception test into an interactive driving simulation running in virtual reality

(VR). The impact of this research was achieved via a significant contribution to a product-in-development; **the company intend to launch a driving training game based on the VR experience created on this project via the Steam Store in December 2020. In addition, the SME were able to both secure further funding from the public sector on the basis of this work, i.e. CGA Simulation successfully obtained funding from Innovate UK on the ALEAD project and lead this £1,000,000 project (with £500,000 of the total funding going directly to the company)**.

"Collaboration with the School of Psychology at Liverpool John Moores University has allowed us to successfully win contracts on innovation, such as ALEAD, that required a deep understanding of human behaviour as part of our simulation work."
Jon Wetherell (Managing Director, CGA Simulation) (6).

The results of the project were disseminated to government bodies at two events, the DfT Innovation Day (25/4/18) (1) that was attended by the Transport Minister and a day-long review meeting organised by the Driving & Vehicle Standards Agency (DVSA) that was also attended by members of the Highways Agency and DfT (2). Our **collaboration led to a second project on the use of simulation for training purposes between the University and CGA Simulation. The Personally Responsive Information Assessment (PRIA) project is funded by DSTL under the Defence and Security Accelerator funding call; this project concerns assessment of mental workload of emergency planners during management of an urban emergency. Our collaboration has allowed the company to secure £100,000 of external funding (3) and the work was presented as part of a Showcase event in November 2019 (4)**.

Understanding immersive experiences is an important strand of applied research with reference to basic research in human-computer interaction (HCI). We are engaged in a Knowledge Transfer Partnership (KTP) with Immersive Interactive (http://immersive.co.uk). This 24-month project, which is worth £173,000 and involves a university employee being based permanently at this SME (started in February 2019). Immersive Interactive, are market leaders in the design of cave automatic virtual environments (CAVE) for training and education. Input from the university and the recruitment of the associate convinced the company to completely **overhaul their software framework used for all content development and delivery in early-mid 2018. This significant innovation to products-in-development led to the company to Unity Engine and the creation of their own Immersive Unity SDK (Software Development Kit) for all future internal development. For the company, there have been two major benefits: improved delivery speed of content at large-scale (e.g. one example is a recent commission for Chester Zoo to create an immersive visitor experience on-site that was worth £60,000 to the company) and enabling direct collaboration with customers on content creation, i.e., Unity content can be created, shared and developed remotely and in real-time between the company and their customers. This shift to Unity Engine has allowed the company to grow – to date, two Unity programmers were permanently employed in early 2020, this recruitment was supplemented by the appointment of a Junior Multimedia Artist and two full-time Immersive Content Creators in mid-late 2020. This addition of five employees to a SME with nine permanent staff represents significant growth for Immersive Interactive. By adopting an open-source software platform for product development, the company are better equipped to grow their business and maintain their position as market leaders**.

"The KTP project with Liverpool John Moores University has already had a huge impact on the projects we do at Immersive Interactive. The KTP created capacity for us to invest in research and development of our software and by incorporating Unity Engine into our product development

cycle, we have massively enhanced our capabilities as a company, both with respect to the types of the project we do and how quickly we can deliver. The Unity SDK that was developed as part of the KTP as a major component of our future growth as a company." **Chris Porter (Director, Immersive Interactive) (6)**.

Emteq Ltd (https://emteq.net) are developing a sensor technology designed to be integrated with a Head-Mounted Display (HMD) to measure psychophysiological data in VR (5). They have invested £42,000 in a co-funded PhD studentship at LJMU that started in July 2018 (5). The work conducted by LJMU has informed changes in product development as we are an early adopter of the system and provided feedback to the company about the utility and efficacy of their product design and the quality of the data collection. For example, we have suggested how the product can be designed to improve signal quality and maintain comfort. For the company, the co-funded studentship allows them to both outsource their research costs and partner with the public sector to develop their product.

The net result of our collaborations with various SMEs is to make specialist expertise available to those companies in order to develop their products and business capacity. This type of knowledge transfer also characterised a collaboration with Onteca Ltd (http://onteca.com/#!home) who wished to incorporate a biofeedback component into their mental health-related smartphone app 'Chill Panda.' We worked with Onteca via the Innovation Voucher scheme (May-July 2017) to provide direct input to the development of a product that is designed to improve wellbeing of children. **The 'Chill Panda' app appeared on the NHS app store in 2018, it has been downloaded approx. 100,000 times (7), featured in the national press (8) and promoted by a number of NHS Trusts, e.g. Mind (Dorset), You In Mind (Cheshire), & NHS Digital across the country (9). Our collaboration allowed the company to secure funding from NHS Digital to the value of £45,000. The latest version of Chill Panda for the Nintendo Switch console was released 14th December 2020 (10)**.

5. Sources to corroborate the impact

1. Agenda for DfT Innovation Day (25/4/18)
2. Agenda for DVSA Review Meeting
3. UK Government Defence and Security Accelerator funded contracts: 1 April 2018 to 31 March 2019
4. News article: DASA showcases innovations that predict and thwart future threats
5. Wired article on Emteq technology (link) & Transfer Report for Emteq Matched-Funded PhD
6. Testimonials from Managing Director, CGA Simulation and Director, Immersive Interactive
7. Chill Panda app on NHS Apps Store (link)
8. Guardian article: Staying appy: mental health apps deliver mixed results (2017)
9. NHS Digital From Childline to online: how mental health apps can support teens (link),
10. Nintendo Chill Panda download page (link)