Institution: Edinburgh Napier University

Unit of Assessment: UoA11 – Computer Science and Informatics

Title of case study: Blended Spaces - Creating Commercial and Social Benefit by Transforming Human Computer Interaction

Period when the underpinning research was undertaken: January 2007 to October 2017

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:
Professor David Benyon	Professor	September 1998 – October 2018
Dr Oli Mival	Principal Research Fellow	November 2006 – ongoing
Dr Brian O'Keefe	Research Fellow	January 2007– October 2009
Dr Tom Flint	Lecturer	September 2009 – ongoing

Period when the claimed impact occurred: October 2014 to July 2020

Is this case study continued from a case study submitted in 2014? No

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

Research at Edinburgh Napier University has developed new methods and principles for designing 'blended spaces' – those that combine elements of the physical and digital worlds.

The work has led to three patents, the establishment of two new companies, and enabled new products to be developed by organisations and businesses worldwide, in sectors including tourism, building energy management, architecture and healthcare. Physical spaces have also been created in educational and healthcare settings.

2. Underpinning research (indicative maximum 500 words)

Human-computer interaction (HCI) experiences have proliferated and advanced over the past two decades, and it has become imperative to find ways of designing them for optimal human experiences.

Research into blended spaces has been undertaken within the Centre for Interaction Design (CiD) at Edinburgh Napier University since 2005, led by Professor David Benyon until his death in 2018. It forms an important part of research into user experience (UX) design issues. The centre has focussed on methods and frameworks for designing blended spaces leading to the formation of the Future Interactions group in 2008 led by Dr Mival (Principal Research Fellow in CiD) collaborating with Dr Brian O'Keefe (Research Fellow, 2007-2009) and more recently Dr Tom Flint (Lecturer) exploring applied blended space design utilising emergent STAG (Speech, Touch and Gesture) and AR (augmented reality) technologies.
The blended spaces research has been supported by GBP870,000 funding from EPSRC, EU, Innovate UK and SICSA, and forms a substantial part of the Centre's GBP5million research portfolio.

Blended Spaces and the Design Framework

Blended spaces allow people who are physically present to interact with a digital world. Benyon **[R1]** argued that, in interaction design, designers need to reflect on and think hard about the concepts that they are using and how these concepts affect their designs. He suggested that the blended space will be more effective if the physical and digital spaces have some recognizable and understandable connections, or correspondences. Five key themes of interaction were

identified forming a critical design framework, TACIT, that focuses on Territoriality, Awareness, Control, Interaction and Transitions in such spaces.
Professor Benyon used these concepts to create a blended spaces framework for use in digital product development. The framework enables both physical and digital space to be described in terms of the objects (the actual distinct objects which make up the medium/space) and the agents (i.e. the users inside the space who interact with the objects), the structure of the objects' relationships (the topology of the space) and the changes that take place in the space (the volatility, or dynamics of the space). The closer the communication between the physical and digital spaces, the richer the experience for the user within the blended space.

Applying the Framework

Benyon posits that blended spaces are those that mix the physical and the digital in a harmonious way that aims to maximize the UX (User Experience) of the whole **[R2].** The body of blended framework research took place from 2007 to 2017 and concentrated on applying the conceptual frameworks in applied scenarios, with the focus of O'Keefe being mobile AR **[R3]**, Flint exploring digital experiences for children **[R6]**, and Mival the application of STAG technologies to facilitate the blend on healthcare **[R4]** and immersive interactive collaborative environments **[R5]**. A range of human-system interface studies were conducted across a series of projects in different domains, leading to the output of a series of new design principles developed by Benyon and Mival. These domains of deployment and studies include:

- digital tourism : informed by Historical Echoes **[G2]** project (2012), led by Benyon, and Innovate UK projects led by Mival working with Scottish tourism partners Jupiter Artland (2014 and Flint 2016), Visit Arran (2014), Glenlivet & Tomintoul (2014) and Royal Edinburgh Military Tattoo (2016).
- healthcare : informed by FI-STAR project **[G1]** design use cases in 7 European countries, (2013-2015) led by Mival & Benyon.
- immersive interactive environments : informed by a KTP **[G3]** with architectural visualisation company Soluis (2015-2017) led by Mival.
- energy management : informed by Future Energy Management project **[G4]** with industrial partner Netthings studying interfaces to energy use in SME workspaces (2014-2017), led by Mival.

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

This research was based on competitively funded projects with robust peer review systems, and commissioned industrial research. The outcomes from the research were published in leading peer review journals, Springer and MIT Press books. Authors from unit in bold.

[R1] Benyon, D. and Imaz, M.(2007). Designing with blends: Conceptual foundations of human-computer interaction and software engineering. MIT Press. DOI:10.7551/mitpress/2377.001.0001

[R2] Benyon, D. (2012). Presence in blended spaces. *Interacting with Computers*, *24*(4), pp.219-226. DOI: 10.1016/j.intcom.2012.04.005

[R3] Benyon, D., Quigley, A., **O'Keefe, B.** and Riva, G. (2014). Presence and digital tourism. *AI & Society*, *29*(4), pp.521-529. DOI: 10.1007/s00146-013-0493-8

[R4] Mival, O., & **Benyon, D**. (2014). User experience (UX) design for medical personnel and patients. In S. Fricker, C. Thuemmler, & A. Gavras (Eds.), *Requirements Engineering for Digital Health and Care*, 117-131. Cham: Springer Verlag. DOI:10.1007/978-3-319-09798-5_6

[R5] Benyon, D., & **Mival, O.** (2015). Designing Blended Spaces for Collaboration. In A. Ferscha, S. Resmerita, C. Holzmann, M. Pieper, & C. Stephanidis (Eds.), *Human Computer Confluence*, 18-39. Konigswinter, Germany: De Gruyter Open. DOI:10.1515/9783110471137-002

[R6] Flint, T., Hall, L., Stewart, F., & Hagan, D. (2018). Virtualizing the real: a virtual reality contemporary sculpture park for children. *Digital Creativity*, *29(2/3)*, 191-207. DOI:10.1080/14626268.2018.1511601

Key Research Grants

[G1] FI-STAR (April 2013 – November 2015), £532,920, funded by EU FP7

[G2] Historical Echoes (February – September 2012), £37,264, funded by SICSA

[G3] KTP Soluis Group Ltd (September 2015 – July 2017), £169,286, funded by Innovate UK

[G4] Future Energy Management of Buildings (November 2014 - January 2017), £131,526, funded by EPSRC

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

The Blended Spaces framework and design principles have been applied in diverse sectors including tourism, energy management and sustainability, architectural visualisation and healthcare. This has enabled improvements in user engagement resulting in a wide range of impacts including commercial, environmental, health and wellbeing and on understanding, learning and participation.

Tourism

The understanding gained from using the Blended Spaces framework and design principles in a number of tourism scenarios led to the creation of a UX architecture for tourism apps. This was the basis of the award-winning VisitScotland 'ScotlandVR' mobile app designed by Benyon and Mival and developed by Whitespace, an Edinburgh based digital media agency. Launched in January 2017 as part of Scotland's Year of History, Heritage and Archaeology, the ScotlandVR app has been downloaded and used by over 100,000 people globally as of the end of 2020. "*Delivering that level of installs in week one is unprecedented for a tourism destination VR app*" said Mark Irwin, VisitScotland's Senior Brand Manager **[C1].** Fiona Hyslop, Cabinet Secretary for Culture, Tourism and External Affairs, said: "*This virtual reality app provides people across the globe with a window into Scotland's fantastic attractions. A team from Edinburgh Napier University developed the concept for this app, which demonstrates the pioneering spirit and ingenuity of Scotland's academic, technology and tourism sectors*." **[C4]**

Designers at Kodak, in collaboration with Professor Brian O'Keefe, applied the Blended Spaces framework to develop novel user interfaces and experiences. The team leading that work (which included Kodak's Chief Scientist Ken Parulski and O'Keefe), launched the spin-out start-up, Tour Blend Innovations LLC, in 2013. Based in New York State, it creates mobile AR apps for tourism and holds 3 US patents for mobile enabled digital tourist experiences created through the blended framework, co-authored by O'Keefe and granted between 2018 and 2020 **[C6].** Ken Parulski said of the work *"The Blended Spaces Framework that Brian O'Keefe worked on with Professor Benyon significantly impacted the way Tour Blend approached the design of the novel, digitally-enabled user experiences for mobile devices that we created."*

Based on the Blended Spaces framework Mival developed and launched an app-enabled blended experience for the internationally renowned Scottish sculpture park Jupiter Artland in 2014. Flint expanded the work **[R6]**, creating a Minecraft version of the park in a mixed reality game in collaboration with primary schools across Scotland, from Ratho to Orkney. By the end of 2020 it had been used by over 1,000 young people, both through physical trips to Jupiter Artland and through virtual visits enabled by the game. In April 2020 a special event using the platform was created as an educational tool for children in the Coronavirus lockdown, with several hundred school children participating, Director of Jupiter Artland, Nicky Wilson said of the platform "*We are thrilled to be able offer people a little slice of Jupiter magic, especially now as parents face increased pressure with home-schooling...it provides a safe space to learn about art.*" **[C7]**

Building Energy Management

The underpinning research in energy management undertaken during the Future Energy Management project **[G4]** focussed on interface and UX design to promote sustainable energy practice in both residential and commercial environments. The blended space framework **[R5]** informed the user interface and interaction design developed by Mival within the project, which industrial partner Netthings (now J-Teq Energy) implemented into their Energy Manager product. The Energy Manager interface leads to reduced energy consumption by blending energy usage data collection, analytics and prediction models with in situ screen interfaces encouraging and influencing behavioural change through energy awareness. Since the start of 2017 the Energy Manager product has been installed into over 15,000 commercial and residential properties across the UK with an approximately 20% average resulting reduction in energy usage after deployment **[C5].** The product has been evaluated to be worth two code credits under the UK Government's voluntary Code for Sustainable Homes.

Design and Sustainability

The Lions' Gate Garden at Edinburgh Napier University uses the blended space framework in its design. The Garden promotes ecologically sustainable activities and education alongside technology. It is a digitally-augmented garden built within the University's Merchiston campus, which uses the application of embedded sensors and augmented reality. Initially a prototype for Scotland's Garden Festival 2017, with over 20,000 visitors, it is now a permanent installation at the University. It has created a direct link to the permaculture community; permaculturist and author Graham Bell, who advised regarding its creation said:" *An additional function of the garden was to connect with the local community, offering a teaching space for the principles involved, a meeting area and a demonstration of how it is possible to grow healthy food in an attractive way in an urban location, whilst also providing a haven for wildlife*." **[C8]** There have been 2,000 visits to the garden since its creation. It performs a central role in the teaching of sustainable design in both the School of Computing and the School of Arts & Creative Industries by providing a real life situation in which students can conduct applied projects and over 200 student projects to date have focused on the garden. Professor Sally Smith, Dean of the School of Computing, said "*The garden is a living, outdoor lab for computing students researching Internet-of-Things, Data Science, Software and Human-Computer Interaction*" **[C8].**

Interactive Collaborative Environments

The underpinning research in immersive interactive environments **[R5]** led to a Knowledge Transfer Partnership (KTP) between Mival and Benyon, and architectural visualisation company Soluis Group Ltd. The KTP combined Soluis's expertise in projection mapping in dome environments and architectural visualisation with the Blended Spaces framework and design principles, leading to the creation of a new product for the company called the Reality Portal. The Reality Portal enables clients and collaborators to 'step in' to a proposed architectural project at full 1:1 scale, so they can experience the transformation of a space and contribute suggestions to improve the final design. The Blended Space framework helped to shape and direct the commercial integrations possible within the Portal space including developments and partnerships with key AECO (Architecture, Engineering, Construction and Owner) suppliers and software companies. In 2017 Soluis created the spinout company 'Sublime' to market and develop the Reality Portal, helping businesses capitalise on better architectural design review, enhance risk reduction, improve stakeholder engagement and attract public attention. It has transformed companies' immersive spaces into collaborative spaces. In 2017, GBP600,000 revenue directly attributable to the KTP project output was generated for the Soluis Group, and the final report projected a GBP3.9million annual increase in revenue by 2020, due to the expansion in functionality and capability. Scott Grant, CEO of Soluis, said "*Global brands such*

as Wework, Reviztu, Jordan's Cereal etc, all became clients directly based on input of the KTP that Soluis' existing business offerings would not have been able to satisfy." **[C2]**

Healthcare

The underpinning research in healthcare and interactive spaces explored designing for clinically useful interactive experiences **[R4]** and led to a collaboration with artist and designer of NHS Dignified Spaces, Alexander Hamilton, who was working on blended space environments in Glasgow's Queen Elizabeth University Hospital (QEUH).

In 2014 Hamilton approached Mival for a collaboration to design and develop the PlayPod installation for Glasgow's Child Protection Unit within the QEUH. The collaboration resulted in an interactive experience that enables children visiting the unit for forensic examination to control and shape aspects of their clinical environment through digital projection, lighting and sound. More than 500 children a year undergo assessment for sexual abuse within the hospital's unit and the surroundings that are intuitively created by the children themselves empower them whilst also engaging with the intent to reduce stress during such a challenging ordeal.

Mival and Hamilton used the same technical and UX framework in a second collaboration between 2016 and 2018 for 3 therapy rooms in Edinburgh's Hospital for Sick Children. These rooms facilitate clinically useful interactions within a Blended Space for physiotherapy, occupation therapy and speech therapy. In addition, 44 'distraction spaces' were embedded across the hospital during the creation of the new hospital wings during 2019 using the knowledge from the Glasgow project, for patients who are undergoing clinical assessment and treatments. When fully utilised the 47 spaces are expected to benefit upwards of 700 patients and more than 100 clinicians a day. Alexander Hamilton said*: "The use of the Blended Spaces design framework was hugely impactful in understanding and developing the digitally blended components of sound and visual work that complemented and enhanced the physical and material aspects of the space."* **[C3].**

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

[C1] Quote from Mark Irwin, Senior Brand Manager, VisitScotland detailing impact and download reach of VR Scotland App.

[C2] KTP summary report with comments from Scott Grant, CEO, Soluis detailing financial impact of KTP.

[C3] Letter from Alexander Hamilton, Creative Director of Designing with Dignity detailing impactful benefits of NHS blended spaces work and link to project details.

[C4] Forbes article detailing the VR Scotland App with quote from Cabinet Secretary for Culture, Tourism & External Affairs.

[C5] J-Teq Energy Ltd (formerly Netthings) webpage detailing energy manager.

[C6] Letter from Ken Parulski, former Chief Scientist at Kodak and co-founder of Tour Blend innovations LLC detailing the impact of the blended spaces framework on the 3 patents registered by the company and co-authored by O'Keefe (links to patent 1, 2 and 3).

[C7] Fad magazine coverage of Jupiter Artland's Minecraft event.

[C8] Letter with supporting material and testimonials from permaculture author Graham Bell, University staff, students and visitors to the Lion's Gate Garden detailing impact on the pedagogical approach to educating people on the relationship of computing in permaculture and ecologically sustainable design practice.