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M. Claudia tom Dieck
Timothy Jung *Editors*

Augmented Reality and Virtual Reality

The Power of AR and VR for Business

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Editors

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The Power of AR and VR for Business

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Preface

Immersive technologies such as augmented reality (AR) and virtual reality (VR) are changing the business landscape, providing new opportunities but also concerns for businesses and consumers. Organised by the Creative Augmented and Virtual Reality Hub at Manchester Metropolitan University, the 4th International Augmented and Virtual Reality Conference attracted researchers and industry from around the globe to discuss opportunities, collaborations and future research directions. The conference theme of "The Power of AR and VR for Business" invited academic and industry speakers from various disciplines, to share their knowledge and experiences of immersive technologies.

Papers presented focussed on the areas of retail, tourism, experience design, education and applications and immersive designs. We hope that the conference and this book will serve as a valuable source for future research and discussion on important issues such as privacy, technology adoption and application design. In addition, this book aims to inform businesses about latest developments in the areas of AR and VR.

Manchester, UK

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Dr. Timothy Jung

International Augmented and Virtual Reality Conference 2018

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Part I
AR & VR Retail Experience

Augmented Reality in Real Stores: Empirical Evidence from Consumers' Interaction with AR in a Retail Format

Francesca Bonetti, Eleonora Pantano, Gary Warnaby, Lee Quinn and Patsy Perry

Abstract This exploratory empirical study elucidates the concept of the 'augmented store', namely a physical retail store modified to accommodate AR technology. It extends previous research into immersive environments and technology-enhanced stores from experimental laboratory settings to a real-life scenario with participating consumers. Qualitative data from interviews and observations of consumers using AR technology in-store are analysed to evidence naturalistic understandings of interactions with, and perceptions of, a physical store enhanced with AR technologies. The findings provide evidence to suggest that consumers experience an enhanced, more immersive and enjoyable perception of the store environment as a consequence of the AR experience. They find interaction with the augmented store to be 'realistic', and hedonic motivations for interacting with the immersive store frequently prevail. The AR enhanced store appears to stimulate brand engagement, increasing consumers' desire to shop at the retailer, which provides managerial opportunities to reinforce brand positioning.

Keywords Retailing · Human-computer interaction · Augmented store · Augmented reality · Consumer behaviour · Immersion

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1 Introduction

Atmospherics are acknowledged as critical elements of the retail store environment, which help convey a satisfactory shopping experience and, ultimately, influence consumer behaviour (Kotler, 1973; Puccinelli et al., 2009). Such factors are arguably even more relevant in fashion and apparel retailing, given the multi-sensory experience of both store environment and the products themselves (Foster & McLelland, 2014). In a constantly evolving competitive context, fashion and apparel retailers are increasingly adopting different types of innovative technologies in physical stores to directly enhance the shopping experience, and thereby achieve competitive advantage (Pantano, 2016). Such technologies (see Bonetti & Perry, 2017; McCormick et al., 2014; Pantano, Rese, & Baier, 2017) can be referred to as 'consumer-facing' in-store technology (Bonetti & Perry, 2017).

'Immersive' technologies (e.g. AR and VR) are rapidly evolving and are increasingly adopted in this context (Bonetti, Warnaby, & Quinn, 2017; Javornik, 2016). In particular, AR applications are developing to combine both the real and virtual worlds into the user's view of the physical world in real time (Carmigniani et al., 2011). This can help enhance the user's visualisation of products and perception of the store environment, and thus, the shopping experience, by enabling interaction with virtual items (Huang & Liao, 2015). Whilst VR blocks out real world sensory experiences through a wearable device (typically a headset), immersing the user in virtual and entertaining 3D worlds (Bonetti et al., 2017), AR allows users to experience enhanced and more realistic experiences within the physical place (Papagiannidis, Pantano, See-To, Dennis, & Bourlakis, 2017).

AR is defined as a combination of 'real and computer-generated digital information into the user's view of the physical world in such a way they appear as one environment' (Olsson, Lagerstam, Kärkkäinen, & Väänänen, 2013, p. 288). By integrating and aligning real and virtual objects (through a virtual layer that can add computer-generated digital elements such as images, videos, textual information, etc.), this technology results in an enhanced (augmented) physical world (Carmigniani et al., 2011; Pantano et al., 2017). Although existing studies have investigated immersive environments and technology-enhanced stores, this research has tended to have been conducted in experimental settings (Huang & Liao, 2015; Kjeldskov & Graham, 2003; Papagiannidis et al., 2017). Therefore, the integration of immersive AR tools within the traditional point-of-sale store environment (i.e. stores that already exist, which are modified to accommodate AR technology, rather than having AR features built into the initial store concept) to investigate users' interaction with—and perception of—stores enhanced with immersive AR technologies in a *real* store environment is still under-investigated. This leads to our research questions:

RQ1. To what extent can traditional stores integrate immersive technologies such as AR, to develop new store forms/concepts?
RQ2. How do consumers perceive the store environment of a more traditional, physical store which has been enhanced by AR technologies?

RQ3. How do consumers interact with a traditional store enhanced with AR technologies?

Using an apparel store enhanced with immersive technologies as a research context, the central aim of this study is to investigate the extent to which immersive AR technologies influence the way consumers interact with, perceive and respond to retail settings and store environments.

2 Theoretical Background

2.1 Augmented Reality in Retailing

A major theme in the existing literature relates to the way(s) in which users adopt, interact with, and experience technology devices and systems (see Dix, 2009; Kjeldskov & Graham, 2003; Rogers, 2004). Of the various forms of innovative technologies used in retail environments, immersive technologies have drawn particular attention (Bonetti et al., 2017; Javornik, 2016; Pantano et al., 2017), particularly AR, which is based on a camera able to capture real-world data and combine information from real and virtual sources into one perception (Oleksy & Wnuk, 2016). Consequently, product simulation, sound, GPS data and media richness contribute to experiential value, with AR enabling consumers to interact with virtual products (McCormick et al., 2014). AR applications have become more popular due to widely distributed personal mobile technology, allowing users to shop using AR, thereby enhancing satisfaction and experience (Dacko, 2016; Javornik, 2016). Early AR retail applications include virtual try-on, and interactive displays providing information on promotion, products and locations (Bonetti et al., 2017). Thus, AR has the potential to improve consumers' visualisation of products, increase engagement and enhance perceptions of the shopping experience, thereby hopefully affecting retailer and brand perception positively which, in turn, can influence consumer behaviour (Huang & Liao, 2015; McCormick et al., 2014).

2.2 Augmented Places

The development of new immersive technologies contributes to the creation of immersive (augmented) places/environments, increasing users' levels of engagement, enjoyment and satisfaction, leading to the enhancement of the user experience (Papagiannidis et al., 2017). Augmented places consist of real, physical places, enhanced by AR technologies to augment users' overall current perception of reality, their experience, and the possibilities offered by the real world (Carmigniani et al., 2011; Oleksy & Wnuk, 2016; Pantano et al., 2017). This can lead to a deeper level of engagement, enjoyment and satisfaction (Dacko, 2016; Papagiannidis et al., 2017).

Existing literature on immersive places arising from the use of AR technology mainly focuses on the entertainment and educational sectors, and museums/other places of historic cultural heritage (Chang, Hou, Pan, Sung, & Chang, 2015). AR technologies potentially enable a deeper *place-based* participation by allowing users to virtually, yet naturally, experience an enhanced version of the physical space in real-time via realistic interfaces. This increases feelings of immersion and engagement (Oleksy & Wnuk, 2016; Pantano et al., 2017), and can result in improved perceptions of the experience and the real environment, by offering new possibilities to see objects not physically available in the real-world context, enriching content and information at users' disposal. This creates an immersive environment and interesting, fun experiences (Oleksy & Wnuk, 2016; Papagiannidis et al., 2017). Oleksy and Wnuk (2016) posited the concept of 'augmented places' as physical places enhanced with AR with the aim to recreate and enhance the experience of the place in question, by overlapping virtual reconstructions of past heritage and actual place, supporting users' understanding of its historical value, and resulting in users' higher emotional attitude towards the place and greater understanding of meaning of multicultural places (Oleksy & Wnuk, 2016). These elements of immersive environments and augmented places could potentially be extended to the retail context.

2.3 Human-Computer Interaction (HCI) in Retail Settings

In order to facilitate technology acceptance, developers need to provide interactional modality that is as realistic and natural as possible (Carmigniani et al., 2011). Consumers' acceptance of, and interaction with, technological innovations in retail settings has received greater attention, due to the growing adoption of technologies at the point of sale to enhance customer experience and increase competitiveness (Bonetti & Perry, 2017; Pantano & Gandini, 2017).

Indeed, research into human-computer interaction (HCI) in retail settings enriched with enhanced and immersive AR and VR technologies has expanded in recent years. Conducted in a laboratory environment, Pantano et al.'s (2017) study investigated the effect of customer interaction with AR technologies when trying on glasses to simulate virtual fit and appearance. Their results showed aesthetic quality and interactivity to be antecedents of perceived ease of use; response time and quality of information influenced consumers' positive attitude; and when combined with the perceived enjoyment in interacting with the technology, improved the online buying decision process. Olsson et al.'s (2013) assessment of potential end users' expectations and requirements of future mobile AR services characteristics and user experience in a shopping centre context revealed that participants expect the technology to be proactive and context-aware, suggesting products and activities based on the user's location, as well as providing relevant and personalised content, with interaction intuitive, natural and easy to learn, flexible and controlled by the user. Dacko's (2016) examination of mobile AR apps and the extent to which they contribute to smart retail settings found user satisfaction to be relatively high, and that technology use provides experiential shopping benefits, including more efficient or better value shopping, more entertaining and more visually appealing shopping.

Research on AR in a retail context mainly concerns online stores, conducted in controlled laboratory environments (Huang & Liao, 2015; Pantano & Laria, 2012; Papagiannidis et al., 2017). However, as physical stores have adopted these technologies, there is an increasing need and opportunity to conduct research in this particular real-world context. In their review of research methods applied within HCI for mobile devices, Kjeldskov and Graham (2003) noted the tendency towards building systems and evaluating consumers' usage and interaction within artificially controlled environments and isolated laboratory-based settings, at the expense of understanding and learning from the actual use of technologies in 'messy' real-world contexts (Dix, 2009), characterised by distractions, noise and interruptions (Rogers, 2004).

3 Methodology

Qualitative research inquiry was used to evaluate users' reaction to immersion in an AR-enhanced store. While it is noted that the majority of studies on technology adoption and usage in retail settings adopt a broadly positivistic perspective (Ha & Stoel, 2009; Huang & Liao, 2015; Pantano et al., 2017)—often applying the Technology Acceptance Model (Davis, 1989), extending and combining it with other frameworks and constructs (Papagiannidis et al., 2017; Venkatesh, Thong, & Xu, 2012)—researchers are increasingly stressing the need for more interpretive research designs in order to gain a richer understanding (Korpelainen, 2011; Rowlands, 2005; Williams, Dwivedi, Lal, & Schwarz, 2009). Indeed, technology adoption is a complex phenomenon (Rowlands, 2005) involving understanding of the unique points of view of the participants involved, human experiences and participant characteristics, the context in which adoption takes place, and the intricate and rapidly changing nature of technology (Pantano & Priporas, 2016). Consistent with this, the intention of this exploratory qualitative study is to gather rich and in-depth data to inform deeper understanding of the phenomenon investigated, rather than generalising more broadly into other contexts.

3.1 Augmented Fashion Store Development

A sportswear fashion and apparel retailer located in central London (UK) was selected as a case study. This retailer sells sportswear and outerwear and an overall lifestyle concept. It occupies a premium market positioning, with an innovative brand image, due to the innovative materials used in products, the sports activities organised by the retailer, and in-store technologies. Moreover, the retailer focuses

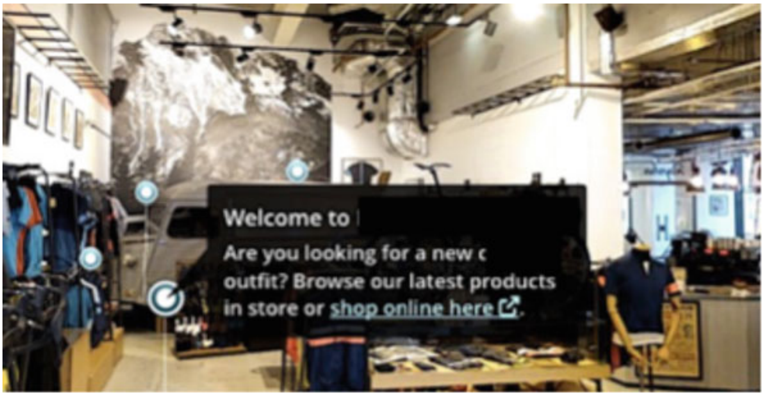

Fig. 1 Example of a point of engagement, as visualised by consumers, welcoming customers, giving information and redirecting users to the retailer's e-store

heavily on providing an overall experience and creating a community among customers, in part by devoting a section of the premises to a café area, thereby providing a place where customers can meet, relax, work, and watch sports events.

The store space was scanned and virtually reconstructed to realise a 3D model of the store, which consumers could access virtually. This allowed the development of immersive technologies, which were installed in the store for the purposes of this research. Three key products and a real model were scanned in detail, to visualise how a product would look when worn, as well as to increase the sense of realism of the experience. Tags or points of engagement were further inserted on specific items such as new products, at the store entrance to welcome customers, and on the in-store images of sports activities organised by the brand. From the highlighted items, tags would pop up by clicking on or walking by them, giving suggestions to the user and providing further information, linking and redirecting the user to the brand's website and e-store, allowing customers to purchase items and view videos of sports events showcased. This served to immerse the user in the enhanced environment and space by interacting with it through the technologies used (Fig. 1). This 3D model can be used with all types of screens and VR headsets to help confer an immersive and enhanced customer experience whilst in the physical store.

3.2 Procedure and Data Collection

A convenience sample of 29 participants was recruited to take part in the research, which consisted of observation of participants trying out the technology and subsequent interviews (lasting approximately 30 min). The selection criteria were: (1) that participants were current loyal customers; and (2) were willing to take part in the research. The sample consisted of 27 male and two female participants, as the brand's target market is predominantly male-oriented consisting of 30–50-year-old men, successful, affluent, into a certain active lifestyle and loyal to the sport category. Three participants were aged from 20 to 24; seven from 25 to 29, two from 30 to 34, one from 35 to 39, twelve from 40 to 49, and four from 50 to 60. In terms of frequency of shopping at the brand premises, seven participants visited the store once a week, eleven once a month, and twelve once every six months.

Participants were first asked to try out the new technology on three formats—laptop, iPad screens and a VR headset—whilst in the physical store, and use each format to experience and autonomously explore the environment and immersive and augmented store experience. The technology included 3D, VR, headset, phones compatible with the headset, computers and iPads. Subsequently, participants were interviewed regarding their experience. The interview questions and themes for discussion were formulated to investigate perceptions of the degree of enhancement of the customer experience and the physical environment (i.e. shopping experience; level of immersion and engagement; degree of realistic experience; visibility and presentation of products and space), interaction with the technologies used (i.e. degree of realistic interactions; degree of immersion in the store space and environment; time in store; brand engagement; perception of the brand; purchase decisions), and further suggestions and considerations. Each participant was invited to talk openly and express their impressions and feelings in their own words. Notes were taken and typed into an online survey instrument to facilitate data collection. An established inductive process (Corbin & Strauss, 2008; Miles, Huberman, & Saldana, 2014) of applied thematic analysis (Guest, MacQueen, & Namey, 2012) was followed. The data analysis began with preparing and familiarising with the data, followed by an initial open and free analysis, exploring and identifying initial codes and sub-codes. As data analysis proceeded iteratively (Spiggle, 1994), codes were refined and then grouped into initial themes and categories. Further analysis then revealed three core themes: *enhancement; interaction; behaviour*. These themes form the structural and discursive basis of the following presentation and discussion of findings.

4 Research Findings

4.1 Enhancement: The New Store Environment and Shopping Experience

In terms of participants' perception of the store environment enriched with immersive AR technologies, most participants (n = 26) commented that this enhanced their shopping experience. Participants appreciated the new in-store experience, and considered the enriched store to be entertaining, engaging, immersive and enjoyable. Some respondents said the immersive technologies contributed to make the in-store experience highly customised, which helped the retailer create a closer relationship with the individual customer and further enhanced perceived service quality and experience (Pantano, 2016). Overall, observations and interviews showed that participants were generally optimistic about the 3D models and the augmented store, and the consequent enhanced in-store experience, and also revealed positive disposition to future developments of this form of store and innovative technologies.

However, three participants did not regard this new type of store as contributing to their shopping experience. This can be linked to participants' degree of acceptance and usage of innovative technologies, which depends on several factors, including perceived usefulness (PU), perceived ease-of-use (PEOU), consumers' characteristics (i.e. level of cognitive innovativeness, level of education, age, store channel preferences), attitudes about the technology (i.e. degree of familiarity and understanding of how to use a specific tool, confidence in using it in public) and context constraints (i.e. time availability, sources of information, store crowding, technology location in-store) (Davis, 1989; Huang & Liao, 2015; McCormick et al., 2014). Some participants stressed that, as these technologies were still quite new, they needed to get used to them, as they were not yet familiar with them, especially in a retail context:

> I have not used it [immersive technology] for browsing products before. Up until now the experience of it has been novelty games on the iPhone.

This suggests a need for retailers to introduce this new technology gradually to potential users, educating them and promoting the new tool by providing all relevant information (e.g. trained staff in-store, in-store posters and signs) (Lee, Meyer, & Smith, 2012).

4.2 Interaction: Consumers' Mobility and Interaction with the Enhanced Store

Most participants (n = 25) said they found the experience realistic, facilitated by the ability to walk around the enhanced store. Several were enthusiastic about aspects related to the visibility and presentation of products and spaces, where colours played an important role. Moreover, participants stressed the important role of the immersive technologies in enhancing product visibility (in terms of features and fitting), which they found very realistic. The enhanced store also helped users find what they were looking for, thus making the interaction informative (Antéblian, Filser, & Roederer, 2014; Huang & Liao, 2015; McCormick et al., 2014).

However, four participants felt the enhanced store needed a better and easier way to show and interact with products:

> I would prefer it [enhanced store], but it needs an easier way to look at products.

Hedonic motivations for interacting with the immersive technologies prevailed. In fact, participants stressed the immersive, engaging, interactive and entertaining aspects of the enriched store. In particular, they pointed out the desire to see this technology being used to tell the 'story' of the brand in more immersive ways, making the in-store experience more informative about to the characteristics and values of the brand, and its associated sporting/brand community activities, instead of merely focusing on selling products. These hedonic drivers—accompanied by utilitarian drivers (i.e. product information, location, availability, being redirected to the retailers' e-store to place an order to speed up service etc.)—underpinned participants' evaluations of the augmented store, leading to perceived enhancement of their experience. This is in line with previous studies showing both hedonic and utilitarian value of immersive AR/VR applications (Huang & Liao, 2015; Olsson et al., 2013), although here results revealed a prevalence of hedonic motivations for interacting with the immersive and enhanced store.

Overall, participants liked the interactive elements of the enhanced store. Being able to move virtually from one part of the store to another and see the space through the immersive technology, and then be re-directed to the brand's website and get extra information or place an order, emerged as important aspects making participants' interactions with the 3D models favourably-perceived and realistic. This allowed users to interact with other retail channels whilst in the physical store, as the adoption of innovative consumer-facing technologies (representing touch points between retailer and consumer) has made the online and offline worlds more interrelated (Bonetti & Perry, 2017; McCormick et al., 2014), and perceived by the customer as integrated and as part of a unique, seamless experience (Verhoef, Kannan, & Inman, 2015).

4.3 Behaviour: The Influence of the Enhanced Store

Many participants found the enhanced store entertaining, and commented that the interaction with the innovative technologies and the enhanced store made them feel engaged with the brand (n = 21), and enhanced their perception of brand value:

> It's engaging and puts you right in the centre of the experience.

This would encourage them to spend more time at the enhanced store interacting with the immersive technologies and store, and nine customers stated that the immersive technologies and enhanced store increased their desire to shop at the retailer.

These reactions are in line with previous environmental psychology studies in a retail context in relation to the influence of consumer-facing technology on consumer behaviour (Dacko, 2016; Pantano, 2016; Papagiannidis et al., 2017), although the present study arguably advances understanding by examining the use of innovative and immersive technologies in the real-world context. Generally, participants found the enhanced store to be different, entertaining, innovative, professional, modern and trendy, whereby the technologies used serve to keep the brand up-to-date. Such innovative in-store technical elements are in line with the retailer's identity, image and positioning, reinforcing how the retailer positions itself and is perceived by consumers and competitors (Pantano et al., 2017), as the retailer also uses innovative technologies and materials for their products—as one respondent commented:

> It pushes the boundaries, I am not surprised, it's the same idea as what they [the brand] are all about; they are innovative in the textile, high quality.

5 Discussion

Building on these exploratory findings, the following discussion suggests ways to enable the possible development of a new store form, enhanced through immersive AR technologies. Resonating with the notion of 'augmented places' mentioned earlier, a schematic framework for this proposed 'augmented store' is outlined below.

5.1 Store Augmentation: The Development of a New Store Form

Immersive AR technologies resulted in an enhanced shopping experience within—and environment of—the *traditional* store of the retailer in question, and overall the respondents in this research were satisfied and impressed with this augmented store. The discussion now considers some more practical implications of existing theory which has been generated in more experimental settings in this real-world context.

The augmented store can be defined as a physical retail store augmented/enhanced by innovative and immersive AR technologies. In this store form, the customer's current perception of the real store space, environment and shopping experience are mediated and enhanced by the use of 3D models and virtual scenarios that consumers explore and naturally interact with while in the real store environment. This augmented store is characterised by the combination of AR technologies with the real store environment, thereby integrating real and virtual objects, store space and environment. The augmented store (Fig. 2) thus extends the traditional and real physical retail space boundaries surrounding the customer (such as the physical limits of the store, the items physically present in the store, the information at consumers' disposal and the way it is provided etc.). Here, consumers' natural interactions with the store environment through innovative and realistic interfaces, space mobility and visibility constitute another key feature, offering new possibilities to see and interact with virtual objects not physically available in the real store space, enriching content, and thereby leading to consumers' deeper participation and helping to confer a richer and more immersive perception of the augmented store environment and shopping experience, entertainment and enjoyment in the real physical store.

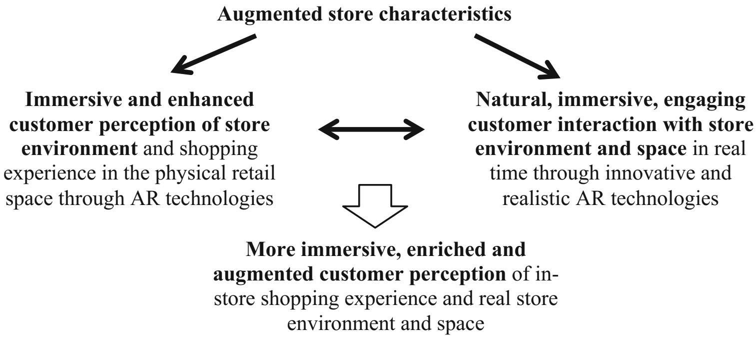

Fig. 2 Key characteristics of the augmented store

6 Conclusions, Contributions and Future Research

This study has explored the integration of AR techniques within a physical store and has suggested ways to develop a new store form, the augmented store, by making the store enriched, enhanced, more accessible, entertaining and efficient for consumers. Results showed that participants perceived the new augmented store to be more immersive, entertaining, engaging and enjoyable. They found the interaction with the store realistic, leading to an enhanced brand perception and further increasing brand engagement.

6.1 Theoretical Contributions and Managerial Implications

This research contributes to the existing literature in multiple ways. First, it extends the existing literature on augmented and immersive places (Carmigniani et al., 2011; Chang et al., 2015; Oleksy & Wnuk, 2016) to a specific real-world context of the retail store, by providing knowledge on the shift towards an augmented store and outlining its key characteristics.

Second, it contributes to the existing literature on HCI (Kjeldskov & Graham, 2003; Rogers, 2004) by focusing on consumers' interaction with the technology (consumer-computer interaction or CCI), thus extending existing research on a generic user's interaction with technology in a generic place. In particular, the study focuses on consumers' interactions with AR technologies in a real-world context of an actual store. This extends previous research conducted in simulated and controlled laboratory environments with simulated consumers (Pantano & Laria, 2012; Pantano et al., 2017; Papagiannidis et al., 2017), by investigating perceptions of current actual consumers of a retailer, their interactions with immersive AR technologies in a real, physical retail store, and their reactions to the new and enhanced store space and environment.

Furthermore, this research has implications for practitioners. It unveils positive consumer reactions to the augmented store form, providing practitioners with a new perspective on a specific new technology to be successfully integrated within traditional points of sale. Retailers willing to further engage with customers by enhancing their in-store experience should therefore consider types of immersive technologies, where these can provide entertaining, informative and engaging experiences.

6.2 Limitations and Future Research

The study also has some limitations. The selected retailer's target market focuses on a particular demographic. Thus, the results do not reveal in detail how other consumer types would react to and perceive this new store form. Further research could involve different retailers with varied target customers, to identify and analyse reactions from a more diverse range of consumers, incorporating participants from different demographic profiles, to gain a more comprehensive understanding which would then help obtain the right balance of innovative technologies and traditional services provided in store, to better satisfy a broader range of customers. Although the research takes a qualitative approach, eye-tracking technology or retailers' EPOS data could be used to link consumer perception to purchase behaviour, for example by exploring whether consumers would spend more time in store due to an enhanced experience, or whether it influences purchase intention. Finally, future research could investigate managerial perspectives of consumers' reactions to, and perceptions of, the store enhanced with AR technologies.

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References

Antéblian, B., Filser, M., & Roederer, C. (2014). Consumption experience in retail environments: A literature review. *Recherche et Applications en Marketing, 28*(3), 82–109.

Bonetti, F., & Perry, P. (2017). A review of consumer-facing digital technologies across different types of fashion store formats. In A. Vecchi (Ed.), *Advanced fashion technology and operations management* (pp. 137–163). IGI Global.

Bonetti, F., Warnaby, G., & Quinn, L. (2017). Augmented reality and virtual reality in physical and online retailing: A review, synthesis and research agenda. In T. Jung & M. Tom Dieck (Eds.), *Augmented reality and virtual reality* (pp. 119–132). New York: Springer.

Carmigniani, J., Furht, B., Anisetti, M., Ceravolo, P., Damiani, E., & Ivkovic, M. (2011). Augmented reality technologies, systems and applications. *Multimedia Tools and Applications, 51,* 341–377.

Chang, Y.-L., Hou, H.-T., Pan, C.-Y., Sung, Y.-T., & Chang, K.-E. (2015). Apply an augmented reality in a mobile guidance to increase sense of place for heritage places. *Educational Technology and Society, 18*(2), 166–178.

Corbin, J., & Strauss, A. (2008). *Basics of qualitative research: Techniques and procedures for developing grounded theory*. Thousand Oaks, CA: Sage.

Dacko, S. G. (2016). Enabling smart retail settings via mobile augmented reality shopping apps. *Technological Forecasting and Social Change, 124,* 243–256.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly, 13*(3), 319–340.

Dix, A. (2009). Human-computer interaction. In L. Liu & M. Tamer Ozsu (Eds.), *Encyclopedia of database systems* (pp. 1327–1331). US: Springer.

Foster, J., & McLelland, M. A. (2014). Retail atmospherics: The impact of a brand dictated theme. *Journal of Retailing and Consumer Services, 22,* 195–205.

Guest, G., MacQueen, K., & Namey, E. (2012). *Applied thematic analysis*. Thousand Oaks, CA: Sage.

Ha, S., & Stoel, L. (2009). Consumer e-shopping acceptance: Antecedents in a technology acceptance model. *Journal of Business Research, 62*(5), 565–571.

Huang, T.-L., & Liao, S. (2015). A model of acceptance of augmented-reality interactive technology: The moderating role of cognitive innovativeness. *Electronic Commerce Research, 15*(2), 269–295.

Javornik, A. (2016). Augmented reality: Research agenda for studying the impact of its media characteristics on consumer behaviour. *Journal of Retailing and Consumer Services, 30,* 252–261.

Kjeldskov, J., & Graham, C. (2003). A review of mobile HCI research methods. In L. L. Chittaro (Ed.), *Human-computer interaction with mobile devices and service* (pp. 317–335). Berlin, Heidelberg: Springer.

Korpelainen, E. (2011). Theories of ICT system implementation and adoption—A critical. *Aalto University Publication Series, 1,* 14–17.

Kotler, P. (1973). Atmospherics as a marketing tool. *Journal of Retailing, 49*(4), 48–64.

Lee, L., Meyer, T., & Smith, J. S. (2012). Reinventing the customer experience: Technology and the service marketing mix. In J. Kandampully (Ed.), *Service management: The new paradigm in retailing* (pp. 143–160). New York: Springer.

McCormick, H., Cartwright, J., Perry, P., Barnes, L., Lynch, S., & Ball, G. (2014). Fashion retailing—Past, present and future. *Textile Progress, 46*(3), 227–321.

Miles, M. B., Huberman, A. M., & Saldana, J. (2014). *Qualitative data analysis: A methods sourcebook*. Thousand Oaks, California: Sage.

Oleksy, T., & Wnuk, A. (2016). Augmented places: An impact of embodied historical experience on attitudes towards places. *Computers in Human Behavior, 57,* 11–16.

Olsson, T., Lagerstam, E., Kärkkäinen, T., & Väänänen, K. (2013). Expected user experience of mobile augmented reality services: A user study in the context of shopping centres. *Personal and Ubiquitous Computing, 17*(2), 287–304.

Pantano, E. (2016). Benefits and risks associated with time choice of innovating in retail settings. *International Journal of Retail and Distribution Management, 44*(1), 58–70.

Pantano, E., & Gandini, A. (2017). Exploring the forms of sociality mediated by innovative technologies in retail settings. *Computers in Human Behavior, 77,* 367–373.

Pantano, E., & Laria, G. (2012). Innovation in retail process: From consumers' experience to immersive store design. *Journal of Technology Management and Innovation, 7*(3), 198–206.

Pantano, E., & Priporas, C.-V. (2016). The effect of mobile retailing on consumers' purchasing experiences: A dynamic perspective. *Computers in Human Behavior, 61,* 548–555.

Pantano, E., Rese, A., & Baier, D. (2017). Enhancing the online decision-making process by using augmented reality: A two country comparison of youth markets. *Journal of Retailing and Consumer Services, 38,* 81–95.

Papagiannidis, S., Pantano, E., See-To, E., Dennis, C., & Bourlakis, M. (2017). To immerse or not? Experimenting with two virtual retail environments. *Information Technology and People, 30*(1), 163–188.

Puccinelli, N. M., Goodstein, R. C., Grewal, D., Price, R., Raghubir, P., & Stewart, D. (2009). Customer experience management in retailing: Understanding the buying process. *Journal of Retailing, 85*(1), 15–30.

Rogers, Y. (2004). New theoretical approaches for human-computer interaction. *Annual Review of Information Science and Technology, 38,* 87–143.

Rowlands, B. H. (2005). Grounded in practice: Using interpretive research to build theory. *The Electronic Journal of Business Research Methodology, 3*(1), 81–92.

Spiggle, S. (1994). Analysis and interpretation of in qualitative data in consumer research. *Journal of Consumer Research, 21*(3), 491–503.

Venkatesh, V., Thong, J. Y. L., & Xu, X. (2012). Consumer acceptance and use of information technology: Extending the unified theory of acceptance and use of technology. *MIS Quarterly, 36*(1), 157–178.

Verhoef, P. C., Kannan, P. K., & Inman, J. J. (2015). From multi-channel retailing to omni-channel retailing: Introduction to the special issue on multi-channel retailing. *Journal of Retailing, 91*(2), 174–181.

Williams, M. D., Dwivedi, Y. K., Lal, B., & Schwarz, A. (2009). Contemporary trends and issues in IT adoption and diffusion research. *Journal of Information Technology, 24*(1), 1–10.

V-Commerce in Retail: Nature and Potential Impact

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Abstract V-commerce is an emerging phenomenon that is gaining traction in marketing and business literature and is becoming specifically more prominent in content related to retail practices. However, interpretations and explanations as to what exactly v-commerce refers to and comprises are inconsistent. This paper addresses the fluid conceptualisation of the v-commerce terminology and advocates the usage of v-commerce terminology exclusively for referring to, and as an abbreviation of, virtual commerce—for which a unified definition will be proposed. Taking a business-to-consumer approach, the current implementations of virtual commerce in the retail sector, as well as the potential and future research implications will be discussed.

Keywords Virtual commerce · V-commerce · Retail · Consumer · Alternate reality

1 Introduction

V-commerce terminology in marketing and business literature is becoming increasingly prevalent. Various authors agree that v-commerce will "reshape the retail landscape" (Ango, 2016; McKone et al., 2017). However, the concept's shared origin between academia, industry and the media combined with ubiquitous implementation, introduced ambiguity to the v-commerce terminology; which currently embodies different, and even contradictory, connotations contingent upon the various stakeholders (i.e., often due to contextual differences). At present, three different usages of v-commerce terminology can be observed: (1) A stream of authors, predominantly practitioner literature, that relates v-commerce to digitally

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native vertical brands and vertically integrated commerce (i.e., vertical commerce; Dunn, 2016). (2) A stream of literature that associates v-commerce with virtual commerce (e.g., Jin & Bolebruch, 2009). (3) A final stream of literature that refers to voice commerce (Beaumont, 2017; Zhang, Liu, & Li, 2009). The following paragraphs will expand on the different interpretations of the v-commerce abbreviation.

1.1 Vertical Commerce

The development of Internet-based commerce and the competitive and fast-paced nature of global markets have revived retailer's interests regarding vertical integration—which can be described as combining two or more stages of production and/or distribution, that are usually separate, under a single ownership (e.g., Buzzell, 1983). Dunn (2016) coined the term Digitally Native Vertical Brands (DNVBs), describing brands that are born on the internet and are maniacally focused on the customer experience (a.k.a., v-commerce brands). DNVBs primarily use e-commerce channels for interaction, transaction, and story-telling and rely heavily on their loyal customer base and user-generated content to spread the word (for examples of DNVBs in different industries see Pixlee, 2017). Adhering to the concept of vertical integration, DNVBs bypass traditional supply chains and distribution channels and implement direct-to-consumer models. This enables these online (niche) retails to offer consumers high-quality products at reduced costs while at the same time enhancing their product gross and contribution margins. Although there are potential downsides to a vertically integrated business model (e.g., supply chain complexities and difficulties in scaling; e.g., Dunn, 2016; Wertz, 2012), rising investment activity and acquisitions (i.e., Unilever bought Dollar Shave Club for US$1 billion; Unilever, 2016) could usher in a new era of cult brand monotheism, e-tailers and vertically integrated commerce.

1.2 Virtual Commerce

A lexical definition of virtual is "not physically existing as such but made by software to appear to do so" (Oxford dictionary, 2018). In line with this definition, Javornik (2016) defined virtuality as a "media's capability of showing virtual elements or virtual worlds, as experienced by the user through immersion or telepresence in the environment created by computer graphics or visual elements"—adopting an experience-based perspective (cf., Steuer, 1992). To facilitate immersive and interactive experiences, alternate reality technologies (Table 1) are utilized; which can be classified along a virtuality continuum (Milgram & Kishino, 1994).

Table 1 Alternate reality technologies

Terminology	Definition
Augmented reality (AR)	Alternate reality technology that provides an enhanced version of the real-world by overlaying our existing reality with an additional layer of digital information, which can be viewed through a (connected) technological device—such as smartphones or Augmented Reality Smart Glasses (ARSGs)
Mixed reality (MR)	Alternate reality technology that facilitates the merger of, and real-time interaction with and between, digitally rendered and real-world data and objects through connected technological devices (e.g., mixed reality headset)
Virtual reality (VR)	Alternate reality technology that is characterized by generating real-time, immersive and interactive multi-sensory experiences situated in, and artificially induced by, a responsive three-dimensional computer-generated virtual environment—usually paired with advanced input and output devices

Virtual commerce encompasses conducting commerce through these medium types. Therefore, this paper defines virtual commerce as: electronically mediated commercial transactions that originate from an alternate reality technological platform and involve either digitally-generated or real-world products and services.

1.3 Voice Commerce

Voice activated commerce pertains to user interaction with commercial platforms and applications that utilize natural language speech recognition to enable self-service transactions over the telephone and other connected devices (e.g., Dennis & Harris, 2003, p. 205)—as such, voice recognition technology substitutes the online point-and-click decision-making process by introducing spoken command methods. This shift towards conversation-based e-commerce is influenced by technological progress, including, but not limited to, improvements in the fields of: artificial intelligence, cloud computing and machine learning. Alongside there is the consumer's rising acceptance and comfort levels towards conversational user interfaces (i.e., smart speakers, such as Amazon's Echo and Google Home, that are often linked and or controlled by virtual voice assistants like Apple's Siri and Microsoft's Cortana). Although voice commerce brings in new challenges for retail (e.g., privacy concerns could fuel increasing restrictions regarding access to walled-garden personal data accumulated from voice interactions, inciting tension among digital ecosystems and potentially raising the cost of platform neutrality; Gartner, 2016), it is likely that consumer demand for voice commerce will continue to rise as industry leaders proceed to innovate.

All of the above-mentioned developments are expected to deeply impact the retail industry. However, to advance marketing research practices and increase understanding regarding v-commerce within the public discourse, it is imperative that we clearly distinguish these advancements. This research advocates to ascribe the v-commerce terminology exclusively to *virtual* commerce; and use different prefixes for the other concepts, respectively *vi*—for vertical (integrated) commerce and *va*—for voice (activated) commerce. The underlying rationale is that throughout the years, commerce has consistently advanced by moving alongside and making use of technological revolutions (i.e., the internet); and most practitioners and academics agree that the rise of virtual and augmented reality can be considered as the next technological revolution (e.g., Steinicke, 2016, pp. 33–43). In addition, former one-letter commerce prefixes all refer to the medium type and or technology. Examples include: E-commerce, which can be defined as “the use of electronic means to exchange information and to carry out activities and transactions” (i.e., electronic commerce; Wyckoff & Colecchia, 1999); M-commerce “any transaction with a monetary value—either direct or indirect—that is conducted over a wireless telecommunication network” (i.e., mobile commerce; Barnes, 2002) and T-commerce “electronically mediated commerce through interactive digital television” (i.e., television commerce; Arroyo-Cañada & Gil-Lafuente, 2016). Adhering to this pattern, v-commerce should relate to virtual technology. It can be argued that virtual commerce, like m-commerce before (Coursaris & Hassanein, 2002), should be regarded as a subset of e-commerce—although some people have phrased it to be the “next step” (e.g., Alexandru, 2017).

2 V-Commerce and the Impact on Business-to-Consumer Retailing

In 2010, Jones stated that “a host of technological and social forces needs to converge in order for v-commerce to flourish” (p. 56) and it can be reasoned that we are currently at that stage. The maturation of VR and AR technologies heralds a fundamental shift in moving from the internet of information towards the internet of experiences (i.e., in which experiences replace information as the basic unit of currency; Kelly, 2016), and it can be argued that therein lies the biggest premise of virtual commerce; the potential to transform online shopping experiences and provide a (near) real-world equivalent (e.g., Papadopoulou, 2007). This is primarily because a virtual commerce interface, if properly designed, can support natural shopping behaviour by providing a more personalized, immersive and interactive experience (e.g., Chittaro & Ration, 2000). From a societal point of view, the consumer shift towards the v-commerce will be mainly driven by the younger age cohorts, since they are technology savvy, known to associate with brands to express their identity (e.g., Saxton, 2005) and already spend more money on ‘experiential purchases’ (cf. Van Boven & Gilovich, 2003).

2.1 Current Implementations of V-Commerce

The retailing industry is starting to transform due to virtual technologies impacting all stages of the retail ecosystem. This paper takes a business-to-consumer approach and focusses on "front-end" implementations of virtual commerce. V-commerce will change the meaning of "what you see is what you get" since it provides consumers with the possibility to experience and explore different features of a product or service before the actual purchase. Notwithstanding the interesting development perspectives for brick-and-mortal retailers, research by Chesney, Chuah, Dobele, and Hoffmann (2017) indicates that this could be a major disrupter for online shopping, potentially bridging the trust deficit that might have prevented people from making purchases in web-based e-tailing environments in the past. Various retailers are already experimenting with different implementations and although currently virtual commerce is still in the early adoption phase, it can be expected that in the (near) future virtual commerce will be implemented on a more global scale. Currently, two main implementations of augmented-reality interactive technology (ARIT; e.g., Huang & Liao, 2015) can be distinguished; namely, enhancing the consumers shopping experience by utilizing it as a product try-on technology and employing location-based intelligence to offer interactive, contextually-relevant (personalized) experiences. With regard to virtual reality technology, the two main implementations that can be identified are employing virtual-reality as a new sales channel and implementing it as a channel for brand building.

AR Implementations The most obvious fit for try-on technology are retailers where fit is crucial (e.g., retailers selling clothing). However, it does not stop there. CaratLane, one of India's largest online jewellery retailers, implemented this technology to introduce the world's first virtual 3D jewellery Try-on app—implementing facial recognition and three-dimensional imaging technology to turn the user's laptop or smartphone screen into a mirror (Business Standard, 2015). MAC Cosmetics implements this technology on location in their New York retail store (Stolyar, 2017; i.e., stationary virtual mirrors, a.k.a, AR-mirrors). Another example is the IKEA Place app, which lets consumers experience how true-to-scale furniture would look, and fit, in their house (IKEA, 2017). Currently, most AR apps require consumers to use their hand-held (mobile) devices. However, it can be argued that with recent technological advancements in the field of wearable augmented reality devices, and particularly Augmented Reality Smart Glasses (i.e., devices that are worn like regular glasses and merge virtual information with physical information in a user's view field; Ro, Brem, & Rauschnabel, 2018), business potential and opportunities for value creation will continue to grow. Regarding location-based augmented reality, multiple apps exist that link augmented reality with GPS systems, geospatial data techniques and location sensors of mobile devices (e.g., Streetmuseum, which provides historical information about landmarks in London; BBC, 2010). Utilizing this technology, Blippar (2017) provides a business implementation by employing rich media units (i.e., digital banner ads) that deliver content and features designed to drive active consumer engagement and interest in products. Since this technology can be implemented in almost any camera-accessible web and mobile environment, it facilitates scaling exposure across audience segments.

VR Implementations Providing the first virtual reality department store, eBay and the Australian retailer Myer provide a good example of implementing VR as a sales channel (eBay, 2016). Utilizing a smartphone based virtual reality viewer, consumers could inspect items (i.e., move, rotate, zoom-in), access real-time product specifications (e.g., product range, pricing and stock information) and finalize purchases through the eBay app. To enhance consumer uptake, Sydney residents could sign up for a special exhibition tour and 15,000 VR viewers were made available to consumers free of charge. Implementing VR technology for brand building can take multiple forms, virtual brand storytelling being the most obvious. A showcase example is provided by The New York Times who partnered up with Google to create a line-up of 360° virtual reality films that could be made available to their (print) subscribers. The first project (i.e., The Displaced, which focusses on the lives of three children whose lives have been uprooted by war) won them the Entertainment Grand Prix at the Cannes Lions International Festival of Creativity (Adweek, 2016). Other examples of VR brand building include: (1) Product demo's, demonstrating product attributes, features and functionalities (e.g., Chevrolet VR experience; Chevrolet, 2018). (2) Live streaming of events (e.g., Topshop London Fashion Week; Campaign, 2014), and (3) co-creation (i.e., NIKEiD VR Studio; RGA, 2016). Overall, it can be concluded that v-commerce offers exciting and new opportunities for brands, businesses and the retail industry—opportunities that we are only just beginning to explore.

3 Discussion

At this point it seems unlikely that v-commerce will render well established m-commerce and e-commerce practices completely obsolete—although, tech executives (e.g., Zuckerberg) have previously mentioned that alternate realities have the potential to become the next major computing platforms in the future (e.g., Heath, 2017). Nevertheless, v-commerce does offer a new platform for consumer-brand interaction that can supplement existing digital and physical channels. Therefore, retailers that are pursuing a true omni-channel strategy should start to consider how v-commerce can become an integral part of their overall approach (e.g., as marketing and or customer service channel). Concurrently, the Marketing Science Institute (MSI, 2016) has encouraged the academic community to gear their research efforts towards the delivery of integrated, real-time and relevant experiences in context. Therefore, future research efforts should focus on addressing: (1) Contextual differences (e.g., online vs. in-store settings). (2) Differences between consumer segments (e.g., acceptance, trust and brand-self connection). (3) Cross-channel effects, interoperability and comparative effectiveness between different v-commerce channels and/ or traditional advertising platforms, preferably relating it to market segments and or product categories. (4) Generating universal v-commerce measurement metrics. (5) Establishing laws and regulations (e.g., regarding data ownership/privacy). We encourage investigations into these potentially fruitful avenues of future research and practice.

References

Adlatina. (2016, December). *R/GA buenos aires launches NIKEiD VR STUDIO*. Retrieved from https://www.rga.com/news/articles/r-ga-buenos-aires-presents-nikeid-vr-studio.

Adweek. (2016, June). *The New York times VR film 'The Displaced' wins the lions entertainment grand prix*. Retrieved from http://www.adweek.com/brand-marketing/new-york-times-vr-film-displaced-wins-lions-entertainment-grand-prix-172225/.

Alexandru, E. (2017, February). *Is virtual commerce the next revolutionary step in ecommerce*. Retrieved from http://ayg.ro/is-virtual-commerce-the-next-revolutionary-step-in-ecommerce/.

Ango, S. (2016, August). *Vertical commerce and how the next generation of retail will be built*. Retrieved from https://medium.com/fuzzy-sharp/vertical-commerce-and-how-the-next-generation-of-retail-will-be-built-1ef35f2fc695.

Arroyo-Cañada, F. J., & Gil-Lafuente, J. (2016). The incidence of incentives for t-commerce acceptance: Improving television as a distribution channel. *Journal of Business & Industrial Marketing, 31*(3), 426–435.

Barnes, S. J. (2002). The mobile commerce value chain: Analysis and future developments. *International Journal of Information Management, 22*(2), 91–108.

BBC. (2010, May). *Old London seen with new eyes thanks to mobile apps. Retrieved* from http://news.bbc.co.uk/local/london/hi/things_to_do/newsid_8700000/8700410.stm.

Beaumont, D. (2017, October). *V-commerce is artificial intelligence and voice capability*. Retrieved from https://chatbotslife.com/what-is-v-commerce-and-why-its-ready-to-explode-c4cc6f696e19.

Blippar. (2017, May). *Bringing augmented reality rich media banners*. Retrieved from https://blippar.com/en/resources/blog/2017/05/08/bringing-augmented-reality-rich-media-banners/.

Bold, B. (2014, February). *Topshop engages VR technology to live-stream fashion show to Oxford Circus shoppers*. Retrieved from https://www.campaignlive.co.uk/article/topshop-engages-vr-technology-live-stream-fashion-show-oxford-circus-shoppers/1230847.

Business Standard. (2015, August). *Caratlane launches virtual jewellery try-on app*. Retrieved from http://www.business-standard.com/article/news-ians/caratlane-launches-virtual-jewellery-try-on-app-115082000799_1.html.

Buzzell, R. D. (1983). Is vertical integration profitable. *Harvard Business Review, 61*(1), 92–102.

Chesney, T., Chuah, S. H., Dobele, A. R., & Hoffmann, R. (2017). Information richness and trust in v-commerce: Implications for services marketing. *Journal of Services Marketing, 31*(3), 295–307.

Chevrolet. (2018, January). *Chevrolet gives auto show goers behind-the-scenes look at vehicle testing*. Retrieved from http://media.gm.com/media/us/en/chevrolet/news.detail.html/content/Pages/news/us/en/2018/jan/0114-4d.html.

Chittaro, L., & Ration, R. (2000, August). Adding adaptive features to virtual reality interfaces for e-commerce. In *International Conference on Adaptive Hypermedia and Adaptive Web-Based Systems* (pp. 86–97). Berlin, Heidelberg: Springer.

Coursaris, C., & Hassanein, K. (2002). Understanding m-commerce: A consumer-centric model. *Quarterly Journal of Electronic Commerce, 3,* 247–272.

Dennis, C., & Harris, L. (2003). *Marketing the e-business*. London: Routledge.
Dunn, A. (2016, May). *What marketers need to know about v-commerce.* Retrieved from https://www.youvisit.com/insight/virtual-reality/what-marketers-need-to-know-about-v-commerce/.
Ebay. (2016, May). *Ebay Australia helps launch the world's first virtual reality department store. Retrieved* from https://www.ebayinc.com/stories/news/ebay-australia-helps-launch-the-worlds-first-virtual-reality-department-store-into-the-world-of-virtual-reality/.
Gartner. (2016). *Top strategic predictions for 2017 and beyond: Surviving the storm winds of digital disruption*. Stamford, CT: Gartner, Inc.
Heath, A. (2017, April). *Facebook's next big thing is augmented reality, says Mark Zuckerberg*. Retrieved from http://uk.businessinsider.com/facebook-next-big-thing-augmented-reality-mark-zuckerberg-2017-4.
Huang, T. L., & Liao, S. (2015). A model of acceptance of augmented-reality interactive technology: The moderating role of cognitive innovativeness. *Electronic Commerce Research, 15*(2), 269–295.
IKEA. (2017). *Try before you buy.* Retrieved from http://www.ikea.com/gb/en/this-is-ikea/ikea-highlights/try-before-you-buy/.
Javornik, A. (2016). Augmented reality: Research agenda for studying the impact of its media characteristics on consumer behaviour. *Journal of Retailing and Consumer Services, 30,* 252–261.
Jin, S. A. A., & Bolebruch, J. (2009). Virtual commerce (v-commerce) in second life: The roles of physical presence and brand-self connection. *Journal for Virtual Worlds Research, 2*(4).
Jones, S. (2010). From e-commerce to v-commerce. In *Virtual worlds and e-commerce: Technologies and applications for building customer relationships* (p. 42).
Kelly, K. (2016, March). *12 inevitable tech forces that will shape our future*. Retrieved from https://www.youtube.com/watch?v=pZwq8eMdYrY.
McKone, D., Haslehurst, R., & Steingoltz, M. (2017, July). *How will v-commerce arrive? Consumers show the way*. Retrieved from https://www.lek.com/insights/how-will-v-commerce-arrive-consumers-show-way.
Milgram, P., & Kishino, F. (1994). A taxonomy of mixed reality visual displays. *IEICE Transactions on Information and Systems, 77*(12), 1321–1329.
MSI Research Priorities 2016–2018. (2016). Cambridge: Marketing Science Institute.
Papadopoulou, P. (2007). Applying virtual reality for trust-building e-commerce environments. *Virtual Reality, 11*(2–3), 107–127.
Pixlee. (2017). *The top 25 digitally native vertical brands 2017*. San Francisco, CA: Pixlee.
Ro, Y. K., Brem, A., & Rauschnabel, P. A. (2018). Augmented reality smart glasses: Definition, concepts and impact on firm value creation. In *Augmented reality and virtual reality* (pp. 169–181). Cham: Springer.
Saxton, G. (2005). Collections of cool. *Young Consumers, 6*(2), 18–27.
Steinicke, F. (2016). *Being really virtual: Immersive natives and the future of virtual reality*. Cham: Springer.
Steuer, J. (1992). Defining virtual reality: Dimensions determining telepresence. *Journal of communication, 42*(4), 73–93.
Stolyar, B. (2017, November). *MAC virtual try-on mirror review*. Retrieved from https://www.digitaltrends.com/photography/mac-virtual-try-on-mirror-review/.
Unilever. (2016, July). *Unilever acquires Dollar Shave Club*. Retrieved from https://www.unilever.com/news/Press-releases/2016/unilever-acquires-dollar-shave-club.html.
Van Boven, L., & Gilovich, T. (2003). To do or to have? That is the question. *Journal of Personality and Social Psychology, 85*(6), 1193.
Virtual. (2018). In Oxford dictionaries.com. Retrieved from https://en.oxforddictionaries.com/definition/virtual.

Wyckoff, A. D., & Colecchia, A. (1999). *Economic and social impact of electronic commerce: Preliminary findings and research agenda*. Organization for Economic Cooperation and Development (OECD).

Wertz, B. (2012, September). *The next big e-commerce wave: Vertically integrated commerce*. Retrieved from https://techcrunch.com/2012/09/29/the-next-big-e-commerce-wave-vertically-integrated-commerce/.

Zhang, L., Liu, Q., & Li, X. (2009). Ubiquitous commerce: Theories, technologies, and applications. *Journal of Networks, 4*(4), 271–278.

A Virtual Reality and Retailing Literature Review: Current Focus, Underlying Themes and Future Directions

Liangchao Xue, Christopher J. Parker and Helen McCormick

Abstract This literature review reveals the current research focus, underlying themes and prominent research gaps in the Virtual Reality (VR) literature. 89 journal articles from the 22 years are thematically analysed in order to non-obvious reveal interconnections and themes, including research focus over time and underlying themes by research discipline. Over half of all papers focus on the need to understand the VR shopping consumer, yet no consensus exists as to what the optimal experience is or how to design effective v-Commerce stores. The most prominent research gaps are related to the unique HCI aspects in v-Commerce that influence shopping behaviours. The impact of this review is establishing the current challenges and future directions for academia in order to make v-Commerce a viable reality. Specifically, future research should mainly focus on develop human factor theory in VR shop design (i.e. social dimension, eye-tracking etc.).

Keywords Virtual reality · Retail · e-Commerce · Human factors · Augmented reality · v-Commerce

1 Introduction

This chapter reviews Electronic Commerce (e-Commerce) and consumer technology focused literature in order to detect key gaps and limitations in the literature must be contrasted to key developments and proposed applications. Through this, future research shall be directed towards making Virtual Reality (VR) and Augmented

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Reality (AR) viable platforms for e-Commerce beyond the two-dimensional limitations of screens.

Previously literature reviews on Virtual Reality have been conducted in fields such as Education (Freina & Ott, 2015), Tourism (Guttentag, 2010), Military (Rizzo et al., 2011), Healthcare (Nichols & Patel, 2002), Clinical trial (Cook & Triola, 2009), Therapy (Moreira, de Amorim Lima, Ferraz, & Benedetti Rodrigues, 2013), Urban planning (Simpson, 2001), Entertainment/Gaming (Connolly, Boyle, MacArthur, Hainey, & Boyle, 2012) and Engineering (Cecil & Kanchanapiboon, 2007). However, retail, e-Commerce and Virtual Commerce (v-Commerce) are absent from contemporary VR/AR literature reviews, presenting a void in academic knowledge which needs to be addressed.

The aim of this literature review is to direct research projects into as yet under explored to increase the efficiency and effectiveness of the retail research community. To achieve this aim, three research objectives were created:

1. We need to reveal the current focus of VR/AR research to appraise the research areas which are well understood and thus less suitable for innovative potential exploration.
2. We need to expose underlying themes in the VR/AR research outside of explicit research focus to understand which disciplines are under researched relating to beneficial technological applications.
3. We need to uncover the most prominent research gaps related to VR/AR to direct research projects that shall address critical issues essential to technological breakthroughs.

In addressing the research objectives, this literature review makes the following key contributions:

- Over half of all papers focus on the need to understand the consumer experience integrating with (Sect. 3.1), and shopping through v-Commerce, yet no consensus as to what the optimal experience is or how to design effective v-Commerce stores exists (Sect. 3.3).
- The majority of papers include underlying themes relating to UX design and purchase behaviour motivators, despite the apparent technological focus of the majority of the literature (Sect. 3.2).
- The most prominent research areas that need addressing are shown to be related to the unique HCI aspects in v-Commerce that effectively influence shopping behaviours in order to make VR/AR platforms financially viable (Sect. 3.3).

2 Methodology

The principle sampling method was protocol driven, outlining the academic databases, search terms and filters the outset of the investigation. To reduce the influence of database bias, three databases were selected for their excellence in the academic research community; Web of Science, Google Scholar and Scopus.

Table 1 Literature review search terms

Technology aspects	Consumer aspects
3D store Future of shopping Interactivity Technological innovation Technology retail V-Commerce Virtual environment Virtual reality Virtual reality retailing Virtual shopping Virtual social Vividness	Consumer perception Consumer reaction Consumer satisfaction Consumer/purchase behaviour Shopping experience Shopping motivations

The search terms used in the resource collection process has been identified as technology and consumer aspects; presented in Bonetti, Warnaby, & Quinn (2018), Dacko (2017), and Papagiannidis, Pantano, See-To, Dennis, & Bourlakis (2017) (Table 1). These were identified through a close initial reading of the most prominent VR/AR literature (Bonetti et al., 2018; Dacko, 2017; Papagiannidis et al., 2017).

To reflect the current state of research into VR/AR, the literature review focused primarily on papers from 2016 onwards. However, inclusion of earlier work (2001 onwards) was allowed for historic comparisons to be drawn. Therefore, 70% of the papers were from 2013 onwards.

To discover more advanced literature than our preconceived notions of protocol driven search strategy would allow for, forward *snowball sampling* was applied; in line with recognised Literature Review guidelines (Jalali & Wohlin, 2012; Kitchenham & Charters, 2007). In this application, key papers on AR and VR were identified from the reference lists of significant articles, revealing important and influential material for the literature review.

Literature collection took place between October ‘17 and February ’18, resulting in 89 pivotal journal articles being collected. Starting with Web of Science, each of the search terms (see Bonetti et al., 2018; Dacko, 2017; Papagiannidis et al., 2017, Table 1) were sought, filtering by the criteria specified above. Selecting high-quality journals which review the literature, beginning with the most recent publications and work back in time. Papers deemed relevant were downloaded in PDF form and stored within NVivo 11. During the analysis of the journals, key cited papers were identified, before being found, critiqued, and subsequently downloaded. Once the snowball sampling trail had stopped being fruitful, the next search term was investigated in the same way. Following this, the additional search engines were checked for the search terms to ensure all key papers were identified. To keep up to date, continue searching the literature during analysis process. Only academic sources (journal articles, conference papers, periodicals and academic books) were accepted in the resource collection phase. This was to ensure the focus of the paper remained academic and grounded in scientific processes.

Thematic analysis was applied to the uncovered VR literature with the aid of NVivo 11. While manual coding techniques have proven successful in traditional literature reviews, the computational power of thematic analysis software helped gain a deeper insight into the data than otherwise possible. Resources were thematically analysed for the papers focus, future recommendations made, gaps and limitations highlighted in the literature, key findings, models, participant and the technology discussed. All data from this literature review (codebooks, classification sheets and figures) that can be made public is available through: https://doi.org/10.17028/rd.lboro.6177005.

3 Literature Review Results

3.1 Current Research Focus on VR/AR

To reveal the current focus of VR/AR research, Fig. 1 shows the key areas of research discussed in the reviewed papers. These topics presented in the hierarchy chart give a picture of the current knowledge of VR/AR technology, retailers, customers and different shopping environment in the VR shopping field.

The key outcome of this analysis is how most research focuses on the Consumer Experience (orange) and the human factors of Virtual Reality (Green). This is despite the literature search focusing on technology literature; see Table 1. While inspecting research distribution over time (Fig. 2) a convergence on the need to

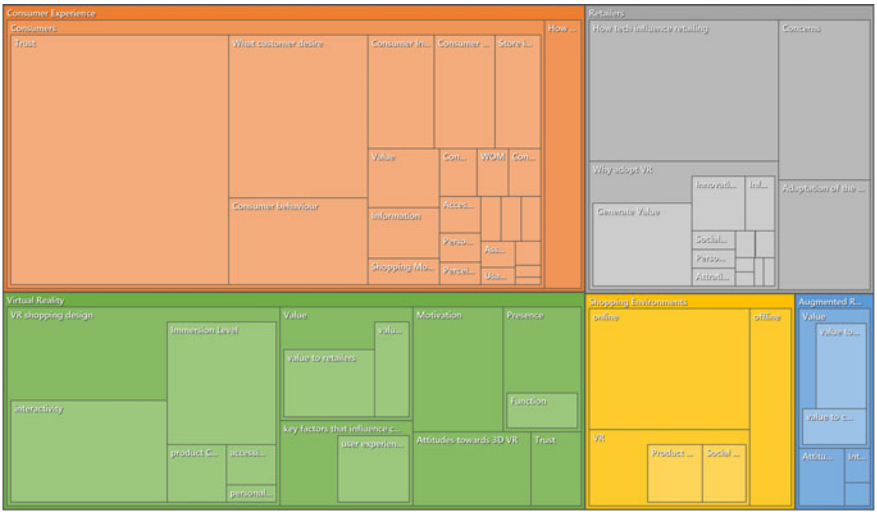

Fig. 1 Hierarchy chart showing research focus

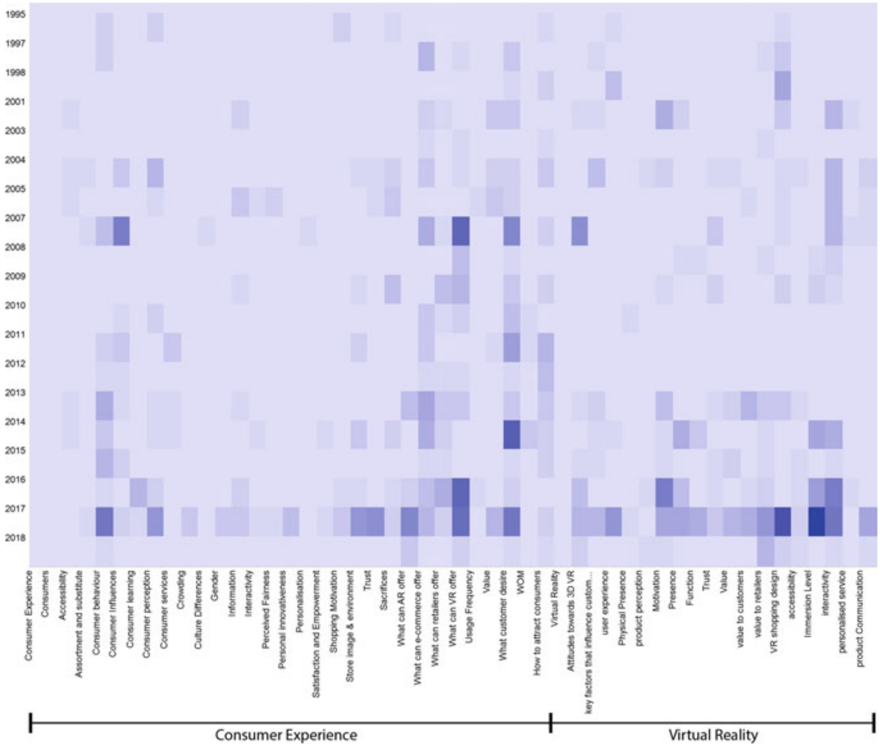

Fig. 2 Heat map of prominent research focus over time

understand the human factors of the v-Commerce consumer occurs from 2016 onwards. These issues have been repeatedly highlighted for over 20 years, yet are still unanswered.

Critically, 15 papers state consumers are positive about AR/VR because they are new technologies that producing a significant novelty effect (Meißner, Pfeiffer, Pfeiffer, & Oppewal, 2018; Yim, Chu, & Sauer, 2017) and providing specific benefit such as efficiency and better shopping value (Dacko, 2017; Papadopoulou, 2007), which further lead to increase their shopping motivation (Altarteer, Charissis, Harrison, & Chan, 2013). Recent market research revealed that 58% of customers consider shopping with digital technology will be more interesting (Perks, 2016), and 63% saying they expect such capabilities to change the way they shop (Parro & Santoro, 2015). While VR requires further improvements in terms of technical solution and operational business, as consumers are still perceive the virtual environment as being in the stage of development (Papagiannidis et al., 2017).

The second most important outcome is that 37% of all papers argue that retailers need to understand those factors that affect consumer perceptions. Specifically, they need to better understand the factors that influence v-Commerce consumers.

These have been classified into comfort, content (environment, information, product display and product features), functionality (accessibility, interactivity, personalised service, vividness), media richness, perceived value (convenience, cost and trust), social networking and user experience (physical presence, product involvement and product perception). Therefore, these factors should be considered when developing VR shopping environment.

The third most important outcome relayed to value theory of VR. To understand consumer behaviours and examine the nature of the experience offered, it is necessary to investigate consumers and retailers and compare different shopping channel (offline; online and VR). Regarding to value to retailers, eight papers state that VR shows great potential for retailers. As it is considered to be highly innovative and market leaders in the adoption of new technologies in the marketplace. As such, benefits to early adopters may be significant. Nine papers report that VR can also provide brand engagement and offer retailers a plethora of profound ways to educate the consumer about a brand, share their brand's story with customers, reinforce brand values and customer loyalty.

Regarding to value to consumers, 11 papers show that consumers' motivation can be considered as either hedonic value (for fun) or utilitarian value (for efficiency). Therefore, VR may provide value for consumer through these two aspects. Consumers can stay at home to compare or choose a certain product; reducing time and effort while shopping. Additionally, hedonic values refer to the emotional state generating from the experience and may include all elements (e.g. colour, music and *other* design elements) that contribute to a state of pleasure. Shoppers can receive value from these experiences, which their satisfaction and loyalty will be affected accordingly. There are benefits and costs associated with not only the products/services being purchased online, but also the processes of obtaining them.

3.2 Underlying Themes in the VR/AR Literature

To expose underlying themes in the VR/AR research outside of explicit research focus, Fig. 3 maps the literature disciplines against key themes common throughout the texts. Critically, these themes are discussed within the literature as separate to the explicit research focus presented within Sect. 3.2.

While key phrases such as shopping, online, shoppers and retail can be expected from the search terms of this review (see Bonetti et al., 2018; Dacko, 2017; Papagiannidis et al., 2017, Table 1), many of the phrases coming from the word frequency search are both unexpected and intriguing. Terms such as 'service', 'museum' and 'tourism' demonstrate the considered application of VR/AR outside the retail or physical items and into the commoditisation of experiences. One of the most interesting terms is 'design'. As fashion companies pursue of higher profit and market share though leverage VR shopping, future research is suggested to feed into the design and expansion of v-Commerce platforms.

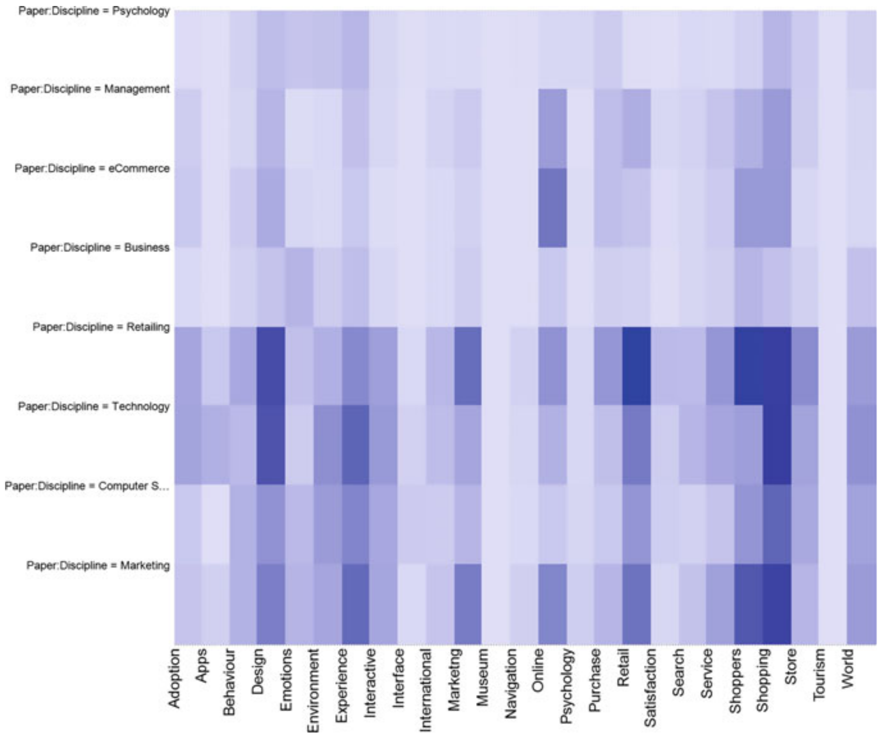

Fig. 3 Heat map of underlying themes versus research discipline

What is crucial though is that the majority of underlying themes centre on UX design or factors that influence buying behaviour. This contradicts the more widespread focus of research presented in Sect. 3.1. Consequently, while the literature may appear to address a wide range of topics, a convergence on the monetary application of VR/AR in an e-Commerce context is of vastly higher prominence than development for experiential or technical benefits.

It is intriguing how website design research indicates that comfortable page layout, efficient search engines, updated information, clear navigational structures, simple checkout procedures and user-friendly interfaces were important to consumers' use of online shopping. These design features could also be applied in VR shop design. Similarly, the layout of store in the 3D environment is regulated by a different concepts because it operates under new store design conditions and customer navigation functions (Vrechopoulos, Apostolou, & Koutsiouris, 2009). Despite this research requirement being made a decade ago, the unique HCI theory required to address it remains elusive within the VR/AR literature. Thus it will increase commercial benefits through appropriate design of commercial premises (e.g., shopping malls Huang et al., 2016).

Apart from design, another critical term is experience. Studies show that user experience refers to consumer participation and the environment relationship that results from the consumer interactions within a product, environment and brand. These have a holistic nature concerning cognitive, emotional, affective, social and physical responses to the shopping environment. On the other hand, Kolko (2011) suggests researchers focus on designing experiences rather than designing artefacts. It is expected that experience design become today's commercial art, for example, as Pine and Gilmore (1998) suggested that create a theme that combines different product demonstrations together into one staged experience.

On the other hand, through exploring shopping environment of online and in-store, it is discovered that v-Commerce may have to make up for some of e-Commerce's inadequacies. This is because e-Commerce cannot include physical and tactile factors, which lack of product perception, and consumers may unable to compare products from the quality, size and style.

Therefore, in order to design effective v-Commerce shopping environments, designers should stand on the consumer's perception to understand the characteristics of consumers' acceptance of technology, keep abreast of technological innovation and market trends, etc. This is to help set up marketing and retail strategies to enrich and improve the consumer shopping experience effectively.

3.3 Research Gaps with VR/AR

To uncover the most prominent research gaps related to VR/AR, Fig. 4 shows that the gaps in the current knowledge of virtual reality and retail sector. These gaps presented in the heat map need to be addressed through future research.

The most resounding calls for research in recent years are Consumer access to VR (7), Level of Interactivity in retail environments (9), reconsideration of traditional HCI theory considering new interaction opportunities in VR/AR (8) and how to design effective v-Commerce environments (8). While the prominence of these research themes has increased in recent years, they have, without exception, been called for by academics for over 13 years.

At a more holistic level, the most prominent questions in recent years relates to designing for v-Commerce. While consumer experience has enjoyed equally important prominence between 2000–2015, the reduction in authors calling for research into these areas suggests that the key questions in these areas have already been answered through existing research.

One important deficiency in the literature is the lack of influence variables concern towards v-Commerce shopping. There are 32 papers called on researchers to examine these moderating variables, including age of user, the interaction effect, prior VR experience, purchase time frame and brand communication. Hence, future research will strongly focus on verify whether a number of independent variables that have been shown to affect consumer perception will have significant impact on virtual retailing.

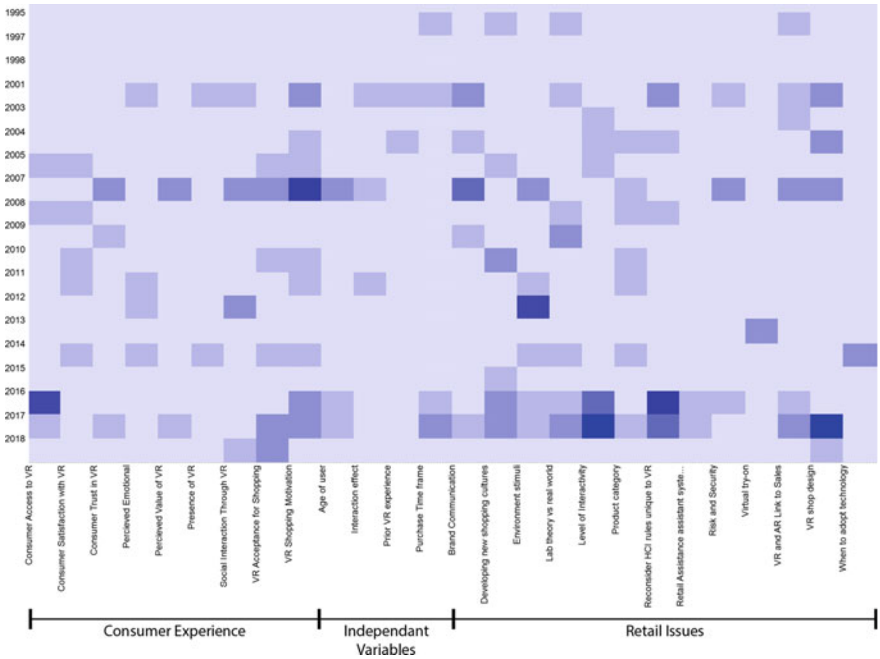

Fig. 4 Heat map identified showing gaps in the literature against time

Furthermore, 50% of all papers state that there are still major gaps in the knowledge related to VR shop design. First, only few studies incorporated social stimuli of the online environments as main constructs in the S-O-R framework. Therefore, the papers proposed further research should develop S-O-R in human-computer interaction environment and social dimension. Second, eye-tracking, as an important technology for VR shopping, the challenges and efforts put into mobile eye-tracking studies are seldom made explicit in academic literature. Therefore, we suggest researchers incorporate eye-tracking methodologies into further VR studies. Third, there is no literature about user interface and design for disadvantages shoppers, which would be a very interesting area to engage with.

Additionally, there are many gaps lie in consumer behaviour and VR/AR-related studies and how they link to sales. It is suggested that more in-depth investigation of human interaction to expand existing knowledge about consumer response to interactive technologies, as well as understand consumer behaviours and motivations within different sales channel. Moreover, Bonetti et al. (2018), Meißner et al. (2018) and Moorhouse, tom Dieck, and Jung (2018) asked researchers to explore these technologies' acceptance.

To generate a bigger impact, 8% of papers also show that the experimental results generated in laboratories might differ from the real-world environment. Therefore, further research should request permission from real VR retailers to manipulate some of their stores' variables in order to run a field instead of a laboratory experiment, it would be very difficult but it is important for theory development (i.e. high external validity). To explore this further, future research should examine the impact of exposure to a Virtual Reality experience via pre- and post-usage measurements of the dependent variables. This also requires a longitudinal study in the future that will review this work and examine whether new outcomes are discovered and whether the immersive environment has become more ‘accepted’ and, thereby, participants perceive more *experienced* with VR.

4 Discussion

4.1 Current Research Focus

The current research extensively investigated the potential of AR/VR as a tool for e-Commerce, whether consumers will have a positive attitude toward these interactive technologies. Since VR/AR currently has more enthusiasts than experts, which suggest that although the technologies are available, most consumers have yet to fully in engage with it. Accordingly, studies explore the value theory of AR/VR. Such technologies open up ample opportunities for retailers to connect with customers from their comfort home. Meanwhile, consumers benefit from both utilitarian and hedonic value. For example, reduce perceived crowding, increase user satisfaction, and then bring a competitive advantage for retailers. Through virtual try-on, reducing risk in customers’ buying process, retailers then benefit from less return rate. However, these papers point out there are many factors will influence consumers’ perceptions in v-Commerce shopping, including comfort, content, functionality, media richness, perceived value, social networking and user experience.

These findings enable us to appraise the research areas which are well understood and thus less suitable for innovative potential exploration in how VR is going to take over shopping malls and will help in making better decisions. However, in consideration of fictitious possibilities offered by virtual worlds, this positive perception then may not available when consumers are looking to buy products that are actually in use (Papagiannidis et al., 2017). Furthermore, the majority of consumers were also concerned about the devices’ pricing along with peripherals, adapting the new technology, which concludes to be worried about the user friendliness of the complete system (Sharma & Bach, 2016). In addition, Papadopoulou (2007) argued that the procedure of shopping in the VR store is more time consuming than the conventional web, because they involved typing instead of clicking. Consequently, they are still perceive the virtual environment as being in the stage of development. The current knowledge still lacks understanding the unique human factors or v-Commerce scenarios well enough to design effective and efficient retail platforms which justify the high access price (retailer platform development and consumer investment in technology).

The industry implications for these outcomes is that within the recent positive consumer response of virtual reality, v-Commerce is predicted to become next generation market platform. Therefore, it strongly encourages retailers to adopt such innovative technology either in-store or online to gain competitive advantages. Before adopting VR, company need to critical assess consumers' perception of the technology and ensure that dimensions that their customers view as being important are designed to be attractive to them.

4.2 Underlying Themes

This review proves that in the current VR/AR literature, the most prominent underlying themes are design and experience. The findings expose website design and virtual store design are important to home shopping. While the traditional retail store layout theory produces predictions that are not consistent with the virtual scene, as consumers are able to reach any virtual shop directly. Thus, more consumer-friendly user experience should be further developed to influence consumer buying behaviour online.

These findings enable us to understand which disciplines are under researched relating to beneficial technological applications in how current literature on VR has emphasised the retail and technological aspects of VR, but it has neglected the end user's needs and problem. Yet, VR is increasingly used in retail sector, even though research has not been able to catch up with the trend from a design perspective. Pantano (2015) suggests these technologies will help create new marketing experiences. In particular, v-Commerce may combine the benefits of the electronic trading environment with the information richness of face-to-face trading through features that compensate for the loss of physical presence associated with e-Commerce (Chesney, Chuah, Dobele, & Hoffmann, 2017), such as absent of merchandising presentation, especially for clothing category (Kaplan & Haenlein, 2009). Thus, the questions that might bring to future are how to effective and efficient combine the value of online and offline shopping environments to v-Commerce, and what are the added-values we can create in v-Commerce to improve shopping experience.

The industry implications for these outcomes is that v-Commerce shopping should support the notion of providing a solution 'design for your needs'. It is important for retailers to mix the value from different sales channels and bring it to build user-friendly VR shopping.

4.3 Research Gaps

This review demonstrates that the most called for (yet unaddressed) research areas are the lack of influence variables concern towards v-Commerce shopping, the lack of knowledge related to VR shop design (social dimension, eye-tracking, disadvantages shoppers' considerations), the lack of understanding of how AR/VR link to sales, lack of understanding of VR acceptance for shopping and the experimental results generated in laboratories might be different from the real-world environment.

Figure 4 reflects that many studies calling for research VR shop design, while design aspect has been the focus a lot of papers for retailing and technology discipline. This means VR as a fresh technology, even though it has been introduced for a long time, researchers have only been paying attention to it since 2013. VR shopping design is an emerging research topic from 2017, thus a more sustained attention and a well-developed system are needed. Designers need to consider various influence factors that might affect shoppers' perception when developing virtual environment for retailing. These factors are not unique, but joins the growing body of research calling for better emotional and cognitive understanding in the consumer in order to develop more effective, and emotionally seductive e-Commerce platforms (e.g. Parker & Doyle, 2018; Parker & Wang, 2016).

The industry implications for these outcomes is that VR is emerging in design aspects to meet the consumer need, including user interface design, user experience design, visual merchandising etc. Successful completion of this research will enable a new means to understanding UI design for VR shopping and provide practical implications for multidisciplinary fields.

5 Conclusion

This chapter set out to direct research projects into as yet under explored to increase the efficiency and effectiveness of the retail research community. Through thematic analysis of 89 pivotal journal articles, the main contribution of this chapter is it signposts a clearer framework for locating future research inquiry and it highlights a research agenda that may provide the catalyst for this process.

The implication of this review is that retailers should be realised that the today's shoppers may have high expectations from these immersive environments and, thus, they will require to adjust and take this into account when developing relevant strategies (Papagiannidis et al., 2017). It should be highlight that it is important to focus on store design features and user experience design to enhance the social dimensions of being a customer in a VR shop as well as the 'utilitarian' and the 'hedonic' dimensions. They should also integrate the benefits of online and offline shopping, which consumers most rely on (e.g. personal advice, after-sales service, etc.).

This literature review is limited in the scope of the VR search terms used (see Bonetti et al., 2018; Dacko, 2017; Papagiannidis et al., 2017, Table 1) and the number of sources used in the search. While computational software NVivo has allowed for the analysis of most sources than before, a greater focus on papers before 2015 could provide a deeper insight into the research avenues that remain uncapitalized upon. Future research should focus on develop the fundamental human factors design theory for VR shopping environments, focusing on the lucrative fashion market, predicted to be worth £64 Billion by 2020 in the UK alone (Sender, 2016). This addresses the issue that until now, successful commercialisation remains elusive due to the lack of human factors theory to direct the interaction design process. Therefore, we need to understand:

1. The format of VR shopping experiences that consumers and retailers best respond to because this will allow designers to create virtual retail environments which efficiently encourage buying behaviours.
2. The ways VR shopping can offer retail experiences of higher value to target consumers than current retail environments because this will allow designers to focus on the retail areas that may profit most.
3. The barriers and enablers of VR adoption for fashion retailers because all commercially viable designs must overcome technological issues to diffuse in the marketplace.

References

Altarteer, S., Charissis, V., Harrison, D., & Chan, W. (2013). Interactive virtual reality shopping and the impact in luxury brands. *International Conference on Virtual, Augmented and Mixed Reality* (pp. 221–230). Springer Berlin Heidelberg. Retrieved from https://link.springer.com/chapter/10.1007%2F978-3-642-39420-1_24.

Bonetti, F., Warnaby, G., & Quinn, L. (2018). Augmented reality and virtual reality in physical and online retailing: A review, synthesis and research agenda. In T. Jung & M. C. tom Dieck (Eds.), *Augmented reality and virtual reality: Empowering human, place and business* (pp. 119–132). Cham, Switzerland. Retrieved from https://doi.org/10.1007/978-3-319-64027-3_9.

Cecil, J., & Kanchanapiboon, A. (2007). Virtual engineering approaches in product and process design. *The International Journal of Advanced Manufacturing Technology*, *31*(9–10), 846–856.

Chesney, T., Chuah, S.-H., Dobele, A. R., & Hoffmann, R. (2017). Information richness and trust in v-commerce: Implications for services marketing. *Journal of Services Marketing*, *31*(3), 295–307. Retrieved from http://www.emeraldinsight.com/doi/10.1108/JSM-02-2015-0099.

Connolly, T. M., Boyle, E. A., MacArthur, E., Hainey, T., & Boyle, J. M. (2012). A systematic literature review of empirical evidence on computer games and serious games. *Computers & Education*, *59*(2), 661–686.

Cook, D. A., & Triola, M. M. (2009). Virtual patients: A critical literature review and proposed next steps. *Medical Education*, *43*(4), 303–311.

Dacko, S. G. (2017). Enabling smart retail settings via mobile augmented reality shopping apps. *Technological Forecasting and Social Change*, *124*, 243–256. Retrieved from http://dx.doi.org/10.1016/j.techfore.2016.09.032.

Freina, L., & Ott, M. (2015). A literature review on immersive virtual reality in education: State of the art and perspectives. In I. Roceanu (Ed.), *The 11th International Scientific Conference eLearning and Software for Education* (pp. 133–141). Bucharest: Carol I NDU Publishing House. Retrieved from https://search.proquest.com/docview/1681252932?accountid=12152.

Guttentag, D. A. (2010). Virtual reality: Applications and implications for tourism. *Tourism Management*, *31*(5), 637–651. Retrieved from http://linkinghub.elsevier.com/retrieve/pii/S0261517709001332.

Huang, H., Lin, N.-C., Barrett, L., Springer, D., Wang, H.-C., Pomplun, M., & Yu, L.-F. (2016). Analyzing visual attention via virtual environments. In *SIGGRAPH ASIA 2016 Virtual Reality Meets Physical Reality: Modelling and Simulating Virtual Humans and Environments on SA '16* (pp. 1–2). New York, USA: ACM Press. Retrieved from http://dl.acm.org/citation.cfm?doid=2992138.2992152.

Jalali, S., & Wohlin, C. (2012). Systematic literature studies. In *Proceedings of the ACM-IEEE International Symposium on Empirical software engineering and Measurement—ESEM '12* (p. 29). New York, USA: ACM Press. Retrieved from http://dl.acm.org/citation.cfm?id=2372257.

Kaplan, A. M., & Haenlein, M. (2009). The fairyland of second life: Virtual social worlds and how to use them. *Business Horizons, 52*(6), 563–572.

Kitchenham, B., & Charters, S. (2007). *Guidelines for performing systematic literature reviews in software engineering*. Retrieved from https://userpages.uni-koblenz.de/~laemmel/esecourse/slides/slr.pdf.

Kolko, J. (2011). *Thoughts on Interaction Design* (2nd ed.). Burlington, MA, USA: Morgan Kaufmann.

Meißner, M., Pfeiffer, J., Pfeiffer, T., & Oppewal, H. (2018). Combining virtual reality and mobile eye tracking to provide a naturalistic experimental environment for shopper research. *Journal of Business Research* (In Press). Retrieved from http://linkinghub.elsevier.com/retrieve/pii/S0148296317303478.

Moorhouse, N., tom Dieck, M. C., & Jung, T. (2018). Technological innovations transforming the consumer retail experience: A review of literature. In T. Jung & M. C. tom Dieck (Eds.), *Augmented reality and virtual reality: Empowering human, place and business* (pp. 133–143). Cham: Springer International Publishing.

Moreira, M. C., de Amorim Lima, A. M., Ferraz, K. M., & Benedetti Rodrigues, M. A. (2013). Use of virtual reality in gait recovery among post stroke patients—A systematic literature review. *Disability and Rehabilitation: Assistive Technology*, *8*(5), 357–362.

Nichols, S., & Patel, H. (2002). Health and safety implications of virtual reality: A review of empirical evidence. *Applied Ergonomics*, *33*(3), 251–271. Retrieved from http://linkinghub.elsevier.com/retrieve/pii/S0003687002000200.

Papadopoulou, P. (2007). Applying virtual reality for trust-building e-commerce environments. *Virtual Reality*, *11*(2–3), 107–127. Retrieved from http://link.springer.com/10.1007/s10055-006-0059-x.

Papagiannidis, S., Pantano, E., See-To, E. W. K., Dennis, C., & Bourlakis, M. (2017). To immerse or not? Experimenting with two virtual retail environments. *Information Technology & People*, *30*(1), 163–188. Retrieved from http://www.emeraldinsight.com/doi/10.1108/ITP-03-2015-0069.

Parker, C. J., & Doyle, S. A. (2018). Designing indulgent interaction: Luxury fashion, M-commerce, and Übermensch. In W. Ozuem & Y. Azemi (Eds.), *Digital marketing strategies for fashion and luxury brands* (pp. 1–21). Hershey, USA: IGI Global. Retrieved from https://www.igi-global.com/book/digital-marketing-strategies-fashion-luxury/178207.

Parker, C. J., & Wang, H. (2016). Examining hedonic and utilitarian motivations for m-commerce fashion retail app engagement. *Journal of Fashion Marketing and Management*, *20*(4), 487–506. Retrieved from http://www.emeraldinsight.com/doi/10.1108/JFMM-02-2016-0015.

Parro, D., & Santoro, M. (2015). *Future of retail study: What businesses need to know for 2015*. Chicago, USA.

Perks, R. (2016). Online retailing—UK—July 2016. *Mintel*. London, UK. Retrieved May 29, 2017, from http://academic.mintel.com/display/748703/.

Pine II, J. B., & Gilmore, J. H. (1998). Welcome to the experience economy. *Harvard Business Review*, *76*(4), 97–105.

Rizzo, A., Parsons, T. D., Lange, B., Kenny, P., Buckwalter, J. G., Rothbaum, B., Difede, J., et al. (2011). Virtual reality goes to war: A brief review of the future of military behavioral healthcare. *Journal of clinical psychology in medical settings*, *18*(2), 176–187.

Sender, T. (2016). Clothing retailing—UK—October 2016. *Mintel*. London, UK. Retrieved July 24, 2017, from http://academic.mintel.com/display/748789/.

Sharma, S., & Bach, C. (2016). An exploratory research on virtual reality and how it affects future of shopping and immerging fields. *European Journal of Engineering Research and Science, 1* (6), 34–43.

Simpson, D. M. (2001). Virtual reality and urban simulation in planning: A literature review and topical bibliography. *Journal of Planning Literature*, *15*(3), 359–376.

Vrechopoulos, A., Apostolou, K., & Koutsiouris, V. (2009). Virtual reality retailing on the web: Emerging consumer behavioural patterns. *International Review of Retail, Distribution and Consumer Research, 19*(5), 469–482.

Yim, M. Y. C., Chu, S. C., & Sauer, P. L. (2017). Is augmented reality technology an effective tool for e-commerce? An interactivity and vividness perspective. *Journal of Interactive Marketing*, *39*, 89–103. Direct Marketing Educational Foundation, Inc. dba Marketing EDGE. Retrieved from http://dx.doi.org/10.1016/j.intmar.2017.04.001.

Part II
AR & VR Experience Design

What We Don't Know. The Effect of Realism in Virtual Reality on Experience and Behaviour

Marnix van Gisbergen, Michelle Kovacs, Fabio Campos, Malou van der Heeft and Valerie Vugts

Abstract This study addresses the question how realistic Virtual Worlds should be designed in order to create engaging experiences and stimulate 'natural' behaviour. Creating high realistic worlds is time consuming and expensive and it is unclear whether it is always needed. With the aim of gaining insights about questions related to presence and realism, an experiment involving 72 participants was set up upon a Virtual Reality cycling apparatus in which different levels of realism were created. Users were observed and evaluated regarding their experience (engagement, presence, naturalness and negative effects), awareness of realism and behaviour. The results indicate that, despite that differences in realism were observed, differences in realism do not have an effect on experience and behaviour. There seem other variables involved that can affect the whole experience in an enough intensity to obliterate the effects of a better sense of presence and realism. In addition, an increase in a perceived higher level of realism seems to be depended on a congruent increase of different elements within the virtual world. Merely increasing the level of realism of one element does not alter levels of perceived realism of users.

Keywords Virtual reality · Realism · Experience · Presence · Behaviour

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1 Introduction

As Virtual Reality (VR) technology, e.g. processing power and screen resolutions, advances rapidly, high realistic and high-fidelity worlds become possible in VR as well. It seems somewhat intuitive that a more realistic environment, able to achieve a higher fidelity with the actual environment which the VR is emulating, would elicit a better sense of presence and experience from the users. However, creating high realistic worlds is time consuming and expensive and it is unclear whether it is always needed in order to engage users and let them behave in a natural manner. VR studies seem to produce mixed results and indicate a more subtle and complex relationship between level of realism and experience. Moreover, the level of realism in most studies seem, despite hard work in development, relatively low compared to what is possible with technologies of today and what is used within the context of current entertainment films and games. In addition, none of these studies analysed experience (presence, naturalness, engagement and negative effects) and VR behaviour when the VR environment represents a real (city) environment in which the realism and resemblance is altered on multiple aspects. With the aim of gaining insights about questions related to presence and realism, an experiment was set up using a VR cycling apparatus developed within Breda University of Applied Sciences in collaboration with Atlantis Games. The virtual world represented a bike experience within a street in a Dutch city (Breda), which differed in level of realism. The subjects were observed and evaluated regarding their awareness of level of realism, the VR experience and physical responses to events within the virtual world. Several studies have been conducted concerning virtual reality and cycling, however, these were mostly focused on the topics of rehabilitation and exercise purposes (Hagen, Chorianopoulos, Wang, Jacceri, & Weie, 2016; Song, Kim, & Kim, 2004). This study tries to contribute to determine optimal levels of realism to a given VR application in order to optimize the cost and time needed to develop it by. As such we might avoid creating levels of realism that won't be perceived by the users or do not improve their VR experience significantly.

2 Theory

Presence and realism are important concepts regarding VR experience (Rettie, 2004, Yu, Mortensen, Khanna, Spanlang, & Slater, 2012). They also seem to become more important, as the technology of displays, miniaturization and computational power evolves making it possible to (re)produce more realistic Virtual Worlds. A combination of four technological dimensions (sensory, interaction, control and location) are expected to increase a sense of realism or presence and enhance an experience within VR (van Gisbergen, 2016). However, realism is a construct with many different meanings. On the one hand it refers to resemblance, in which realism is operationalized as reproducing something that is known and familiar for the observer. The object, environment or event in that case also exists in the 'real', non-mediated, world. On the other hand, realism can refer to something that is perceived as real without any knowledge or reference to an object or event that is known to the observer. Even to the extent that the object or environment does not exist in the 'real' world (van Gisbergen, 2016). In this study we focus on the latter, meaning users "subjective sense of being in the place depicted by the Virtual Environment" (Yu et al., 2012) without knowing the (resemblance with the) real situation but instead reproducing a feeling in which the VR experience is like the real world (Rettie, 2004). However, it remains unclear how much effort should be put in creating high levels of realism (Bailenson et al., 2005).

On the one hand theories, such as gestalt, claim that high realism increases experience and natural behaviour. Users will behave more real when the world is perceived as more real (Pertaub, Slater, & Baker, 2002). On the other hand, there are theories, such as the uncanny valley (Slater and Steed, 2000), that propose that too much realism (resemblance) brings about a very strong drop in believability and comfort and as such may be forcefully rejected by humans as a defence mechanism (Bryant, 2001; Dautenhahn, 2002; Reichardt, 1978). It has been acknowledged by Brenton, Gillies, Ballin, and Chatting (2005) that there is hardly any research regarding manipulated realism as an experimental condition, and further research needs to be conducted in this area. Studies that have been conducted show mixed results. Research on the effect of realism in VR worlds indicated positive effects of increased realism on presence, arousal and liking (e.g. Barlett & Rodeheffer, 2009; Bailenson & Yee, 2006; Bailenson, Yee, Merget, & Schroeder 2006; Ivory & Kalyanaraman, 2007; Nowak, 2001; Nowak & Biocca, 2001; Zanola, Fabrikant, & Çöltekin, 2009), as well as no effects or negative effects of higher realism in games or avatars on emotions, presence and behaviour (e.g., Anderson, Rothbaum, & Hodges, 2001; Bailenson, Blascovich, Beall, & Loomis 2001; Garau, Slater, Pertaub, & Razzaque, 2005; Ivory & Kalyanaraman, 2007; Slater & Steed, 2000). This leads to the first research question (RQ1): What is the effect of realism in virtual worlds on user experience and behaviour? As it is unclear whether realism has an effect on experience, it also remains unclear whether it will affect user behaviour in VR towards more 'natural' behaviour. Leading to the second research question (RQ2): will a more realistic environment cause a more natural response in a virtual world compared to less realistic environment? Although the effect of realism on experience and behaviour remains unclear, we do expect that users will notice differences in level of realism even when they have not used virtual reality before, leading to the following hypothesis (H1): A more realistic virtual environment will cause a higher perceived feeling of realism than a less realistic virtual environment.

3 Method

A between-group (low versus high realism) design experiment was carried out which included an online questionnaire after the VR experience. Figure 1 shows an overview of the research design and data collection method.

The research took place at Breda University of Applied Sciences (June 2017). The VR gear was connected to a regular bike mounted in an intelligent trainer, able to interact with the virtual environment (e.g. back-pedal brake). The virtual environment was presented to the users by means of immersive goggles (an Oculus Rift DK2 head-mounted display). The bicycle was placed in the middle of a silent room (Fig. 2).

The virtual environment used in each virtual ride could be switched between a low realistic and a high realistic one (Fig. 3). A video camera recorded all sessions to observe the behaviour of the participants and a researcher was constantly present in the room. Participants were invited in the room and had to sign the informed consent form and read the information sheet. They were orally briefed about the procedures of the experiment and we asked to act as natural as possible on the

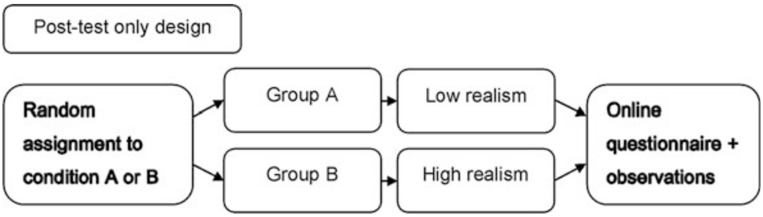

Fig. 1 Overview of the research design and data collection method

Fig. 2 Bike connected to the VR system

Fig. 3 Low and high Realism VR environment. *Source* CycleSpex

bicycle as if they were cycling outside. Each participant was able to observe the virtual environment for 30 seconds to become acclimated to the assigned virtual environment. The VR experience lasted for approximately two minutes. The online questionnaire took approximately 10–15 minutes. In the end, the participants were thanked and little treats were present to show gratitude for their participation.

3.1 Materials

The virtual world consisted of a simulation of a straight-ahead bike path within a city in the Netherlands (Breda). At the end of each VR cycle experience, a dangerous intersection with a traffic light was created. The traffic light would turn orange when a participant would approach the traffic light, and it would subsequently turn red. After approximately three to four seconds the traffic light would turn green again. A low and high realistic world was created. Both conditions contained the same environmental sounds (e.g. wind and bird sounds). Also, the following items were the same: characters, billboards, bicycle, traffic lights, and leaves on the ground. However, the following items were more detailed and in depth in the high realistic condition: buildings, street, lighting, sky, lighting, textures. In addition, only the high realistic condition contained street lights, shadows and graffiti.

3.2 Participants

The participant sample of the study consisted of 72 BA and MA students that were recruited at Breda University of Applied Science. The mean age was 23 years (SD = 3.465) and did not differ between groups. Per condition, 36 people participated in the experiment following the criterion of a minimum of 30 participants used in many VR experimental studies (e.g. van den Boom, Stupar-Rutenfrans, Bastiaens, & van Gisbergen, 2015; North & North, 2016). The number of female participants was the same for each group (50%). In the low realism condition, there were 10 people who originated from abroad, while in the high realism condition there were 8 foreign people. None of the participants were familiar with the bike route in the city.

3.3 Measures

Presence

We measured presence using the ITC-Sense of Presence Inventory (ITC-SOPI) scale developed by Lessiter, Freeman, Keogh, and Davidoff (2001). A scale commonly used to measure VR experiences (e.g. by Baños et al., 2004; Bruce & Regenbrecht, 2009; van den Boom et al., 2015). The questionnaire consists out of four factors: *Spatial presence*, *Engagement*, *Naturalness* and *Negative effects*. All items were measured using a 5-point scale (1 = *strongly disagree*, 5 = *strongly agree*). Presence was measured using 19 items (using statements such as "*I felt I could interact with the displayed environment*", 13 items were used to measure Engagement (e.g. "*I felt sad that my experience was over*"), Naturalness was measured using 5 items (e.g. "*The displayed environment seemed natural*"*)* and for Negative effects 6 items were used (e.g., "*I felt disorientated*"). For all four factors separately, the items were averaged to form a scale which showed reliable results for the low and high realism conditions: Presence ($\alpha = 0.86$ and $\alpha = 0.90$), Engagement ($\alpha = 0.65$ and $\alpha = 0.75$), Naturalness ($\alpha = 0.66$ and $\alpha = 0.77$) and Negative effects ($\alpha = 0.77$ and $\alpha = 0.63$).

Overall Perceived Realism

Overall realism was measured using two subscales of the German VR Simulation Realism Scale (Poeschl & Doering, 2013; Witmer & Singer, 1998). This scale has been used in many other studies (e.g. Fromberger, Jordan, & Müller, 2014; Reuter, 2015). The scale consists out of two items *Scene Realism* (5 items, e.g. "*Reflection in virtual space seemed to be natural*", $\alpha = 0.70$ and $\alpha = 0.82$) and *Audience behaviour* (4 items, e.g. "*Behaviour of virtual humans in the virtual environment was authentic*", $\alpha = 0.84$ and $\alpha = 0.85$). All items were measured on a 7-point Likert scale (1 = *strongly disagree*, 7 = *strongly agree).*

Item Perceived Realism

Perceived realism was measured for 15 elements within the virtual world such as shadows, traffic lights and cars using 7-point scales (1 = *strongly disagree*, 7 = *strongly agree,* e.g. "*The cars seemed very realistic to me*"). The items were analysed separately as well as combined as one factor showing reliable results for the low and high realism condition ($\alpha = 0.87$ and $\alpha = 0.92$).

VR Attention

Attention was measured for the dangerous traffic light condition using three recall questions. The first question was whether the traffic light was noticed, the second was whether the colour of the traffic light was noticed, and the third question was whether the colour change of the traffic light was noticed.

VR Excitement
VR Excitement was measured by means of the question: did your excitement level change when you approached the traffic light? (answer options were I did not see a traffic light, yes and no).

VR Behaviour
Observed VR behaviour was first measured by asking the participants what they did during the dangerous traffic light situation that turned red. Participants indicated whether they did not stop (because they did no see the traffic light or colour change or did see it but not stopped) or did stop cycling (as they observed the traffic light turned orange or red). In addition, using video footage and live observations it was checked whether the participants stopped or not. Also, VR behaviour was categorized into an active level behaviour (1 = *passive*, 2 = *active*) as participants themselves are often unaware of their physical behaviour as it is difficult to detach themselves from the interactions they performed (Kumar, 2014). The footage was watched numerous times before interpretations were made. Two researchers coded the behaviour as either being passive or active based on physical movement and how they communicated when approaching the dangerous traffic light situation. Participants in the passive stage did not physically react (e.g., stop for traffic light) and/or spoke out loud about the traffic light situation while participants in the active stage reacted to the traffic light with a physical reaction (such as expressions of surprise, laughter or alertness) or by mentioning the traffic light situation.

4 Results

Presence
The results showed no differences between the low and high realism conditions on all four factors of presence: Spatial presence ($M_{low} = 3.11$, $SD = 0.49$, $M_{high} = 3.12$, $SD = 0.56$, $t(70) = 0.34$, $p = 0.74$), Engagement ($M_{low} = 3.56$, $SD = 0.38$, $M_{high} = 3.61$, $SD = 0.41$, $t(70) = 0.57$, $p = 0.57$), Naturalness ($M_{low} = 3.31$, $SD = 0.64$, $M_{high} = 3.39$, $SD = 0.70$, $t(70) = 0.50$, $p = 0.62$) and negative effects ($M_{low} = 2.37$, $SD = 0.73$, $M_{high} = 2.16$, $SD = 0.52$, $t(70) = 1.40$, $p = 0.17$).

Overall Perceived Realism
The low and high realism conditions seemed not to be perceived as different in their amount of reflecting reality. No differences were found between low and high realism conditions for Scene realism ($M_{low} = 4.70$, $SD = 1.02$, $M_{high} = 5.14$, $SD = 1.02$, $t(70) = 1.83$, $p = 0.04$, 1-sided) but not for VR Audience behaviour ($M_{low} = 4.08$, $SD = 1.32$, $M_{high} = 4.24$, $SD = 1.35$, $t(70) = 0.51$, $p = 0.31$, 1-sided).

Item Perceived Realism
Participants experienced differences in realism between the items within the two conditions. Although both conditions were perceived as real, the high realism condition was perceived as more real when combining the evaluation of all elements that were altered in realism between the conditions (M_{low} = 4.15, SD = 1.13, M_{high} = 4.76, SD = 1.10, t(2) = 2.33, p = 0.023). Closer inspection reveals that five out of eight items were perceived as more real in the high realism condition: the buildings, the street, the lighting, the textures and the bicycle path. Shadows, Sky and cars showed the same direction, however not significant. All elements that were identical in both conditions, such as traffic lights and characters, were as expected not perceived as different on their level of realism from each other.

VR Attention
The results indicate no effects of realism on attention for VR objects within a virtual world. In the low as in the high realism condition, no differences were found in the percentage of participants that noticed the traffic light (M_{low} = 81%, M_{high} = 78%, χ^2(1, N = 72) = 0.08, p = 0.77), the colour of the traffic light (M_{low} = 72%, M_{high} = 70%, χ^2(2, N = 72) = 0.46, p = 0.79) and observed the traffic light colour change (M_{low} = 64%, M_{high} = 56%, χ^2(2, N = 72) = 0.76, p = 0.68). In both conditions most of the participants were aware of the traffic light situation although many also missed the fact that the colour changed right in front of them.

VR Excitement
Realism changed feelings of excitement. More participants within the high realism condition felt a change in excitement when having to all of a sudden stop in front of a traffic light compared to the low realism condition (M_{low} = 57%, M_{high} = 78%, χ^2(3, N = 72) = 7.90, p = 0.04).

Observed VR behaviour
No differences were found between the low and high realism condition concerning behaviour in front of the dangerous traffic light situation. In both conditions most participants stopped in front of the traffic light (M_{low} = 67%, M_{high} = 61%, χ^2(5, N = 72) = 2.68, p = 0.75). Almost none (3%) kept on cycling when seeing the traffic light was orange or red. This result was confirmed in the observations as an equal number of participants stopped in front of traffic light in both conditions. In addition the video footage showed no significant differences in percentage of active participants between the low (53%) and high (67% realism conditions χ^2(1, N = 72) = 1.44, p = 0.23).

5 Conclusions

The aim of this research was to gain a deeper understanding about the effects of different levels of realism in virtual worlds on VR experience and behaviour. Two levels of realism were created within a VR city cycling experience and contrasted to each other. Participants were able to cycle, while sitting on a stand-alone bicycle with a VR headset on. As expected (H1), VR users notice differences in realism. More effort in creating high realistic worlds will be observed and seen by VR users. However, the results also reveal that merely increasing specific VR elements is not enough create a higher experience or change behaviour. As indicated in the study of Bailenson et al. (2006), to generate more engagement and excitement there also need to be congruency in levels of realism between elements that create a virtual avatar or in our case a virtual world. Indeed, participants in our study for instance observed that the characters used within the high realism virtual world were not as real as other elements. As such participants proclaimed that this stops further feelings of a high overall perceived realism of the virtual world even when putting more realism effort in those elements. If one 'stays behind' (in our case the characters) this hinders the overall perceived feeling of realism. This is for instance indicated in one of our results in which the high and low realism conditions did not differ on (character) human behaviour realism.

On the other hand, a higher perceived level of realism also does not immediately result in more natural behaviour (RQ2). The low and high realism condition seemed to stimulate the same natural VR behaviour. Both levels of realism elicited the same looking behaviour, resulting in noticing the same elements within the VR world. Also, user behaviour was the same for the high and low realism condition. Meaning that in our study users in low and high realism conditions seemed to cycle in the same realistic manner, for instance by stopping in front of a red or orange traffic light that reflected a relative dangerous situation. An explanation for the similar behaviour in VR worlds that differ in level of creative realism, seems to be connected to a generic level of VR experience that is elicited. No differences were found in experience between a low and high level of realism measured by means of presence, negative effects, naturalness and engagement (RQ1). A reason for the similarity in experience might be that several elements within the VR world already create a high level of experience. As such increasing realism of some elements within the virtual word might not do much more on experience. In particular, the relative new and innovative experience of cycling in a virtual world, might already have created a large feeling of experience and presence. Indeed, a study conducted by Slater, McCarthy, and Maringelli (1998) demonstrated that the greater participants would move their bodies, the greater the sense of presence was felt. This also explains why these results seem to contradict the finding of another study conducted by Slater, Khanna, Mortensen, and Yu (2009), which indicated that more realism in VR causes a higher sense of presence. As in the study of Slater et al. (2009), users were not physically active in VR. Being active in an innovative way in VR, like cycling through a virtual city, might create a VR presence ceiling effect, especially for those who have little experience in VR. Previous studies did indicate that new VR users are highly immersed and feel very present in virtual worlds often leading to probably unnatural VR behaviour such as observing a VR world more intense compared to experienced users (Stupar-Rutenfrans, Ketelaars, & van Gisbergen, 2017; Syrett, Calvi, & van Gisbergen, 2017).

The outcome that more realism not always leads to increased experiences and more natural behaviour might be good news for some VR applications. A very expensive highly realistic virtual environment does not always seem necessary to achieve results. For our case this would mean that the cycling VR application could be used to create and test new cycling roads without having to invest a lot of money in a high realistic world. The same might go for other VR applications developed in other areas such as health, retail or culture. And even within the domain of robotics, where experts also believe that a certain level of realism is needed to create meaningfull experiences (Dautenhahn & Werry, 2004). However, more needs to be investigated and theorized on in order to extend these results to other domains.

First there is the question how real our environments were. Where are we on the realism continuum with these tested VR worlds? Of course much more effort could have been put in creating even more realistic words up to a level they use in the gaming triple A industry. And although with current VR technology that would maybe not be very useful (e.g., the resolution in VR is not as good as used in non VR simulations), VR technology developments go fast. It would be wise in past and future studies to somehow be clearer about the level of realism and fidelity used in VR worlds used for research in order to be able to better understand results acquired using VR worlds. However a judging system in how and where to position VR worlds on the VR realism continuum does not exist yet.

In line with the level of realism, it is also unclear how to create virtual worlds that can be compared on level of realism for research purposes. The level of realism in this study was manipulated by means of altering elements (creating more fidelity) and adding realism in the environments by adding objects or elements (such as shadows) or even the way it is possible to navigate and manipulate the VR world (e.g. by adding more stirring options). It is unclear how different elements create realism and it might be the case that adding other elements or altering different elements (such as the characters) might create more differences or higher levels of realism. However, it is difficult to research the different roles of different elements or to not add (or leave out) specific elements as the congruency between the different elements is important to create high perceived levels of realism. More research should be conducted on how different elements affect realism in order to also better be able to compare results from studies that (different level of realism in) virtual worlds.

Finally, a relevant possibility to explain the contradictions among the different studies could be the existence of unknown variables influencing the phenomena. Some of these variables could potentially overshadow the influences that a better level of realism would provoke. Preliminary studies indicate that delay and expect experience can influence significantly the perception and opinions of the users regarding the evaluation of VR applications.

Although more studies are needed to extend the reach of being able to apply the outcomes of this study, it is clear that investing effort and costs in creating a higher level of realism to obtain a better VR experience and more natural VR behaviour is not always needed. VR users observe realism differences in virtual worlds but not always experience them differently or act different based on those (unconscious) observations and experiences. In order to be able to pinpoint ideal levels of realism attached to the purpose of the VR world and the experience of the VR users, more research is needed as well as a joint effort to classify VR worlds used in research on level of realism.

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References

Anderson, P. L., Rothbaum, B. O., & Hodges, L. (2001). Virtual reality: Using the virtual world to improve quality of life in the real world. *Bulletin of the Menninger Clinic, 65*(1: Special issue), 78–91.

Bailenson, J. N., Blascovich, J., Beall, A. C., & Loomis, J. M. (2001). Equilibrium theory revisited: Mutual gaze and personal space in virtual environments. *Presence: Teleoperators & Virtual Environments, 10*(6), 583–598.

Bailenson, J. N., Swinth, K., Hoyt, C., Persky, S., Dimov, A., & Blascovich, J. (2005). The independent and interactive effects of embodied-agent appearance and behavior on self-report, cognitive, and behavioral markers of copresence in immersive virtual environments. *Presence: Teleoperators & Virtual Environments, 14*(4), 379–393.

Bailenson, J. N., & Yee, N. (2006). A longitudinal study of task performance, head movements, subjective report, simulator sickness, and transformed social interaction in collaborative virtual environments. *Presence: Teleoperators and Virtual Environments, 15*(6), 699–716.

Bailenson, J. N., Yee, N., Merget, D., & Schroeder, R. (2006). The effect of behavioral realism and form realism of real-time avatar faces on verbal disclosure, nonverbal disclosure, emotion recognition, and copresence in dyadic interaction. *Presence: Teleoperators and Virtual Environments, 15*(4), 359–372.

Baños, R. M., Botella, C., Alcañiz, M., Liaño, V., Guerrero, B., & Rey, B. (2004). Immersion and emotion: Their impact on the sense of presence. *CyberPsychology & Behavior*, *7*(6), 734–741.

Barlett, C. P., & Rodeheffer, C. (2009). Effects of realism on extended violent and nonviolent video game play on aggressive thoughts, feelings, and physiological arousal. *Aggressive Behavior, 35*(3), 213–224.

Brenton, H., Gillies, M., Ballin, D., & Chatting, D. (2005). *The Uncanny Valley: Does it exist and is it related to presence*. Presence Connect (www.presence-connect.com).

Bruce, M., & Regenbrecht, H. (2009, March). A virtual reality claustrophobia therapy system-implementation and test. In *Virtual Reality Conference*, 2009. VR 2009. IEEE (pp. 179–182). IEEE.

Bryant, D. (2001). *Why are monster-movie zombies so horrifying and talking animals so fascinating?* Retrieved from: http://www.arclight.net/~pdb/nonfiction/uncanny-valley.html.

Dautenhahn, K. (2002). Design spaces and niche spaces of believable social robots. In *Proceedings of 11th IEEE International Workshop on Robot and Human Interactive Communication* (pp. 192–197). IEEE.

Dautenhahn, K., & Werry, I. (2004). Towards interactive robots in autism therapy: Background, motivation and challenges. *Pragmatics and Cognition, 12*(1), 1–35.

Fromberger, P., Jordan, K., & Müller, J. L. (2014). Anwendung virtueller Realitäten in der forensischen Psychiatrie. *Der Nervenarzt, 85*(3), 298–303.

Garau, M., Slater, M., Pertaub, D. P., & Razzaque, S. (2005). The responses of people to virtual humans in an immersive virtual environment. *Presence: Teleoperators & Virtual Environments, 14*(1), 104–116.

Hagen, K., Chorianopoulos, K., Wang, A. I., Jaccheri, L., & Weie, S. (2016, May). Gameplay as exercise. In *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems* (pp. 1872–1878). ACM.

Ivory, J. D., & Kalyanaraman, S. (2007). The effects of technological advancement and violent content in video games on players' feelings of presence, involvement, physiological arousal, and aggression. *Journal of Communication, 57*(3), 532–555.

Kumar, R. (2014). *Research methodology: A step-by-step guide for beginners*. SAGE Publications.

Lessiter, J., Freeman, J., Keogh, E., & Davidoff, J. (2001). A cross-media presence questionnaire: The ITC-Sense of Presence Inventory. *Presence: Teleoperators and virtual environments*, *10* (3), 282–297.

North, M. M., & North, S. M. (2016). A comparative study of sense of presence of traditional virtual reality and immersive environments. *Australasian Journal of Information Systems, 20*.

Nowak, K. (2001, May). Defining and differentiating copresence, social presence and presence as transportation. In *Presence 2001 Conference*, Philadelphia, PA (pp. 1–23).

Nowak, K., & Biocca, F. (2001). Understanding the influence of agency and anthropomorphism on copresence, social presence and physical presence with virtual humans. *Presence: Teleoperators and Virtual Environments, 12*(5), 481–494.

Pertaub, D. P., Slater, M., & Barker, C. (2002). An experiment on public speaking anxiety in response to three different types of virtual audience. *Presence: Teleoperators & Virtual Environments*, *11*(1), 68–78.

Poeschl, S., & Doering, N. (2013). *The German VR simulation realism scale-psychometric construction for virtual reality applications with virtual humans*.

Reichardt, J. (1978). *Robots: Fact, fiction, and prediction*. London: Thames and Hudson.

Rettie, R. (2004). *Using Goffman's frameworks to explain presence and reality*.

Reuter, C. (2015). Special Issue on Human Computer Interaction in Critical Systems II: Authorities and Industry. *International Journal of Information Systems for Crisis Response and Management (IJISCRAM)*, *7*(3).

Slater, M., Khanna, P., Mortensen, J., & Yu, I. (2009). Visual realism enhances realistic response in an immersive virtual environment. *IEEE Computer Graphics and Applications*, *29*(3).

Slater, M., McCarthy, J., & Maringelli, F. (1998). The influence of body movement on subjective presence in virtual environments. *Human Factors, 40*(3), 469–477.

Slater, M., & Steed, A. (2000). A virtual presence counter. *Presence: Teleoperators and virtual environments*, *9*(5), 413–434.

Song, C. G., Kim, J. Y., & Kim, N. G. (2004). A new postural balance control system for rehabilitation training based on virtual cycling. *IEEE Transactions on Information Technology in Biomedicine, 8*(2), 200–207.

Stupar-Rutenfrans, S., Ketelaars, L. E., & van Gisbergen, M. S. (2017). Beat the Fear of public speaking: Mobile 360° video virtual reality exposure training in home environment reduces public speaking anxiety. *Cyberpsychology, Behavior, and Social Networking, 20*(10), 624–633.

Syrett, H., Calvi, L., & van Gisbergen, M. S. (2017). Intelligent technologies for interactive entertainment. In R. Poppe, J. J. Meyer, R. Veltkamp, & M. Dastani (Eds.). Springer, p. 197–208 12 p. (Lecture notes of the Institute for Computer Science, Social-Informatics and Telecommunications Engineering, LNICST; Vol. 178).

van den Boom, A. L. F. M., Stupar-Rutenfrans, S., Bastiaens, O. S. P., & van Gisbergen, M. S. (2015). Observe or participate: The effect of point-of-view on presence and enjoyment in 360 degree movies for head mounted displays. Paper presented at AML 2015: The European Conference on Ambient Intelligence, 12-11-2015; 2015, Athens. Greece.

van Gisbergen, M. S. (2016). *Contextual connected media: How rearranging a media puzzle, brings virtual reality into being*. Breda: NHTV.

Witmer, B. G., & Singer, M. J. (1998). Measuring presence in virtual environments: A presence questionnaire. *Presence: Teleoperators and virtual environments*, *7*(3), 225–240.

Yu, I., Mortensen, J., Khanna, P., Spanlang, B., & Slater, M. (2012). Visual realism enhances realistic response in an immersive virtual environment. *IEEE Computer Graphics and Applications, 32*(6), 36–45.

Zanola, S., Fabrikant, S. I., & Çöltekin, A. (2009, November). The effect of realism on the confidence in spatial data quality in stereoscopic 3D displays. *In Proceedings of the 24th International Cartography Conference (ICC 2009),* Santiago, Chile (pp. 15–21).

Adapting Jake Knapp's Design Sprint Approach for AR/VR Applications in Digital Heritage

Helen Southall, Maeve Marmion and Andrew Davies

Abstract Modern digital devices offer huge potential for the delivery of engaging heritage experiences to visitors, offering a better visitor experience, higher visitor numbers, and opportunities for increased tourism income. However, all software development entails risk, including the risk of developing a product which few will want, or be able, to use. Identifying user experience priorities and problems at an early stage is therefore extremely important. This chapter describes work in progress on a shortened version of Jake Knapp's Design Sprint approach, and its application to designing VR/AR solutions for a specific heritage case study.

Keywords Augmented reality (AR) · Virtual reality (VR) · Digital heritage · Digital tourism · Digital humanities · User-centred design · User experience · Design thinking · Usability

1 Introduction

This chapter presents work in progress on a new approach to the design of AR/VR applications for heritage sites, based on a shortened version of the Design Sprint approach developed by Jake Knapp at Google Ventures (Knapp, Zeratsky, & Kowitz, 2016). A heritage-rich area around the River Dee at Chester is used as a case study.

Modern smartphones allow the delivery of engaging, customised experiences direct to the general public, on devices that they already carry with them (Tussyadiah, Wang, Jung, & Tom Dieck, 2018). Applications previously requiring specialised hardware at each point of use can now be delivered via smartphone.

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AR experiences do not usually require extra equipment, and VR is also possible, e.g. via a Google Cardboard headset. (Fabola, Miller, & Fawcett, 2015; Casella & Coelho, 2013) Other affordable and versatile digital devices, such as tablets and media players, offer options previously beyond the scope of smaller heritage sites. However, as Power et al. (2017) point out, technology which stops users from achieving their goals, or delivers a negative experience, is destined to go unused. A fast, effective method of developing and testing outline designs before committing to expensive full-scale development is therefore required.

Knapp's Design Sprint schedule is a pragmatic tool for rapid production and testing of software design prototypes, designed to cut down the resources needed to produce the final application, and avoid expensive user experience mistakes. However, scheduling an expert team for the full five days of Knapp's sprint format is expensive and difficult. A compressed three-day version is therefore proposed, which still covers the key phases defined by Knapp et al. (2016): *understand*; *diverge*; *converge*; *prototype, test*. The objectives of this study were: to compress, refine and develop Jake Knapp's Design Sprint Approach to foster and facilitate small scale development; to design a tourism heritage experience able to develop new narratives, and to attract and engage new audiences; and to design and test a new AR/VR solution that meets the needs of diverse stakeholders.

2 Designing Digital Solutions for Enhanced Usability

Software project failures of all types cause wider problems, ranging from inconveniences such as flight delays, to risk to life (Charette, 2005; Fitzgerald & Russo, 2005). In the cultural heritage (CH) field, a software project which does not deliver required output can cause issues ranging from lower engagement by visitors/users at best, to a complete failure to produce a usable product at worst, possibly discouraging funders from backing similar projects in the future. As Still and Crane (2016) put it, "No product is cheap if it does not work for its intended users."

Charette (2005) describes the root causes of many such failures as a combination of technical, project management and business decisions, which interact in complex ways to increase project risk. Projects always entail risk (Bennett & AXELOS, 2017), and early detection of such problems is critical. If they are not identified until the final system testing phase, or, worse, until the system has been released to end users, the costs are usually many times higher than if the mistake had been identified when it first occurred.

Despite the wide use of software development in the CH field, CH projects are still vulnerable to these pitfalls. Positively, this means that CH projects can make use of existing methodologies to overcome them. One such approach is Human-Centred Design (Fig. 1), as encoded by ISO 9241:210 (2010), which lists four activities required to establish user needs and requirements when developing

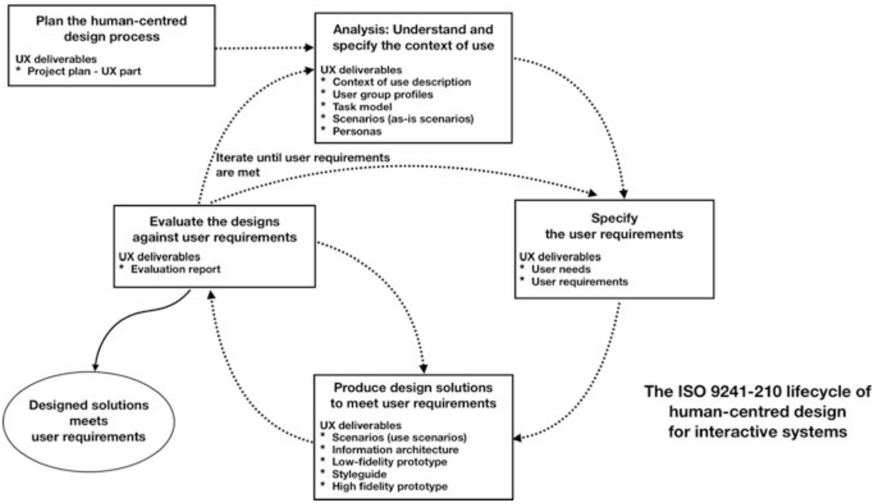

Fig. 1 The ISO 9241-210 lifecycle of human-centred design for interactive systems

software systems. These are: to understand and specify the context of use; to specify the user and organisational requirements; to produce design solutions; and to evaluate designs against requirements.

Several design approaches make use of the essential recommendations of ISO 9241:210. One of particular interest to us is the 'design sprint' approach developed by Jake Knapp while at Google Ventures (Knapp et al., 2016). This approach draws on the ideas of design thinking, a 5-stage process for identifying and resolving a problem in a human-centric way (Design Thinking, n.d.; Rikke & Siang, 2018). Knapp's design sprints follow the general principals of human-centred design, and also validate design proposals by involving typical users at a very early stage, before committing to full-scale development of the proposed system. Design sprints, as the name suggests, aim to achieve validation quickly. They also fit in with a wider trend in the industry away from traditional technology-centred design (TCD) approaches, and towards cyclical approaches such as Lean and Agile. According to Knapp et al. (2016), combining lean approaches with design thinking is a fast and cost-effective way of solving software design problems.

While Knapp's original design sprint approach encourages empathy for customers and designing with human needs first, the 5-day duration remains a barrier to adoption. Five days is a short time compared to the effort required for many software projects, but getting the required people together for the five consecutive days is often difficult. In 2018, Knapp and colleagues began promoting a 'semi-official' version of the process they call Design Sprint 2, which runs over four days rather than five (Courtney, 2018). In 2017, staff at the University of Chester had also recognised this problem, and proposed a compressed three day version of the design sprint process. The current study tests the feasibility and effectiveness of this version, in the context of a heritage-rich area around the River Dee at Chester.

3 AR and VR for Heritage and Heritage Tourism

As technology has advanced over the past 50 years, so too have its applications in specific disciplines such as archaeology. Archaeologists soon recognised the power of technology for enhancing their practice and embraced its capabilities. In the 1990s, this progressed to the discussion and use of specific tools such as GIS, AI, internet applications, interactive computer graphics, and virtual 3D modelling, followed by the creation of interactive, multi-user, virtual, augmented and mixed reality environments (Ch'ng, 2009). Technology in experiential archaeology, for instance, aims to 'bring a distant world [the past] into a psychological reality' and relates to the emergent concept of 'virtual time travel' (ibid, p. 459).

Technology has also been adopted across a wider range of heritage-related contexts, including the management, interpretation, communication and presentation of historic sites, places, museums and visitor attractions. Museums and CH sites have led the way in the use of technological innovation in tourism, and AR/VR user interfaces have taken a variety of forms including the use of small screens (including mobile phones and wearable devices such as smart watches/glasses), fixed or projected wall displays, overlays of information onto real museum artefacts or objects and more (de Carolis, Gena, Kuflik, & Lanir, 2018). These technologies enable museums and CH sites to engage new and existing audiences, improve the accessibility and relevance of their collections, and ultimately enhance the overall visitor/tourist experience (ibid).

Whilst the CH sector has embraced advanced technology, there has been a skills gap between technology developers and those with the context-specific expertise to employ them (Ch'ng, 2009; Guttentag, 2010). Guttentag (2010) recognises that a potential barrier to adoption in tourism more generally stems from the fact that advances in technology often take place outside of this field, and hence beyond the scope or awareness of tourism organisations or destinations that might ultimately benefit from them. Such technological advances, which are neither led by nor designed for tourism experts, may lack clear opportunities or straightforward application (ibid). e-Tourism explores the advances in, and potential for, technology in tourism management from a variety of stakeholder perspectives (Buhalis, 2003; Buhalis & Deimezi, 2004; Buhalis & Law, 2008), and Smart Tourism seeks the integrated, strategic use of technology in destinations to offer personalised, enhanced and meaningful experiences for visitors and residents (Wang, Li, & Li 2013; Buhalis & Amaranggana, 2014, 2015). However, there remains a potential disconnect between those experts well versed in technology and its potential for problem solving and experience creation, and those tourism stakeholders (in this case in heritage tourism) who have context-rich, industry specific challenges that could fruitfully employ, test, and capitalise upon the capabilities of the technology that exists.

Despite this disconnect, authors have long understood that technology presents a major opportunity for tourism, (Williams & Hobson, 1995; Dewailly, 1999; Buhalis, 2003). From a CH and heritage tourism perspective, this opportunity is particularly significant, as technology can help the CH sector meet its intrinsic aims of protecting, interpreting, communicating and presenting their heritage to diverse audiences in engaging, innovative, competitive and sustainable ways. The UN Sustainable Development Goals are seen as relevant to CH due to its "historical, social and anthropological value" and its critical role in sustainable development (Xiao et al., 2018) and hence finding sustainable ways to improve and/or manage access is increasingly important. Furthermore, there is an educational value in the use of AR/VR in CH. Digital curation can enrich the learning experience of different aged learners, from children exploring new CH environments and contexts to help them construct new meaning, to students developing enhanced critical thinking skills and emotional connection to their subjects. As a result, there is also a wider social value in CH and advanced technologies, as wider and more engaged audiences create better understandings of the past, and help develop or renew shared cultural values (Schaper et al., 2018).

A further rationale for CH sites making use of advanced technologies relates to their long and often complex histories, and the fact that many have experienced considerable change over time. As such, fixed, traditional interpretation and communication methods are not always appropriate or sustainable for heritage sites as they either impact on the aesthetic of the site, fail to capture the attention of their varied audiences, or both. Furthermore, it may be hard for visitors to appreciate the significance of a CH site, or independently identify or understand historically relevant features, given that such features may no longer remain visible in the landscape (Younes et al., 2017). Advanced technologies such as VR and AR can enable visitors to become immersed in such sites, using a reconstructed version of a historic site or place to recreate what has been lost, and/or augment what exists, in order to facilitate an interactive experience for audiences (ibid; Fineschi & Pozzebon, 2015). Increased presence, or the feeling of being present in a VR environment, has been shown to lead to a higher level of enjoyment and emotional involvement, and may also positively influence the intention to physically visit a place remotely experienced through VR (Marasco, Buonincontri, van Niekerk, Orlowski, & Okumus, 2018; Tussyadiah et al., 2018). This suggests that VR may afford a 'try before you buy' opportunity to enhance the effectiveness of destination marketing (Tussyadiah et al., 2018, p. 141), or alternatively even protect vulnerable sites from visitation when deemed necessary by allowing access in a different form (ibid; Manghisi et al., 2018; Marasco et al., 2018).

The use of interactive technology has the distinct benefit of allowing personal interests to shape and tailor an individual's experience (Neuhofer, Buhalis, & Ladkin, 2015). Interactive technology based on agents, for instance, can allow for different levels of experience, dependent on specific user profiles (Machidon, Duguleana, & Carrozzino, 2018). These might include specialist CH audiences versus more general visitors, different ages, skill levels, language requirements, the extent to which a visitor prefers a straight or more fun interpretation, and so on. With diverse audiences, accessibility is important. For example, while technology offers many benefits for older adults, they may also be excluded from some AR/VR interfaces due to difficulties processing or understanding data, or problems interacting with the software due to lack of experience with the technology (Peleg-Adler, Lanir, & Korman, 2018). Accounting for differences in human cognitive processing, perception and ability to understand visual and other data is vital, and should be accounted for in the design process as much as possible (Raptis, Fidas, & Avouris, 2018). Likewise, the differing technical requirements and output quality of (e.g.) smartphone-based mobile VR, and VR headsets tethered to personal computers, must also be allowed for (Marasco et al., 2018). The extent to which virtual time travel, with realism, interactivity, avatars and AI agents, multi-sensory engagement and a minimal feeling of mediation is achievable or desirable (Ch'ng, 2009) warrants further research in a heritage tourism context.

4 Case Study Context: Chester, UK

The Roman city of Chester (Fig. 1) is a well-established tourist destination in the North West of England. Its Roman walls form the most complete circuit of a walled city in the country, outlining the site of the original Roman fortress, and are a popular tourist attraction in their own right (Chester: Explore the Walls, 2012; Chester City Walls, n.d.). There are many tourist destinations within the walls, including a fine medieval cathedral, and the half-timbered galleries of the Rows, which attract visitors for their shops as much as for their architecture and historical significance (Chester Cathedral, n.d.; The Rows, n.d.). However, a challenge for the city is that many visitors do not explore beyond the city walls.

5 The Digital Dee

The area around the River Dee at Chester, about half a mile from Chester city centre, is recognised as having untapped potential in terms of its natural, cultural and historic significance, much of which is not evident in the current landscape (Wilding, 1997). The area is bounded by two historic bridges—the Old Dee Bridge and Queen's Park suspension bridge. On the city side of the river, important features include Grosvenor Park, St. John's Church (Chester's original cathedral church), the Roman amphitheatre, the riverside promenade known as The Groves, a corner of the Roman walls, and the building which housed Chester's Edwardian hydroelectric power station. Near to the Old Dee Bridge is a medieval weir and fish ladder. On the other side of the river, beside the remains of Roman stone quarry, a reconstructed water mill marks the sites of medieval fulling and corn mills, and a Victorian snuff mill. Further upstream is Churchill House, which was built in the 1930s as the British Army's Western Command Headquarters, and is currently home to the University of Chester's Faculty of Business and Management. The Western Command Headquarters included a large network of underground rooms and tunnels; these have fallen into disrepair, having gone unused since the 1960s, but are of great historical importance, having hosted meetings between Churchill, de Gaulle and Eisenhower in the run up to D-Day in World War II. They are an example of the type of site discussed in Sect. 3, where VR or AR may offer an appropriate way for visitors to gain a fully immersive experience of the site, since physical access is dangerous and impractical. Overall, the goal of the Digital Dee project is to use digital methods to encourage both local and non-local people to visit, enjoy and learn about these interesting and historic features of Chester's landscape.

6 Testing the Three-Day Design Sprint Approach

The goal of this study was to test the effectiveness of the 3-day design sprint schedule (Fig. 2) introduced earlier in this chapter. The Digital Dee heritage tourism project was chosen as a case study because it was at an appropriate point in development, and offered a suitable range of materials and opportunities. Data collection on the effectiveness of the 3-day approach itself was largely qualitative, consisting of daily reflections from members of the design team, post-activity reflections, and analysis of the sprint output. This was in addition to the feedback provided by the five testers on the prototype design produced by the design team during the first two days of the sprint.

Substantial preparation was required before the sprint, including date selection, design team selection, ethical approval, venue booking, catering arrangements, and tester selection. Issues of availability and commercial confidentiality had to be managed when selecting participants. Other preparations including physically visiting the Digital Dee area, and amassing a collection of relevant photographs, plans, and other information likely to be needed by the design team.

During the three day sprint, a hi-fidelity interactive software prototype (Fig. 3) was produced and moderated, and testing was conducted with a variety of local stakeholders. User feedback was then analysed, and refined prototypes will form the basis of future business and academic projects in the fields of digital heritage,

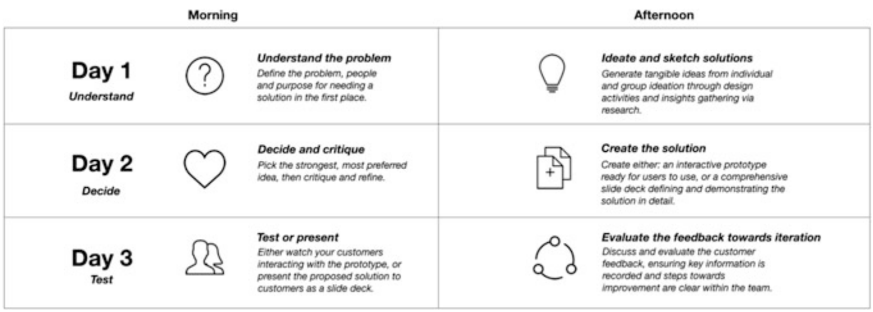

Fig. 2 Adapted design sprint schedule

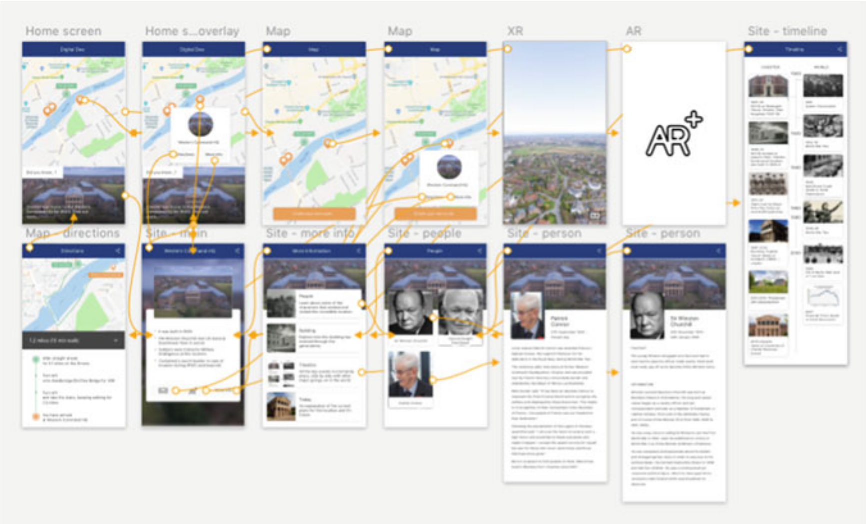

Fig. 3 An overview of the high-fidelity screens for the proposed 'Digital Dee' mobile application, created using Sketch

marketing and tourism. This user-centred design approach and sprint process ensured that both iteration and empathy remained at the heart of the project, with the aim of designing the system to work for the expected users, rather than expecting users to adapt to the product.

The full design team consisted of seven people, which is the maximum number recommended for a design sprint (Knapp et al., 2016). All were members of staff or researchers at the University of Chester. The key design sprint roles of facilitator and decider were fulfilled by staff with ISO 9241 and design sprint experience from the Department of Computer Science and the Informatics Centre. The other team members were an application designer, a Ph.D. student with VR and AR expertise, and researchers from the university's departments of Computer Science and History & Archaeology, and Faculty of Business and Management, who acted as domain experts in the fields of tourism, digital humanities, Chester history, and heritage interpretation.

The working venue for the design team had space for seven people to work comfortably, with a large whiteboard, video display screen, wall-space for posters and visual materials, and a stock of essential stationery, including sticky notes and voting dots. The room was booked for the sole use of the group for the full duration of the sprint. Hot and cold drinks were constantly available, and buffet lunches were brought to the room each day. This helped to maintain concentration levels and avoid distractions. Laptop computers were used for research, design and authoring, and iPhones and Google Cardboard headsets for usability testing. An IPEVO Ziggi-HD Plus Visualiser/Document Camera was used to record the usability testing. Sketch (2018) was used to create testable prototype screen designs for a smartphone app designed to introduce visitors to the heritage of the Western Command Headquarters and its underground bunkers. ReactJS, A-Frame and WebVR were used for building interfaces and a prototype VR panorama of Churchill House (formerly the Western Command Headquarters) (React, n.d; A-Frame, n.d; WebVR Rocks, n.d.).

The three day sprint was completed successfully. The design team worked well together, with a good balance of skills, knowledge and personalities. From a very wide initial brief, the sprint process enabled the design team to refine a specific example to prototype for the testers. This prototype was created on Day 2, with some work running on beyond the normal working day. The biggest challenge for this sprint was completing the necessary preparation in time for testing on the morning of Day 3.

Following design sprint guidelines, five individuals were recruited to test our prototype. This number of testers is specified because, typically, 85% of usability problems are identified after only five tests (Nielsen & Landauer, 1993). For comparison, it should be noted that TCD approaches such as the waterfall approach would not involve users at all at this stage, and as Nielsen writes, "zero users give zero insights" (Nielsen, 2000). Our five testers were chosen to be representative of a range of typical users and stakeholders expected for the Digital Dee project. They were: a local heritage expert with experience of opening Chester heritage sites to the public; a long-term local resident with a high level of local knowledge and community involvement, and expertise in the performing arts; a short-term local resident, originally from Africa, staying in Chester as a student, with some knowledge of local heritage; and two Cheshire residents with very limited knowledge of Chester heritage (acting as 'tourists unfamiliar with the area').

Feedback from the testers suggested that superimposing directions and information about attractions in AR could encourage visitors to explore different areas of Chester. Testers' perceptions of the team's proposed use of AR technology to enhance the Digital Dee prototype were positive, although there is clearly a need to make the host system easy to learn to improve acceptance of the technology. Similarly, there is a need to explore ways to make VR interactions more intuitive, familiar and usable (e.g., some testers initially had trouble understanding how to use the VR headset). However, testers did find the VR technology engaging, and were excited about the potential for it being utilised in the context of Chester's heritage.

7 Conclusion

All design sprints are unique, as they all focus on different design problems, involve different people and organisations, have different priorities, and different technical and financial challenges. This was a pilot project, where all of the design team (though not the testers) were from the same organisation, with a very broad initial brief, but a relatively low level of financial risk. As with the original five day design sprint schedule, a different group of people using the same schedule in a different context would have got different results (Jezovit, 2016). These reservations notwithstanding, the following findings and recommendations followed from the team's experience with this pilot project.

Members of the design sprint team must understand the 'sprint mindset'. Sprints are structured, time pressured, follow a process, and are goal-orientated, with everyone having a clear role. Commitment and concentration are required, but pay dividends in terms of high productivity and cross-pollination of ideas. The composition of the team must balance specialist expertise and technical skills, and dialogue between sub-teams at strategic points is critical for maintaining momentum and cohesion.

Regarding the three day schedule, this was certainly effective in this case. Advance planning is important (e.g., organising access to resources which are not available online, or from the sprint location), and the key design sprint roles of facilitator and decider are even more critical than for a five day sprint. Proper UX testing is vital to ensure reliable results, and must be built into the plan for the design sprint from the start. Due to the tight timescales, it is essential to establish realistic deliverables quickly, to avoid becoming too ambitious, and being forced to scale back due to time pressure. Even so, the scheduled breaks are important, as they help people to maintain energy levels. Design sprint tools such as 'crazy 8 s' and 'dot voting' encourage creativity and give everyone a voice, and collaborative digital workspaces allow efficient sharing of information.

Overall, as well as validating a proposed design approach for a specific local context, the three day design sprint approach was shown to have great potential for use in the CH and digital heritage fields, particularly where new or unfamiliar technologies are proposed as solutions.

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References

A-Frame. (n.d.). *Introduction*. Retrieved 24th July, 2018, from https://aframe.io/docs/0.8.0/introduction/.

Bennett, N., & AXELOS. (2017). *Managing successful projects with PRINCE2* (6th ed.). Stationery Office.

Buhalis, D. (2003). *eTourism: Information technology for strategic tourism management*. Toronto: Prentice Hall.

Buhalis, D., & Deimezi, O. (2004). eTourism developments in Greece: Information communication technologies adoption for the strategic management of the Greek tourism industry. *Tourism and Hospitality Research, 5*(2), 103–130.

Buhalis, D., & Law, R. (2008). Progress in information technology and tourism management: 20 years on and 10 years after the internet—the state of eTourism research. *Tourism Management, 29*(4), 609–623.

Buhalis, D., & Amaranggana, A. (2014). *Smart tourism destinations.* Paper presented at the International Conference on Information and Communication Technologies in Tourism 2014, Dublin, Republic of Ireland.

Buhalis, D., & Amaranggana, A. (2015). *Smart tourism destinations: Enhancing tourism experience through personalisation of services.* Paper presented at the International Conference on Information and communication technologies in tourism 2015, Lugano, Switzerland.

Casella, G., & Coelho, M. (2013). *Augmented heritage: Situating augmented reality mobile apps in cultural heritage communication.* Paper presented at the 2013 International Conference on Information Systems and Design of Communication, Lisboa, Portugal.

Charette, R. N. (2005). *Why software fails*. Retrieved from https://spectrum.ieee.org/computing/software/why-software-fails.

Chester Cathedral. (n.d.). *Chester, cheshire & beyond.* Retrieved 26th July, 2018, from https://www.visitcheshire.com/things-to-do/chester-cathedral-p20601.

Chester City Walls. (n.d.). *Engineering timelines.* Retrieved 26th July, 2018, from http://www.engineering-timelines.com/scripts/engineeringItem.asp?id=54.

Chester: Explore the Walls. (2012). Retrieved 26th July, 2018, from http://www.explorethewalls.com.

Ch'ng, E. (2009). Experiential archaeology: Is virtual time travel possible? *Journal of Cultural Heritage, 10,* 458–470.

Courtney, J. (2018). *The design sprint 2.0; What is it and what does it look like?* Retrieved from https://www.invisionapp.com/blog/design-sprint-2/.

de Carolis, B., Gena, C., Kuflik, T., & Lanir, J. (2018). Editorial: Special issue on advanced interfaces for cultural heritage. *International Journal of Human-Computer Studies, 114*, 1–2.

Design Thinking,. (n.d.). Retrieved 24th July, 2018, from https://www.ideou.com/pages/design-thinking.

Dewailly, J. M. (1999). Sustainable tourist space: From reality to virtual reality? *Tourism Geographies, 1*(1), 41–55.

Fabola, A., Miller, A., & Fawcett, R. (2015). *Exploring the past with Google cardboard.* Paper presented at 2015 Digital Heritage, Granada, Spain.

Fineschi, A., & Pozzebon, A. (2015). *A 3D virtual tour of the Santa Maria della Scala Museum Complex in Siena, Italy, based on the use of Oculus Rift HMD.* Paper presented at the 2015 International Conference on 3D Imaging (IC3D), Liege, Belgium.

Fitzgerald, G., & Russo, N. (2005). The turnaround of the London ambulance service computer-aided dispatch system (LASCAD). *European Journal of Information Systems, 14*(3), 244–257.

Guttentag, D. A. (2010). Virtual reality: applications and implications for tourism. *Tourism Management* 31(5), 637–651

ISO 9241-210:2010. (2010). *Ergonomics of human-system interaction. Human-centred design for interactive systems*. International Organization for Standardization.

Jezovit, A. (2016). *The art of the design sprint*. Retrieved from https://www.theguardian.com/info/developer-blog/2016/dec/02/the-art-of-the-design-sprint.

Knapp, J., Zeratsky, J., & Kowitz, B. (2016). *Sprint: How to solve big problems and test new ideas in just five days*. Bantam Press.

Machidon, O. M., Duguleana, M., & Carrozzino, M. (2018). Virtual humans in cultural heritage ICT applications: A review. *Journal of Cultural Heritage*.

Manghisi, V. M., Uva, A. E., Fiorentino, M., Gattullo, M., Boccaccio, A., & Monno, G. (2018). Enhancing user engagement through the user centric design of a mid-air gesture-based interface for the navigation of virtual-tours in cultural heritage expositions. *Journal of Cultural Heritage, 32,* 186–197.

Marasco, A., Buonincontri, P., van Niekerk, M., Orlowski, M., & Okumus, F. (2018). Exploring the role of next-generation virtual technologies in destination marketing. *Journal of Destination Marketing & Management, 9,* 138–148.

Neuhofer, B., Buhalis, D., & Ladkin, A. (2015). Smart technologies for personalized experiences: A case study in the hospitality domain. *Electronic Markets—The International Journal of Networked Business, 25*(3), 243–254.

Nielsen, J., & Landauer, T. K. (1993). *A mathematical model of the finding of usability problems.* Paper presented at the INTERACT ‘93 and CHI ‘93 Conference on Human Factors in Computing Systems.

Nielsen, J. (2000). *Why you only need to test with 5 Users*. Retrieved 24th July, 2018, from https://www.nngroup.com/articles/why-you-only-need-to-test-with-5-users/.

Peleg-Adler, R., Lanir, J., & Korman, M. (2018). The effects of aging on the use of handheld augmented reality in a route planning task. *Computers in Human Behavior, 81,* 52–62.

Power, C., Lewis, A., Petrie, H., Green, K., Richards, J., Eramian, M., et al. (2017). Improving archaeologists’ online archive experiences through user-centred design. *Journal on Computing and Cultural Heritage, 10*(1), 1–20.

Raptis, G. E., Fidas, C., & Avouris, N. (2018). Effects of mixed-reality on players’ behaviour and immersion in a cultural tourism game: A cognitive processing perspective. *International Journal of Human-Computer Studies, 114,* 69–79.

React. (n.d). *A JavaScript library for building user interfaces*. Retrieved 24th July, 2018, from https://reactjs.org.

Rikke, D., & Siang, T. (2018). *5 stages in the design thinking process*. From https://www.interaction-design.org/literature/article/5-stages-in-the-design-thinking-process.

Schaper, M.-M., Santos, M., Malinverni, L., Berro, J. Z., & Pares, N. (2018). Learning about the past through situatedness, embodied exploration and digital augmentation of cultural heritage sites. *International Journal of Human-Computer Studies*, 114, 36–50

Sketch. (2018). *The digital design toolkit*. Retrieved 2018, 24th July, from https://www.sketchapp.com.

Still, B., & Crane, K. (2016). *Fundamentals of user-centred design: A practical approach*. CRC Press.

The Rows. (n.d.). *Chester, cheshire & beyond.* Retrieved 26th August, 2018, from https://www.visitcheshire.com/things-to-do/chester-attractions/shopping-in-chester/the-rows.

Tussyadiah, I. P., Wang, D., Jung, T. H., & Tom Dieck, M. C. (2018). Virtual reality, presence, and attitude change: Empirical evidence from tourism. *Tourism Management, 66*, 140–154.

WebVR Rocks. (n.d.). Retrieved 24th July, 2018, from https://webvr.rocks.

Wang, D., Li, X. R., & Li, Y. (2013). China’s “smart tourism destination” initiative: A taste of the service-dominant logic. *Journal of Destination Marketing & Management, 2*(2), 59–61.

Wilding, R. (1997). *Miller of Dee: The story of Chester mills and millers, their trades and wares, the weir, the water engine and the salmon*. Chester: Gordon Emery.

Williams, A. P., & Hobson, J. S. P. (1995). Virtual reality and tourism: Fact or fantasy? *Tourism Management, 16*(6), 423–427.

Xiao, W., Mills, J., Guidi, G., Rodriguez-Gonzalvaz, P., Gonizzi Barsanti, S., & Gonzalez-Aguilera, D. (2018). Geoinformatics for the conservation and promotion of cultural heritage in support of the UN Sustainable Development Goals. *ISPRS Journal of Photogrammetry and Remote Sensing*.

Younes, G., Kahil, R., Jallad, M., Asmar, D., Elhajj, I., Turkiyyah, G., et al. (2017). Virtual and augmented reality for rich interaction with cultural heritage sites: A case study form the Roman Theater at Byblos. *Digital Applications in Archaeology and Cultural Heritage, 5,* 1–9.

Part III
AR & VR in Tourism

Designing Valuable Augmented Reality Tourism Application Experiences

Eleanor E. Cranmer

Abstract Augmented Reality (AR) has gained increased popularity in the tourism sector, for its ability to create enhanced tourist experiences. This, coupled with the proliferation of technologies has increased pressure for tourism organisations design and add value to tourist experiences. Whilst much research attention has focused on the potential of AR, exploring areas such as adoption, acceptance and usability, there is a lack of research outlining guidelines for the design of valuable AR application tourist experiences. This study uses a small UNESCO recognised museum in the UK, to identify key value adding features for the effective design of AR tourism applications. Adopting a multi-stakeholder approach, fifty interviews were held with five stakeholder groups, revealing four AR design categories; visitor value, organisational value, stakeholder value, economic value. Findings identified these categories should be considered for the effective design and implementation of enhanced tourist experiences, bridging a gap in current research.

Keywords Augmented reality · Experience design · Value creation · Value enhancement

1 Introduction

Technology use has reached the point it has become fully integrated into our everyday lives (Wang, Xiang, & Fesenmaier 2016). The unique characteristics of mobile technologies, namely ubiquity, flexibility, personalization and dissemination make it a useful tool for both tourism providers and consumers (Ukpadi & Karjaluoto, 2016). Emerging technologies offer more ways for tourism organizations to engage, attract, communicate and enhance the tourist experience. As a result of the increased use of technology, the sector has witnessed changes to travel behaviours, decision-making, information searching (Wang, Kim, Love, & Kang, 2013), use of

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idle time, experience-documenting, sharing (Tussyadiah & Zach, 2012; Wang et al., 2016), experience enhancement, value-adding services and unique experience creation (Leue, tom Dieck, & Jung, 2014). Nowadays, tourists are increasingly dependent on the internet and smartphones to obtain information about unknowns (Selvam, Yap, Ng, Tong, & Ho, 2016). Therefore, it is crucial that visitor attractions and tourist organizations address these changes and begin exploring new ways to attract tourists (Jung & tom Dieck, 2017).

AR is the digital overlay of information onto a users' immediate surroundings (Rauschnabel, Brem, & Ivens, 2015), and has received much interest within the tourism sector as a method to create enhanced tourist experiences (tom Dieck & Jung, 2017). An increasing number of scholars have explored its potential in areas such as user requirements (tom Dieck, Jung, & Han, 2016), acceptance and behavioural studies (Rauschnabel & Ro, 2016), AR tourist experiences (Han, tom Dieck, & Jung, 2017), AR value from a stakeholder perspective (tom Dieck & Jung, 2017), and the benefits of AR from an organizational perspective (Cranmer, Jung, tom Dieck, & Miller, 2016). Yet, a limited number of studies outline guidelines or principles for the design of enhanced AR experiences (Sá & Churchill, 2013; Kourouthanassis, Boletsis, & Lekakos, 2015). Due to the emerging nature of AR, it is suggested the design of AR experiences presents a number of challenges and thus should be approached holistically (Kourouthanassis et al., 2015). Further, the number of successful implication use cases of AR applications are still limited (Han et al., 2017). Hence, this study aims to identify key areas for the effective design of enhanced, value-adding AR applications to create enhanced tourist experiences, adopting a multi-stakeholder approach to provide a holistic understanding.

2 Literature Review

2.1 Augmented Reality and Cultural Heritage Tourism

AR's ability to overlay information on the real environment has propelled it to become a popular tool to enhance the tourist experience. The pressure for tourism organisations to adopt modern technologies, such as AR, has reached the point it is now considered a necessity (Han, Jung, & Gibson, 2014). Researchers believe that to stay competitive, organisations must find new ways to create added value by enriching tourist experiences (Scarles, Casey, & Treharne, 2016). tom Dieck and Jung (2017, p. 2) confirmed "nowadays many destinations and organisations have either implemented or begun to consider the opportunities offered by this new and innovative technology to enhance the visitor experience".

Hence, an increasing number of applications have been developed to explore how AR can add value to the tourist experience, creating 'info-cultural-attainment' combining leisure, entertainment, cultural, educational and social experiences

(Palumbo, Dominci, & Basile, 2013). Previous studies revealed AR can improve education and interpretation (Casella & Coelho, 2013), tailor information to tourists' specific preferences (Kounavis, Kasimati, & Zamani, 2012), increase interactivity (tom Deick & Jung, 2015), entertainment and engagement (Xu, Buhalis, & Weber, 2017). It has also been praised for its ability to market and promote cultural assets (Selvam et al., 2016), and has been reported to create deeper and more 'exclusive' experiences at heritage sites (Minazzi, 2015). Jung and tom Dieck (2017) proposed when used in this way AR can increase tourist attraction competitiveness. Recent studies also revealed AR increased dwell time, empowering tourists to personalise and deepen their experiences (Scarles et al., 2016), as well as facilitating co-production and increasing tourists' intention to spend (Jung & tom Dieck, 2017). However, whilst the majority of studies report positive experiences (Yovcheva, Buhalis, & Gatzidis, 2013), AR has been found to affect tourists' behaviour and interactions, reducing interaction among groups and proximity to exhibits (Lanir, Kuflik, Dim, Wecker, & Stock, 2013). Crucially, the availability of AR applications does not guarantee enhanced experiences (Jung & Han, 2014). Therefore, there is a need to further explore how to design effective AR applications to create positive and enhanced tourist experiences.

Although there are a number of successful examples of AR applications in cultural heritage, they still represent a small proportion of the market (Tscheu & Buhalis, 2016). Concern has been expressed towards low user adoption, because of a lack of AR acceptance studies in cultural heritage (Haugstvedt & Krogstie, 2012; Olsson, Lagerstam, Karkkainen, & Vaananen-Vainio-Mattila, 2012). Moreover, Jung and tom Dieck (2017) and tom Dieck and Jung (2017) acknowledge difficulty for smaller cultural heritage organisations to develop effective AR experiences, since large investments present too much risk without prior proof of concept. Nonetheless, implementation is considered feasible in terms of costs and content creation (Kasinathan, Mustapha, & Subramaniam, 2016). However, further research is necessary to identify how to best design value adding AR application experiences, reducing the risks for small organisations and strengthening the proof of concept.

2.2 Augmented Reality Experiences

Regardless of the fact that AR applications present much potential, existing literature outlining guidelines or principles for the effective design of valuable application experiences is scarce (Sá & Churchill, 2013; Kourouthanassis et al., 2015). It has been suggested designing AR applications presents a number of intrinsic challenges and thus should be addressed from a holistic perspective (Kourouthanassis et al., 2015). Tristan et al. (2017, p. 2103) supported that "AR has a specific and unique set of challenges designers need to overcome in order for this technology and its applications to be integrated into workflows, tasks, and experiences more seamlessly". Furthermore, Nordam (2016) claimed failure to address usability in the design of AR applications results in increased user errors, which reduces trust and undermines users' perceptions of the technology. Therefore, it is considered imperative to understand multiple stakeholders perspective towards the use of AR in cultural heritage organisations to inform the effective design of value adding AR application experiences.

At present, AR research has predominantly focused on the augmentation of human cognition (Webb, Vincent, Patnaik, & Schwartz, 2016), and interaction with AR applications. Tristan et al. (2017) identified whist the full potential of such applications remains to be seen, the negative consequences of inappropriately designed applications are significant such as; loss of situational awareness, cognitive overload, interrupted work flow causing poor performance and increased human error. It is suggested AR applications should be designed to provide practical benefits, which cannot be created via other forms of media (Olsson et al., 2012). Further, AR experiences should provide quality information to create enhanced experiences (Jung, Chung, & Leue, 2015). Yet, there is a lack of research exploring the necessary design components to create valuable AR tourist experiences. In a study of the heuristics of AR applications it was identified AR applications should; fit the user environment and task, form communication functions; minimise distraction and overload, adapt physical and virtual worlds, fit with the users physical and perceptual abilities and provide access to off-screen objects (Tristan et al., 2017). Whilst these are useful considerations for the design of AR applications, they do not focus on value adding content creation or the type of enhanced experiences AR should create to add value for both visitors and the organisation.

Previous studies have explored AR user acceptance in cultural heritage tourism, (e.g. tom Dieck & Jung, 2018; Leue et al., 2014), cultural differences in adoption of AR (Jung et al., 2018), AR applications heuristics (e.g. Tristan et al., 2017) and generic principles for the effective design of AR (e.g. Sá & Churchill, 2013; Kourouthanassis et al., 2015), but a limited number adopted a stakeholder approach to understand how to best design value-adding AR application experiences, despite the fact it is crucial to incorporate stakeholders' view for enhanced AR experience design. Moreover, Tristan et al. (2017, p. 2014) suggested "the growth and expansion of new AR capabilities needs to be informed by good design. We need to evolve our design methods to incorporate this expansion". Therefore, this study aims to understand, from a stakeholder perspective how to design value-adding AR applications to create enhanced tourist experiences.

2.3 Stakeholder Approach

In a tourism context, stakeholder involvement and collaboration are important to create enhanced tourist experiences (Kourtit, Macharis, & Nijkamp, 2014; McCabe, Sharples, & Foster, 2012). The stakeholder theory developed by Freeman (1983) proposed that organisations are characterised and influenced by their relationships with groups and individuals. In tourism, a stakeholder is considered "any group or individual who can affect or is affected by the achievement of the organisation's objectives" (Sautter & Leisen, 1999, p. 313). More specifically in a museum context, external stakeholders are individuals or groups with the power to impose rules, thus internal stakeholders have a strong interest in satisfying such rules to maintain integrity (Kotler, Kotler, & Kotler, 2008).

Stakeholder involvement, particularly understanding visitors' perceptions is crucial to create enhanced and creative experiences in the design and development stages of new technologies (McCabe et al., 2012). Kourouthanassis et al. (2015) identified that a common reason for the failure of mobile AR application experiences is because they are often technology driven, and ignore users' needs or address them in the latter stages of the development process. Thus, to design value adding AR application experiences, it is important to engage all stakeholders from the start, since their perception is a critical ingredient for decision-making (Yang, Shen, & Ho, 2009). Adopting a stakeholder approach was praised by McCabe et al. (2012) for the effective design and implementation of new technologies, as a method of reducing knowledge barriers by involving a range of perceptions. Hence, such an approach plays a significant role in addressing the concerns of a wide range of stakeholders when implementing and designing experiences involving innovative technologies (Hall & Martin, 2005).

Of the few existing studies which identify key design components for new AR tourism application experiences, Kourouthanassis et al. (2015) identified they are often technologically focussed, ignoring users' needs. This is considered a hindrance to the successful implementation of valuable AR tourist experiences. Olsson et al. (2013) found that mobile AR user-centred design is challenging by virtue of the fact users of emerging technologies, like AR can find it difficult to express their needs because of a limited knowledge or understanding of its potential. Therefore, this study employed a stakeholder approach, to encompass the views of all individuals and groups that had power, influence or a stake in the design of an AR application experience to add value to Geevor. A stakeholder approach helps overcome the challenges presented by a lack of guidance outlining design criteria, often considered a key reason for the delayed implementation of AR in tourism.

3 Methods

This study focuses on Geevor Tin Mine museum, in Cornwall, UK a small cultural heritage tourist attraction. UNESCO recognised and multi-award winning, Geevor attracts over 40,000 visitors a year. The museum experience does not currently involve technology, and as a publicly funded organisation, management are eager to explore the potential of AR to enhance the tourist experience. Similar to other small organisations, Geevor are unable to make large investments without prior proof of concept (tom Dieck & Jung, 2017). To overcome issues associated with technology focused design and create a value adding AR application experiences, a multi-stakeholder approach was adopted. A stakeholder approach will yield a holistic perception of key design areas to develop valuable AR applications that create enhanced experiences and reduce the risk involved in investing in AR technology. Stakeholder analysis was performed, identifying five groups; 9 internal stakeholders (G), 6 Tourist Bodies (B), 3 Tertiary Groups (T), 2 Local Businesses (LB) and 30 Visitors (V). The sample was chosen on the assumption that "the sample must be appropriate and comprise respondents who best represent or have knowledge of the research topic" (Elo et al., 2014, p. 4). Non-probability purposive sampling was employed to interview all stakeholder groups except visitors, where due to practicality, convenience sampling was used.

A total of 50 interviews were conducted between March 2015 and February 2016. In light of the exploratory nature of this study, a semi-structured interview approach was employed providing freedom for stakeholders to add to, and extend questions (Saunders, Lewis, & Thornhill, 2012). Such an approach is considered crucial to increase the quality of data (Gillham, 2005). To ensure all stakeholders had a proficient understanding of AR to participate, prior to interview, all were shown a short video demonstration of AR in a museum context and provided with an AR information sheet. All interviews were recorded and transcribed and data were analysed using content analysis. Table 1 demonstrates internal, tertiary, tourist bodies and business stakeholder profiles. The majority (60%) of visitors identified themselves as 'very much' or 'much' in regard to their technical savviness, which is

Table 1 Stakeholder respondent profile

Code	Organisation	Position
G1	Geevor	Trustee
G2	Geevor	Chair of Trustees
G3	Geevor	Marketing Officer
G4	Geevor	Learning Officer
G5	Geevor	Mine Development Officer
G6	Geevor	Mine Guide
G7	Geevor	Curator
G8	Geevor	IT Manager
G9	Geevor	Mine Manager
B1	Cornwall Council	Cultural Programme Officer
B2	Visit Cornwall	Chief Executive Officer
B3	Cornwall Museum Partnership	Chief Executive Officer
B4	Cornwall Museum Partnership	Development Officer
B5	(Freelance)	Museum Marketing Expert
B6	Cornwall National Trust	General Manager
T1	University of Falmouth	University Lecturer
T2	University of Falmouth	University Professor
T3	St Ives Secondary School	Secondary school teacher
LB1	Count House café	Assistant Manager
LB2	Geevor Shop	General Manager

suggestive they are regular users of technologies. This was synonymous by the fact, that 83% owed a smartphone, and the majority of those who did not said they owned a tablet (see Table 2).

Table 2 Visitor respondent profile

Code	Gender	Age group	Visiting with	Visiting from	Smartphone owner
V1	F	18–24	Family	USA	Yes
V2	M	18–24	Family	USA	Yes
V3	M	45–54	Family	USA	Yes
V4	F	45–54	Family	USA	No
V5	F	18–24	Family	Nottingham, UK	Yes
V6	F	45–54	Family	Nottingham, UK	Yes
V7	F	25–34	Partner	Hull, UK	No
V8	M	35–44	Partner	Hull, UK	Yes
V9	F	45–54	Family	Birmingham, UK	Yes
V10	M	35–44	Family	Solihull, UK	Yes
V11	F	55–64	Friends	London, UK	No
V12	F	55–64	Friends	France	No
V13	M	35–44	Family	Weston-Super-Mare, UK	Yes
V14	F	35–44	Family	Weston-Super-Mare, UK	Yes
V15	M	45–54	Partner	Netherlands	Yes
V16	F	45–54	Family	Netherlands	Yes
V17	F	55–64	Friends	Staffordshire, UK	Yes
V18	F	18–24	Family	Bolton, UK	Yes
V19	F	35–44	Family	Bolton, UK	Yes
V20	F	35–44	Partner	Toronto, Canada	Yes
V21	M	45–54	Partner	Toronto, Canada	Yes
V22	F	45–54	Family	Hertfordshire, UK	No
V23	F	45–54	Family	Essex, UK	Yes
V24	M	45–54	Family	Hertfordshire, UK	Yes
V25	F	45–54	Family	Reading, UK	Yes
V26	M	45–54	Family	Reading, UK	Yes
V27	F	25–34	Family	Cheltenham, UK	Yes
V28	M	45–54	Family	Cambridge, UK	Yes
V29	M	55–64	Partner	Milton Keynes, UK	Yes
V30	F	55–64	Partner	Milton Keynes, UK	Yes

4 Findings

4.1 Visitor Value

Many studies have explored the ability for AR to add value to the visitor experience, enhancing their interactions with the real-world. This was confirmed by stakeholders who recognised AR experiences improve interpretation, bring the site to life, whilst catering to different knowledge levels and interests. AR was perceived as a method to help visitors "digest" complex information and exhibits (T1). Local Business (B1) supported that AR would be an effective way to "tie it together" in reference to sporadic exhibitions and buildings across Geevor. Importantly, AR was considered a method to improve visitors ability to comprehend and access parts of Geevor that are currently inaccessible, such as the underground mining works.

Visitors in particular praised AR for its educational abilities, identifying that it should be a key focus in the design of experiences, incorporating elements of fun and entertainment. Through the effective design of AR experiences, Tourist Body (B4) commended AR as a tool to engage "non-traditional museum audiences". This was further supported by a number of visitors, such as V2 who felt AR would allow you to "see it and really experience it". Tertiary Leader (T2) believed it would improve tourists social and situated learning experiences. In the same way, AR was regarded particularly useful to engage children, providing visual representations allowing them to see exhibits come to life.

Research widely acknowledges the navigational and orientational benefits of AR. Stakeholders confirmed this considering AR a way to improve the efficiency of tourists navigating the site, whilst improving their comprehension of the site as a whole. Further, AR was considered a tool to increase awareness of facilities (e.g. café and shop), potentially increasing traffic and thus improving onsite businesses revenue generation.

4.2 Organisational Value

Improving organisational sustainability was revealed as important by all stakeholders. AR was identified as an effective tool to increase visitors dwell time, and intention to spend. Furthermore, a number of stakeholders considered AR would broaden the visitor appeal. Visit Cornwall (B2) commented this would engage more "generalist not specialist" visitors, targeting all market segments. Increased visitor numbers and engagement would increase tickets sales and revenue, ensuring Geevor remained economically viable and sustainable year-round attraction.

T2 recognised AR as a way to bypass the need for visitors to pre-plan their participation in guided tours, whilst ensuring all visitors shared the same level of experience. Geevor IT Manager (G8) proposed "AR is the prefect substitute for people" offering many advantages as a tool to improve both organisational and visitor experience sustainability. Thus, it was agreed that introducing AR tours would maintain the authenticity of the existing experience, whilst enabling future generations to share the same level of experience.

The marketing potential and merits of AR are much discussed within literature. Supporting this stakeholders strongly acknowledged ARs potential to increase Geevors marketing presence, raising the profile of the site, and on a larger scale Cornwall as a tourist destination. It was suggested AR could give Geevor competitive edge, whilst helping to attract more generalist audiences as well as appeal to younger target groups. Simply, by implementing AR it was suggested that more tourists would visit, inspired by a desire to try the new technology and experience something unique (B1, G2). In turn, a number of visitors suggested this would positively increase word-of-mouth marketing, sharing on social medial platforms and likelihood to recommend. Tertiary Group (T2) commented that society are used to instant sharing, suggesting AR would inspire higher visitor numbers "based on new visits rather than repeat visits".

Moreover, AR was recognised as a way to improve efficiency; managing the site, communication and performing daily operations. In busy periods there is a lack of staff availability, therefore visitors can find it hard to navigate, interpret and understand the site. To overcome this, stakeholders suggested designing AR to help staff explain complex processes, with the use of 3D animations and diagrams to enhance understanding and improve the efficiency of explanations (G4, B1). In the same way, introducing an AR self-guided tour was considered a solution to provide interpretation to more visitors, whilst engaging different ages and interests by tailoring content to an individuals preferences, and enabling visitors to return to, or repeat information (G1, G2). Similarly, external stakeholders supported that AR would supplement existing tours, providing interpretation to all visitors, thus overcoming challenges of limited staff availability during busy periods. Visitors felt AR would be a valuable alternative, creating memorable experiences (V4, V12, V16, V18, V23, V25).

4.3 Stakeholder Value

The preservation of knowledge using AR emerged as a key design area when developing new AR experiences. Ex-miners currently working at Geevor are praised for their ability to create authentic visitor experiences, incorporating their first-hand knowledge (B2, T2). Tourists are motivated to visit by virtue of the fact ex-miners create such experiences, thus preserving this knowledge for future generations is crucial. Stakeholders recognise ex-miners will not be working at Geevor forever and highlighted the ability of AR to preserve the integrity and authenticity of the experience they create and stories they tell "preserving that knowledge" (G5). Numerous visitors supported this, such as V7 who commenting "first-hand knowledge, that is key".

It was recognised as important for AR experiences to be designed to secure jobs for existing staff. Stakeholders considered AR would increase job security and employment opportunities, because the more successful and profitable Geevor, the more profits available to invest into staffing. Internal stakeholder (G2) added that designing a value adding AR experience would help staff to “secure their jobs, the more money we have on site the more secure their jobs are”. Similarly, it was considered the design and implementation of an AR experience would help create further employment opportunities.

Heritage value and community pride are fundamentally important to the Geevor experience and on a broader scale Cornwall as a tourism destination. AR was perceived as a tool to help reignite and maintain a sense of pride in the history and heritage of the area. Cornwall Museums Partnership (B4) suggested through the effective implementation of an AR experience, visitors appreciation of Cornish heritage would be deepened, creating a behavioural change and increasing awareness of the need to protect and conserve heritage sites. Similarly, the process of curating and designing an AR experience was predicted as a method to improve the local sense of identity and significance of Geevor (B1). Moreover, implementing and designing value adding tourist experiences was seen as a way to increase staff engagement, raising the profile of the site, and improving staff morale, whilst making daily tasks easier (G1, G2, G4, G5, G9).

4.4 Economic Value

Implementing an AR experience was perceived as a method to attract further investment and funding, bettering the site and local area. AR was suggested as a way to demonstrate Geevor were shifting focus from being a mine to a tourist attraction (G3) and that efforts were being made to secure the longevity and future of the site. Cornwall National Trust (B6) summarised “the better the experience we can give people in the whole area, the more people will visit, and the more the economy will grow and the more money you will have to invest back into conservation of those areas”. This was further supported by T2 and B2 who felt the introduction of AR would illustrate Geevor’s intentions to enhance and add value to the visitor experience, ensuring the longer-term viability of the attraction.

In addition to attracting revenue, implementing AR was considered a tool to increase and secure additional sources of revenue. Stakeholders were of agreement that creating an enhanced visitor experience would engage wider audiences, increasing visitor numbers and thus ticket sales. It was considered this would have a positive multiplier attracting more people to local areas, who would spend more at local amenities, therefore helping to sustain businesses and improve local infrastructure. Yet, there was debate among stakeholders regarding the most suitable way to integrate AR, whether it be offered free or visitors were changed an additional fee for an enhanced experience. No AR revenue model solution was agreed, and thus required further research.

5 Discussion and Conclusions

5.1 Discussion

This study aimed to identify key areas to focus the design of valuable AR tourism applications experiences at cultural heritage sites. The research used a case study of UNESCO, award winning Geevor Museum, in Cornwall, UK. Stakeholders agreed that AR would add value to the existing tourist experience and identified four main areas that should be addressed in the design of AR applications to create enhanced experiences. Few previous studies have explored design features, outlining ways to create enhanced AR application experiences. To progress current understanding, this study revealed when implementing and designing AR application experiences, the prevailing focus should centre on four key areas; visitor value, organisational value, stakeholder value and economic value.

The need to add value, creating enhanced visitor experiences has been identified by a number of researchers (e.g. Wang et al., 2013; tom Dieck & Jung, 2017). The present study confirmed the importance of designing AR applications to enhance existing visitor experiences, for example improving interpretation, catering to different knowledge levels and interests, and creating enjoyable, exciting educational experiences. This was supported by Palumbo et al. (2013) who claimed AR should develop "info-cultural-tainment" experiences. It is also suggested that designing AR applications to create value for visitors is important to increase competitiveness (Jung & tom Dieck, 2017).

Kourouthanassis et al. (2015) stated that because of intrinsic challenges associated with designing AR applications, it should be approached from a holistic perspective. Hence, adopting a multi-stakeholder approach was central in gaining a holistic understanding of ARs potential. This was confirmed by stakeholders, who supported that AR applications should be designed to create value for the both visitors and organisation. Cranmer et al. (2016) proposed AR added value for visitors and stakeholders, besides this, few studies have explored the design and implementation of AR to create value for organisations. Stakeholders were in agreement AR would broaden the visitor appeal, engage all visitor segments, increasing ticket sales and thus revenue. Whilst some past studies recognise AR can be designed to increase visitor numbers and ticket sales (e.g. Jung & tom Dieck, 2017; Scarles et al., 2016), none have explored the specific value or benefits such opportunities create for the organisation.

Similarly, studies recognising the importance of designing AR to create stakeholder value, in addition to visitor benefits, are scarce. Stakeholders revealed AR should be designed to preserve knowledge and ensure the continuation of the award-winning visitor experience for future generations. This confirmed Olsson et al. (2012) findings that AR design should create practical benefits. Moreover, in a study of AR application heuristics, Tristan et al. (2017) suggested AR should fit the user environment, tasks and offer communication functions. Stakeholders also agreed that AR should be designed to preserve knowledge, ensuring the authenticity and integrity of the current visitor experience. Further, stakeholders confirmed AR would help improve communication across site, whilst enhancing the efficiency of managing and organising, for example crowd management and guided tours.

This study also revealed AR should be designed to create economic value. Whilst previous studies discuss ARs potential to generate economic return, few identify areas of design to create financial gain. For example, stakeholders considered AR a method to increase tickets sales and intention to spend, highlighting economic value as a key design area. Jung and tom Dieck (2017) confirmed AR has the potential to increase intention to spend from the context of AR value, but not from an AR application design perspective. Few previous studies identified the economic multiplier effect resulting from the effective design of AR application experiences as recognised by stakeholders. Further research is necessary to identify the most appropriate revenue model for the implementation of AR, since stakeholders expressed mixed opinions. Moreover, whilst this study identified some key economic benefits of AR application experiences, further research is necessary to understand ARs full economic potential.

5.2 Theoretical Contributions and Managerial Implications

This study makes a number of theoretical contributions, at present existing research has failed to identify key design areas to inform the development and creation of enhanced AR application experiences. Few previous studies outline principles or guidelines for the design of effective AR application experiences (Sá & Churchill, 2013; Kourouthanassis et al., 2015). The present study extends current understanding, through the identification of four design areas to inform future developments of enhanced AR tourism application experiences.

In many cases, previous studies have not adopted a holistic approach to understand complex stakeholder perceptions (Kourouthanassis et al., 2015). Therefore, the adoption of a stakeholder approach, advances current understanding of the effective design of AR application experiences from a stakeholder perspective, providing a holistic overview. In addition, the present study deepens existing understanding of AR experience design guidelines. Tristan et al. (2017, p. 2104) commented "the growth and expansion of new AR capabilities needs to be informed by good design. We need to evolve our design methods". The present study contributes to the existing pool of knowledge towards good AR application design by identifying four key areas of focus. The use of a stakeholder approach to provide a holistic understanding further strengthens this contribution.

Overall, whilst some findings are supported in previous research, the context from which these were examined have not previously focused on the effective design of AR application experiences in a cultural heritage tourism. Thus, the present study extends current understanding of the effective design of AR tourism applications to create enhanced experiences and should be used to inform future AR development projects.

5.3 Limitations and Future Research

Organisational value emerged as a key area for focus when designing new AR applications, however, because of the case study approach employed, it is suggested to conduct further research at other similar organisations to substantiate the findings. Stakeholders did not agree an optimal revene model for the design and implementation of AR. Whilst adopting a stakeholder approach yielded an important holistic understanding, however, it limits the findings to the case under investigation. Thus, it is suggested further research examines the perception of stakeholders from other attractions and tourism organisations, not limited to the context of cultural heritage.

References

Casella, G., & Coelho, M. (2013). Augmented heritage—Situating augmented reality mobile apps in cultural heritage communication. In *International Conference on Information Systems and Design of Communication* (pp. 138–140). Lisboa, Portugal: ACM.

Cranmer, E., Jung, T., tom Dieck, M. C., & Miller, A. (2016). Understanding the acceptance of augmented reality at an organisational level: the case of Geevor Tin Mine Museum. In A. Inversini & R. Schegg, (Eds.), *Information and Communication Technologies in Tourism* (pp. 637–650). Heidelberg: Springer International Publishing.

Elo, S., Kääriäinen, M., Kanste, O., Pölkki, T., Utriainen, K., & Kyngäs, H. (2014). Qualitative content analysis: A focus on trustworthyness. *SAGE Open, 4*(1), 1–10.

Freeman, R. E. (1983). Strategic management: A stakeholder approach. *Advances in strategic management, 1*(1), 31–60.

Gillham, B. (2005). *Research interviewing: The range of techniques*. Berkshire, UK: McGraw-Hill Education.

Hall, J. K., & Martin, M. J. C. (2005). Disruptive technologies, stakeholders and the innovation value-added chain: a framework for evaluating radical technology development. *R&D Management, 35*(3), 273–284.

Han, D.-I., Jung, T., & Gibson, A. (2014). Dublin AR: Implementing augmented reality in tourism. In Z. Xiang & I. Tussyadiah (Eds.), *Information and Communication Technologies in Tourism 2014* (pp. 511–523). New York: Springer International Publishing.

Han, D. I., tom Dieck, M. C., & Jung, T. (2017). User experience model for augmented reality applications in urban heritage tourism. *Journal of Heritage Tourism, 13*(1), 1–16.

Haugstvedt, A., & Krogstie, J. (2012). Mobile augmented reality for cultural heritage: A technology acceptance study. In B. MacIntyre & G. Welch (Eds.), *IEEE, Mixed and Augmented Reality (ISMAR)* (pp. 247–255). USA: IEEE.

Jung, T., Chung, N., & Leue, M. (2015). The determinants of recommendations to use augmented reality technologies: The case of a Korean theme park. *Tourism Management, 49*(2015), 75–86.

Jung, T., & Han, D. (2014). Augmented Reality (AR) in Urban Heritage Tourism. *e-Review of Tourism Research, 5*, 1–7.

Jung, T. H., Lee, H., Chung, N., tom Dieck, M. C. (2018). Cross-cultural differences in adopting mobile augmented reality at cultural heritage tourism sites. *International Journal of Contemporary Hospitality Management 30,*(3), 1621–1645.

Jung, T. H., & tom Dieck, M. C. (2017). Augmented reality, virtual reality and 3D printing for co-creation of value for visitor experience at cultural heritage places. *Journal of Place Management and Development,* https://doi.org/10.1108/jpmd-07216-0045.

Kasinathan, V., Mustapha, A., & Subramaniam, T. (2016). SmartG: Spontaneous Malaysian augmented reality tourist guide. *IOP Conference Series: Materials Science and Engineering, 160*(1), 1–9.

Kotler, N. G., Kotler, P., & Kotler, W. I. (2008). *Museum marketing and strategy: Designing missions, building audiences, generating revenue and resources*. San Fransisco, CA: Wiley.

Kounavis, C., Kasimati, A., & Zamani, E. (2012). Enhancing the tourist experience through mobil augmented reality: Challenges and prospects. *International Journal of Engineering Business Management, 4*(10), 1–6.

Kourouthanassis, P. E., Boletsis, C., & Lekakos, G. (2015). Demystifying the design of mobile augmented reality applications. *Multimedia Tools Applied, 74*(2015), 1045–1066.

Kourtit, K., Macharis, C., & Nijkamp, P. (2014). Planning for urban historical-cultural heritage: A geo-imaging multicriteria approach. *Built Environment, 40*(4), 521–533.

Lanir, J., Kuflik, T., Dim, E., Wecker, A. J., & Stock, O. (2013). The influence of a location-aware mobile guide on museum visitors' behavior. *Interacting with Computers, 25*(6), 443–460.

Leue, M. C., tom Dieck, D., & Jung, T. (2014). A theoretical model of augmented reality acceptance. *e-Review of Tourism Research, 5*(1), 1–5.

McCabe, S., Sharples, M., & Foster, C. (2012). Stakeholder engagement in the design of scenarios of technology-enhanced tourism services. *Tourism Management Perspectives, 4*(1), 36–44.

Minazzi, R. (2015). *Social media marketing in tourism and hospitality*. Heidelberg, Germany: Springer.

Nordam, A. (2016, November). The fuzzy future of virtual reality and augmented reality. http://spectrum.ieee.org/techtalk/consumer-electronics/gadgets/can-you-see-it-thefuture-of-virtual-and-augmented-reality. Retrieved March 9, 2017.

Olsson, T. (2013). Concepts and subjective measures for evaluating user experience of mobile Augmented technology in tourism: A review. http://doi.org/10.1016/j.tele.2016.12.0020736-5853/.

Olsson, T., Kärkkäinen, T., Langerstam, E., & Ventä-Olkkonen, L. (2012). User evaluation of mobile augmented reality scenarios. *Journal of Ambient Intelligence and Smart Environments, 4*(1), 29–47.

Olsson, T., Lagerstam, E., Karkkainen, T., & Vaananen-Vainio-Mattila, K. (2013). Expected user experience of mobile augmented reality services: A user study in the context of shopping centres. *Personal and Ubiquitous Computing, 17*(2), 287–304. https://doi.org/10.1007/s00779-011-0494-x.

Palumbo, F., Dominci, G., & Basile, G. (2013). *Designing a mobile app for museums according to the drivers of visitor satisfaction* [Online]. Accessed on 3rd November 2014. http://www.wseas.us/e-library/conferences/2013/Dubrovnik/MATREFC/MATREFC-24.pdf.

Rauschnabel, P. A., Brem, A., & Ivens, B. S. (2015). Who will buy smart glasses? Empirical results of two pre-market-entry studies on the role of personality in individual awareness and intended adoption of Google Glass wearables. *Computers in Human Behavior, 49*(1), 635–647.

Rauschnabel, P. A., & Ro, Y. K. (2016). Augmented reality smart glasses: An investigation of technology acceptance drivers. *International Journal of Technology Marketing, 11*(2), 123–148.

Sá, M., & Churchill, E., (2013). Mobile augmented reality: A design perspective. In W. Huang, A. Alem & M. A. Livingston (Eds.), *Human factors in augmented reality environments* (pp. 139–164). New York: Springer.

Saunders, M., Lewis, P., & Thornhill, A. (2012). *Research methods for business students*. New York: Pearson.

Sautter, E., & Leisen, B. (1999). Managing stakeholders a tourism planning model. *Annals of Tourism Research, 26*(2), 312–328.

Scarles, C., Casey, M., & Treharne, H. (2016). Enriching the visitor experience: Augmented reality and image recognition in tourism. In: Scerri, M. & Hui, L. K. (Eds.), *CAUTHE 2016: The Changing Landscape of Tourism and Hospitality: The Impact of Emerging Markets and Emerging Destinations*. (pp. 1177–1184). Sydeney: Australia: CAUTHE.

Selvam, A., Yap, T. T.-V., Ng, H., Tong, H.-L., & Ho, C.-C. (2016). Augmented reality for information retrieval aimed at museum exhibitions using smartphones. *Journal of Engineering and Applied Sciences, 100*(3), 635–639.

tom Dieck, M. C., & Jung, T. (2017). Value of augmented reality at cultural heritage sites: A stakeholder approach. *Journal of Destination Marketing and Management.* https://doi.org/10.1016/j.jdmm.2017.03.00.

tom Dieck, M. C., & Jung, T. (2015). A theoretical model of mobile augmented reality acceptance in urban heritage tourism. *Current Issues in Tourism,* https://doi.org/10.1080/136853500.2015.1070801.

tom Dieck, M. C., & Jung, T. (2018). A theoretical model of mobile augmented reality acceptance in urban heritage tourism. *Current Issues in Tourism, 21*(2), 154–174. https://doi.org/10.1080/13683500.2015.1070801.

tom Dieck, M. C., Jung, T., & Han, D.-I. (2016). Mapping requirements for the wearable smart glasses augmented reality museum application. *Journal of Hospitality and Tourism Technology*, *7*(3), 230–253.

Tristan, C., Endsley, K. A., Sprehn, A., Brill, K. J., Vincent, E. C., James, M., & Marin, D. (2017). Augmented Reality design heuristics: Designing for dynamic interactions. In *Proceedings of the Human Factors and Ergonomics Society 2017 Annual Meeting.*

Tscheu, F., & Buhalis, D. (2016). Augmented reality at cultural heritage sites. *In Information and Communication Technologies in Tourism 2016* (pp. 607–619). Berlin: Springer.

Tussyadiah, I., & Zach, F. (2012). The role of geo-based technology in place experiences. *Annals of Tourism Research, 39*(2), 780–800.

Ukpabi, D. C., & Karjaluoto, H. (2016). Consumers' acceptance of information and communications: A review. http://doi.org/10.1016/j.tele.2016.12.0020736-5853/.

Wang, X., Kim, M., Love, P., & Kang, S.-C. (2013). Augmented reality in built environment: Classification and implications for future research. *Automation in Construction, 32*(1), 1–13.

Wang, D., Xiang, Z., & Fesenmaier, D. R. (2016). Smartphone use in everyday life and travel'. *Journal of Travel Research, 55*(1), 52–63.

Webb, A. K., Vincent, E. C., Patnaik, P., & Schwartz, J. L. (2016). A systems approach for augmented reality design. In *International Conference on Augmented Cognition* (pp. 382–389). https://www.researchgate.net/publication/320544042_Augmented_Reality_Design_Heuristics_Designing_for_Dynamic_Interactions. Accessed May 30, 2018.

Xu, F., Buhalis, D., & Weber, J. (2017). Serious games and the gasification of tourism. *Tourism Management, 60*(2017), 244–256.

Yang, J., Shen, Q., & Ho, M. (2009). An overview of previous studies in stakeholder management and its implications for the construction industry. *Journal of facilities management, 7*(2), 159–175.

Yovcheva, Z., Buhalis, D., & Gatzidis, C. (2013). Engineering augmented tourism experiences. In L. Cantoni & Z. Xiang (Eds.), *Information and Communication Technologies in Tourism 2013* (pp. 24–35). Berlin Heidelberg: Springer.

Experiencing Virtual Reality in Heritage Attractions: Perceptions of Elderly Users

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Abstract Recently, there has been an increased interest in the opportunities of virtual reality (VR) for the enhancement of the tourism experience. However, few studies have qualitatively explored the experience from elderly tourists perspective. Latest technology needs to be relevant and easy to use for elderly users in order to be accepted. Therefore, this study aims to examine the impact of VR on elderly tourists' experience. In order to achieve the aim, the present study conducted 23 interviews with elderly tourists at a cultural heritage tourism attraction in the UK. Interviews were analysed using thematic analysis and findings revealed impacts of VR onto elderly visitors' experience as well as requirements with regards to VR applications within cultural heritage sites. There has been an overall positive attitude towards the use of VR among elderly visitors and strong intentions to return as a result of experiencing VR.

Keywords Virtual reality · E-Tourism · Tourism experiences · Elderly users

1 Introduction

Recently, there has been an increased interest in the opportunities of virtual reality (VR) for the enhancement of the user experience (Tredinnick, 2018). Numerous use cases emerged on how VR can be utilized as part of the tourism experience (Huang, K. F. Backman, S. J. Backman, & Chang, 2016). Through the digital recreation of content, tourists are able to experience unknown destinations and inaccessible places

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which adds to the overall value of the tourism experience (Yung & Khoo-Lattimore, 2017). Recently, Jung and tom Dieck (2017) found that cultural heritage attractions can offer children, elderly or disabled visitors with an enhanced experience by providing VR experiences of inaccessible attractions. Furthermore, Tussyadiah, Wang, & Jia, (2017) revealed that VR can be considered a good substitute for virtually visiting endangered areas, making it ideal for sustainable tourism. Museums worldwide have started to provide its visitors with interactive virtual experience. For instance, the Salvador Dali Museum allows visitors to "enter" paintings and virtually see scenery. Other examples include museums that offer users at home the virtual museum experience to bring culture and heritage to everyone (Unimersiv, 2016). However, empirical research on the importance of VR as part of the tourism experience for elderly is still scarce and further research is needed to fully understand the potential in terms of opening up new tourism business and experience opportunities. According to Quan-Haase, Martin, and Schreurs (2016), latest technology needs to be relevant and easy to use for elderly users in order to be accepted and therefore, tourism attractions have to play close attention to elderly users' acceptance to ensure full adoption. Therefore, the aim of the present study is to examine the impact of VR on elderly tourists' experiences. In addition, tom Dieck and Jung (2016) revealed the importance of exploring context-specific user requirements prior to implementing applications within the tourism domain. However, user requirement studies within VR and tourism are scarce, in particular from the elderly visitors point-of-view. Therefore, we furthermore aim to identify elderly tourist requirements for using VR.

2 Literature Review

2.1 Technology Enhanced Tourism Experiences in Heritage Attractions

Tourism is a very dynamic industry and thus, tourism attractions have to constantly respond to changes in order to remain competitive (Neuhofer, Buhalis, & Ladkin, 2014). Technology is thereby playing and increasingly important role as today's tourists are used to using mobile devices pre, during and after trips. Consequently, tourism heritage attractions have started to explore the opportunities of implementing latest technologies to enhance the tourism experience (Han, Jung, & Gibson, 2014). Recently, studies found that mobile augmented reality (tom Dieck & Jung, 2016) as well as wearable augmented reality (Leue, Jung, & tom Dieck, 2015) strengthen the learning experience at cultural heritage attractions. Through the use of latest technologies, tourists experience an enhanced form of interaction with the attraction, which was found to be more memorable after the experience. More recently, the effect of VR was explored in the cultural heritage context (Jung, tom Dieck, Lee, & Chung, 2016; Tussyadiah et al., 2017). The latest importance of VR for the tourism context is largely linked to the birth of devices such as Samsung Gear VR or HTC Vive which allow for users' to have an immersive experience. Tussyadiah et al. (2017) found VR enhances tourists desire to experience places while tourism attraction have to create highly aesthetic VR experiences without distractions from tourists' surroundings to ensure continuity during the experience.

2.2 Virtual Reality in Tourism and Attitudes of the Elderly

Technology is developing rapidly with the tourism sector being among the industries that are mostly affected by changing means of distribution due to its information intensity as well as the intangibility of products involved. A further trend is population ageing as particularly within Western Europe the increase in older people is supposed to have huge impacts on tourism attractions (Kotler, Bowen, & Makens, 2010). As a result considering the trend of emerging technologies in conjunction with population ageing becomes apparent. Charness and Holley (2004, p. 418) identified the main barriers of technology adoption from the senior market including "access, motivation, ability, design and training". The major problem of technological use by older people is the rapid pace of development. In particularly, it was identified that older people often have cognitive barriers with regards to understanding connections between computer, programs and the internet which, again, decreases the intention to use latest technologies (Charness & Boot, 2009). Quan-Haase et al. (2016) explored the phenomena of elderly technology users and found an often "forced-adoption" imposed by younger family members who expect the elderly to engage with technology. Instead, it was identified that elder technology users' will engage if technology fits their preferences, affordability and ease-of-use (Quan-Haase et al., 2016). Especially in the context of a tourism mining attraction, VR technology could be considered ideal in order to allow elderly visitors to access the mine experience without the necessity of physically climbing down a mine. This raises the issue of accessibility and how technologies, such as VR, can be utilised to provide new opportunities for elderly tourism experiences (Jung & tom Dieck, 2017). Yung and Khoo-Lattimore (2017, p. 2) defined VR as "the use of computer-generated 3D environment, that the user can navigate and interact with, resulting in real-time simulation of one or more of the user's five senses". Quan-Haase et al. (2016) confirmed the importance of ensuring technology's ease of use to ensure adoption by elderly tourists. Previous studies started to explore the adoption of VR for tourism attractions (e.g. D. tom Dieck, M. C. tom Dieck, Moorhouse, & Jung, 2018) however, the adoption behaviour by elderly is relatively unexplored. Therefore, this study aims to investigate the impact of VR on the tourism experience and VR requirements from elderly tourists' point of view.

3 Methodology

Research with regards to tourists' attitudes (elderly tourists in particular) towards the use of VR in tourism has been limited. This study examines elderly tourists' perceptions of VR as it links to consumption of tourism experiences, and the objectives are to:

- Explore the impact of VR on tourist experiences
- Identify elderly tourist requirements for using VR

With a focus of understanding elderly tourists' attitudes towards and perceptions of VR as linked to tourism experiences, an exploratory, inductive inquiry was launched. The qualitative methodology adopted, assists in better understanding the phenomenon at hand, as it is grounded in peoples' experiences.

This study was conducted at Geevor Tin Mine Museum which is a UNESCO World heritage site and cultural mining heritage tourism attraction in Cornwall, United Kingdom. Geevor is an old tin and copper mine from the Eighteenth century and has been preserved as the largest mining site in the UK. The museum's target market is varied and encompasses school groups, families and elderly visitors. However, parts of the museum are difficult accessible (e.g. underground mines) and older visitors often struggle to have the full museum experience. Therefore, as part of a project, VR was thought to be a good alternative to provide elderly tourists with an enhanced experience.

The aim of the study is to examine the impact of VR on elderly tourists' experiences and therefore participants were recruited on site. Sampling was purposive and judgemental to ensure participants already had the motivation to visit the site, which allowed the researchers to assess whether VR had an impact on the actual experience (as opposed to intention to visit). Any participants below 60 years of age were excluded from the study.

Participants were initially asked to experience a five minute VR application using a Samsung Gear VR Headset. The virtual experience show-cased 3 museum locations, including miner's preparatory area/changing rooms, elevator shaft and an underground area. These three stories aimed to show-case visitors a typical daily journey of a miner; arriving at the mine, changing into working clothes and then descending into the mine. Sound was also an important part of the experience and users were able to hear miners talking as part of experiencing the changing rooms; going down the mineshaft involved the noises of metal and the lift opening and closing its gates. After participants experienced the VR application, they were invited for the interviews.

All the participating interviewees were asked for approval to be involved in the study, and certain rights including their anonymity were guaranteed. In total, a number of 23 semi-structured interviews were conducted in June 2016, and lasted on average 20 min. The qualitative answers and the notes taken during the interviews underwent thematic analysis, a method for identifying, analysing and reporting patterns (themes) within data (Braun & Clarke, 2006), in order to identify key concepts expressed by the interviewees. These were then cross-checked for accuracy and validity by an academic moderator who was present during the research. This involved comparing notes to assist in the interpretation of data and to ensure the inclusion of key topics (Gibson & Brown, 2009). Saturation was achieved fairly early in the analysis and last interviews were confirmatory.

4 Findings

A total of 23 semi-structured interviews were conducted. All participants were aged over 60, 11 participants were female and 12 male. The results of the study indicate the perceived impacts of VR on the experience of visiting a heritage attraction by elderly users and their requirements for using it. These two themes were most dominant across all interviews and a number of sub themes emerged throughout the analysis as shown in Table 1.

4.1 Impacts of VR on Tourism Experiences

Participants viewed the VR application as an excellent addition to the real museum experience. All but one participant, found that the VR session in fact enhanced the actual tourism experience, in several ways.

4.1.1 Link Between Past and Present

First, it gave them an opportunity to compare and contrast the past and the present (*P3:* '*Visiting the mine today is fantastic…it sparks your imagination of how it was for the people down there…but the VR makes you…feel how it was there…it brings you a step closer to what it was*'). Whilst the actual visit to the museum today provides a better understanding of the place, space and conditions, miners were

Table 1 Themes and sub-themes of VR experience

Themes	Subthemes
Impact of VR on tourism experience	*Link between past and present*
	Accessibility
	Sharing experiences
	Novelty
Elderly tourists' requirements for using VR	*Presence and Immersion*
	Control
	Storytelling and Human Elements

working under, it remains a museum void of processes and interactions people had with that environment. The virtual reality experience however, provides visual cues of the environment as it were in the past; more 'alive', fully operational with miners performing their everyday duties in that environment.

4.1.2 Accessibility

Secondly, it provided value to those with reduced mobility. Parts of the actual site can be prohibitive to people with access needs, as it entails long and narrow corridors, steps and very low ceilings. Therefore, when moving, walking and bending are difficult to perform, the site becomes inaccessible. The VR application therefore, was perceived by the participants as a valuable addition to the real tourism experience, because it provided a glimpse of the spaces that would otherwise be unreachable. According to one participant: '*P8: it is great value when the legs are weak…I can't go all the way, but now I know what it looks like*'.

Some of the participants also claimed that because of the confined nature of the actual physical environment, they felt uncomfortable to take the risk of visiting due to feelings of claustrophobia (*P21:* '*I wouldn't like to go down am mine like that but that VR is fabulous…there is no fear…*'). Some of the participants also claimed that although they were not usually suffering from claustrophobia, they still would not visit the actual mine because they were afraid of what would happen if they couldn't finish the route (*P10:* '*I don't know what can happen to me or if I'll feel ok for the whole duration of the tour…I need to have the option to sit down or get out…if I don't, I won't go…I won't take the risk*').

4.1.3 Sharing Experiences

Many of the participants visiting the museum were part of larger family groups. Some of the participants mentioned that using the VR experience was beneficial for themselves as well as other members of the family: '*P19: I liked the VR experience, but what I liked even more was that it gave me an opportunity to see the [grand] kids excited, and us bonding over it…it wasn't just babysitting, it was educational*'. Another participant mentioned: '*P14: My daughter-in-law is now 6 months pregnant, and she can't bend to enter the mine. It is not nice to leave one behind, but now at least when we talk about the visit afterwards, she can also feel part of the group*'. The VR experience was therefore viewed by some participants, not just as an integral part of the visit, or even adding value to the visit, it was seen as the only alternative to an otherwise unattainable experience. The added value of the experience is also resonating in the fact that allows the experience to be shared with other members of the group.

4.1.4 Novelty

Also, many of the participants viewed the use of the VR application as '*P11: an attraction in itself*'. None of the participants were familiar with VR applications, although some had 3D experiences in other attractions. For most participants, the VR experience was considered a novelty, and a tourism experience in itself. They felt that it enhanced their visit to the museum greatly, as it not only provided '*P6: an extra layer of conversation*' but it also made the museum '*P9: more worthwhile to visit*'. This attitude is particularly interesting, as the participants who were already at the museum (already had the intention to visit) explained that the VR experience (that they were unaware of before the visit) enhanced the perceived attractiveness of the museum. They felt that the VR experience made the attraction more enjoyable and appealing to visit and re-visit.

4.2 Elderly Tourists' Requirements for Using VR

4.2.1 Presence and Immersion

One of the main points expressed by the participants refers to the sense of 'presence' whilst experiencing the virtual reality application. Most participants commented in very positive terms that they sensed they 'were there' and felt surrounded by the virtual world. Many of the participants even considered that they visited a place rather than they watched a series of images. Those that considered they visited a place, and had high levels of experienced realism, suggested that noise cancelling headsets would assist into minimising the awareness of the real world and therefore enable the immersion into the virtual world, as a way of optimising the experience. Those that felt they watched images, also attributed it to being aware of the real world. For instance, noises and sounds from the real world were distracting from the experience, and therefore could not immerse themselves in the virtual experience. However, for some participants, this simultaneous sense of virtual and real worlds was comforting. It provided a sense of security, reducing levels of stress and anxiety associated with engaging with an unknown experience. As one female participant stated: '*P5: I liked what I saw but I also liked to know I'm still here… you know…it was nice to hear the gentleman's voice…and also I could feel Jake's hand in mine…I knew I was here and it made me feel safe*'.

4.2.2 Control

Users also expressed mixed views with regards to the element of control of the VR experience. Some claimed that they would have preferred to have more control over the pace and speed of the application. They claimed it would have been '*P11: …helpful to be able to pause and take more time me to look at something*' or

‘*P13: …speed up the elevator shaft part that was boring*’. They claimed that being able to start/stop at will and speed up/slow down the pace would make the experience more enjoyable because they would be able to decide how long they could spend on different sections according to the level of interest. On the other hand, there were those who preferred to relinquish control, and just observe the virtual environment as it appeared in front of them. Reasons for this preference included concerns of performance and competency of use [‘*P9: …I'm not sure I could handle it*’, ‘P2: *I would probably do something wrong and miss out on what I could have seen, or even destroy it*’]. Lack of control was welcomed as a means to reduce anxiety which allowed to ‘*P15: …focus on what you see, rather what to do with it*’. Some mentioned that the experience was particularly nice because it felt like ‘*P3: …you were on a conveyor belt*’, and therefore had a chance to immerse in the environment.

4.2.3 Storytelling and Human Elements

One of the key findings regarding elderly tourists’ requirements of VR application is its use for storytelling. All participants agreed that one of the main positive features the VR application is its potential to deliver a story in a more visual, immediate, and lively way. They explained that core motivation to visit the museum in the first place, is to listen to the stories of the people that lived and worked there. The VR application ‘*P16: …goes beyond the narrative*’ making it easier to ‘*P16: … remember facts in a story form*’. For instance, they explained that the experience becomes invaluable, when ‘*P8: … you have a miner walk with you and tell his story of his one hour of preparation and what happened on a typical working day*’.

Participants also highlighted the importance of the inclusion of ‘human elements’ to compliment the storyline, particularly with regards to engaging the senses. They explained that the VR experience on its own is predominantly a visually stimulating experience. They suggested that the experience could be far more immersive if attention was paid to other senses. For instance, incorporating sounds, smells and adjusting room temperature, would make the experience more realistic and convey a better interpretation of the authentic experience. The explained that the story becomes more exciting when visual cues are congruent with the environment (i.e. tools, hats and jackets lying around in the preparation area) and also when ‘atypical’ or ‘special’ events are described (i.e. view of the blasts/ explosions in the mine). Also, sounds such as ‘workers on the background chatting’, ‘rattling of the cage elevator’, ‘water running’, and ‘tools hitting the rock’, create an ambience that better represents the sense of a busy place (perhaps with vibrations). Participants explained that although the VR experience will always be different to the real experience, it can tell the story of the people in a most educational, fun and engaging way.

5 Discussion and Conclusion

This research has contributed to the growing body of literature, through the examination of the impact of VR on elderly tourists' experiences. The findings of the present study are twofold. With regards to the impacts of VR, the study found that the vast majority felt a positive impact of VR onto their museum experience. VR is offering elderly tourists' to reminisce about miners' past and provides them with perceived mobility to experience the mine which would otherwise be inaccessible. In addition, VR allows families to share the entire mining experience as previously elderly visitors were not able to have the same experience as their children and grandchildren. This was considered an essential aspect of an enhanced social experience. Finally, elderly visitors found that VR makes the overall visit more attractive and worth visiting again. With regards to requirements, storytelling came up as an important element of the VR experience, presence and immersion as well as control which was considered highly important when visiting virtual attractions.

Theoretically, these findings add in-depth knowledge into elderly tourists' experience of VR. Previously, there has been limited qualitative research on VR experiences in the tourism context with a specific focus on elderly users. The present study provides a theoretical foundation for further analysis revealing the importance of presence, experienced realism, control and involvement.

Practically, tourism managers can draw important conclusions from these findings regarding the enhancement of their tourism offering for elderly tourists. The study has shown that VR is considered a viable alternative for the provision of content in order to enhance storytelling and increase accessibility. Previously it was unknown whether elderly tourists accept or reject latest technologies such as VR. However, this study has shown an overall positive impact of the VR experience on elderly visitors' experience.

The present qualitative study was conducted using one VR application in a rural tourism attraction. Findings are therefore not generalisable to the wider tourism context. Further qualitative research is required to compare and contrast findings.

References

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77–101.

Charness, N., & Boot, W. R. (2009). Aging and information technology use. *Current Directions in Psychological Science, 18*(5), 253–258.

Charness, N., & Holley, P. (2004). The new media and older adults: Usable and useful? *American Behavioral Scientist, 48*(4), 416–433.

Gibson, W. J., & Brown, A. (2009). *Working with qualitative data*. London: Sage.

Han, D. I., Jung, T., & Gibson, A. (2014). Dublin AR: Implementing augmented reality in tourism. In Z. Xiang & I. Tussyadiah (Eds.), *Information and comunication technolgies in tourism 2014* (pp. 511–523). Vienna: Springer.

Huang, Y. C., Backman, K. F., Backman, S. J., & Chang, L. L. (2016). Exploring the implications of virtual reality technology in tourism marketing: An integrated research framework. *International Journal of Tourism Research, 18*(2), 116–128.

Jung, T., tom Dieck, M. C., Lee, H., & Chung, N. (2016). Effects of virtual reality and augmented reality on visitor experiences in museum. In A. Inversini & R. Schegg (Eds.), *Information and communication technologies in tourism* (pp. 621–635). Heidelberg: Springer.

Jung, T. H., & tom Dieck, M. C. (2017). Augmented reality, virtual reality and 3D printing for the co-creation of value for the visitor experience at cultural heritage places. *Journal of Place Management and Development*, *10*(2), 140–151.

Kotler, P., Bowen, J., & Makens, J. (2010). *Marketing for hospitality in tourism* (5th ed.). Upper Saddle River: Prentice Hall.

Leue, M., Jung, T., & tom Dieck, D. (2015). Google glass augmented reality: Generic learning outcomes for art galleries. In I. Tussyadiah & A. Invesini (Eds.), *Information and communication technologies in tourism 2015* (pp. 463–476). Heidelberg: Springer.

Neuhofer, B., Buhalis, D., & Ladkin, A. (2014). A typology of technology-enhanced tourism experiences. *International Journal of Tourism Research, 16*(4), 340–350.

Quan-Haase, A., Martin, K., & Schreurs, K. (2016). Interviews with digital seniors: ICT use in the context of everyday life. *Information, Communication & Society, 19*(5), 691–707.

tom Dieck, M. C., & Jung, T. (2016). Value of augmented reality to enhance the visitor experience: A case study of Manchester Jewish Museum. *eReview of Tourism Research*, 1–5.

tom Dieck, D., tom Dieck, M. C., Moorhouse, N., & Jung, T. (2018). Tourists' virtual reality adoption: An exploratory study from Lake District National Park, *Leisure studies*.

Tredinnick, L. (2018). Virtual realities in the business world. *Business Information Review, 35*(1), 39–42.

Tussyadiah, I. P., Wang, D., & Jia, C. H. (2017). Virtual reality and attitudes toward tourism destinations. In R. Schegg & B. Stangl (Eds.), *Information and communication technologies in tourism 2017*. Heidelberg: Springer.

Unimersiv (2016). How virtual reality is being used in museums. Received from: https://unimersiv.com/virtual-reality-used-museums/. Accessed December 12, 2016.

Yung, R., & Khoo-Lattimore, C. (2017). New realities: A systematic literature review on virtual reality and augmented reality in tourism research. *Current Issues in Tourism*, 1–26. https://doi.org/10.1080/13683500.2017.1417359.

A Case Study: Assessing Effectiveness of the Augmented Reality Application in Augusta Raurica

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Abstract This paper aims to study and compare the augmented reality experience of two user groups at Augusta Raurica, a Roman archaeological site and an open-air museum in Switzerland. The user groups differentiated within the scope of this study digital natives and digital immigrants. The paper applies the experience economy framework for assessing the differences between the user groups. The data gathered from the surveys and analysis of selected interviews reveal that digital immigrants have better engagement with the augmented reality application of Augusta Raurica than digital natives do. The findings are supporting the debate on assisting tourism destinations to develop more engaging augmented reality content targeting both user groups.

Keywords Augmented reality · Tourism · Experience economy · Digital native · Digital immigrant

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1 Introduction

The tourism industry accounts for a significant portion of the GDP of many countries. Due to increased mobility and the constant increase of tourists globally, the industry is pressured to remain competitive in a very hard-fought global market. Per Han, Jung, and Gibson (2013), tourist destinations that want to become a competitive need to invest in technologies and find ways to derive value from them. Therefore, leveraging advancements in technology to provide efficient services should be one of the top priorities for the industry (García-Crespo et al., 2009). Because of declining visitor numbers in some countries, museums and cultural sites should be the forerunners in adopting new technologies to enhance visitor experience which is currently often perceived as boring and not engaging. Furthermore, because of product customization and personalization, customers are constantly seeking meaningful personal experiences rather than standardized ones (Neuburger & Egger, 2017).

As García-Crespo et al. (2009) argues, "Currently, the tourism industry is demanding an ever-increasing level of value-added services in technologically complete environments, which are integrated and highly dynamic". As a result, the introduction of emerging technologies in the sector benefits both, cultural heritage sites as well as tourists (Tscheu & Buhalis, 2016).

Augmented Reality (AR) allows superimposing virtual objects into real-life views that does not require the detachment of the user from reality (Azuma, 1997). There is a growing interest by the research community in AR. This is seen by the constant increase in the number of scientific papers related to the field in the last years (Werrlich, Nitsche, & Notni, 2017). Although AR technologies have been around for many years, they have only recently shown potential for value creation in the tourism industry (Han et al., 2013). The increased interest in this field is unavoidably related to technological advances in mobile and wireless communications and sensor technologies, leading to the widespread use of smartphones and other devices, allowing for the introduction of AR into the mass market (Yovcheva, Buhalis, & Gatzidis, 2013).

Tourist destinations and service providers that are able to re-think their value creation process through investment and introduction of new technologies are more likely to enhance customer experience (Tscheu & Buhalis, 2016). Moreover, the introduction of AR can increase the entertainment level of tourists concerning information access and the education process at specific sites of interest (Kečkeš & Tomičić, 2017). Cranmer, tom Dieck, and Jung (2018) argue that technology has re-shaped business models in the tourism industry by affecting the behavior, information searching and decision-making process of tourists. Gartner Inc. estimated that in the upcoming decade AR would have a significant influence on the market (as cited in Barsom, Graafland, & Schijven, 2016). The potential of AR to influence the tourism industry has been noted by many researchers.

This paper starts with a literature review on the effectiveness of AR in the tourism industry, by identifying the benefits, challenges, and summarizing existing studies in the field. Furthermore, through a case study at the Augusta Raurica archaeological site we compare the effects of AR on the experience of different user groups, namely digital immigrants and digital natives by applying the experience economy framework. Consequently, the results are analysed and discussed in detail.

Our motivation is to assist the research community and tourist destinations in better understanding the prevailing differences between different user groups with different needs/priorities, in order to develop tailored and more engaging content for them.

2 Literature Review

2.1 *Effectiveness of AR in Tourism—Benefits and Challenges*

There are many applications with AR capabilities have been developed around the world for the tourism industry. The strategies behind the analyzed apps are to serve as tourist guides, to recreate the past, or to give a glimpse into no access zones of significant cultural value (Boletsis, n.d.; Donovan, 2014; "EHC", n.d.; Kim, 2010; "See what is not (yet) there—With the NAI and Augmented Reality", n.d.).

AR is particularly well suited for usage in the tourist industry because of its applicability inside four walls as well as in the open environment (Fritz, Susperregui, & Linaza, 2005). The ability to receive new information through AR while visiting a cultural heritage site or exhibit improves the learning process and leaves an enduring impact on the visitor (Moorhouse, tom Dieck, & Jung, 2017). A study undertaken by Střelák, Škola, and Liarokapis (2016) found out that users adapted easily to AR applications at cultural heritage sites because they perceived them as simple and intuitive. Moreover, by delivering information through AR about different exhibitions and curator processes, museums can enhance the visitor experience (Neuburger & Egger, 2017).

In addition, using AR in museums can provide a solution to issues arising from spatial limitations and the physical exhibitions of valuable objects, as well as hardware investments (Neuburger & Egger, 2017).

Yovcheva, Buhalis, and Gatzidis (2012) identify the relatively recent introduction into the market, limited coverage achieved and the inability to effectively compete against traditional means of information as some of the prevailing challenges for AR in the tourism industry. Kounavis, Kasimati, and Zamani (2012) identify missing compatibility across operating systems affecting content accumulation, dependency on an internet connection for usage, and the high prices of mobile internet bundles as some of the key challenges. Additionally, processing information through AR might result in cognitive overload and confusion, depending on the complexity of the information (Wu, Lee, Chang, & Liang, 2013).

A fundamental challenge for the further development of AR is social acceptance and corresponding issues arising from it such as privacy and fashion aspect for wearables (Azuma et al., 2001).

A study was undertaken by Jung, tom Dieck, Lee, and Chung (2016) in the Geevor Tine Mine Museum with 163 participants found out that the visitor experience was enhanced by the use of mixed reality applications. Similarly, a study carried out with school-children by Moorhouse et al. (2017) at the Manchester Jewish Museum in the UK aimed at assessing whether the technology enhances the experience of visitors, found out that AR adds value to the museum and enhances learning as well as the overall experience of the visitors. Furthermore, another study carried out by Chung, Han, and Joun (2015) aimed at assessing whether AR has the potential to influence a visitor's decision to re-visit a cultural heritage site, found out that the technology has the capability to do so. Moreover, a study undertaken by Neuburger and Egger (2017) at the Dommuseum in Salzburg, arrived at the conclusion that AR enhanced the experience of the participants and has the potential to enhance the experience of museum visitors in general.

3 Problem Statement

A study carried out with the purpose of examining AR user experience in the tourism sector by Střelák et al. (2016) analyzed general differences with regards to the perceived ease of using AR between old and young participants. However, the authors were not able to identify any studies specifically aimed at investigating differences in the augmented reality experience between digital natives and digital immigrants.

Prensky (2001) categorizes users into two groups, the digital natives, born after 1980 and the digital immigrants, born before 1980. Additionally, Prensky (2001) suggests that there is an unfillable gap between these generations and that tech-savviness is a born feature and cannot be learned. On the other hand, Helsper and Enyon (2010) and Wang, Myers, and Sundaram (2013) argue that besides age, additional factors need to be taken into account when assessing whether someone is a digital native or a digital immigrant.

In line with this, we debate further on this topic and investigate on a specific distinction between the user groups, relying on Helsper's and Enyon's (2010) critique of Prensky's (2001) digital natives and digital immigrants categorization. The main question is to assess whether any differences with regard to the overall AR experience between the two user groups exist. Moreover, we investigate if the user's technical skills and technological habits influence their perception of AR have an impact on the effectiveness of AR applications.

4 Methods

We chose the experience economy framework proposed by Pine and Gillmore (1998) for carrying out their case study, as it has already been used in several research papers focused on assessing the effectiveness of AR in enhancing customer experience in the tourism industry (e.g. Jung et al., 2016; Neuburger & Egger, 2017; Radder & Han, 2015).

Pine and Gilmore (1998) propose 4 realms of experience: entertainment, educational, aesthetical, and escapist in which the visitor's participation can either be passive or active and the relative degree to which they can be absorbed or immersed in the experience. With regard to the education experience, nowadays, tourists want to be actively engaged with the destinations they visit and want to educate themselves about them (Falk, Ballantyne, Packer, & Benckendorff, 2012). In line with this, Fotaris, Pellas, Kazanidis, and Smith (2017) argue that AR's potential for making the education process more engaging and immersive has been recognized, and stakeholders are looking for ways to utilize these competencies of the technology in various sectors. With regard to the entertainment domain of the framework, tourists are willing to be entertained while themselves being passive and merely spectators during the process (Pearce, 2008).

Besides, escapist and aesthetic realms are quite similar, as both of them achieve to immerse the visitor during the experience. The major distinction between them is the relative degree of participation during the experience. For example, rafting in the Grand Canyon would represent an escapist experience as it involves active participation, whereas standing over the canyon and overviewing it would be an aesthetic experience, as it does not require active participation (Pine & Gillmore, 1998).

4.1 Survey and Case Study

In order to determine which user group (i.e. digital natives or digital immigrants) the participants belong to, a questionnaire was prepared based on the features proposed by Helsper and Enyon (2010). All the questions are formulated as dichotomous statements (except question 6).

1. *I multi-task when using different technologies.*
2. *I have access to a range of new technologies.*
3. *I am confident in the use of technologies.*
4. *I use the Internet as a first port of call for information.*
5. *I use the Internet for learning as well as other activities.*
6. *I have the following number of ICT devices (mobile phone, computer, smart devices, etc.) in my household.*

7. *I use the Internet first for school/work information.*
8. *I have good or excellent user skills in mobile and internet technologies.*

Using the survey, we categorized participants into user groups, by looking at additional factors besides age. Seven questions (Use of multitasking, Access to new technology, confidence in use, Internet first for information, Internet for learning, Internet for school or work and good or excellent skills) had to be answered positively to qualify as a digital native. Participants, who responded to one or more questions negatively were classified as digital immigrants.

Afterwards, a structured Likert scale survey with questions formulated as statements about the four realms of experience proposed by Pine and Gilmore (1998) was prepared. The survey entailed three questions about each of the four realms of experience adapted from a study carried out by Jung et al. (2016).

Education

1. *I was able to learn new things by using the AR app.*
2. *The experience made me curious and I wanted to explore the topic in more detail after using the AR app.*
3. *I enjoyed the overall learning experience facilitated by the AR app.*

Aesthetic

4. *I found the visual appearance of the content presented by the AR app attractive.*
5. *I liked the level of detail provided by the AR app.*
6. *I found the AR app pleasant and user-friendly.*

Entertainment

7. *I could focus on the content provided by the AR app without getting distracted.*
8. *I was very entertained by the content provided by the AR app.*
9. *The overall experience of using the AR app was fun.*

Escapist

10. *I felt I went back in time and place while using the AR app.*
11. *I felt I was someone else while using the AR app.*
12. *I was completely detached from reality while using the AR app.*

The authors went together with the participants at the site and cautiously instructed them through the AR installment. After having completed the tour, both surveys were handed to all participants. After collecting the completed surveys from the participants, the findings were analyzed so that they allow a comparison between both user groups. Moreover, based on the subsequent analysis, outliers in the responses were identified, and questions were prepared for holding qualitative interviews with selected participants for assisting the authors in gaining a better understanding about the responses.

4.2 Making Visible the Invisible—Augusta Raurica AR App

The location chosen for carrying out the case study is the archaeological site of Augusta Raurica located in Kaiseraugst, Switzerland. The AR-enabled app aims to recreate parts of the archaeological site of Augusta Raurica by providing a look into what life might have looked like during Roman times. In addition, the app provides information about publicly inaccessible artifacts discovered at the site ("APP—Making visible the invisible", n.d.). The AR app is divided into four sections focusing on different visitor areas.

The app supports the visitor to find the locations presented in different sections with the help of an online map. The visitor receives information on a physical information panel (see Fig. 1). Within the app, the visitor is guided through extra information and an audio guide, as well as access to the AR mode. A 3D model will be superimposed onto the information panel. Figure 2 shows the AR experience of the section "The Baths".

For the case study, the app version 1.0.1 was used. Both Android and iPhone variants were tested. No difference in experience and usage was noted between the two fabrics.

Fig. 1 Information panel with visitors

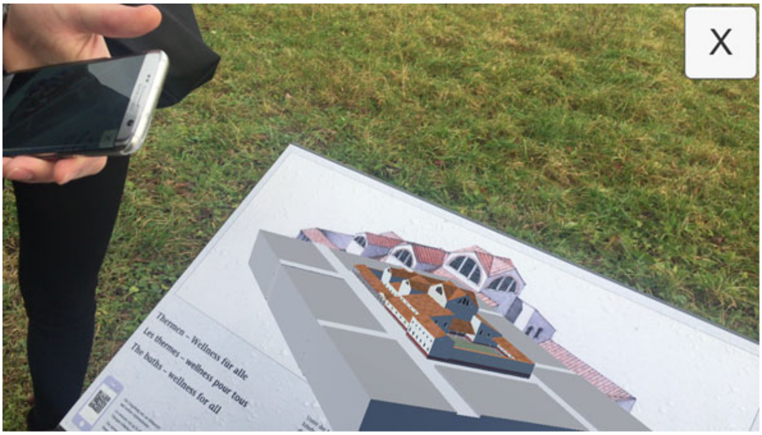

Fig. 2 Screenshot of the AR mode, section "The Baths"

5 Results

5.1 Characteristics of Study Participants

The case study was conducted on-site at Augusta Raurica in Kaiseraugst, Switzerland between January 15 and January 19, 2018, with 16 participants (9 female/7 male). The participants had various professional backgrounds and were aged between 25 and 67 years old. Ten participants were classified as digital native and the remaining six as digital immigrants. Table 1 shows the results of the initial survey including the classification.

Digital immigrants were of a higher age with an average of 55 years. However, it is important to state that age is not a reliable variable to categorize the participants into the respective groups. One participant, who was 63 years old, answered all

Table 1 Characteristics of user groups

	Digital natives	Digital immigrants	Overall
Total participants (female/male)	10 (3/7)	6 (6/0)	16 (9/7)
Mean age	34	55	42
Mean number of ICT devices	5.90	4.83	5.50
Multitasking (%)	100	0	63
Access to technology (%)	100	50	81
Confidence in use (%)	100	67	88
Internet first for information (%)	100	83	94
Internet for learning (%)	100	67	88
Internet for school/work (%)	100	33	75
Good or excellent skills (%)	100	0	63

questions positively, and therefore was categorized as a digital native. Digital natives had typically more ICT devices in their households. None of the digital immigrants said that they were multitasking when using different technologies.

5.2 *Results of the Case Study*

When we observed case study results, digital immigrants rated almost all questions higher than digital natives. There were only two exceptions: Q1: "I was able to learn new things by using the AR app", Q6: "I found the AR app pleasant and user-friendly". The biggest difference in rating was for Q10: "I felt like being back in time". While digital immigrants rated a mean score of 4.0, digital natives only rated 2.2. The detailed results are shown in Table 2.

By combining the 12 Questions into the four realms, it is possible to obtain a clearer overview. Digital immigrants have rated all four realms slightly better with a difference of 0.3–0.6 points on the Likert scale. The best rating by both user groups was the *education* and the worst was *escapist* realm. Table 3 shows this analysis.

Table 2 Likert scale rating of the survey

Question[a]	Digital natives	Digital immigrants	Mean total
Q1. Learning new thing	3.4	3.2	3.3
Q2. Made curious and wanted to explore	3.4	4.5	3.8
Q3. I enjoyed the learning	3.1	3.2	3.1
Q4. Visual appearance attractive	2.6	3.5	2.9
Q5. Level of detail	2.3	3.2	2.6
Q6. Pleasant and user-friendly	3.7	3.3	3.6
Q7. Could focus	3.5	4.5	3.9
Q8. Very entertained	2.5	3.2	2.8
Q9. Was fun	3.7	3.8	3.8
Q10. Felt back in time	2.2	4.0	2.9
Q11. Felt like someone else	1.9	1.5	1.8
Q12. Was completely detached	1.6	2.0	1.8
Mean total score	33.2	38.8	36.0

[a]Questions have been shortened for visibility

Table 3 User groups rating in the experience economy realms

	Digital natives	Digital immigrants	Mean
Education	3.3	3.6	3.4
Aesthetic	2.9	3.3	3.0
Entertainment	3.2	3.8	3.5
Escapist	1.9	2.5	2.1

6 Interviews

The qualitative data helped the authors to get a holistic or general overview of the differences, whereas the four qualitative interviews held with six participants, two digital natives, and four digital immigrants, helped to gain a more detailed understanding about the differences in user experience.

The paper's objective of assessing effectiveness in the AR experience in Augusta Raurica between the different user groups was successfully met. The results from the performed case study revealed that there are expectation differences in the AR experience between the user groups. Overall, digital immigrants were more engaged by the technology than digital natives. Moreover, during the interview with a digital native, it became evident that they had high expectations about the AR Installation and the app. The actual capabilities and functionalities of the AR application did not match the expectation, as can be derived from the statement below:

> The idea of the app was good in my opinion, and I was very excited before using it. However, the moment I started using the AR app I did not like it at all. The app itself was complicated, the visuals were nothing special and did not even open correctly on my phone. […] I was expecting much more from the app and to be more interactive. If they don't improve the AR, the app will not find any admirers. I was totally disappointed. (Digital Native, 1)

Moreover, the same attitude can be observed by the statement below from another digital native:

> Initially I was quite excited about having to try the AR app at the Augusta Raurica, as the idea itself seemed very innovative and intriguing to me. Nonetheless, I have to say that after the whole experience I was quite disappointed. I expected a lot more from the app in terms of the augmented reality technology. It did not add any value to what you could already see in the picture at the sight. (Digital Native, 2)

Another aspect regarding user-friendliness met the literature review findings. Střelák et al. (2016) found out that the perceived ease of using AR technologies differs between older and younger participants. The case study came to the same conclusion if we refer to the results of Q6 of Table 2. This is also supported by the following statement from a digital native when asked why the young respondent gave a good rating to Q6: "I found the AR app pleasant and user-friendly":

> Well, this is because the app was easy to install and navigate through. The design was appealing, and nothing was too messy, so it was quite easy to find what you were looking for. (Digital Native, 3)

Contrary, as part of the qualitative interview an older digital immigrant, when asked why a bad rating is assigned to the same question:

> Yes, it confused me. If I had not been looked after by you (referring to the instructor), I would not have tried it. I would have given up quickly, it would be difficult. (Digital Immigrant, 1)

This is in line with Wu et al. (2013), who state that processing information through AR can lead to cognitive overload and confusion. Furthermore, Yovcheva et al. (2012) identify the inability to effectively compete against traditional means of information as a prevailing challenge for AR in the tourism industry. This is confirmed by the statement from a digital immigrant below:

> I'd rather read something, look at something, but don't like to deal with technology. Access to technology is not my topic. I prefer other ways. (Digital Immigrant, 2)

Observations showed, that digital immigrants found it hard to install the app and start using it. To overcome this issue, digital immigrants suggested to provide ready-to-use systems, for example, pre-installed tablets or VR glasses, which would be rentable on-site. They would be willing to pay for this kind of service:

> The idea to use VR glasses, which display more details and has more information included, would make the installation much more interesting. You would need to pay something for such a service, but that is fine. (Digital Immigrant, 3)

Furthermore, Moorhouse et al. (2017) argue that AR can improve the learning process at cultural heritage sites. Participants of the case study were aware of the capabilities of AR to enhance the learning process judging by the following statement from a digital immigrant:

> Historical backgrounds can be conveyed in a playful way without having to learn. If the knowledge comes with pictures, it would be much more interesting to learn. That would be less dry for learning: Learning without being aware of it. (Digital Immigrant, 3)

7 Conclusion

As already discusses thoroughly throughout this paper, one of the most promising technologies that have the potential to support tourist destinations is AR. Although the technology has been around for quite some time, we have only recently witnessed the development and implementation of use cases in the tourism industry. Given its infancy stage, the research community and tourist destinations have only now started to conceptualize and understand how the technology can deliver actual benefits to the destinations implementing such technologies and to the customers using them.

We looked closely to the AR experience of digital natives and digital immigrants with Augusta Raurica's app. The data from the surveys showed that digital natives rated their experience in all four experience economy realms slightly worse. Interviews revealed, that digital natives had higher expectations of AR than digital immigrants. Deriving from this study, we assess that the tourist destinations with AR experiences should target both user groups and aim to fulfil the expectations by providing richer content and user-friendly applications.

As mentioned in the introduction chapter, our motivation is to assist the research community and tourist destinations in better understanding the prevailing differences between both user groups, in order to develop tailored and more engaging AR experiences and AR content for them. There are clear limitations that we are aware of and should be improved in further investigations; small sample size, and the single case study site making this study not representative of AR installations in the tourism industry in general. Furthermore, the AR installation at Augusta Raurica can be considered as a small project and a more developed AR installation might have led to different results. Our opinion is that a bigger sample size and performing case studies at several state-of-the-art AR installations in tourist destinations could lead to better and more detailed results. Subsequently, applying a combination between the experience economy and another framework might deliver additional input that this study was not able to cover.

References

Azuma, R., Baillot, Y., Behringer, R., Feiner, S., Julier, S., & MacIntyre, B. (2001). Recent advances in augmented reality. *IEEE Computer Graphics and Applications, 21*(6), 34–47.

Azuma, R. T. (1997). A survey of augmented reality. *Presence: Teleoperators and Virtual Environments*, *6*(4), 355–385.

Barsom, E. Z., Graafland, M., & Schijven, M. P. (2016). Systematic review on the effectiveness of augmented reality applications in medical training. *Surgical Endoscopy, 30*(10), 4174–4183.

Boletsis, C. (n.d.). Welcome to CorfuAR website! CorfuAR. Retrieved November 26, 2017 from http://www.corfuar.com/.

Chung, N., Han, H., & Joun, Y. (2015). Tourists' intention to visit a destination: The role of augmented reality (AR) application for a heritage site. *Computers in Human Behavior, 50,* 588–599.

Cranmer, E. E., tom Dieck, M. C., & Jung, T. (2018). How can tourist attractions profit from augmented reality? In *Augmented reality and virtual reality* (pp. 21–32). Cham: Springer.

Donovan, J. (2014). Timetraveler app allows you to see the berlin wall story in augmented reality-Techcrunch. Retrieved November 26, 2017 from https://techcrunch.com/2014/09/22/timetraveler-app-allows-you-to-see-the-berlin-wall-story-in-augmented-reality/.

EHC. (n.d.). Heritagecities. Retrieved November 26, 2017 from http://www.heritagecities.com/stories/explore.

Falk, J. H., Ballantyne, R., Packer, J., & Benckendorff, P. (2012). Travel and learning: A neglected tourism research area. *Annals of Tourism Research, 39*(2), 908–927.

Fotaris, P., Pellas, N., Kazanidis, I., & Smith, P. (2017, October). A systematic review of augmented reality game-based applications in primary education. In *Proceedings of the 11th European Conference on Game-Based Learning (ECGBL 2017)* (p. 181).

Fritz, F., Susperregui, A., & Linaza, M. T. (2005). Enhancing cultural tourism experiences with augmented reality technologies. In *6th International Symposium on Virtual Reality, Archaeology and Cultural Heritage (VAST).*

García-Crespo, A., Chamizo, J., Rivera, I., Mencke, M., Colomo-Palacios, R., & Gómez-Berbís, J. M. (2009). SPETA: Social pervasive e-tourism advisor. *Telematics and Informatics, 26*(3), 306–315.

Han, D. I., Jung, T., & Gibson, A. (2013). Dublin AR: Implementing augmented reality in tourism. In *Information and communication technologies in tourism 2014* (pp. 511–523). Cham: Springer.

Helsper, E. J., & Eynon, R. (2010). Digital natives: Where is the evidence? *British Educational Research Journal, 36*(3), 503–520.

Jung, T., tom Dieck, M. C., Lee, H., & Chung, N. (2016). Effects of virtual reality and augmented reality on visitor experiences in museum. In *Information and communication technologies in tourism 2016* (pp. 621–635). Cham: Springer.

Kečkeš, A. L., & Tomičić, I. (2017). Augmented reality in tourism-research and applications overview. *Interdisciplinary Description of Complex Systems (INDECS), 15*(2), 157–167.

Kim, G. (2010). Tuscany +: Augmented reality tourism app. Mobile marketing and technology. Retrieved November 26, 2017 from http://mobilemarketingandtechnology.com/2010/05/07/tuscany-augmented-reality-tourism-app/.

Kounavis, C. D., Kasimati, A. E., & Zamani, E. D. (2012). Enhancing the tourism experience through mobile augmented reality: Challenges and prospects. *International Journal of Engineering Business Management, 4,* 10.

Moorhouse, N., tom Dieck, M. C., & Jung, T. (2017). Augmented reality to enhance the learning experience in cultural heritage tourism: An experiential learning cycle perspective. *eReview of Tourism Research*, *8*.

Neuburger, L., & Egger, R. (2017). An afternoon at the museum: Through the lens of augmented reality. In *Information and communication technologies in tourism 2017* (pp. 241–254). Cham: Springer.

Pearce, P. L. (2008). Tourism and entertainment: Boundaries and connections. *Tourism Recreation Research, 33*(2), 125–130.

Pine, B. J., & Gilmore, J. H. (1998). Welcome to the experience economy. *Harvard Business Review, 76,* 97–105.

Prensky, M. (2001). Digital natives, digital immigrants part 1. *On the Horizon, 9*(5), 1–6.

Radder, L., & Han, X. (2015). An examination of the museum experience based on Pine and Gilmore's experience economy realms. *Journal of Applied Business Research, 31*(2), 455.

See what is not (yet) there—With the NAI and augmented reality. (n.d.). Het Nieuwe Instituut. Retrieved November 26, 2017 from http://en.nai.nl/museum/architecture_app/item/_pid/kolom2-1/_rp_kolom2-1_elementId/1_601695.

Střelák, D., Škola, F., & Liarokapis, F. (2016, June). Examining user experiences in a mobile augmented reality tourist guide. In *Proceedings of the 9th ACM International Conference on Pervasive Technologies Related to Assistive Environments* (p. 19). ACM.

Tscheu, F., & Buhalis, D. (2016). Augmented reality at cultural heritage sites. In *Information and communication technologies in tourism 2016* (pp. 607–619). Cham: Springer.

Wang, Q. E., Myers, M. D., & Sundaram, D. (2013). Digital natives and digital immigrants. *Business & Information Systems Engineering, 5*(6), 409–419.

Werrlich, S., Nitsche, K., & Notni, G. (2017, June). Demand analysis for an augmented reality based assembly training. In *Proceedings of the 10th International Conference on PErvasive Technologies Related to Assistive Environments* (pp. 416–422). ACM.

Wu, H. K., Lee, S. W. Y., Chang, H. Y., & Liang, J. C. (2013). Current status, opportunities and challenges of augmented reality in education. *Computers & Education, 62,* 41–49.

Yovcheva, Z., Buhalis, D., & Gatzidis, C. (2012). Overview of smartphone augmented reality applications for tourism. *e-Review of Tourism Research*, *10*(2), 63–66.

Yovcheva, Z., Buhalis, D., & Gatzidis, C. (2013). Engineering augmented tourism experiences. In *Information and communication technologies in tourism 2013* (pp. 24–35). Berlin, Heidelberg: Springer.

Virtual and Augmented Reality Technologies to Enhance the Visitor Experience in Cultural Tourism

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Abstract Cultural tourism has been identified as an important economic and social contributor worldwide. Main drivers have been linked to an increasing desire for cultural awareness, meaning-creation and learning. An increasing body of research explores the application of VR and AR in this context. While previous studies outline VR and AR as promising technologies to positively influence the visitor experience, these typically do not focus on how such technologies should be built to suit the context or add value to tourists. This study investigates elements affecting the tourist experience in the cultural tourism context from a theoretical perspective by discussing the impact of VR and AR technology on the visitor's learning experience. It offers contributions in the area of cultural tourism and consumer psychology, discussing tourist sites mediated by engaging technologies to enhance the visitor experience. Further research is highlighted in the area of VR and AR development through purpose-driven design.

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1 Introduction

Cultural tourism has long been identified as an important economic and social contributor in Europe and globally (Richards, 1996), developing from a niche market to a key driver of tourism in a number of destinations. According to McKercher, Wong, and Lau (2006), this development has been largely triggered by tourists seeking cultural awareness in form of meaning-creation and learning. As a result, numerous cultural tourist attractions have attempted to differentiate themselves by exploring opportunities to offer visitors an enhanced experience on site to amplify tourists' enjoyment. Self-motivated and self-guided learning was identified as one of the key motivators of visitors to engage with cultural tourism products (Ismagilova, Safiullin, & Gafurov, 2015), suggesting a number of use cases to support tourists along the visitor journey. Self-motivated and self-guided learning have made noteworthy contributions in form of audio guides as well as more recent developments such as mobile applications that are able to present information and storytelling to the individual's pace and interest. However, as technology opens new opportunities to reshape the visitor experience, a number of studies have started to investigate the benefits of augmented (AR) and virtual reality (VR) applications in the cultural tourism context (Chung, Lee, Kim, & Koo, 2017; Jung, Chung, & Leue, 2015; Raptis, Fidas, & Avouris, 2018).

Offering an added layer of virtual enhancement, AR and VR have been positioned as a promising tool in the cultural tourism context to enhance the tourist experience (Jung, tom Dieck, Lee, & Chung, 2016). However, previous studies lack discussion on how AR and VR should be implemented for mass adoption and return on investment. As previous studies were exploratory, it is questionable whether a recommendation to invest in AR and VR is practical from an industry perspective. Because research outcomes have depended on prototype applications and demos, in-depth investigations of user interaction and impact on the visitor experience have been lacking. Thus, we lack the full picture on how AR and VR applications impact the visitor experience as a whole. A key question remains whether such technologies would help visitors to connect with cultural heritage or degrade the experience due to the added digital layer between the tourist and the cultural object, or technological challenges that prevent the unobtrusive interaction. Such developments need to be carefully designed in order to be perceived as meaningful and desirable for tourists.

This study aims to conceptually outline factors that shape the visitor experience in the cultural tourism context with a focus on the visitor's learning experience as key motivator for visiting cultural tourism destinations. Furthermore, the paper discusses how AR and VR technology development should be approached to ultimately enhance the overall visitor experience, linking consumer behaviour and psychological perspectives with the cultural tourism context in an attempt to bridge the two research areas with purpose-driven AR and VR development.

2 Literature Review

2.1 Cultural Tourism

While cultural tourism has often been difficult to define due to the complex nature of the meaning of ‘culture’ (McKercher et al., 2006; Richards, 1996), Silberberg (1995) characterized cultural tourism as ‘visits by persons from outside the host community motivated wholly or in part by interest in the historical, artistic, scientific or lifestyle/heritage offerings of a community, region, group or institution’. Cultural tourism, which was once considered as a niche market, has developed into a conventional building block for contemporary tourism and became a key driver for many tourists to travel. Thus, cultural tourism turned into an important economic and social contributor in Europe and globally (Richards, 1996) offering diverse products and services to a broad target audience.

Visitors’ self-motivation of understanding and meaning making for cultural exposure in the context of foreign and own history motivates millions of tourists yearly to engage in cultural sites and destinations. Travelers created an appetite for authentic cultural experiences in heritage, ethnicity, cuisine, crafts, arts, and music, continues to expand. Cultural tourists are tourists who have interest in visiting heritage or cultural sites. According to different tourism studies (Kerstetter, Confer, & Graefe, 2001; Silberberg, 1995), they are believed to spend more than the average tourist, be highly educated, have a higher disposable income, be older and stay longer at a destination. However, culturally-motivated visits range from purposeful to incidental cultural travel. McKercher et al. (2006) distinguish between five cultural tourist categories: (1) Purposeful cultural tourists whose primary motivation for visiting a destination is to gain a deep cultural experiences; (2) sightseeing cultural tourists whose experiences are less deep but still primarily driven by culture; (3) serendipitous cultural tourists who do not travel for cultural reasons in the first place, but happen to have a deep cultural experience; (4) casual cultural tourists who do not have a particular motive and a shallow experience and finally (5) incidental cultural tourists which have no motive whatsoever to travel for culture and have very shallow experiences.

While Liu (2014) argues that the growing cultural tourism segment can be attributed to a growing demand for travel driven by economic growth, Falk, Ballantyne, Packer, and Benckendorff (2012) and Ismagilova et al. (2015) suggest that cultural tourism has often been linked to an increasing desire for cultural awareness and learning. Altunel and Erkut (2015) agree that learning, enjoyment and escape are the main factors determining the visitor experience in heritage destinations. In this sense, it is important to understand the whole tourism experience when visiting a cultural destination—what are the needs and motivations of a visitor and can culture, meaning making and learning me made more accessible?

Recently, experiential and participative tourism activities stimulated by arts, authentic artefacts, local festivals and cultural attractions allow tourists to engage in and witness extraordinary experiences (Rojek, 2002). Nevertheless, cultural visitors primarily prefer to see historic sites, buildings and monuments where they are seeking to encounter historic places (Hall & Zeppel, 1990). According to Brida, Dalle Nogare, and Scuderi (2016), most museum visitors are searching for a 'light consumption' experience. Thus, people are not particularly interested in culture outside their travel experience. Serendipitous and casual cultural visitors find it difficult to connect to presented cultural artefacts. Some tourism scholars (Chang, Backman, & Huang, 2014) propose a more creative and engaging form of tourism by integrating tourists in an active, long-lasting form of experience.

2.2 Visitor Experience

Grounded in early psychological research (see Jantzen, 2013 for an extensive review), experience has been an essential object of study in tourism research (e.g. Arnould & Price, 1993; Beedie & Hudson, 2003; Sims, 2009; Tan, Kung, & Luh, 2013; Tsaur, Yen, & Hsiao, 2013; Zajchowski, Schwab, & Dustin, 2016; for review, see Scott & Le, 2017). The reason for this is twofold. First, the experience of the (cultural) tourist is of essential importance to the cultural tourism industry, as experience is the core economic offering in tourism, and adds substantial economic value (Pine & Gilmore, 1998). Second, the tourist experience has been of interest to academics as it is the main pull factor for tourism destinations, heritage sites and related cultural venues, and additionally because of its demonstrable relationship with psychological well-being and quality of life (Fredrickson, 1998, 2000).

2.2.1 Elements Affecting the Visitor Experience

The interest in the tourist experience has led academics to search for the core elements that define or constitute an experience. As reviewed by Scott and colleagues (Scott & Le, 2017), besides the physical context of the heritage site or destination—the stage on which the experience takes place—a number of prime candidates have been identified: *Attention* directs our mental resources to stimuli that are perceived as being salient. *Involvement* refers to a person's level of interest and personal relevance in relation to the staged offerings at a site or destination; *Engagement* is a complex construct involving multiple mental processes, all related to the feeling of being 'in the moment'; *Immersion* is the sensation of being surrounded by a completely different reality, and is most prominently studied in the context of gaming and virtual reality (Ermi & Mäyrä, 2005). Finally, there is the related notion of c*ognitive absorption*, conceptually close to flow (Csikszentmihalyi, 1990), in which five dimensions are distinguished: temporal dissociation, attentional focus, increased enjoyment, personal control and curiosity. Besides these well-established constituent elements of tourist experiences, more recently there has been a growing awareness of the importance of *emotions* in shaping tourist experiences and in making them memorable (Li, Scott, & Walters, 2014; Moyle, Moyle, Bec, & Scott, 2017; Skavronskaya et al., 2017). Hooper-Greenhill et al. (2003) among others investigated factors that increase the retention of information and enhance learning in the cultural tourism context due to emotional connectedness. According to Bond (2014), active visitor engagement was identified as key driver of improved information retention.

2.2.2 Visitor Engagement for Enhanced Learning Experience

According to Hooper-Greenhill et al. (2003), learning was argued to influence the development of attitudes and values, while emotions positively influenced the desire to acquire knowledge. This view closely follows Kolb's definition of learning, as "the process whereby knowledge is created through the transformation of experience" (Kolb, 1984, p. 38) and the suggested attachment of the learner's emotions. While learning is often seen as a lifelong process, Minocha, Tudor, and Tilling (2017) suggest that the learning process entails reflective observation as well as active experimentation, both of which affect the overall learning experience and are closely linked to the learner's emotions. While the Experiential Cycle (Kolb, 1984) is a useful tool to study the implementation of technology to enhance the learning experience, it also identifies a need to clearly understand the factors that shape the learner's experience. Ultimately, understanding how emotions affect the concrete experience and abstract conceptualization of the learning process is vital to attain a better grasp of what the learning experience entails.

Implementation of technology to support the learning process was recognized as an opportunity to redefine innovative learning possibilities. However, Bond (2014) argued that implementation alone was not sufficient to make a measurable impact on the learning experience of users. Instead, user interaction had to be carefully designed to encourage engagement of the learner with the provided content and result in an enhanced learning outcome. Stewart (2014) similarly suggested that technology should support concentration and motivation of learners to achieve the desired result. Naturally, development of emerging technologies such as AR and VR requires in-depth investigation how these can enhance the learning experience in a cultural tourism context.

2.3 AR and VR

AR and VR have received a lot of attention since being introduced in the consumer market through devices such as Oculus Rift, Google Cardboard or Magic Leap Lightwear. However, according to Bonetti, Warnaby, and Quinn (2018), AR as well as VR have already been implemented in a number of industry contexts. While both types of technology are often packaged into the frame of ‘mixed reality’, it needs to be recognized that each has its unique approach to generating a virtual enhancement of reality and deserve to be considered individually for purposeful development and implementation. AR was defined as the overlay of computerized information that is projected into the view of the user through devices such as smartphones, tablet computers and wearable devices such as AR glasses (Rauschnabel & Ro, 2016). In this form, AR can be categorized into two key pillars, marker-based and GPS-based AR. While GPS-based augmentation of the real environment seems to be the logical method of AR implementation for tourism purposes, it was argued to lack sufficient accuracy as well as processing power of current devices to project meaningful AR overlays to enhance the tourist experience (Gherghina, Olteanu, & Tapus, 2013). On the other hand, marker-based AR enhancements are triggered through ‘markers’ that bind virtual content to specific objects or pictures and were therefore regarded the more accessible form of AR enhancements. Apart from mobile-based AR applications, site-based AR was mentioned as a third form of AR, which uses fixed installations at certain locations such as theme parks and retail outlets, enabling virtual augmentations for on-site users (Williams & Mascioni, 2017). In contrast to AR, VR uses a computer-generated environment to completely immerse the user into a virtual world (Tussyadiah, Wang, Jung, & tom Dieck, 2018). VR has received more attention due to the exploding amount of demos and applications, both in form of CG animated as well as 360-degree virtual environments particularly in the gaming and entertainment sector. However, it has made little impact in the consumer market relative to expectations and predictions (Abrash, 2016), despite the increasing amount of use cases in theme parks or other tourist destinations. Underlying reasons might be the previously largely limited accessibility to consumers due to the need of using a set of VR-glasses or VR-enabling headset such as Samsung Gear VR or Google Cardboard using high-end smartphones, or the currently limited value that VR can provide compared to the required financial investment. A number of cultural tourism providers have attempted to implement AR and VR in their context to enhance the visitor experience and attract more tourists.

2.4 AR, VR Use Cases and Prior Studies in Cultural Tourism

Many cultural tourism sites such as art galleries, museum or cultural heritage sites have discovered AR and VR in the past few years. They have enhanced their visitor experiences with innovations ranging from virtual enhancements to re-live historical sites and events, engage with content in museums, or to visit remote destinations in virtual environments. Whereas most AR/VR experiences start off as a research or pilot project (Fino, Martín-Gutiérrez, Fernández, & Davara, 2013; Fritz, Susperregui, & Linaza, 2005; Han, Jung, & Gibson, 2013), some have recently expanded and commercialized. Cultural heritage sites and destinations follow different strategies in implementing AR/VR.

A recent study of Marasco, Buonincontri, van Niekerk, Orlowski, and Okumus (2018) examined the potential of VR to increase destination competitiveness. The study revealed a positive and significant effect of visual appeal (PVA) of VR and emotional involvement (EI) on tourists' behaviour visiting a cultural heritages site. Appealing visuals and emotional triggers in VR applications allegedly increase likelihood of visiting cultural sites, as AR/VR often portrays an optimal virtual representation of the real experience. AR and VR can also increase cultural tourism accessibility. Cultural sites welcome a more diverse target group, with different interests. To stay attractive for visitors, new technologies are often key for visitor engagement. A recent study from Puyuelo, Higón, Merino, and Contero (2013) analysed AR as a tool to increase accessibility to architectural and cultural monument sites. The AR application supported the understanding of a UNESCO World Heritage location by letting users identify and visualise 3D models. The experience was positively evaluated, reporting a more engaged experience in terms of aesthetic and figurative appeal, enjoyment, and interactivity.

Industry is following these research pioneers, implementing VR on a large scale by launching these technologies mostly as interactive storytelling platforms engaging visitors in tourist attractions or urban destinations. Thirty-five major art museums in France cooperate in the project *eMotion* to animate art exhibitions and let the visitor travel around the world. Animated characters come to life in a symbiosis of photo, art, and digital animation to tell stories and let the visitor explore the virtual world (De Paola, 2018). Commercial projects often aim at engaging potential visitors in the pre-travel phase to trigger their interest. Microsoft's HoloMaps and HoloTour, for instance, uses 360-degree video content and spatial sound to encourage the user to move around the CG-augmented places such as Machu Picchu or the Colosseum in Rome without traveling to the actual location (Microsoft, 2017). However, as the HoloLens AR headset, which delivers these experiences, might not be yet affordable for mainstream tourism applications, other commercial projects using VR make use of cheaper headsets such as Google Daydream View headset or Cardboard. The *Discovery TRVLR* application from Google and Discovery Communications try to address a bigger audience with their VR experiences. The project aims to make remote locations more accessible by inviting the virtual traveller to follow a local host in spectacular tour guides (Discovery VR, 2018). Other early adopters, largely developing VR experiences on the HTC Vive, have access to much of the VR travel content, ranging from a Grant Canyon CR Experience to Stonehenge VR Sandbox (Steam, 2017a, 2017b).

3 Proposed Framework

Based on the reviewed literature, we propose the following conceptual framework. In this framework, the final aim is defined in the cultural tourism context as the overall learning experience of the visitor. The framework adapts the Experiential Cycle (Kolb, 1984) to define the effect of AR and VR implementations on the visitor's learning experience. In this regard, the concrete experience, which was defined by Kolb and Kolb (2005) by sensory and post-sensory experience of the visitor, is linked to the visitor's emotional attachment of the learning experience. Thus, emotions are needed to solidify the impact on the overall learning experience and therefore should be clearly understood to avoid creating negative emotions in the process, which influences the overall experience. Furthermore, we propose that active experimentation is triggered by the degree of visitor engagement with the tourism product. The higher the visitor engagement, the higher the impact on the learning experience by means of increased active experimentation. AR and VR implementation has therefore a high potential to influence the degree of visitor engagement through the interactive user experience the technology can provide. Furthermore, AR could potentially produce means of enhancing reflective observation through virtual enhancements. As abstract conceptualization in the Experiential Cycle (Kolb, 1984) was regarded a process that takes place within the individual, it is not further discussed in this paper. Nonetheless, to develop and implement AR and VR technology meaningfully in the cultural tourism context, it is vital to understand the benefit this technology will provide for the end-user. In the case of employing AR and VR in the cultural tourism context, it is therefore imperative to understand what the underlying tourist motivations to visit the destination entail. Potential applications need to be developed to support tourists' motivations and should not be developed separately from the overall experience. The need to understand how emotions affect the learning experience and the resulting overall tourist experience in the cultural tourism context is often overlooked, despite being a crucial element in the learning process (Fig. 1).

4 Discussion

This paper aimed to investigate elements affecting visitor experience in the cultural tourism context by discussing the impact of VR and AR technology and the resulting paradoxical effects on the overall experience in the cultural tourism context. In this

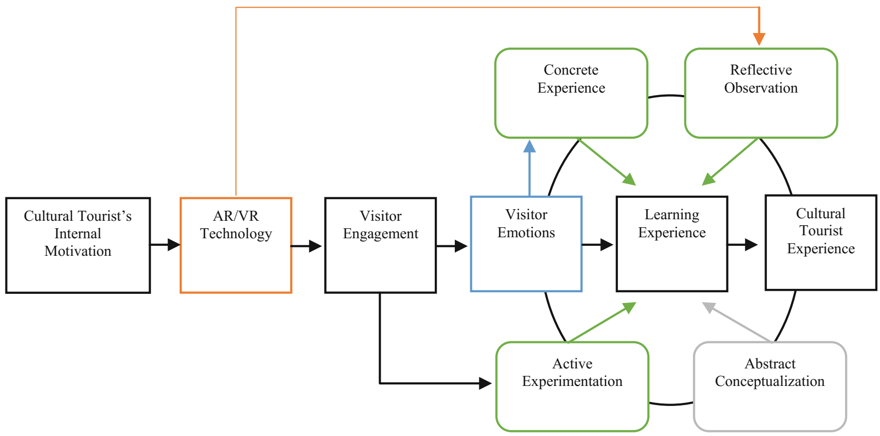

Fig. 1 Conceptual framework for AR/VR impact on the learning experience of cultural tourism visitors

discussion we reflect on five elements: (1) the importance of customer-centric design; (2) the objective of technology implementation; (3) technological issues with AR/VR implementation; (4) effects of AR/VR on the visitor experience and (5) the increasing use of EEG and physiology in measuring experiences.

4.1 The Importance of Consumer-Centric Design of Visitor Experiences

As pointed out previously in this paper, tourists are increasingly seeking authentic and meaningful visitor experiences. Although the degree of sought meaningfulness and authenticity may differ between tourist groups (McKercher et al., 2006), it seems that in many cases the authenticity and meaningfulness are more in the eye of the beholder, the visitor. As Wang (2000) pointed out, many visitors are seeking a specific form of authenticity in the locations they visit, namely existential authenticity. What this means is that not so much the objective authenticity of the touristic object matters, but the way in which it helps visitors to create their own idiosyncratic, meaningful authentic experience. This means that in presenting the touristic object, one should carefully consider how this object creates meaning for the visitor, how it connects to his/her values and enables the visitor to create his/her own version of the experience. This is where customer-centric design becomes highly relevant, and in particular so-called user empathy—finding out what truly matters to the visitor at the level that the visitor may not even be consciously aware (Kouprie & Visser, 2009). Having this deeper level of understanding allows AR/VR designers to build emotionally engaging layers to enhance the experience of cultural tourism sites.

4.2 Objective of Technology Implementation—Need for Meaningful Design of Emerging Consumer Technologies Such as AR/VR

Technology has continuously enhanced human life, making processes faster, more effective, convenient and accessible. However, when looking at early stages of consumer technologies until mass adoption, a common cycle can be observed time and time again (Weaver, Jansen, Van Grootveld, Van Spiegel, & Vergragt, 2017). While early studies are often focussed on the capabilities of an emerging technology to get a full grasp on how the technology performs, later studies tend to change the focus to take a larger perspective on the potential value emerging technology can provide. Considering AR and VR research, it is time we investigate how the technology will benefit consumers, industry and other stakeholders, and think about specific value propositions that can be realised through meaningful design of AR and VR applications. While firms are still often responsible to design and stage consumer experiences in meaningful ways through proper understanding of customer needs and wants, a shift towards value co-creation by peers is becoming more evident. Particularly with interactive consumer technologies such as AR and VR, we propose in the conceptual framework that visitor engagement plays a crucial role in the aim of influencing the cultural tourist experience. Prebensen (2013) supported this view suggesting that customers should be part of the value creating process in order to create meaningful experiences for themselves. However, the value that AR and VR are promising to provide needs to be clearly understood and relevant for the tourists' context to encourage use of the application and ultimately influencing the cultural tourist experience.

While a number of studies are highlighting the potential that AR and VR can provide in the cultural tourism context, it is not clear at what stage in the visitor journey this technology is indeed sought after by visitors and what the economic and non-economic benefits entail for other stakeholders. A number of papers have highlighted the technological challenges that are still evident with AR and VR technologies (Han, tom Dieck, & Jung, 2018; tom Dieck & Jung, 2018) and will therefore not be explicitly indicated here. However, it needs to be understood that technological challenges such as inconsistent interaction are not only challenges for user interaction, but detrimental for the tourist experience. In an industry that promotes itself as dealing with 'experiences', a small glitch in a visitor application could potentially have a much higher cost of damage than the understandably underwhelming AR or VR experience. In order to understand how and where AR and VR will influence the tourist experience, the visitor journey needs to be fully understood. Therefore, we propose that contextual information will play a key role in defining and designing the added value of AR and VR enhancements. Comparing AR and VR use cases in tourism and retail, it can be observed that two rather different stages of the customer journey are tackled. While AR and VR studies in tourism often explore how the visitor experience can be enhanced at the tourist site (Chung et al., 2017; Jung et al., 2016), studies in the retail industry largely explore the use of AR and VR in the pre-purchase stage, more specifically in the product selection process (Bonetti et al., 2018). Evidently, studies in tourism are focused on the 'tourist experience', however, we should keep in mind that the experience is not limited to the activities and engagement on-site, but have a much wider scope before and after that is able to influence the overall perception and memories of visitors. Furthermore, it seems rather contradicting that AR and VR implementation is studied on-site at a time when tourists are looking to engage with the destination or attraction. Considering the internal motivation of visitors to make the effort and travel to specific tourist sites to learn, be inspired and get emotionally attached (Falk et al., 2012), it is questionable whether implementing an application to be interacted by means of a device such as smartphones or headsets is the logical solution. Arguably, this is creating an additional barrier between tourists and tourism product, which potentially prevents the establishment of a deeper connection and is rather detrimental to the tourists' internal motivation. This of course does not propose that AR and VR implementation should be avoided on-site. However, it is crucial to understand and consider tourist motivations such as the intention to learn and the value that such technologies can provide along other touchpoints of the visitor journey, in order to create meaningful applications that will ultimately enhance and not deter the cultural tourist experience. To measure how the tourist experience is actually affected, we propose the use of EEG and physiology as complementing methods to get a clearer indication on what is actually happening at the time of experience consumption when interacting with technology such as AR and VR that supposedly enhance the visitor experience.

4.3 Increasing Use of EEG and Physiology for Measuring Experiences in Addition to Reflective Indications

As discussed in the section on visitor experience, there has been a growing awareness that emotions play an essential role in shaping the tourist experience, and in making experiences meaningful and memorable (Li et al., 2014; Moyle et al., 2017; Skavronskaya et al., 2017). This in turn has led academics to consider which experience measurement tools would be most effective in capturing the emotional dimension of experience (Li et al., 2014). To date the dominant research methodology has been to rely on post-experience self-reports in the form of questionnaires or interviews. However, one may question whether relying exclusively on these traditional research techniques constitutes the optimal research methodology for measuring the emotions that create memorable experiences. It has been argued (see Larsen & Fredrickson, 1999 for extensive discussion) that self-reports inherently fail to fully capture the essential emotional dynamics of experiences in a sufficiently valid manner (Larsen & Fredrickson, 1999). In order to overcome these methodological shortcomings, and to more fully and validly capture the ebb and flow of emotions as an experience unfolds over time, researchers in the field of tourism are increasingly using biometric (physiological) measures as well as recordings of brain activity.

Physiological measures such as Skin Conductance Responses (SCR) and Heart Rate Variability (HRV) have long been used in psychological research as proxies of emotional arousal (Appelhans & Luecken, 2006; Bradley, Miccoli, Escrig, & Lang, 2008), and can nowadays be reliably recorded with wearable devices (e.g. wristbands). This technological development allows for reliable emotion measurements as tourists are freely walking around and are experiencing a destination or cultural heritage site, and therefore has become an accessible and affordable tool for scholars in tourism research. Consequently, these tools are increasingly being used by researchers in our field. For example, Kim and Fesenmaier (2015) measured the SCR of two heritage tour participants in the city of Philadelphia and linked a descriptive qualitative analysis of these data to their verbal descriptions of the experience. Li et al. (2012) studied HR along with self-reports of emotions while tourists were interacting with macaques in a Chinese natural park, and found both indicators to reveal positive responses to these interactions. Tröndle and colleagues conducted a large-scale study on museum visitors (Tschacher et al., 2012) in which they continuously measured HR and SCR in more than 500 visitors while their exact location was tracked. It enabled them, amongst others, to make 'emotion maps' of the museum floorplan (Tröndle, Greenwood, Kirchberg, & Tschacher, 2014), and to identify emotional responses to individual artworks (Tröndle & Tschacher, 2012).

Recordings of electrical brain activity (electroencephalography, or EEG) also reliably measure emotional responses (Hajcak, Weinberg, MacNamara, & Foti, 2012; Harmon-Jones, Gable, & Peterson, 2010). They offer greater precision than the physiological measures discussed in the previous paragraph, at the expense of only being usable in a laboratory setting. Ongoing work in our research group is seeking to validate the use of so-called frontal alpha EEG asymmetry (which is a continuous EEG-based measure of positive and negative emotions; Harmon-Jones et al., 2010) in experience research. In this project, short VR movies (durations ranging from three to 14 min), delivered through Samsung VR Gear equipment, were used to engage research participants in an immersive experience. Preliminary analyses show that, amongst others, there are significant correlations between valence ratings and frontal alpha asymmetry. These findings validate EEG as a tool to study, with sub-second resolution, the succession of positive and negative emotions during an experiential episode, which bypasses the use of self-reports.

As said, a major limitation of EEG as a tool for measuring emotions during a tourist experience is that it can only be reliably recorded in a lab setting. It is precisely here that we see a great potential advantage of combining EEG measurements with AR/VR technology, as this technology allows for immersing tourists and visitors in realistic, ecologically valid experiences while at the same time being in a well-controlled laboratory condition. EEG is therefore a potentially very useful tool for AR/VR experience design and optimization: it can be used for evaluating the emotional contents of an AR/VR experience, and by systematically varying elements of the AR/VR experience and subsequently optimizing the design, it allows for truly evidence-based AR/VR experience design.

5 Conclusion

The aim of the present paper was to examine the connection between AR/VR and the visitor experience of cultural tourism attractions. Cultural tourism institutions are increasingly implementing technologies such as AR and VR. Academic research on these experiences is in a nascent stage, and is in need of theoretical development. Based on the Experiential Cycle of Kolb (1984), we have proposed a theoretical model for understanding the visitor experience of AR/VR in the context of cultural tourism. This model implies the need for further research into appropriate measurement methodologies of these experiences. Biometric methods such as EEG and wearable measurement of peripheral emotion physiology holds particular promise herein. Furthermore, additional research is needed to develop existing theories of cultural tourism to keep pace with the technological landscape. The AR/VR technologies discussed, the software they use, and the cultural tourism experiences they can support are becoming increasingly accessible and, therefore, increasingly widespread. It is reasonable to predict that AR and VR will soon be seen as common dimensions of cultural tourism experiences. It is our urging that academic research in cultural tourism should keep pace.

References

Abrash, M. (2016). Welcome to the virtual age. *Blog* [Online] https://www.oculus.com/en-us/blog/welcome-to-the-virtual-age.

Altunel, M. C., & Erkut, B. (2015). Cultural tourism in Istanbul: The mediation effect of tourist experience and satisfaction on the relationship between involvement and recommendation intention. *Journal of Destination Marketing & Management*, *4*(4), 213–221.

Appelhans, B. M., & Luecken, L. J. (2006). Heart rate variability as an index of regulated emotional responding. *Review of General Psychology, 10*(3), 229–240. https://doi.org/10.1037/1089-2680.10.3.229.

Arnould, E. J., & Price, L. L. (1993). River magic: Extraordinary experience and the extended service encounter. *Journal of Consumer Research, 20*(1), 24–45.

Beedie, P., & Hudson, S. (2003). Emergence of mountain-based adventure tourism. *Annals of Tourism Research, 30*(3), 625–643.

Bond, E. (2014). *Childhood, mobile technologies and everyday experiences: Changing technologies = changing childhoods?*. Hampshire: Palgrave Macmillan.

Bonetti, F., Warnaby, G., & Quinn, L. (2018). Augmented reality and virtual reality in physical and online retailing: A review, synthesis and research agenda. *Augmented Reality and Virtual Reality*, 119–132.

Bradley, M. M., Miccoli, L., Escrig, M. A., & Lang, P. J. (2008). The pupil as a measure of emotional arousal and autonomic activation. *Psychophysiology, 45*(4), 602–607. https://doi.org/10.1111/j.1469-8986.2008.00654.x.

Brida, J. G., Dalle Nogare, C., & Scuderi, R. (2016). Frequency of museum attendance: Motivation matters. *Journal of Cultural Economics, 40*(3), 261–283.

Chang, L. L., Backman, K. F., & Huang, Y. C. (2014). Creative tourism: A preliminary examination of creative tourists' motivation, experience, perceived value and revisit intention. *International Journal of Culture, Tourism and Hospitality Research, 8*(4), 401–419.

Chung, N., Lee, H., Kim, J. Y., & Koo, C. (2017). The role of augmented reality for experience-influenced environments: The case of cultural heritage tourism in Korea. *Journal of Travel Research*, 0047287517708255.

Csikszentmihalyi, M. (1990). *Flow: The psychology of optimal performance*. New York: Harper and Row.

De Paola, F. (2018). *La destination France s'anime en realite augmentee* [Online] https://www.lechotouristique.com/article/la-france-se-montre-en-realite-augmentee.

Discovery VR. (2018). *Travel the world from the edge of your seat* [Online] https://www.discoveryvr.com.

Ermi, L., & Mäyrä, F. (2005). Fundamental components of the gameplay experience: Analysing immersion. *Worlds in Play: International Perspectives on Digital Games Research, 37*(2), 37–53.

Falk, J. H., Ballantyne, R., Packer, J., & Benckendorff, P. (2012). Travel and learning: A neglected tourism research area. *Annals of Tourism Research, 39*(2), 908–927.

Fino, E. R., Martín-Gutiérrez, J., Fernández, M. D. M., & Davara, E. A. (2013). Interactive tourist guide: Connecting web 2.0, augmented reality and QR codes. *Procedia Computer Science, 25,* 338–344. https://doi.org/10.1016/j.procs.2013.11.040.

Fredrickson, B. L. (1998). What good are positive emotions? *Review of General Psychology, 2*(3), 300.

Fredrickson, B. L. (2000). Extracting meaning from past affective experiences: The importance of peaks, ends, and specific emotions. *Cognition and Emotion, 14*(4), 577–606.

Fritz, F., Susperregui, A., & Linaza, M. (2005). Enhancing cultural tourism experiences with augmented reality technologies. In *The 6th International Symposium on Virtual Reality Archaeology and Cultural Heritage VAST* (pp. 20–21). Retrieved from http://public-repository.epoch-net.org/publications/VAST2005/shortpapers/short2005.pdf.

Gherghina, A., Olteanu, A. C., & Tapus, N. (2013). A marker-based augmented reality system for mobile devices. In *Roedunet International Conference (RoEduNet)* (pp. 1–6).

Hajcak, G., Weinberg, A., MacNamara, A., & Foti, D. (2012). ERPs and the study of emotion. In *Oxford handbook of event-related potential components*.

Han, D.-I., Jung, T., & Gibson, A. (2013). Dublin AR: Implementing augmented reality in tourism. In Z. Xiang & I. Tussyadiah (Eds.), *Information and communication technologies in tourism 2014* (pp. 511–523). Cham: Springer.

Han, D. I., tom Dieck, M. C., & Jung, T. (2018). User experience model for augmented reality applications in urban heritage tourism. *Journal of Heritage Tourism, 13*(1), 46–61.

Harmon-Jones, E., Gable, P. A., & Peterson, C. K. (2010). The role of asymmetric frontal cortical activity in emotion-related phenomena: A review and update. *Biological Psychology, 84*(3), 451–462.

Hooper-Greenhill, E., Dodd, J., Moussouri, T., Jones, C., Pickford, C., Herman, C., et al. (2003). *Measuring the outcomes and impact of learning in museums, archives and libraries* (pp. 1–24). Leicester: Research Centre for Museum and Galleries, University of Leicester.

Ismagilova, G., Safiullin, L., & Gafurov, I. (2015). Using historical heritage as a factor in tourism development. *Procedia-Social and Behavioral Sciences, 188,* 157–162.

Jantzen, C. (2013). Experiencing and experiences: A psychological framework. In J. Sundbo & F. Sørensen (Eds.), *Handbook on the experience economy* (pp. 146–170). Cheltenham: Edward Elgar.

Jung, T., Chung, N., & Leue, M. C. (2015). The determinants of recommendations to use augmented reality technologies: The case of a Korean theme park. *Tourism Management, 49,* 75–86.

Jung, T., tom Dieck, M. C., Lee, H., & Chung, N. (2016). Effects of virtual reality and augmented reality on visitor experiences in museum. In *Information and communication technologies in tourism 2016* (pp. 621–635). Cham: Springer.

Kerstetter, D. L., Confer, J. J., & Graefe, A. R. (2001). An exploration of the specialization concept within the context of heritage tourism. *Journal of Travel Research*, *39*(3), 267–274.

Kim, J., & Fesenmaier, D. R. (2015). Measuring emotions in real time: Implications for tourism experience design. *Journal of Travel Research, 54*(4), 419–429.

Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development*. New Jersey: Pearson Education.

Kolb, A. Y., & Kolb, D. A. (2005). Learning styles and learning spaces: Enhancing experiential learning in higher education. *Academy of Management Learning & Education, 4*(2), 193–212.

Kouprie, M., & Visser, F. S. (2009). A framework for empathy in design: Stepping into and out of the user's life. *Journal of Engineering Design, 20*(5), 437–448.

Larsen, R. J., & Fredrickson, B. L. (1999). *Measurement issues in emotion research*.

Li, J., Yang, D., He, L., Tao, S., Zeng, L., & Buckley, R. (2012). Psychological, physiological and behavioural responses of tourists to interactions with rhesus macaques at Zhangjiajie, China. *Journal of Ecotourism, 11*(3), 202–206.

Li, S., Scott, N., & Walters, G. (2014). Current and potential methods for measuring emotion in tourism experiences: A review. *Current Issues in Tourism*. https://doi.org/10.1080/13683500.2014.975679.

Liu, Y. D. (2014). Cultural events and cultural tourism development: Lessons from the European Capitals of Culture. *European Planning Studies*, *22*(3), 498–514.

Marasco, A., Buonincontri, P., van Niekerk, M., Orlowski, M., & Okumus, F. (2018). Exploring the role of next-generation virtual technologies in destination marketing. *Journal of Destination Marketing and Management* (December 2016), 0–1. https://doi.org/10.1016/j.jdmm.2017.12.002.

McKercher, B., Wong, C., & Lau, G. (2006). How tourists consume a destination. *Journal of Business Research, 59*(5), 647–652.

Microsoft. (2017). HoloTour. *Microsoft* [Online] https://www.microsoft.com/en-us/hololens/apps/holotour.

Minocha, S., Tudor, A. D., & Tilling, S. (2017). Affordances of mobile virtual reality and their role in learning and teaching. In *Proceedings of British HCI 2017—Digital Make Believe*. Sunderland, UK: BCS Learning and Development Ltd.

Moyle, B. D., Moyle, C.-l., Bec, A., & Scott, N. (2017). The next frontier in tourism emotion research. *Current Issues in Tourism*, 1–7.

Pine, B. J., & Gilmore, J. H. (1998). Welcome to the experience economy. *Harvard Business Review, 76,* 97–105.

Prebensen, N. K. (2013). Value co-creation significance of tourist resources. *Annals of Tourism Research, 42,* 240–261.

Puyuelo, M., Higón, J. L., Merino, L., & Contero, M. (2013). Experiencing augmented reality as an accessibility resource in the UNESCO heritage site called "la lonja", valencia. *Procedia Computer Science, 25,* 171–178. https://doi.org/10.1016/j.procs.2013.11.021.

Raptis, G. E., Fidas, C., & Avouris, N. (2018). Effects of mixed-reality on players' behaviour and immersion in a cultural tourism game: A cognitive processing perspective. *International Journal of Human-Computer Studies*.

Rauschnabel, P. A., & Ro, Y. K. (2016). Augmented reality smart glasses: An investigation of technology acceptance drivers. *International Journal of Technology Marketing, 11*(2), 123–148.

Richards, G. (Ed.). (1996). *Cultural tourism in Europe*. Cab International.

Rojek, C. (2002). Indexing, dragging and the social construction of tourist sights. In *Touring cultures* (pp. 62–84). Routledge.

Scott, N., & Le, D. (2017). Tourism experience: A review. In N. Scott, J. Gao, & J. Y. Ma (Eds.), *Visitor experience design* (Vol. 5). CABI.

Silberberg, T. (1995). Cultural tourism and business opportunities for museums and heritage sites. *Tourism Management, 16*(5), 361–365. https://doi.org/10.1016/0261-5177(95)00039-Q.

Sims, R. (2009). Food, place and authenticity: Local food and the sustainable tourism experience. *Journal of Sustainable Tourism, 17*(3), 321–336.

Skavronskaya, L., Scott, N., Moyle, B., Le, D., Hadinejad, A., Zhang, R., et al. (2017). Cognitive psychology and tourism research: State of the art. *Tourism Review, 72*(2), 221–237.

Steam. (2017a). *Stonehenge VR experience sandbox* [Online]. https://store.steampowered.com/app/457650/Stonehenge_VR_SANDBOX/.

Steam. (2017b). *The Grand Canyon VR experience* [Online]. https://store.steampowered.com/app/407710/The_Grand_Canyon_VR_Experience/.

Stewart, N. (2014). Active learning. In H. Moylett (Ed.), *Characteristics of effective early learning: Helping young children become learners for life*. Maidenhead: Open University Press.

Tan, S.-K., Kung, S.-F., & Luh, D.-B. (2013). A model of 'creative experience' in creative tourism. *Annals of Tourism Research, 41,* 153–174.

tom Dieck, M. C., & Jung, T. (2018). A theoretical model of mobile augmented reality acceptance in urban heritage tourism. *Current Issues in Tourism, 21*(2), 154–174.

Tröndle, M., Greenwood, S., Kirchberg, V., & Tschacher, W. (2014). An integrative and comprehensive methodology for studying aesthetic experience in the field: Merging movement tracking, physiology, and psychological data. *Environment and Behavior, 46*(1), 102–135.

Tröndle, M., & Tschacher, W. (2012). The physiology of phenomenology: The effects of artworks. *Empirical Studies of the Arts, 30*(1), 75–113.

Tsaur, S. H., Yen, C. H., & Hsiao, S. L. (2013). Transcendent experience, flow and happiness for mountain climbers. *International Journal of Tourism Research, 15*(4), 360–374.

Tschacher, W., Greenwood, S., Kirchberg, V., Wintzerith, S., van den Berg, K., & Tröndle, M. (2012). Physiological correlates of aesthetic perception of artworks in a museum. *Psychology of Aesthetics, Creativity, and the Arts, 6*(1), 96.

Tussyadiah, I. P., Wang, D., Jung, T. H., & tom Dieck, M. C. (2018). Virtual reality, presence, and attitude change: Empirical evidence from tourism. *Tourism Management, 66,* 140–154.

Wang, N. (2000). *Tourism and modernity: A sociological analysis*. Oxford, UK: Pergamon.

Weaver, P., Jansen, L., Van Grootveld, G., Van Spiegel, E., & Vergragt, P. (2017). *Sustainable technology development*. Routledge.

Williams, K., & Mascioni, M. (2017). *The out-of-home immersive entertainment frontier: Expanding interactive boundaries in leisure facilities*. Routledge.

Zajchowski, C. A., Schwab, K. A., & Dustin, D. L. (2016). The experiencing self and the remembering self: Implications for leisure science. *Leisure Sciences*, 1–8.

Tourism Marketers Perspectives on Enriching Visitors City Experience with Augmented Reality: An Exploratory Study

Natasha Moorhouse, Timothy Jung and M. Claudia tom Dieck

Abstract The purpose of this exploratory study is to provide initial insights into tourism marketers' perspectives on and intention to adopt Augmented Reality (AR) to enhance the visitor experience in urban tourism destinations. Interviews were conducted with seven participants from four Destination Marketing Organisations (DMOs) in three urban tourism destinations in the UK. Using thematic analysis, the results were mapped to the Technology, Organisation, and Environment (TOE) framework. Three sub-themes were identified in accordance to each component of the framework, totalling nine themes overall. The findings highlighted four perceived opportunities of tourism marketers AR adoption including three technological factors: *valuable visitor experiences*, *visitor satisfaction*, and *increased social media presence*, and one environment factors: *positive destination image*. Further, the perceived challenges included three organisation factors: *resource limitation*, *perceived financial cost*, and *return on investment*, and two environment factors: *visitor adoption* and *external concerns*. Theoretical contributions, practical implications, and recommendations for further research and action are presented.

Keywords Augmented reality · Tourism marketers · Urban tourism destinations · Visitor experience

1 Introduction

Tourism marketers such as Destination Marketing Organisations (DMOs) are challenged with adapting their ways to adhere to the transformation of the designed experience offerings into personalised experiences (Volo, 2009). Indeed, the use of modern technologies is critical for destinations (Marasco, Buonincontri, van Niekerk, Orlowski, & Okumus, 2018), and tourism marketers show a keen interest

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in new technologies to guide visitors (Baktash, Krey, Nair, & Rauschnabel, 2018). Recent advancements in Augmented Reality (AR) has meant that it could tremendously advance the tourism landscape (Baktash et al., 2018). In the tourism literature, AR has received increasing acknowledgment as a tool to facilitate positive visitor experiences in a variety of contexts (e.g. Chung, Lee, Kim, & Koo, 2017; tom Dieck, Jung, & Rauschnabel, 2018) including urban tourism (e.g. Markouzis & Fesakid, 2015). However, studies exploring tourism marketers' views on this topic in a specific urban tourism context are limited. Indeed, this perspective is required to gain insights into industry perceptions and intention to adopt this innovative technology. Extensive research indicated that barriers to new technology adoption at firm-level exist in the internal and external environment, and more specifically, adoption is determined by technological, adopter-specific, and environment factors (Cooper & Zmud, 1990; Hafeez, Keoy, & Hanneman, 2006). Therefore, this study aims to contribute preliminary research by exploring tourism marketers' views on adopting AR to enrich visitors' city experience, by identifying influential adoption factors existing in both the internal and external environment. More specifically, this study has two research objectives:

(1) *To identify the perceived opportunities and challenges in the internal environment influencing tourism marketers' AR adoption*
(2) *To examine the perceived opportunities and challenges in the external environment influencing tourism marketers' AR adoption.*

This article begins with an overview of how Information and Communication Technologies (ICTs) have forced tourism marketers to change their ways to remain competitive. This is followed by an exploration of the tourism literature on AR and visitor experiences with specific focus on urban tourism destinations. Then, the methods and findings and discussion are presented, and finally, conclusions, limitations, and avenues for future research are offered.

2 Literature Review

2.1 Impact of ICTs on Tourism Marketers' Competitive Strategy

DMOs are responsible for the strategic management and marketing of destinations (Martins, Costa, & Pacheco, 2013). They must play an active role in the destinations competitive position in the industry by gaining increasingly demanding and experienced consumers through the intensive use of ICTs (Martins et al., 2013). The way people find destination-related information, purchase travel products, and experience, communicate and perceive destinations has changed (Buhalis & Jun, 2011; Neuhofer, Buhalis, & Ladkin, 2012; Xiang & Gretzel, 2010). This is largely due to new technological trends and changes in software and infrastructures, as well as human participatory culture involved in virtual environments (Buhalis & Jun, 2011; Neuhofer et al., 2012; Xiang & Gretzel, 2010). To date, the internet remains important in the communication of destination marketing to secure new and existing clients (Li, Robinson, & Oriade, 2017). In addition, word-of-mouth (WOM) communication, where consumers can converse about their experiences in an open channel and customer reviews (Óskarsson & Georgsdóttir, 2017) remains fundamental. In 2013, Hays, Page, and Buhalis (2013) stated that DMOs are turning to social media as a relatively low-cost and global reach marketing tool. Prior to this, several studies (Schegg, Liebrich, Scaglione, & Ahmad, 2008; Stankov, Lazic, & Dragicevic, 2010; Wang, Quaehee, & Fesenmaier, 2002) suggested those tourism organisations that fail to adopt social media will lack a competitive advantage. The increase in User Generated Content (UGC) is a result of the internet and mobile technologies that provide individuals with unprecedented power to instantly add "digital traces" when conducting tasks (Lu & Stepchenkova, 2015). This could include reviewing tourism service providers, documenting a travel experience, or uploading photos and videos, hence, social media platforms contain a wealth of UGC (Lu & Stepchenkova, 2015). It is therefore evident that tourism marketers are continuously exploring ICTs and new forms of human interactions with a view to offer new opportunities for visitors to engage in the process of co-creating enhanced destination experiences in a technology-based environment (Agapito & Lacerda, 2014). Indeed, digital tourism was previously concerned with the use of digital technologies to enhance the visitor experience such as posting recommendations on a tourist website (Benyon, Quigley, O'Keefe, & Riva, 2014). However, more recently the focus has shifted and is increasingly concerned with mixing of the real world with digital content designed to enhance the visitor experience, and with the proliferation of smartphones and tablet devices, AR is becoming more widespread (Benyon et al., 2014).

2.2 AR-Enhanced Visitor Experiences

In the tourism literature, AR-enhanced visitor experiences have received strong interest in a variety of contexts including urban heritage tourism (e.g. Han, Jung, & Gibson, 2013; tom Dieck & Jung, 2015), nature-based tourism (e.g. Linaza, Gutierrez, & Garcia, 2014), cultural heritage tourism (e.g. Chung et al., 2017; Cranmer & Jung, 2014; Jung, Chung, & Leue, 2015; Seo, Kim, & Park, 2010), museums (e.g. Haugstvedt & Krogstie, 2012; Jung, tom Dieck, Lee, & Chung, 2016; Moorhouse, tom Dieck, & Jung, 2017), art galleries (e.g. Leue, Jung, & tom Dieck, 2015; tom Dieck, Jung, & tom Dieck, 2016), city tours (e.g. Fino, Martín-Gutiérrez, Fernández, & Davara, 2013), travel guide (e.g. Kourouthanassis, Boletsis, Bardaki, & Chasanidou, 2014), theme park (e.g. Jung, Chung, & tom Dieck, 2015), and festival (e.g. tom Dieck et al., 2018). Studies have indicated that AR provides visitors with the opportunity to become more informed on unknown surroundings in an enjoyable and interactive manner (Han et al., 2014), by providing interesting and valuable information and therefore enhancing the overall touristic experience (tom Dieck & Jung, 2015). In an urban tourism context, AR makes visiting cities more efficient and meaningful by supporting the improvement of the environment perception by users' interaction, while the GPS enables the location-based retrieval of information and services (Markouzis & Fesakid, 2015). Visitors are empowered to enjoy more freedom in searching, viewing, selecting, and purchasing products and services (Dadwal & Hassan, 2016). The important functions of AR are its resources at the destination, agenda, photo gallery, and the possibility of sharing comments (Markouzis & Fesakid, 2015). From a managerial perspective, ARs development and operation offers new employment and business opportunities (Markouzis & Fesakid, 2015), and its use in tourism will aid in designing effective marketing strategies in the future (Daim, Barri, Kamarudin, & Zakaria, 2012). However, the use of AR for tourism marketing purposes is fully dependent on the access and resource availability (Rahimi, Hassan, & Tekin, 2016). Indeed, innovative technologies including AR are forcing tourism marketers to adapt their competitive strategy. However, limited studies have investigated their perceptions on AR and their intention to adopt this technology. Therefore, this study aims to explore the perceived opportunities and challenges in both the internal and external environment to demonstrate tourism marketers' current views on AR and adoption intentions of AR.

2.3 Tourism Marketers' Adoption of Innovative Technologies

Theories dedicated to IT adoption at firm level have been developed. Most studies investigating this perspective are derived from two theories: Diffusion of Innovation Theory (DOI) (Rogers, 1995) and the Technology, Organisation, and Environment (TOE) framework (Chong, Ooi, Lin, & Raman, 2009; Tornatzky & Fleischer, 1990). The DOI theory relates to how, why, and at what rate new ideas and technology spread through culture operating at the individual and firm level (Oliveira & Martins, 2011). However, the DOI theory does not consider the environment context that other theories such as the TOE framework consider, and thus, other theoretical models are considered to be more complete (Oliveira & Martins, 2011). The TOE theory identifies aspects of an organisations context that influence the process by which it adopts and implements a technological innovation including the technological context, organisational context, and environmental context. Table 1 provides an explanation of each context in more detail.

There is a plethora of research investigating organisational acceptance of new technologies using the TOE framework as a theoretical foundation (e.g. Chang, Magobe, & Kim, 2015; Gibbs & Kraemer, 2004; Iacovou, Benbasat, & Dexter, 1995; Kuan & Chau, 2001; Wang, Li, Li, & Zhang, 2016; Zhu & Kraemer, 2005). For example, Iacovou et al. (1995) investigated perceived benefits (technological context),

Table 1 TOE framework dimensions

Context	Description
Technological context	Describes both the internal and external technologies relevant to the firm (e.g. current practices and equipment internal to the firm, and available technologies external to the firm)
Organisational context	The descriptive measures about the organization (e.g. scope, size, and managerial structure)
Environmental context	The area in which a firm conducts its business (including its industry, competitors, and government interactions)

Source Oliveira and Martins (2011)

organisational readiness (organisational context), and external pressures (environment context) as drivers of Electronic Data Interchange (EDI). Similarly, Kuan and Chau (2001) explored perceived direct benefits (technological context), perceived financial cost, perceived technical competence (organisational context), perceived industry pressures, and perceived government pressure (environmental context) in the context of EDI in small businesses. In the tourism literature, the TOE framework has been applied in a variety of contexts such as hotel adoption of reservation systems (Wang et al., 2016), e-commerce usage (Chang et al., 2015), mobile technology adoption in travel agencies (Lin, 2016), and adoption of electronic customer service management (eCRM) systems in hospitality organisations (Racherla & Hu, 2008). Although the specific elements identified within the three contexts vary across different studies, the TOE framework shows consistent empirical support (Lippert & Govindarajulu, 2006). Indeed, there are limited studies applying the TOE framework in the context of tourism marketers' perceptions and intention to adopt AR in urban tourism destinations. Therefore, given that this research investigates the perceived opportunities and challenges in the internal and external environment surrounding this topic, the TOE framework provides a useful theoretical base for this study.

3 Methods

3.1 Context of Study

Exploratory studies provide insights into, and a fuller understanding of, an issue or situation, and are well suited to qualitative research methods such as interviews (Saunders & Lewis, 2011). Therefore, the present study adopts a qualitative interview approach to investigate tourism marketers' perspectives on and intention to adopt AR to enrich visitors' city experience. A multiple case study strategy was employed using three urban tourism destinations in the UK, and interviews were conducted with seven employees from four DMOs in the three selected destinations. Interview participants included one Commercial Director (P1), four Marketing Managers (P2, P4, P6, and P7), one Digital Executive (P3), and one Head of Visitor Economy (P5). P1–P7 represents the coding allocated for the analysis. Since DMOs are central to the marketing of regional tourism (McCamley, Gilmore, & McCartan-Quinn, 2012), and many nations and cities are now funding a DMO as the main vehicle to compete and attract visitors to their distinctive place or visitor space (Pike & Page, 2014), the selection of a DMO sample seems appropriate. The interviews took place during summer 2017 (lasting approximately 30–40 min) and broadly explored the perceived opportunities and challenges in the internal environment and the external environment influencing tourism marketers' intention to adopt AR to enhance the visitor experience in this specific context.

3.2 Data Analysis

Thematic analysis is a useful method for identifying and reporting patterns and themes (Costa, Breda, Pinho, Bakas, & Durão, 2016), and given the exploratory nature of this study, this method was perceived to be the most suitable. The analysis of the findings where mapped to the three contexts of the TOE framework given their relevance to this study investigating the adoption of technologies at firm level. Using the three TOE contexts as initial themes, three sub-themes emerged under each theme, totalling nine overall, as presented in Table 2. Furthermore, the themes are presented in more detail using direct quotations from the data set to support the discussion.

Table 2 Themes and sub-themes

Themes	Technological context		
	Perceived opportunities		
Sub-themes	Valuable visitor experiences	Visitor satisfaction	Increased social media presence
Themes	Organisational context		
	Perceived challenges		
Sub-themes	Resource limitation	Perceived financial cost	Return on investment
Themes	Environmental context		
	Perceived opportunities		*Perceived challenge*
Sub-themes	Positive destination image	Visitor adoption	External concerns

4 Findings and Discussion

4.1 Technological Context

4.1.1 Valuable Visitor Experiences

Numerous opportunities for creating more valuable visitor experiences emerged such as "AR for navigation or for searching for products nearby attractions" (P2), and "for visitors to be guided around the city through AR, such as walking tours … to access offers and deals, and for visiting new places … especially from the historic perspective, there would be lots of opportunities to show what areas used to be like … I could see AR working in that way" (P1). In support of this, P4 stated, "AR can enhance experiences, whether its increasing interactivity in museums or accessing offers". Further, the potential of AR in creating personalised experiences emerged as P1 stated, "it will definitely add value to the visitor experience. If there was a targeting mechanism within the application then the visitor will be seeing and visiting things that are more in tune with what they like, so to me that equals a more satisfied visitor". However, "the most important is the content … so that visitors feel more fulfilled and satisfied by our destination" (P2).

4.1.2 Visitor Satisfaction

Participants confirmed that implementing AR into the visitor experience could provide visitors with a more unique experience than they have previously experienced and allow them to visit attractions they might not have previously considered. Therefore, this would increase visitor satisfaction and generate visitor expenditure throughout the entire tourism offer (P1, P2, P4, P5, P6, P7). For example, P5 stated, "I think AR could change visitor satisfaction because it focuses on enhancing the experience once they are here". In addition, "I hope AR could be something that would make the visitor feel they have had a unique experience, that they are getting something that not everyone is getting" (P2), and "they would be trying different things to eat, going to different parts of the city, seeing new attractions … it would give them chance to find out about new attractions" (P1). "It will certainly add to visitor satisfaction … they would walk away like they had been more immersed in the city, like they had been provided with something more, and experienced something more in their own eyes" (P6). Overall, "I think there is big potential for AR … it would bring the destination to life" (P6).

4.1.3 Increased Social Media Presence

Several participants (P1, P2, P3, P6) noted that implementing AR into the destination experience could be a useful way to encourage visitors to share their experiences on social media and enhance the organisation's social media presence. Drawing on first-hand experiences P6 stated, "just from friends and family that have been to the destination and used AR, they have really enjoyed it and shared experiences on social media and it has been fun for them to do, so I think it has got potential … it is a good way to get the city product out there on social media". In addition, "if AR had a social aspect, that would be a good way to get our brand out there because UGC always works best anyway" (P3). Moreover, it is important to integrate newly adopted technologies into existing platforms where funding is already implemented: "as an organization, we invest a lot of money into online and social media so AR could be integrated into that" (P6). Importantly, AR provides visitors with "something to show off about … we value that user-generated, driven approach to marketing because we don't have a huge budget so we rely on small things like WOM and social media" (P2). Further, P1 added "if there is something visitors can take away with them, to create memories, and sharing them via social media, that is undoubtedly a great way to get our brand out there. It works both ways—it can work as a negative as well, but generally it is really good".

4.2 Organisational Context

4.2.1 Perceived Financial Cost

The main concern for all the tourism marketers (P1–P7) when investing in technologies such as AR is perceived financial cost and the limited funding that is available to tourism organisations such as DMOs. This is evident as P2 stated, "the costs are the major challenges … because the costs are quite high, you have really got to evaluate the commercial return that you are going to get from it". Likewise, P5 added, "I wonder how these things will be funded … our recent project costs fifteen thousand pounds, which is a lot of money, and we wouldn't have been able to do that without the funding". P1 pointed out that, "our budgets are different now to how they were five years ago. Going back five years we would have EU money and funding and since the demise of the regional development agencies etc. we have turned ourselves into more of an agency. We are very much self-funding projects and campaigns so that budget for the likes of the development projects and things, I don't know where that money would come from". Nevertheless, P3 stated that the organisation has considered investing in AR despite the cost, "although it costs quite a lot of money to implement AR applications and features, we were considering investing in that area for a recent campaign targeting the international market. There is potential definitely".

4.2.2 Resource Limitation

The findings indicated that resource availability in terms of developing and implementing AR technologies could require more time to allocate funding, training of employees, and time to gain knowledge and better understand where ARs value would be best situated in the urban tourism offer (P1, P3, P5, P6). For instance, P3 stated "I do not know how we would utilize AR or what platform we would use", and P5, "I am sure there is potential for AR … as with anything through, we need to identify where it would add value to the visitor experience". Further, "in terms of leisure, I think AR will be there in the future but I don't know how". In addition, P6 added "I think it would be worth the investment, however, I am not aware of the cost … if it wasn't massively expensive it would definitely be worth it". Given the perceived high investment costs, P3 added "I don't know what the numbers would be in terms of increasing visitor number … it would have to be a trial run depending on the response we get … it would be hard to measure … we would rely on [an external organisation] to analyse footfall".

4.2.3 Return on Investment

Assessing the return on investment (ROI) was raised as a key concern for all participants (P1–P7). Providing an incentive for visitors to use the application would provide tourism marketers with a method to analyse the ROI, as P2 stated, "it is hard to say whether the benefits would be worth the investment from destination marketers over time … it is about evaluating the commercial return, so there would need to be an incentive for visitors to purchase something or access promotions on the application to be motivated to get on board". P1 argued that the "traditionalist market" (i.e. older generation) "still like to have printed visitor guides. They won't use their mobile phone to find their way around the city but they all have spare time, disposable income. Will they be tech-savvy enough to use something like that? I'm not sure". Nevertheless, P2 noted the potential future sales and engagement opportunities that could derive from the initial download of an AR application. For example, "AR experiences could motivate people to revisit and if they have downloaded the application previously … it gives us the opportunity to resell them something … it gives us a communication channel of continual engagement" (P2).

4.3 Environmental Context

4.3.1 Positive Destination Image

According to the findings, deploying AR technologies throughout the city's tourism offer has the potential to change the destination image from the perspective of visitors, however, this is dependent upon the type of visitor/individual they are and their unique preferences (P4, P5, P6, P7). This is evident as P6 argued, "implementing AR has the power to change the destination image … there is such a broad range of visitors to the destination and I think it would depend on their preferences". In addition, P4 stated that, "it could potentially change perceptions and the desire and interest to visit", and "I think AR could change the destination image from the visitor perception" (P4). Further, several participants identified how implementing innovative technologies such as AR could challenge visitors' preconceptions of the destination if they are first time visitors. For example, "we struggle with the US market because they either have no idea what [the city] is like, or they have the wrong perception of it still being an industrial city from years ago. We work closely with the media, and influencers to change that perception of the global market … I think AR could really help with that" (P4).

4.3.2 Visitor Adoption

Encouraging visitors to adopt AR applications when at the destination could be challenging and would be dependent on the perceived benefits and therefore, would require an incentive for usage (P1, P2). As P1 stated "another challenge is getting people to use the application. I guess that is going to be a generational issue … It might be directed at millennials, but with the cost implications for development and the service, would the end price be out of reach for that market? Those are all the things that must be considered". In support of this, P6 stated, "the barrier is awareness and getting people to use the AR application once it is available. It needs to be made as easy as possible for people to use and understand. I see that as a massive challenge. It needs to be quite clear on what the AR application is trying to do". In addition, P2 highlighted that targeted messages through AR could be problematic and deter visitor adoption as "I think that is bordering intrusive and people could start to shut off from those things. Having said that, a [local organization] is starting a WiFi project [in the city] where people sign up and they receive push messages about things they are near as they are exploring the city".

4.3.3 External Concerns

Several concerns were raised with regards to concerns in the external environment such as visitors' mobile device capacity (P2), WiFi in the city (P2, P3), usability (P2), and user acceptance (P3). For example, P2 stated "things like people's phones being old or out of date and not having the ability to use the application well, they also rely on being housed within an application and peoples phone capacities might limit this. Also, at the moment the provision of WiFi is pretty bad in the cities, often in [the city] 3G is inaccessible so if you want to download something on the go it would be quite difficult to do so". In support of this, "having WiFi in the city that is accessible is something we need to consider … It would definitely set us ahead of the crowd and make the city more attractive to the younger crowd" (P3).

Nevertheless, P2 explained "overtime destinations will adopt the technologies but at the moment it is still early days … I think there will be a lot of trial and error over the next few years". At the moment, "we don't feel like we are missing out as a city because we don't have lots of AR experiences, but that might be different in ten years' time" (P5). Having said, given that "AR is mobile enabled, it would be more attractive for user acceptance … the local airport is considering implementing AR because they are already using Beacons technology" (P3).

5 Conclusion

This exploratory study investigated tourism marketers' perspectives on implementing AR to enrich visitors' city experience by exploring the perceived opportunities and challenges of AR adoption in both the internal and external environment. By drawing on the TOE framework, it was revealed that the perceived opportunities are related to the technological and environmental contexts, while the perceived challenges are related to the organisational and environmental contexts. AR implementation could generate more valuable visitor experiences and increased visitor satisfaction (e.g. Han et al., 2014; tom Dieck & Jung, 2015), thus, increasing destination competitiveness (*technological context*). The significance of UGC in tourism marketing and its amplification through social media platforms (e.g. Twitter, Facebook, and TripAdvisor) is evident (e.g. Lu & Stepchenkova, 2015), and the present study further complements this breadth of research by suggesting for AR to be seamlessly integrated with existing platforms to increase the organisations social media presence and optimize existing channels (*technological context*). From the visitor perspective, integrating AR could improve destination image by portraying the destination as more innovative (*environmental context*). However, access to and availability of resources (e.g. Rahimi et al., 2016) including funding limitations (Hays et al., 2013) are critical factors negatively associated with tourism marketers' AR adoption, and of importance to tourism marketers is evidence of ROI (*organisational context*). Hence, encouraging visitors to download and utilise the AR application (*environmental context*) once it's been developed is concerning for tourism marketers given the financial constraints and concern for wasted resources. Finally, technological advancements (e.g. WiFi in the city and visitors' mobile device capability) are required for visitors to take full advantage of AR in the urban tourism environment, therefore, indicating tourism marketers' adoption of AR will likely arrive in the near future in accordance to smart tourism initiatives (*environmental context*).

6 Theoretical Contribution

The present exploratory study complements research relating to tourism marketers use of innovative ICTs such as AR to enrich the visitor experience. Several studies have employed a visitor/user experience perspective when investigating AR and visitor experiences (e.g. Han et al., 2014; Markouzis & Fesakid, 2015; tom Dieck & Jung, 2015). However, this study adds an alternative perspective to this body of literature as such research is limited. More specifically, the findings offer some of the perceived opportunities and challenges in both the internal and external environment that tourism marketers could encounter when implementing latest technologies such as AR, therefore, contributing theoretically to the tourism literature and indicating avenues for further research to expand on this exploratory study. Furthermore, this study employs the TOE framework in a largely unexplored context, therefore, offering some contribution to TOE research by mapping several factors to the three dimensions of the framework that could influence tourism marketers' adoption of AR technologies. However, further research is required in order to strengthen this potential contribution and reveal additional emergent themes.

7 Practical Implications

The findings provide practical implications for tourism professionals, researchers, and AR designers and developers. First, tourism professionals could potentially benefit from the perceived technological (valuable visitor experiences, visitor satisfaction, and increased social media presence) and environmental (positive destination image) opportunities of AR implementation in this study, which could effectively encourage investments in AR. Second, this study provides initial exploratory research for tourism researchers on tourism marketers perspectives on implementing AR technologies to enhance visitors' city experience. Third, the empirical evidence presented in this study could be beneficial for designers and developers as it indicates that tourism marketers require AR applications that are cost-effective, simple to implement, and able to seamlessly integrate with existing channels (e.g. social media), therefore, requiring limited time (e.g. training employees to develop/use) and monetary investment (due to funding constraints).

8 Limitations

This study has some limitations which could be mitigated by future research. Firstly, the sample size was limited therefore limiting the scope of the analysis. Although the sample allowed for reasonable conclusions to be drawn, it cannot be considered representative of the entire population of DMOs in UK-based urban tourism destinations. Second, the empirical part explored AR mobile applications without providing a physical demonstration and therefore assumed participants prior understanding of AR applications. However, participants had varying levels of AR knowledge and experience with AR technologies, therefore, experimenting with an AR application during qualitative data collection could have allowed for more in-depth conversations. Finally, given the qualitative nature of this study, future research could employ quantitative approaches and analyses to compliment and extend the insights presented within this study.

References

Agapito, A., & Lacerda, A. (2014). Marketing and brand design of destination experience: The role of ICT. *Journal of Spatial and Organisational Dynamics, 2*(3), 201–216.

Baktash, A., Krey, N., Nair, V., & Rauschnabel, P. A. (2018). Adoption of augmented reality technologies in tourism: Visitors' acceptance of smart glasses: An abstract. In N. Krey & P. Rossi (Eds.), *Back to the future: Using marketing basics to provide customer value, developments in marketing science: Proceedings of the Academy of Marketing Science*.

Benyon, D., Quigley, A., O'Keefe, B., & Riva, G. (2014). Presence and digital tourism. *AI & Society, 29*(4), 521–529.

Buhalis, D., & Jun, S. H. (2011). E-tourism. In *Contemporary tourism reviews*.

Chang, B. Y., Magobe, M. J., & Kim, Y. B. (2015). E-commerce applications in the tourism industry: A Tanzania case study. *South African Journal of Business Management, 46*(4), 53–64.

Chong, A. Y. L., Ooi, K. B., Lin, B. S., & Raman, M. (2009). Factors affecting the adoption level of c-commerce: An empirical study. *Journal of Computer Information Systems, 50*(2), 13–22.

Chung, N., Lee, H., Kim, J. Y., & Koo, C. (2017). The role of augmented reality for experience-influenced environments: The case of cultural heritage tourism in Korea. *Journal of Travel Research*.

Cooper, R. B., & Zmud, R. W. (1990). IT implementation research—A technological diffusion approach. *Management Science, 36*(2), 123–139.

Costa, C., Breda, Z., Pinho, I., Bakas, F., & Durão, M. (2016). Performing a thematic analysis: An exploratory study about managers' perceptions on gender equality. *The Qualitative Report, 21* (13), 34–47.

Cranmer, E., & Jung, T. (2014). Augmented reality (AR): Business models in urban cultural heritage tourist destinations. In *Asia Pacific Council on Hotel, Restaurant and Institutional Education: APacCHRIE*. Kuala Lumpur, Manchester: Research Gate.

Dadwal, S. S., & Hassan, A. (2016). The augmented reality marketing: A merger of marketing and technology in tourism. In N. Ray (ed). *Emerging Innovative Marketing Strategies in the Tourism Industry* (pp. 63–80). IGI Global.

Daim, M. S., Barri, A. F., Kamarudin, H., & Zakaria, S. A. (2012). Being neighbour to a National Park: Are we ready for community participation? *Procedia - Social and Behavioural Sciences, 36*, 211–220.

Fino, E. R., Martín-Gutiérrez, J., Fernández, M. D. M., & Davara, E. A. (2013). Interactive tourist guide: Connecting web 2.0, augmented reality and QR codes. *Procedia Computer Science, 25,* 338–344.

Gibbs, L. J., & Kraemer, K. L. (2004). A cross-country investigation of the determinants of scope of e-commerce use: An institutional approach. *Electronic Markets, 14*(2), 124–137.

Hafeez, K., Keoy, K. H., & Hanneman, R. (2006). e-Business capabilities model validation and comparison between adopter and non-adopter of e-business companies in UK. *Journal of Manufacturing Technology Management, 17*(6), 806–828.

Han, D., Jung, T., & Gibson, A. (2013). Dublin AR: Implementing augmented reality (AR) in tourism. In Z. Xiang & I. Tussyadiah (Eds.), *Information and communication technologies in tourism* (pp. 511–523). Wien, New York: Springer.

Haugstvedt, A. C., & Krogstie, J. (2012). Mobile augmented reality for cultural heritage: A technology acceptance study. In *IEEE International Symposium on Mixed and Augmented Reality*.

Hays, S., Page, S. J., & Buhalis, D. (2013). Social media as destination marketing tool: Its use by national tourism organisations. *Current Issues in Tourism, 16*(3), 211–239.

Iacovou, C. L., Benbasat, I., & Dexter, A. S. (1995). Electronic data interchange and small organizations: Adoption and impact of technology. *MIS Quarterly, 19*(A), 465–485.

Jung, T., Chung, N., & Leue, M. C. (2015). The determinants of recommendations to use augmented reality technologies: The case of a Korean theme park. *Tourism Management, 49*, 75–86.

Jung, T., tom Dieck, M. C., Lee, H., & Chung, N. (2016). Effects of virtual reality and augmented reality on visitor experiences in museum. In A. Inversini & R. Schegg (Eds.), *Information and communication technologies in tourism* (pp. 621–635). Wien, New York: Springer.

Kourouthanassis, P., Boletsis, C., Bardaki, C., & Chasanidou, D. (2014). Tourists responses to mobile augmented reality travel guides: The role of emotions on adoption behaviour. *Pervasive and Mobile Computing*, 1–30.

Kuan, K. K. Y., & Chau, P. Y. K. (2001). A perception-based model for EDI adoption in small business using a technology-organization-environment framework. *Information & Management, 3S*(8), 507–512.

Lee, H., Chung, N., & Jung, T. (2015). Examining the cultural differences in acceptance of mobile augmented reality: Comparison of South Korea and Ireland. In I. Tussyadiah & A. Inversini (Eds.), *Information and communication technologies in tourism* (pp. 477–491). Wien, New York: Springer.

Leue, M. C., Jung, T., & tom Dieck, D. (2015). Google glass augmented reality: Generic learning outcomes for art galleries. In I. Tussyadiah & A. Inversini (Eds.), *Information and communication technologies in tourism* (pp. 463–476). Vienna, New York: Springer.

Li, S. C. H., Robinson, P., & Oriade, A. (2017). Destination marketing: The use of technology since the millenium. *Journal of Destination Marketing & Management, 6*, 95–102.

Lin, S. (2016). Identifying the critical success factors and an optimal solution for mobile technology adoption in travel agencies. *International Journal of Tourism Research, 19*(2), 127–144.

Linaza, M. T., Gutierrez, A., & Garcia, A. (2014). Pervasive augmented reality games to experience tourism destinations. In Z. Xiang & I. Tussyadiah (Eds.), *Information and communication technologies in tourism*. Cham: Springer.

Lippert, S. K., & Govindarajulu, G. (2006). Technological, organisational, and environmental antecedents to web services adoption. *Communications of the IIMA, 6*(1).

Lu, W., & Stepchenkova, S. (2015). User-generated content as a research mode in tourism and hospitality applications: Topics, methods, and software. *Journal of Hospitality Marketing & Management, 24*(2), 119–154.

Marasco, A., Buonincontri, P., van Niekerk, M., Orlowski, M., & Okumus, F. (2018). Exploring the role of next-generation virtual technologies in destination marketing. *Journal of Destination Marketing, 9,* 138–148.

Markouzis, D., & Fesakid, G. (2015). Enriching the city environment with mobile augmented reality edutainment applications for residents and tourists. In I. Theona & D. Charitos (Eds.), *Proceedings of the 3rd International Biennial Conference*.

Martins, C. A., Costa, C. M. M., & Pacheco, O. R. (2013). The e-business strategies for destination management organisations. *Biblioteca Digital*, 2–13.

McCamley, C., Gilmore, A., & McCartan-Quinn, D. (2012). The role of destination marketing organisation in strategic marketing management for tourism. In *Proceedings of the Academy of Marketing Conference (2012)*. Marketing Catching the Technology Wave, Academy of Marketing.

Moorhouse, N., tom Dieck, M. C., & Jung, T. (2017). Augmented reality to enhance the learning experience in cultural heritage tourism: An experiential learning cycle perspective. *e-Review of Tourism Research*.

Neuhofer, B., Buhalis, D., & Ladkin, A. (2012). Conceptualising technology enhanced destination experiences. *Journal of Destination Marketing and Management, 1*(1–2), 36–46.

Oliveira, T., & Martins, M. F. (2011). Literature review of information technology adoption models at firm level. *The Electronic Journal Information Systems Evaluation, 14*(1), 110–121.

Óskarsson, G., & Georgsdóttir, I. (2017). Marketing communication towards cruise ship passengers: The implications of market segmentation. *Research in Applied Business and Economics, 14*(1), 43–77.

Pike, S., & Page, S. (2014). Destination marketing organisations and destination marketing: A narrative analysis of the literature. *Tourism Management, 41,* 1–26.

Racherla, P., & Hu, C. (2008). eCRM system adoption by hospitality organisations: A technology-organisation-environment (TOE) framework. *Journal of Hospitality & Leisure Marketing, 17*(1–2), 30–58.

Rahimi, R., Hassan, A., & Tekin, O. (2016). Augmented reality apps for tourism destination promotion. In R. Sajad (Ed.), *Apps management and e-commerce transactions in real-time*. Advances in e-Business Research, IGI Global.

Rogers, E. M. (1995). Diffusion of innovations: Modifications of a model for telecommunications. In M. W. Stoetzer & A. Mahler (Eds.), *Die Diffusion von Innovationen in der Telekommunikation.* Schriftenreihe des Wissenschaftlichen Instituts für Kommunikationsdienste, vol. 17. Springer, Berlin, Heidelberg.

Saunders, M. N. K., & Lewis, P. (2011). *Doing research in business and management: An essential guide to planning your project*.

Schegg, R., Liebrich, A., Scaglione, M., & Ahmad, S. F. S. (2008). An exploratory field study of web 2.0 in tourism. *Information and Communication Technologies in Tourism, 5,* 152–163.

Seo, B. K., Kim, K., & Park, J. I. (2010). Augmented reality-based on-site tour guide: A study in Gyeongbokgung. In *Asian Conference on Computer Vision* (pp. 276–285).

Stankov, U., Lazic, L., & Dragicevic, V. (2010). The extent of use of basic Facebook user-generated content by the national tourism organizations in Europe. *European Journal of Tourism Research, 3*(2), 105–113.

tom Dieck, M. C., & Jung, T. (2015). A theoretical model of mobile augmented reality acceptance in urban heritage tourism. *Current Issues in Tourism, 21*(2), 154–174. https://doi.org/10.1080/13683500.2015.1070801.

tom Dieck, M. C., Jung, T. H., & Rauschnabel, P. (2018). Determining visitor engagement through augmented reality at science festivals: An experience economy perspective. *Computers in Human Behavior, 82,* 44–53.

tom Dieck, M. C., Jung, T., & tom Dieck, D. (2016). Enhancing art gallery visitors' learning experience using wearable augmented reality: Generic learning outcomes perspective. In *Current issues in tourism* (pp. 1–21). Taylor & Francis.

Tornatzky, L., & Fleischer, M. (1990). *The process of technology innovation*. Lexington, MA: Lexington Books.

Volo, S. (2009). Conceptualising experience: A tourist based approach. *Journal of Hospitality Marketing & Management, 18*(2–3), 111–126.

Wang, Y., Li, H. T., Li, C., & Zhang, D. (2016). Factors affecting hotels' adoption of mobile reservation systems: A technology-organisation-environment framework. *Tourism Management, 53,* 163–172.

Wang, Y., Quaehee, Y., & Fesenmaier, D. (2002). Defining the virtual tourism community: Implications for tourism marketing. *Tourism Management, 23,* 407–417.

Xiang, X., & Gretzel, U. (2010). Role of social media in online travel information search. *Tourism Management, 31*(2), 179–188.

Zhu, K., & Kraemer, K. L. (2005). Post-adoption variations in usage and value of e-business by organizations: Cross country evidence from the retail industry. *Information Systems Research, 16*(1), 61–84.

Part IV
AR & VR in Education

Creating Virtual Reality in a Business and Technology Educational Context

Diana Andone and Mark Frydenberg

Abstract Virtual reality applications have enabled students to experience the world through visually immersive experiences in business and educational contexts. This paper shares the results of a collaborative project in which students from universities in the United States and Romania work together to study uses for virtual reality in a business context, and then create their own VR scenes for a selected business or industry. In doing so, students follow a virtual mobility learning scenario in which they explore the capabilities of virtual reality in both business and technology educational contexts.

Keywords Virtual reality · Mobile technologies · CoSpaces · Project-based learning · Collaborative learning · Online communication

1 Introduction

Creating opportunities to learn about Virtual Reality (VR) from business and technology perspectives was the driving force for TalkTech 2017, the ninth edition of the TalkTech project, a virtual mobility, collaborative learning project between students at universities in the United States and Romania. To complete this project, students from each school research relevant applications of VR in a chosen business or select an industry, visit a local business or location related to that industry, and create their own VR scenes to share with their international partners. In this project, students used CoSpaces, a VR web-based authoring tool, to create their original VR content. The authors argue that the TalkTech project fosters entrepreneurship and helps students build their own technology literacy skills.

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The TalkTech project described in this paper extends ongoing research on students' attitudes toward AR and VR tools and their applications (Andone & Frydenberg, 2017; Frydenberg & Andone, 2017a, 2017b; Li, Li, Zheng, & Zhao, 2015; Vishwanath, Kam, & Kumar, 2017). In addition, the authors have studied how students use information and communication technologies (ICT) such as video chat, messaging apps, email, and collaboration tools and their impact on computational thinking (Andone & Frydenberg, 2014) and digital literacy (Andone & Frydenberg, 2017).

The research contribution in this paper is a discussion of the following questions about student learning related to digital literacy and VR business applications when creating original VR artefacts:

- What is the students' experience using tools and applications to create original VR artefacts?
- How does the process of creating VR artefacts give students insights into future business applications of these technologies?
- What challenges and opportunities are presented when introducing VR in a global collaborative learning project?

2 Applications of VR in Education

AR and VR have been referred to as "the fourth wave" in technology platforms (Kamenov, 2017). Following personal computers, the Internet, and mobile devices, AR and VR applications now are taking their place in both business and educational contexts. Like their predecessors, AR and VR have changed the way we connect and interact with the people and the world around us. "VR is an opportunity to … connect with both learners and teachers in a novel and meaningful way" (Kolo, 2017, p. 1) as users are able to experience and remember their learning. The availability of mobile devices, Google Cardboard and dedicated VR headsets such as Oculus Rift and HTC Vive, combined with a growing collection of free apps and tools, have made VR a worthwhile educational opportunity. Dalgarno and Lee (2010) explore the benefits of 3-dimensional learning environments. They find that "there will be more effective real-world application of newly acquired knowledge and skills if the learning environment is modelled on the context in which the knowledge is expected to be applied" (Dalgarno & Lee, 2010, p. 21). Adoption of these tools may enhance or improve the learning process. The introduction of Google Cardboard ("Google Cardboard," 2018) and the ubiquity of smartphones make the experience widely accessible. Advantages for introducing VR an educational context include relevance, creativity and engagement, interacting with new technology, and innovative ways to communicate and share information (Greenwald et al., 2017; Kolo, 2017; Reynard, 2017).

A recent study (Ott & Freina, 2015) shows that virtual reality and immersive VR experiences have been used in higher education, mostly in the United States and the

United Kingdom, for adults seeking specialized training, or at universities, especially in the areas of sciences and medicine. High schools also support VR for physics and chemistry simulations. In the K-12 space, virtual reality is one of the most popular developments in educational technology, as Google Expeditions and Google Earth allow students to visit landmarks around the world without leaving their classrooms (Vishwanath et al., 2017) in Mind and Anatomy 4D enable students to explore their brains and body organs; EON Experience offers content for learning history and physics (Lynch, 2017). VR gives the possibility to "visualise and simulate events that are not perceivable in real life" (Ott & Freina, 2015, p. 6).

In each of these scenarios, learners at all levels use VR applications created for them as a tool for furthering their own subject matter understanding. The TalkTech 2017 project examines the process of creating *one's own* VR content to develop information technology literacy skills and explore applications of VR in business as future entrepreneurs.

3 Designing VR with the CoSpaces Platform

3.1 CoSpaces in Education

Web-based VR authoring tools such as InstaVR, WondaVR, and CoSpaces make it possible to create original VR artefacts with little or no programming experience. This study chose CoSpaces because of its simple visual, drag-and-drop interface and built-in support for use in educational settings. "CoSpaces Edu offers a complement to traditional teaching methods by immersing students into a world where they can create anything in 3D, learn coding while having fun, and connect with the curriculum on a completely new level" (Delightex GmbH, 2017).

Virtual reality systems promote situated learning through the immersive experience of interactive objects, environments and processes (Greenwald et al., 2017). CoSpaces "allows you to create virtual 3D worlds that can be explored using smartphones, tablets, and PCs with the ability to take advantage of the VR viewer" (Bertolini et al., 2018, p. 121). CoSpaces uses a visual programming editor similar to the Scratch programming environment, to specify code for modelling and animating simple virtual worlds. In primary and secondary education, students have used CoSpaces for digital storytelling, creating virtual art exhibitions (Bertolini et al., 2018) and recreating historical scenes (Boedo Naya, 2017; Krause, 2017). Creating VR lessons accelerates learning by allowing students to apply their own subject-matter knowledge.

CoSpaces allows users to select from provided scenes or upload original 360-degree or panoramic images to use as backgrounds for their VR artefacts. They enhance the scene with sprites, objects, gestures, and interactions. After designing, developing, and coding their virtual worlds with the CoSpaces web app, students can explore their virtual worlds using mobile devices with the CoSpaces mobile app, available for Android and iOS devices. The mobile app enables users to visit their virtual worlds using a Google Cardboard headset or similar VR viewers, creating fully immersive experiences. Users may share their worlds with others by providing a link, or a QR code, or embedding it on a blog or website.

3.2 CoSpaces in the TalkTech 2017 Project

As a requirement of the TalkTech 2017 project, students at each university researched the same business or industry in their country as their international partners and created a related VR scene to share. Students then viewed their partners' VR scenes and compared them with their own experience of similar scenes in their home country, providing a glimpse into another country's culture.

For example, the team learning about VR applications in the restaurant industry each prepared a VR scene at their local Starbucks coffee shops, as shown in Fig. 1. They captured the background image of the facility using a 360-degree camera app on a smartphone, and then imported the image into CoSpaces to add additional content and context. In both cases, animated sprites greet the customer. The Romanian students added engaging conversation in chat bubbles while spinning yellow stars highlight the bakery items or coffee selections. The American team added a unicorn and a spinning jewel to their scene. Figure 1b shows how a VR artefact created in CoSpaces appears in a browser, and on a mobile device to be inserted into a Google Cardboard VR viewer.

Fig. 1 Starbucks coffee shop **a** in Romania, **b** in Google Cardboard, and **c** in the United States, created in CoSpaces VR

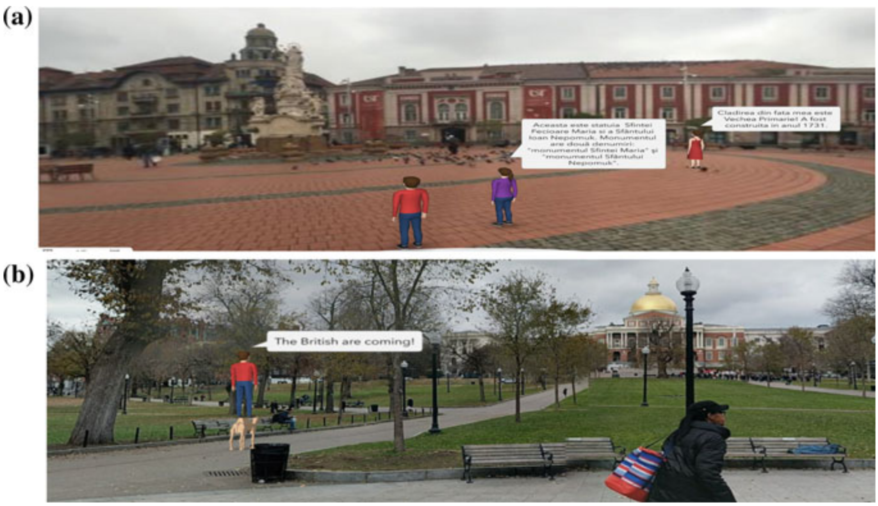

Fig. 2 Creating CoSpaces VR for tourism **a** in Romania and **b** in Boston

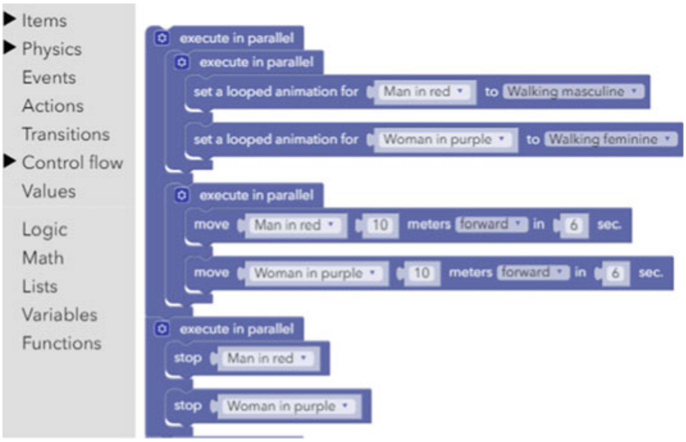

Fig. 3 Blockly code for animating scenes in CoSpaces

The experience of Fig. 1a and b is available at https://goo.gl/Uc4ETT using CoSpaces, or with a short video at https://flipgrid.com/be7f23.

In another VR scene created by students investigating applications of VR and tourism, students created VR experiences for local landmarks. Figure 2 shows a VR scene at a public square in Romania and the United States.

Figure 3 shows a portion of Blockly code to animate some sprites in Fig. 2a.

Fig. 4 CoSpaces tours of campus libraries **a** in Romania and **b** the United States

Figure 4 shows scenes that each group created for promoting campus recruitment by offering virtual tours of the libraries at their respective schools. Both scenes employ sprites that welcome the visitor and provide information about the library and its facilities.

4 TalkTech 2017 Implementation

A cohort of 67 students (37 honours students in a first-year introductory Information Technology course at Bentley University in the United States, and 30 students enrolled in a Technologies of Multimedia course in their fourth year at Politehnica University of Timisoara, Romania) participated in this study. Of those who participated, 43 students (completed a survey about their experiences at the end of the project. All students had some previous experience using the web, collaboration tools, and mobile devices. Participants formed self-selected groups of four of five (two or three students from each country) collaborate with their international partners. Students were mostly between 21 and 23 years old (46%), and between 18 and 20 years old (54%). The Romanian students were, on average, about 3 years older than their American partners. The authors recognize that differences exist in age, programs of study, technical abilities, and class sizes of students at each university. For the purposes of this research, the authors embraced these differences to design a learning project that encouraged collaboration among group participants. The project's common language is English.

This study implements a project-based learning approach to introduce VR concepts by engaging students to create original VR content related to a business or industry. In a project-based learning activity, "learners construct knowledge by solving complex problems in situations in which they use cognitive tools, multiple sources of information, and other individuals as resources" (Blumenfeld et al., 1991, p. 371).

4.1 Exploring Uses of VR in a Business and Technology Context

The TalkTech 2017 project engages students to select and research applications of VR in one of these businesses or industries: culture and tourism, technology retail, fast food/restaurants, sports, university recruitment, and then create their own VR scenes to share with their partners. The learning scenario enables students to demonstrate several technology literacy skills and develop subject-related knowledge as they create and share their original VR scenes.

- Research how an assigned industry or enterprise to see examples of how it might use VR
- Create a background image for the VR scene
- Design and implement avatars, sprites, or other virtual content and their interactions with this VR scene using CoSpaces
- Test on a mobile device, or with Google Cardboard headset
- Create a demonstration video on FlipGrid, a video sharing platform, and instructions for sharing with international partners
- Share the VR artefact and related research on ZeeMaps, a collaborative mapping tool

Completing these steps requires using search engines, transferring files from one device to another, interacting with content in multiple file formats, navigating the Web, and learning basic coding concepts such as performing steps "in parallel", looping, actions, and interacting with objects. Students must choose which tools they will use to interact with their partners and manage the project, from synchronous communication by voice and video conferencing to asynchronous chats and email; file sharing, multimedia creation, and project management.

5 Findings

This section summarizes student prior experience with and attitudes toward learning about VR, the importance of VR in business, and a desirability test reflecting student satisfaction with the TechTalk project.

5.1 Experience and Attitudes Toward Learning About VR

When asked which tools they used for VR, all students identified CoSpaces, and many of the American students also said they had experience using Oculus Rift because a related assignment required them to experiment with that headset. Prior to this project, fewer than half of the students claimed to have personal experience using AR or VR tools, as shown in Fig. 5.

A survey question after the project ended asked students about their perception of the usefulness of AR and VR technologies. Results, shown in Fig. 6 suggest that the majority found AR and VR to be easy to use, clear and understandable, productive, and educational.

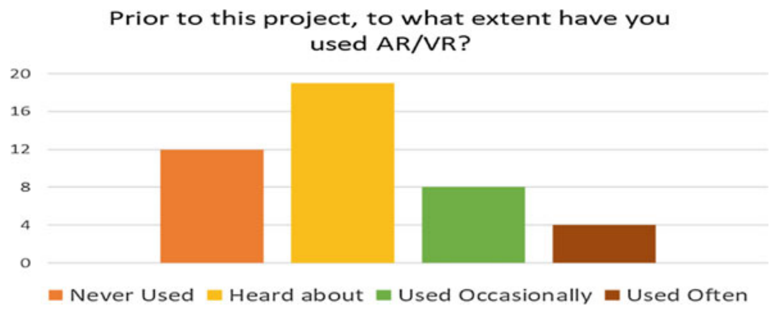

Fig. 5 Prior experience with AR/VR

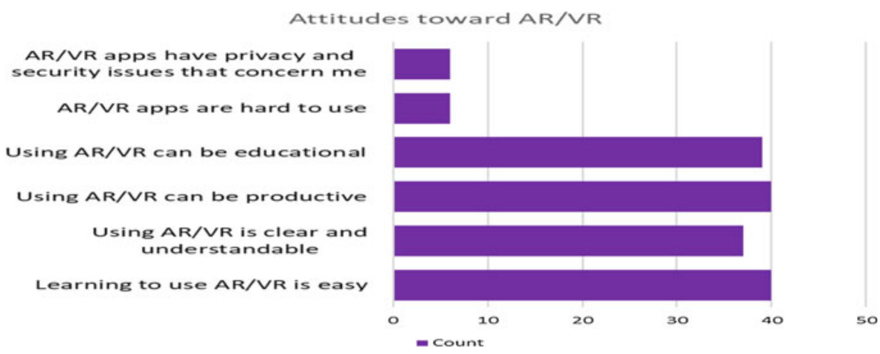

Fig. 6 Attitudes toward AR/VR

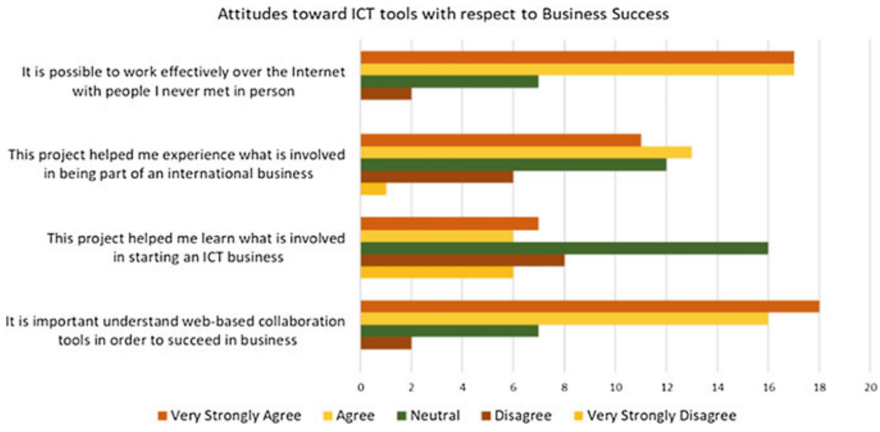

Fig. 7 Attitudes of TalkTech 2017 on using ICTs for business success

Students commented about applications of VR in the industries they studied, and the promise that VR holds. Said one student, "Virtual reality … [gives] its users a simulated experience of what it would be like to be in certain spaces or environments. For example, I may use virtual reality technology to go on a trip to Venice, Italy without ever setting foot outside my home." They recognize the need for collaboration and being productive in virtual environments: "Above all, the project provided me with an experience which gave me a better understanding of collaborative work in the business world. It is not always that business people will be in the same city, state, or country. Therefore, as difficult as it may be, it becomes necessary for individuals to find ways to maintain productivity and efficiency within their fields of work."

Figure 7 shows students' attitudes on using technology and collaboration tools, being members of international teams, and how useful they think these experiences will be in contributing toward their future careers. Most students agree or strongly agree that participating in the TalkTech project taught them about culture, collaboration, working on international teams, and the importance of web-based collaboration tools in an information/technology business.

5.2 *Desirability Test*

To measure how desirable students found this experience, the authors followed a selection exercise developed by Benedek and Miner (2003) based on a set of 40 words, both positive and negative, covering a variety of dimensions. To account for any bias to give positive feedback, at least 40% of the words were negative. After the project, students selected five words that best describe their experience

Fig. 8 TalkTech 2017 desirability word cloud

participating in this project. Students ranked the words they selected on a scale from 1 to 5, where 1 is the most precise. This method presents results visually in the word cloud in Fig. 8.

Students chose the words that appear in a larger font more frequently than words shown in smaller fonts. The four words in grey in the largest font size (stressful, frustrating, time-consuming, rigid) are the most often selected words that describe the students' experience in this project in a negative context. They found it "stressful" and "frustrating" at times dealing with differences in time zones, slow Internet connections, and occasionally non-responsive international partners; "time-consuming" reflects that several students felt that completing the project took longer than they had anticipated; "rigid" suggests that some students felt the requirements were very strict despite their open-ended nature.

The most popular positive words were collaborative, fun, useful, and attractive. Collaborative describes their experiences with many of collaboration tools used and the opportunity to be a member of an international team. "Fun" describes students' engagement with the project: they had the opportunity to get off campus to visit a local business or place of interest, and view completed VR scenes in Google Cardboard. Useful hints that the students recognize the value in becoming familiar with VR technologies and their applications for their own future careers. Attractive suggests that the project was at the appropriate level, and that students learned new skills by participating.

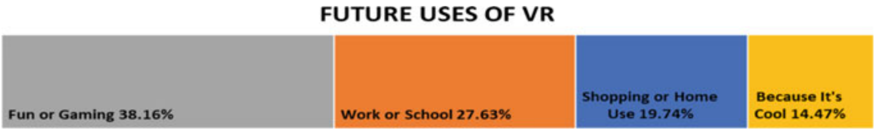

Fig. 9 Future uses of AR/VR

5.3 Future Uses of AR/VR: From an Entrepreneurship Point of View

When asked for what purposes they might use AR/VR apps in the future, students recognized the large market of VR in the gaming industry. Others noted retail and educational applications, and some simply would use VR "because it is cool" as shown in Fig. 9.

Students recognized the potential of VR in future business opportunities especially in the areas of advertising and marketing. Comments included, "we can advertise with this"; "I learned how to include information in these experiences, which would be helpful to advertise a product", "AR/VR are tools that can be used to have products and ideas stand out. Therefore, AR/VR can be used as marketing tools." and "[I learned] different tools for marketing, partnering with strangers and working together on a project." Students came away with practical possible future applications, such as "a restaurant which you can visit in Virtual Reality and have the menu appear on your phone screen when you scan a QR code." Another student said, "VR can be implemented by a business to immerse a customer in any experience or environment that the business chooses."

When asked, after completing this project, "would you consider using AR/VR if starting a new business or start-up?" students varied in their enthusiasm for these technologies. Responses included "VR and AR can reduce language barriers [because of their visual nature]"; "they make it easier to give customers information". One student said he would use AR or VR "only as long as it would enhance the product or experience for the customers." Another student was sceptical of the technology in its current state, saying "There is definitely potential (especially in AR), but right now the products don't seem very efficient for whatever practicality they provide, so I would not use AR or VR."

6 Discussion and Conclusion

The process of creating original VR scenes was new for most students and provided a useful way to apply knowledge gained by researching VR applications in business. Said one student, "Virtual reality is often linked to applications that deliver virtual immersion in high-definition 3D visual environments. Such applications include, for example, CAD software, display acceleration hardware, head mounted displays, electronic gloves for databases, electronic clothing, and more." Students recognized the potential of this technology in industries beyond gaming, the one with which they were most familiar.

Creating VR also offers a new way for students to use their mobile devices. Researching panoramic camera apps, using a 360-camera connected to a smartphone over Bluetooth, designing or running the CoSpaces app with Google Cardboard, all incorporated the use of mobile devices to this project. Students found CoSpaces to be "very user-friendly" and most students, even with little or no coding experience, were able to add basic animations to their scenes through the visual Blockly development tools. Although challenged by using new apps and tools, and not always having the tech skills needed to apply them, all students prevailed in this project, and often relied on their team members, the Internet, and their instructors for additional information and guidance when necessary.

The TalkTech 2017 project introduced VR as a relevant current technology, and as the goal for student-created multimedia. The authors conclude that TalkTech 2017 provides a project-based learning environment in which students develop and demonstrate their technology literacy skills, while learning about VR and its business applications. Students learned that business applications of VR will change how companies present and sell products and how customers experience them, across several industries. Students also learned that creating, sharing, and exploring VR scenes can change how they experience virtual worlds, as well as how they apply their knowledge gained in those virtual worlds, to the real world.

References

Andone, D., & Frydenberg, M. (2014). Becoming creative creators: Simulating a global workplace using computational thinking practices. In *Proceedings of EdMedia: World Conference on Educational Media and Technology* (pp. 564–571). Presented at the EdMedia, Tampere, Finland: Association for the Advancement of Computing in Education (AACE).

Andone, D., & Frydenberg, M. (2017). Experiences in online collaborative learning with augmented reality. In *The International Scientific Conference eLearning and Software for Education* (Vol. 2, p. 239). Presented at the ICALT, Timisoara, Romania.

Benedek, J., & Miner, T. (2003). Measuring desirability: New methods for evaluating desirability in a usability lab setting. In *Proceedings of Usability Professionals Association* (Vol. 8–12, p. 57).

Bertolini, M., Scali, F., Poletti, G., Guerreschi, A., Fontana, F., & Thun Hohenstein, U. (2018). *Virtual Portable Art: un percorso virtuale per le pietre incise di Riparo Tagliente* [Virtual portable art: A virtual path for the engraved stones of Riparo Tagliente]. Sezione di Museologia Scientifica e Naturalistica.

Blumenfeld, P. C., Soloway, E., Marx, R. W., Krajcik, J. S., Guzdial, M., & Palincsar, A. (1991). Motivating project-based learning: Sustaining the doing, supporting the learning. *Educational Psychologist, 26*(3–4), 369–398.

Boedo Naya, P. (2017). Construyendo el mundo, recreando la historia. Una experiencia virtual en el aula. In *Innovación docente y uso de las TIC en educación* (p. 54). Malaga.

Dalgarno, B., & Lee, M. J. W. (2010). What are the learning affordances of 3-D virtual environments? *British Journal of Educational Technology, 41*(1), 10–32.

Delightex GmbH. (2017). CoSpaces EDU: Create virtually anything in the classroom. *Co-Spaces Edu*. Retrieved February 1, 2018, from https://cospaces.io/edu/.

Frydenberg, M., & Andone, D. (2017a). Enhancing and transforming global learning communities with augmented reality. In *2017 Proceedings of the EDSIG Conference* (Vol. 3, no. 4335, p. 9). Presented at the EDIG, Austin, Texas: ISCAP.

Frydenberg, M., & Andone, D. (2017b). *Collaborative learning about augmented reality from technology and business perspectives* (pp. 493–495). IEEE. Retrieved February 15, 2018, from http://ieeexplore.ieee.org/document/8001841/.

Google Cardboard. (2018). *Google VR*. Retrieved January 15, 2018, from https://vr.google.com/cardboard/.

Greenwald, S., Kulik, A., Kunert, A., Beck, S., Frohlich, B., Cobb, S., Parsons, S., et al. (2017). Technology and applications for collaborative learning in virtual reality. In B. Smith, M. Borge, E. Mercier, K. Lim, B. Smith, M. Borge, E. Mercier, et al. (Eds.), *Making a difference: Prioritizing equity and access in CSCL, 12th International Conference on Computer Supported Collaborative Learning (CSCL)* (pp. 719–726). Philadelphia, PA, USA: International Society of the Learning Sciences. Retrieved January 30, 2018, from https://repository.isls.org/handle/1/210.

Kamenov, K. (2017, August 16). Immersive experience—The 4th wave in tech: An AR history lesson. *Living Innovation*. Retrieved from https://www.accenture.com/gb-en/blogs/blogs-long-time-no-speak.

Kolo, K. (2017, December 13). Virtual reality: The next generation of education, learning and training. *Forbes Business NewTech*. Retrieved February 1, 2018, from https://www.forbes.com/sites/forbesagencycouncil/2017/12/13/virtual-reality-the-next-generation-of-education-learning-and-training/#42f662ca733f.

Krause, S. (2017, January 23). Build your own battle field. *CoSpaces*. Retrieved February 1, 2018, from https://blog.cospaces.io/build-your-own-battle-field-30eddd18097d.

Li, F., Li, D., Zheng, J., & Zhao, S. (2015). *Virtual experiments for introduction of computing: Using virtual reality technology* (pp. 1–5). IEEE. Retrieved January 21, 2018, from http://ieeexplore.ieee.org/document/7344376/.

Lynch, M. (2017, March 11). 20 top virtual reality apps that are changing education. *The Tech Advocate*. Retrieved from http://www.thetechedvocate.org/20-top-virtual-reality-apps-that-are-changing-education/.

Ott, M., & Freina, L. (2015). A literature review on immersive virtual reality in education: State of the art and perspectives. In *Conference Proceedings of »eLearning and Software for Education« (eLSE)* (pp. 133–141). Presented at the eLSE.

Reynard, R. (2017, April 26). The impact of virtual reality on learning. *Campus Technology*. Retrieved January 30, 2018, from https://campustechnology.com/articles/2017/04/26/the-impact-of-virtual-reality-on-learning.aspx.

Vishwanath, A., Kam, M., & Kumar, N. (2017). *Examining low-cost virtual reality for learning in low-resource environments* (pp. 1277–1281). ACM Press. Retrieved February 25, 2018, from http://dl.acm.org/citation.cfm?doid=3064663.3064696.

Immersive Virtual Reality (IVR) in Higher Education: Development and Implementation

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Abstract University educators anticipate better engagement with students through the adoption of the three-dimensional visualization made possible by immersive virtual reality (IVR). Materials can be captured in 360° video for viewing through smartphones bracketed in head-mounted displays (HMDs) with motion sensors. Alternatively, materials can be viewed on notebook computers and tablets to offer some degree of VR experience. The paper reports on the first two undergraduate courses that have adopted both VR and IVR modes for classroom learning: 'Pharmacology and Therapeutics' and 'Understanding Ecotourism'. The 360° videos have undergone a complete cycle of design, development, implementation and evaluation. These video captures can transcend physical boundaries in both clinical cases simulating a hospital ward and natural countryside landmarks. With VR and IVR embedded in the classroom, students expressed greater learning

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satisfaction while experiencing more opportunities to rehearse professional skills and explore historical artefacts with deeper cultural understanding.

Keywords Immersive virtual reality · Higher education · ADDIE

1 Introduction

Virtual reality (VR) is defined as 'a real or simulated environment in which a perceiver experiences telepresence' (Steue, 1992: 76). Users may visualize from two to three dimensions of an environment or an object, experience simulated situations to explore virtual locations as preparation for or replacement for actual visits or field exploration, interact with simulated clients or patients, simulate experiments and processes, and take actions while interacting with the virtual environment or object. VR can be in the form of a non-immersive mode, presented in a screen setting showing programmed scenarios for stakeholders to rehearse interactions in safe and naturalistic environments (Kandalaft, Didehbani, Krawczyk, Allen, & Chapman, 2013), and there is the possibility for users to explore destinations in the context of virtual tourism (Huang, K. F. Backman, S. J. Backman, & Chang, 2016). Putting virtual 3D images in a screen setting (whether it is a laptop or desktop) means that users can access without additional tools.

However, immersive virtual reality (IVR) enables users to have an experience that perceptually surrounds them and gives them a sense of presence or actually being within it. This can be of two types: a computer automatic virtual environment (CAVE); and head-mounted displays (HMDs), sometimes equipped with motion sensors. The first type is set in a room in which computer-generated graphics are projected onto the walls and users' head and hands are tracked as they interact with the simulated environment in the VR room (Cruz-Neira, Sandin, DeFanti, Kenyon, & Hart, 1992). There is a second type of virtual experience, without being confined to a space with projectors, in which learners can interact with the immersive learning environment by wearing an HMD.

IVR may also offer simulated settings to provide a virtual tour with panoramic views of destinations; allow students to practise the procedural steps in a physical environment, such as operating an overhead crane (Huang, 2003); function in daily life activities at home (Lee et al., 2003) or away from the home environment (Grewe et al., 2013); learn physical movement (Bailenson et al., 2008), and train how to deal with hazards such as radiation (Koepnick et al., 2010). Research has shown many positive outcomes through applying VR for rehabilitation purposes (Grealy, Johnson, & Rushton, 1999; Grewe et al., 2013; Lee et al., 2003). Applications of IVR have been used in museum exhibitions to illustrate archaeological artefacts (Bruno et al., 2010); in flight simulation with low latency and at a low cost (Yavrucuk, Kubali, & Tarimci, 2011); and the adoption of VR storytelling techniques in journalism (Hodgson, 2017). More importantly, there is growing interest in adopting VR or IVR in university classrooms. Fagan, Kilmon and

Pandey (2012) find positive acceptance of VR simulation in nursing education. This type of learning experience can be applied in many disciplines, including life sciences, education, law, architecture, archaeology, history, geography resources and management, nursing, and business.

2 Adoption of IVR in Higher Education

Both three-dimensional and 360° VR video capture have created an alternative mode of learning experience in universities. A comprehensive virtual tour can be constructed in a non-immersive mode, including images, videos and interviews with key stakeholders when students need to explore core concepts and practise skills in a course (Patiar, Ma, Kensbock, & Cox, 2017). In addition, 360° viewing may provide a full panoramic view for students to be engaged in a novel environment in which the location may be remote, difficult to reach, or politically unstable (e.g. archaeological sites). Students can rehearse procedural steps or examine virtual sites close up, with a bird's-eye view as they build new concepts in disciplines. Moreover, students can 'visit' locations and observe natural phenomena across seasons and in different weather conditions (e.g. field trips exploring nature reserves). Chang, Lin, and Hsiao (2009) find that earth science students appreciate the VR option as preparation for actual field visits; students can use a 3D building tool to undertake exploration and apply theories to Google Earth for geography education (Krakow, 2012). Tawhai (2017) advocates that IVR can be used for teaching of forensic investigation. Students may develop transferable professional skills through revisiting crime scenes to make a variety of attempts when learning how to carry out a crime investigation.

IVR settings also allow visualizing and testing of abstract concepts, such as manipulating cells from different structures at the microscopic level, simulating muscle responses during dissection while exploring abstract concepts, or conducting virtual laboratory experiments when there are ethical concerns. IVR can also be applied in laboratory settings, and students can rehearse through rich-media presentations in VR before working on high-end laboratory equipment, which may not be accessible at all times. By maximizing the learning opportunities, engineering students have a sense of the product through 3D visualization before producing an actual prototype (Abulrub, Attridge, & Williams, 2011).

University students are expected to have fluent communication skills, and Harris, Kemmerling and North (2002) report that they build confidence in public speaking as one of the generic skills if these can be practised first in a virtual setting. Moreover, students attending professional programs are required to acquire professional manners of communication with stakeholders. For instance, medical students are required to communicate well with patients having different kinds of medical condition, where responses are often affected by a state of emotional distress. Through the virtual environment, they can practise and rehearse communication skills with a virtual patient, family members and other professional practitioners before dealing with real people. Beggan, Morton, and Simpson (2017) find that nursing students may build empathy when they experience being patients in a busy ward setting through 360° video VR clinical scenarios. A head-tracking sensor built into an HMD allows users to move their head to interact with full-vision immersion.

3 VR/IVR Design and Development: A Teaching-Development Grant Project

In Hong Kong, university educators have started to venture into the emerging immersive learning environment. Adopting the Assessment, Design, Development, Implementation and Evaluation ADDIE model, this paper reports a university-wide project that is supported through the Teaching Development and Language Enhancement Grant funded by a university in Hong Kong. The ADDIE model is still one of the most widely adopted for designing and developing prototypes for the virtual learning environment (Soto, 2013). This project aims to support academics on using VR/IVR to provide an enhanced learning experiences in disciplines. Design and development of each VR/IVR will include an initial phase of prototyping, followed by fine-tuning after a small-scale pilot with students, followed by implementation in class and evaluation of the learning experience immediately after the class. As a university-wide project, we aim to support six courses in departments through a funding of HK$800,000 (*circa* £72,700) between December 2016 and July 2018. Two courses are reported in this paper because they are the first two sub-projects to have completed the full cycle. The remaining four sub-projects are still in the development phase. This paper will examine the two courses that have embedded IVR in class to determine whether in-depth inquiries are being triggered through the novel learning setting. There is variation in the production process of the two sub-project types of VR/IVR that have completed the full ADDIE cycle, while 'Pharmacology and Therapeutics' is set for an indoor scenario and 'Understanding Ecotourism' is set for an outdoor scenario.

3.1 Designing and Developing VR/IVR Cases for Practising Professional Clinical Skills in 'Pharmacology and Therapeutics'

Pharmacy students in Hong Kong face a common challenge of having limited opportunities to experience professional clinical practice, even though they are required to interpret clinical cases and attend pharmacy ward rounds during Years 3 and 4 of their study. There is a chronic lack of systematic teaching materials for pharmacy students on the preparation of clinical cases, the interpretation of clinical notes and clinical abbreviations, and the assessment of clinical cases.

Aligned with the teaching content in the program, the VR/IVR cases were constructed to prepare Year 3 pharmacy students before they attended clinical settings the following year. Staff from the Pharmacy Department produced a storyboard of two scenarios with patient backgrounds extracted from authentic cases in Prince of Wales Hospital. The scenarios simulated the process of consultation with a patient and with a medical team of doctors. Screenshots were set and agreed with the staff on the storyboard with a view to being a pharmacist interacting with the professional staff and the patient. The scripts were sent to 'actors', who were invited as doctors and the patient before the date for filming. The technical team took shots of a clinical scene setting on campus. Six cameras held in a rig were used to capture a full spherical indoor view: nine shots to capture case 1 and seven shots for case 2. The best captures were selected and converted for the IVR cases by the technical team, with occasional review meetings by both teams. A pilot was conducted with a few pharmacy students to collect feedback on their experiences when viewing with smartphones connected to VR headsets and tablets in a web-based environment to test the feasibility of the whole setup for teaching (Fig. 1). To provide a better understanding of this type of learning experience, the teacher was also invited in the pilot so that she could have a personal experience with the HMD with sensors because she planned to introduce a totally new method in her teaching. During the class, one student walked through the scenario with the HMD and sensors, while the professor explained the clinical diagnostic processes (Fig. 2).

Fig. 1 Conducting a pilot with some pharmacy students on 360° viewing mounted in Google cardboard boxes

Fig. 2 Student using HMD with sensors while the professor explained the clinical diagnostic processes to the class

3.2 Designing and Developing VR/IVR Outdoor Field Trips for Students Taking 'Understanding Ecotourism'

A two-credit course on 'Understanding Ecotourism' has a field trip as part of the learning activities in addition to lectures and invited guest talks on campus. However, only one field trip is feasible per semester. Therefore, virtual field trips can provide a wider exposure to other ecotourism sites while students gain extended knowledge in the course. As a pilot, only one virtual field trip was set up, to Lai Chi Wo, a popular attraction with historical heritage and declared monuments. An initial meeting was arranged to discuss the route and foci of the virtual field trip with the teaching faculty, while samples of 360° video capture were shown. Site shooting by the filming crew and the teaching faculty was arranged. Much work on film editing was done after the trip, and hot spots with additional images and historical information provided by the teacher were added to the 360° video-based educational site. Markers were created so that students could navigate from one location to the next. A pilot test was set up with a few students in the same teaching classroom to collect feedback on viewing with different mobile devices and their comments on improvements to the prototype. HMDs were not intended to be used with over 50 students in the class, and students were given full instruction before the class to bring their notebook computers or pre-load the videos to their smartphones for viewing with cardboard boxes. The notebook used by the teacher was also pre-loaded with the VR video capture before class. The professor first made initial guided discovery in the lesson, illustrating the virtual tour with the screen projector (Fig. 3). However, students could view the virtual site in their own time at https://s3.amazonaws.com/aws-website-laichiwo-trial-7mewp/index.html.

Fig. 3 Showing the virtual tour to Lai Chi Wo in class (left-hand panel: satellite view; the high-resolution 360° images are displayed in the right-hand main frame)

4 VR/IVR Implementation in the Classroom

Huge bandwidth is required to transmit high-quality VR videos (He, Hu, Jiang, & Li, 2018). The learning experience will be hampered if students cannot view the VR videos during class time. Therefore, to lower the demand on Wi-Fi access to the VR materials through the smartphones that students normally bring to class, they were given full instructions to download the video and application to view VR materials. In addition, six tablets preloaded with the VR teaching materials and thirty sets of VR headsets were delivered to the venue for the teaching sessions. An hour before the teaching session, a high-speed notebook with the HMD and sensors was prepared in the locations for the teaching sessions on pharmacy.

4.1 Pharmacy Class

Two VR clinical cases were developed on the topic of acute coronary syndrome and heart failure for the class with 38 pharmacy students. An hour-long lecture was conducted before the one-hour VR/IVR teaching session for students to learn conceptual understanding of pharmacological treatment with patients having these types of medical complication in a VR clinical context. As it was the first time for the teacher to adopt the VR technology in class, one student put on the HMD and sensors to go through the IVR case with the video displayed in a front screen for the class, and the teacher explained the medical concepts and paused between questions for students to think and reply. Tablets and VR headsets were set aside for students to use. Student feedback was collected after the first class of VR implementation.

Materials and case questions on the second topic were sent to students before class so that they could review and prepare for the VR case discussion. Students were divided into small groups (four–five students per group) to facilitate in-class discussion.

4.2 Ecotourism Class

One VR video-capture field trip to Lai Chi Wo in the north-eastern New Territories of Hong Kong was produced based on the real environment in June 2017. The VR materials were used in a university general education course with over fifty students. The two-hour session was split, with the first hour conducted by a guest speaker from the Agriculture, Fisheries and Conservation Department presenting a talk on ecotourism. The VR session took place afterwards. The teacher showed the VR with a front screen display, and his students could view the site either with their own notebook computers or tablets, or using VR headsets with their smartphones. The teacher first walked through some checkpoints to illustrate ways of viewing while students watched individually. They were then given time to work in small groups to go through the rest of the virtual tour with digital devices to discuss questions and issues relating to ecotourism, such that they had to think critically about different perspectives while viewing the high-resolution 360° video capture with embedded information. The VR platform was set to provide an alternative opportunity for students to experience and study the environment in Lai Chi Wo without an actual site visit. This served to prepare students with skills on observation and critical awareness when they went on a field trip to a different location.

5 Evaluation of the IVR Project

Various stages of evaluation are crucial to informing an innovative dimension embedded in classroom teaching. Evaluation becomes a focal point, from the design and development stage to classroom implementation. Feedback by teaching faculty on the storyboard was sought and confirmed before shooting was arranged. The technical team, including an instructional designer and two technical staff, held reviews periodically of prototypes of sub-projects, 'Pharmacy' and 'Ecotourism', during the VR production stage. Students were involved in key stages, from testing to post-class evaluation. In the testing stage, their comments guided the technical team in choosing types of VR headset from Google cardboard boxes to other handheld VR headsets. Their suggestions provided fine-tuning of the VR development before the VR sessions were launched.

Student interviews were conducted after their first VR experience in the Pharmacy class. Many remarked that they were overwhelmed by all the information provided in the first VR case and felt some degree of disorientation, not knowing how to respond to some of the questions during case discussion. Having reviewed their comments, this brought forward re-examination of the process of in-class teaching. Subsequently, case questions and materials relating to the second topic for the second VR case were sent to students to study in advance before attending the class. A survey of students was conducted after they had experienced two VR sessions, and 34 responses were collected.

A seven-point Likert scale, with 7 'strongly agree' and 1 'strongly disagree', was used in the item statements and students had very positive responses (Table 1).

Students commented that 'good with images of patient's clinical symptoms', 'the VR allows us to see the patient non-pharm aspect'. However, some commented that 'the technical problems may cause waste of time', and 'can skip the part with VR glasses'. One student suggested that 'It would be nice if there are notes which summarize what to monitor for each of these diseases and the ideal dosage of the drugs next to the case studies'.

While only one VR session was held for the Ecotourism class, a post-class survey with a seven-point Likert scale was also conducted on their perceptions of the VR experience on the virtual tour, but only 17 responses were collected. Among them, 88.2% had not visited Lai Chi Wo. Feedback on these students is shown in Table 2.

Here are additional comments expressed by few students: 'feeling very dizzy', 'to include audio explanation in various checkpoints' and 'good experience, and appreciate the technical team support'.

Table 1 Pharmacy students' feedback on experiencing the VR sessions

Survey items	Strongly agree (%)	Agree (%)	Fairly agree (%)	Neutral (%)	Fairly disagree (%)	Disagree (%)	Strongly disagree (%)
I am alert to non-pharmaceutical management (e.g. patient responses) in the VR clinic	41	29	27	3	0	0	0
Discussion of VR cases can enhance my learning interest	15	65	9	6	6	0	0
I feel that I am better prepared for the clinical practice in the final year with the VR clinic experience	9	50	27	9	3	3	0

Table 2 Students' feedback on virtual visit to Lai Chi Wo

Survey items	Strongly agree (%)	Agree	Fairly agree (%)	Neutral (%)	Fairly disagree (%)	Disagree (%)	Strongly disagree (%)
The VR trail enables me to visualize the site	41	29	27	3	0	0	0
I enjoy the IVR headset to view the trail	15	65	9	6	6	0	0
I enjoy the tablet/ web nIVR to view the trail	9	50	27	9	3	3	0
I have interest to find out more about the VR trail site after class	18	35	18	24	0	0	6
I consider visiting Lai Chi Wo in my own time	24	24	24	29	0	0	0
I appreciate the VR experience as part of my university study	35	41	18	0	0	0	6

6 Discussion

Wi-Fi access has been made available in university campuses in Hong Kong, so the majority of students can view materials on learning management systems using their mobile phones or notebook computers for academic study. However, leaping to viewing high-quality video with VR headsets for immersive experience or tablets and notebook computers for in-class activities may require much preparation. Students need to be familiar with the new tools and require more time in preparation before starting the first class. Although students can be provided with full instructions to download viewing applications and VR video to their mobile phones before class, VR headsets with sensors are not readily available in classrooms. If students prefer to watch with their notebook computers, bandwidth in a classroom may be limited for transmitting high-quality videos. Choices of alternative viewing modes need to be considered when staff use VR/IVR teaching in a classroom.

Nevertheless, a VR environment goes beyond the virtual presence and there is an affective dimension in which emotions are induced when learners interact through the medium (Riva et al., 2007; Huang, Cerekovic, Pandzic, Nakano, & Nishida, 2009). Bringing a clinical ward setting into a traditional classroom, students experienced first-hand clinical exposure in class with guided, step-by-step VR teaching materials on clinical cardiology pharmacy while translating clinical knowledge into practice. Patient-centred treatment can start in class, because they can learn to observe symptoms presenting in a patient and practise communication with virtual doctors. Although students can visualize patients in a ward, they start to broaden their scope of learning pharmaceutical treatments from reading paper-based cases with information on medical history to focusing on patient's observable physical conditions with reference to medical data collected. With pre-clinical preparation, they may draw a closer connection between academic study and the complexity in a hospital ward that they face during the internship in the final year of the pharmacy curriculum. Educators may need to reconsider ways to maximize the new learning environment when adopting IVR in a classroom (Iglesias & Galvez, 2008). As students can view the IVR videos with VR headsets individually and can form groups to work on VR scenarios, educators can consider converting the lecture mode with VR video projecting on a front screen to interactive group tasks providing that personal immersive experience.

Moreover, research findings support positive learning outcomes: learners can find it easier to understand abstract concepts in three dimensions, bridge space over time, and examine trends and changes (Fernandez, 2017). And 360° video capture on a virtual tour can provide students with a space to explore and examine the virtual field when it is not readily accessible, or have preparations to review materials in a virtual setting before conducting a thorough study on site. However, it is resource-intensive to create a single 360° VR video, although educators can make use of publicly accessible, high-quality, 360° video galleries in 360 cities (https://www.360cities.net/video_gallery). In addition, high-quality, 360° VR videos are produced by journalists as immersive news (http://bbcnewslabs.co.uk/projects/360-video-and-vr/). Depending on the intended learning outcomes and how educators design the VR content, students may observe passively or explore actively when they discuss and make critiques between peers in the VR environment (Black, 2017).

7 Conclusion and Recommendations

This is the first institution-wide project creating VR/IVR educational materials for classroom teaching. The project has been centrally funded, and therefore knowledge in producing the VR/IVR projects can be channelled across departments. Second, adoption of emerging technologies in teaching can encourage better student engagement, as evidenced in various stages of student evaluation, although there is much higher demand in time for early adopters of VR and IVR technologies in the process of planning, design and development for classroom implementation (Iglesias & Galvez, 2008). Although HMDs with sensors are becoming more affordable, it is still an add-on device to be arranged before class. With advances in integration of artificial intelligence and new models of VR devices on the market each year, the mode of interaction with VR materials is still evolving. As reported in this paper, interactions through VR materials can serve to build professional competence and instil interest and curiosity while exploring various virtual tours, whether 360° videos are adopted in VR or IVR mode. To provide a sustainable impact on student learning, educators can set a variety of learning tasks with the VR materials from different perspectives and foci before and after in-class implementation.

As tools for building VR materials are emerging in the market, learners are no longer just consumers. Instead, they can take part in the creation of VR materials so that more creative and advanced VR objects can be built to gear up the next generation of mixed reality native.

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References

Abulrub, A. H. G., Attridge, A. N., & Williams, M. A. (2011). Virtual reality in engineering education: The future of creative learning. In *Proceedings of IEEE global engineering education conference (EDUCON) 2011* (pp. 751–757).

Bailenson, J., Patel, K., Nielsen, A., Bajscy, R., Jung, S., & Kurillo, G. (2008). The effect of interactivity on learning physical actions in virtual reality. *Media Psychology, 11*(3), 354–376.

Beggan, A., Morton, S., & Simpson, T. (2017). How did it make you feel? Using immersive 360 VR video to build empathy within clinical settings. Accessed on January 30, 2018 https://altc.alt.ac.uk/2017/sessions/how-did-it-make-you-feel-using-immersive-360-vr-video-to-build-empathy-within-clinical-settings-1739/.

Black, E. R. (2017). Learning then and there: An exploration of virtual reality in K-12 history education (doctoral dissertation). Accessed on February 23, 2018 at https://repositories.lib.utexas.edu/bitstream/handle/2152/63616/Black_Thesis_Exploration.of.VR.in.K12.education_2017.pdf?sequence=2.

Bruno, F., Bruno, S., De Sensi, G., Luchi, M. L., Mancuso, S., & Muzzupappa, M. (2010). From 3D reconstruction to virtual reality: A complete methodology for digital archaeological exhibition. *Journal of Cultural Heritage, 11*(1), 42–49.

Chang, C. Y., Lin, M. C., & Hsiao, C. H. (2009). 3D compound virtual field trip system and its comparisons with an actual field trip. In Proceedings—2009 9th IEEE International Conference on Advanced Learning Technologies, ICALT 2009 (pp. 6–7).

Cruz-Neira, C., Sandin, D. J., DeFanti, T. A., Kenyon, R. V., & Hart, J. C. (1992). The CAVE: Audio visual experience automatic virtual environment. *Communications of the ACM, 35*(6), 64–73.

Fagan, M., Kilmon, C., & Pandey, V. (2012). Exploring the adoption of a virtual reality simulation: The role of perceived ease of use, perceived usefulness and personal innovativeness. *Campus-Wide Information Systems, 29*(2), 117–127.

Fernandez, M. (2017). Augmented virtual reality: How to improve education systems. *Higher Learning Research Communications, 7*(1), 1–15.

Grealy, M. A., Johnson, D. A., & Rushton, S. K. (1999). Improving cognitive function after brain injury: The use of exercise and virtual reality. *Archives of Physical Medicine and Rehabilitation, 80*(6), 661–667.

Grewe, P., Kohsik, A., Flentge, D., Dyck, E., Botsch, M., Winter, Y., et al. (2013). Learning real-life cognitive abilities in a novel 360-virtual reality supermarket: A neuropsychological study of healthy participants and patients with epilepsy. *Journal of Neuroengineering and Rehabilitation, 10*(1), 42.

Harris, S., Kemmerling, R., & North, M. (2002). Brief virtual reality therapy for public speaking anxiety. *CyberPsychology & Behavior, 5*(6), 543–550.

He, G., Hu, J., Jiang, H., & Li, Y. (2018). Scalable video coding based on user's view for real-time virtual reality applications. *IEEE Communications Letters, 22*(1), 25–28.

Hodgson, P. (2017). Media literacy: Enhancing teaching and empowering learning. In A. Y. L. Lee, K. Zhang, and K. Chan (Eds.), *Multidisciplinary approach to media literacy: Research and practice* (pp. 306–315). Beijing: The Institute of Communication Studies of Communication University of China. ISSN: 978-7-5657-2142-7.

Huang, J. Y. (2003). An omnidirectional stroll-based virtual reality interface and its application on overhead crane training. *IEEE Transactions on Multimedia, 5*(1), 39–51.

Huang, Y. C., Backman, K. F., Backman, S. J., & Chang, L. L. (2016). Exploring the implications of virtual reality technology in tourism marketing: An integrated research framework. *International Journal of Tourism Research, 18*(2), 116–128.

Huang, H., Cerekovic, A., Pandzic, I., Nakano, S., & Nishida, Y. (2009). Toward a multi-culture adaptive virtual tour guide agent with a modular approach. *AI & Society, 24*(3), 225–235.

Iglesias, & Galvez. (2008). Effective BD-binding edutainment approach for powering students' engagement at university through videogames and VR technology. In *Proceedings of 2008 the third international conference on convergence and hybrid information technology* (Vol. 1, pp. 307–314).

Kandalaft, M., Didehbani, R., Krawczyk, N., Allen, D., & Chapman, C. (2013). Virtual reality social cognition training for young adults with high-functioning autism. *Journal of Autism and Developmental Disorders, 43*(1), 34–44.

Koepnick, S., Hoang, R. V., Sgambati, M. R., Coming, D. S., Suma, E. A., & Sherman, W. R. (2010). RIST: Radiological immersive survey training for two simultaneous users. *Computers & Graphics, 34*(6), 665–676. https://doi.org/10.1016/J.CAG.2010.09.008.

Krakowka, A. R. (2012). Field trips as valuable learning experiences in geography courses. *Journal of Geography, 111*(6), 236–244.

Lee, J. H., Ku, J., Cho, W., Hahn, W. Y., Kim, I. Y., Lee, S. M., et al. (2003). A virtual reality system for the assessment and rehabilitation of the activities of daily living. *CyberPsychology & Behavior, 6*(4), 383–388.

Patiar, A., Ma, E., Kensbock, S., & Cox, R. (2017). Hospitality management students' expectation and perception of a virtual field trip web site: An Australian case study using importance—Performance analysis. *Journal of Hospitality & Tourism Education, 29*(1), 1–12.

Riva, G., Mantovani, F., Capideville, C. S., Preziosa, A., Morganti, F., Villani, D., et al. (2007). Affective interactions using virtual reality: The link between presence and emotions. *CyberPsychology & Behavior, 10*(1), 45–56.

Soto, V. J. (2013). Which instructional design models are educators using to design virtual world instruction? *Journal of Online Learning and Teaching*, *9*(3), 364. Accessed at http://jolt.merlot.org/vol9no3/soto_0913.htm.

Steuer, J. (1992). Defining virtual reality: Dimensions determining telepresence. *Journal of Communication, 42*(4), 73–93.

Tawhai, C. (2017). *Immersive 360° video for forensic education* (Doctoral dissertation). Murdoch University. Accessed on January 29, 2018 at http://researchrepository.murdoch.edu.au/id/eprint/37677/1/Tawhai2017.pdf.

Yavrucuk, I., Kubali, E., & Tarimci, O. (2011). A low cost flight simulator using virtual reality tools. *IEEE Aerospace and Electronic Systems Magazine, 26*(4), 10–14.

Cultural Heritage Objects in Education by Virtual and Augmented Reality

Ján Lacko

Abstract In this paper, we focus on the use of cultural heritage objects (historical, natural and technical) in the education process. We create universal content that can be used in education in schools, but also at home with the use of virtual and augmented reality. We discuss the potential of the VR and AR tools for better memorising of the information based on the virtual objects and scenes. We describe the selection of individual objects in order to be able to communicate information about individual objects in pairs across the Slovak-Ukrainian border and to use them appropriately on the tools created in the InovEduc project to improve the education at secondary schools on subjects like history, geography, religion, regional education, civics and languages. We also focus on creating content so that it can be used in other areas such as tourism, museums and other cultural institutions.

Keywords Education · Cultural heritage · Virtual reality · Augmented reality

1 Introduction

The use of modern digital technology in the teaching process is currently a modern approach to education at various levels of schools. In terms of acquiring knowledge, the memorability of the information obtained is also an important factor. Virtual and augmented reality technologies can be increasingly integrated into the learning process and profited by an innovative approach to learning. In this paper we present the possibilities of using digitised objects of cultural heritage mediated through virtual and augmented reality in the teaching process. The use of virtual and augmented reality in teaching has begun to be considered from the very first prototypes of the device. Virtual reality is used to create different interactive learning environments in different areas. As Thorsteinsson (2013) teaches using virtual reality,

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it is possible to create a virtual reality learning environment that promotes online communication between students and teachers. A similar solution is also being promoted by Monahan, McArdle and Bertolotto (2008). It is also possible to use virtual reality for teaching within specific domains, etc. as stated in Machado, Moraes, Nunes and Costa (2011) for teaching medicine, or Häfner, Häfner, and Ovtcharova (2013) in engineering education. Education based on virtual reality is also possible for disadvantaged groups, as stated in their article Ip et al. (2016). As stated in Lee (2012) augmented reality is one technology that dramatically shifts the location and timing of education and training. The experimental results show that augmented reality based mobile learning system is able to improve the students learning achievements as stated in Chiang, Yang and Hwang (2014). Cultural heritage objects can be used for teaching through modern ICT. As stated in Ott and Pozzi (2011), ICT can really provide any added value to Cultural Heritage pedagogy, education and learning. As stated in Angelopoulou et al. (2011), one of the most promising aspects of augmented reality is that it can be used for visual and highly interactive forms of game-based learning. Devices that are used for augmented reality education can be simple and easy to use (smartphones, tablets) or may require special setup as mentioned in Novotný, Lacko, Samuelčík (2013).

Nowadays, students are highly influenced by individual technologies, and therefore new forms of education must be sought to respect current trends and teaching will be a good experience for students. As stated in Martín-Gutiérrez et al. (2015) "Right now, education and teaching institutions try to avoid traditional teaching methods despite their validity and successful results, as the interest now focuses on more productive methods that may improve the learning experience and the students' intellectual level. Computer technologies have provided a strong improvement according to educational tools, allowing development of new teaching methodologies." If they are trained in a traditional way, they are mostly in the position of passive recipients of information, with very likely that much of the information that comes to them will not be remembered. If, in connection with receiving information, students are exposed to an emotional experience, through simulation in the virtual world, increases the share of information stored not only in the short-term but also in the long-term memory. Results of Pan, Cheok, Yang, Zhu and Shi (2006) show that the attitude towards virtual learning is an important predictor for learning effectiveness and that the self-efficacy had more influence on subject effectiveness while technology efficacy predicts more on general effectiveness. Thanks to digital technology solutions, it is possible to create positive emotions, thanks to feeling embedded into the virtual environment.

In our work we focus on the use of virtual and augmented reality in the teaching process so that the content represented by cultural, natural and technical objects can be used for independent learning and teacher-led learning with an emphasis on obtaining information and memorizing them through technology-induced emotion and we have created a series of applications that are independently deployable in teaching, presenting cultural heritage in museums, right on landmarks, or in home entertainment that share the same content. As stated in Dunleavy and Dede (2014) AR is primarily aligned with situated and constructivist learning theory, as it positions the learner within a real-world physical and social context while guiding, scaffolding and facilitating participatory and metacognitive learning processes such as authentic inquiry, active observation, peer coaching, reciprocal teaching and legitimate peripheral participation with multiple modes of representation.

Presentation of digitised cultural heritage objects in virtual and augmented reality can have a variety of uses. Most often, we can meet their presentations in the area of tourism but also within the museums as presented in Rodriguez, Agus, Bettio, Marton and Gobbetti (2015) either in the form of extended information about the objects directly on the site where the monument is located, or we present them outside the places to attract visitors or provide information about the meaning of the monument. In the context of education, it is possible to use cultural heritage objects as complementary objects in the teaching of history, religion, geography, civic education as well as, for example, languages. The objects themselves are not the wearer but the intermediary of important information about historical, technical, natural and other contexts. By using individual objects and storytelling, stories directly included in the lesson can be conveyed.

2 Issues

The one of the goal of learning is to provide relevant information so that it can be remembered quickly and efficiently. This kind of surface learning can lead with adequate teacher to deep conceptual learning as mentioned in Rillero and Padget (2012). An important fact may be whether the information given is related to an object, time value, or emotion. We have tried to find a way for students to memorize information effectively in connection with a visual experience. As part of the "InovEduc" project—Innovative Methods of Education to Promote Partnerships, we focused on creating a series of tools that would communicate visual information about cultural heritage objects via virtual and augmented reality. The objective of the InovEduc project was, through selected cultural, natural and technical objects, to point out different and common features that represent the real boundary between the two states of Slovakia and Ukraine in the context of their common history, gender relations and cultural traditions. The aim of the individual software tools that were created within the framework of the project was through their content and form to make these questions accessible to the students and to encourage them to think critically and to remove the barriers in the thinking of the current young population based on the evaluation of individual facts and their memorization, which is divided by the border.

The project was implemented in border areas of Slovakia and Ukraine. Given that historically the territory was in the past a common development in terms of common statehood, religion, cultural development, it was possible to identify on both sides of the border the objects of cultural, natural and technical heritage that were digitised. Selected objects, despite their apparent disconnect, point to ethnological, historical and cultural significance to the common features of the

Table 1 List of digitised objects

Group	Object names	Digitisation outcomes
Castle ruins	Zborov Castle, Nevice Castle	3D models, ideological reconstruction of Zborov castle
Jewish monuments	Jewish cemetery in Topoľa, Jewish cemetery in Uzhhorod, Synagogue in Bardejov	3D models of synagogue, gravestones, panoramas
Greek Catholic wooden Churches	Church in Topoľa, Hrabová roztoka, Šmigovec, Inovce and Kostryna	3D models, interior panoramas
Orthodox wooden Churches	Church in Ruský Potok, Danilovo	3D models, interior panoramas
Wine cellars	Wine cellar in Veľká Tŕňa and Wine cellar in Serednie	3D models, interior panoramas
Objects of folk dwelling	Residential house with water mill from Vyšná Jablonka, The Lemko settlement in Zarychevo	3D models, interior panoramas
Castles connected by Drughet family	Château in Humenné, Castle in Uzhhorod	3D models, interior panoramas
Technical monuments	The Railway viaduct in Hanušovce nad Topľou, Blacksmith in Forge in Lysychovo	3D models, interior panoramas
Important historical churches	Church in Veľká Tŕňa, Horjany rotunda in Uzhhorod	3D models, interior panoramas
Natural monuments	European Bison from Poloniny, The Valley of daffodils in Khust	3D model, panorama

development of the society in Slovakia through Ukrainian interdependence in particular periods. As mentioned in Voľanská (2017), the objects selected for the 3D digitization shall demonstrate in what manner the common features of the region's history are more significant than the differences. Within the final phase, 24 objects (14 from Slovakia, 10 from Ukraine) were selected for the digitisation process, which had common elements in the history, the way of using, the religious confessions, the type of monument, etc. The selected 24 objects were divided into pairs so that it is possible to compare common architectural features and ways of using objects on both sides of the common border. Object selection was based on consultation with ethnologists and teachers from the regions, as they participated in the preparation of worksheets that served as a basis for the teaching process with defined application scenarios with virtual and augmented reality. Table 1 shows a list of objects divided into common groups by type of use.

As is evident from Table 1, it was necessary to create an effective way of presenting objects so that different types of digitised objects could be displayed in virtual and augmented reality.

Our goal was to create individual tools with the use of virtual and augmented reality so that individual technologies can be directly involved in the learning process. Teachers use different approaches, from individual work to collegiate student work and various techniques of serving information. We focused on the individual work of students and try to solve problems related to how each application should be designed to be used in environment of school, when information are interpreted by the teacher as well as independently for students in the home environment.

3 Procedures

In preparing each application, we assumed that they should have adequate hardware at schools. For virtual reality applications, schools should have Oculus rift + Oculus touch controllers or HTC VIVE headset. Augmented reality apps should be available with Android or iOS smartphones or tablets. However, as it turned out, schools are not equipped with sufficient hardware or technical expertise to use such applications. For this reason, we decided to create also a web application and a standalone application for the Windows operating system in addition to the virtual and augmented reality applications.

Because we wanted to share the same content through individual apps, factors such as the size of individual 3D models and additional objects in the scene, the rendering speed of individual devices, and the visual quality of each 3D model were needed to digitise cultural heritage objects. As much as possible, we wanted to keep the same visual impression within each app. For these reasons, we have decided to minimize the use of photogrammetry to create 3D models and replace it where it was possible by manual modelling to control the number of individual polygons in 3D models. Individual models showed the external appearance of individual cultural heritage objects. For interior design, we decided to take advantage of the panorama, because the interior model would require a lot of data for quality display in the form of a 3D model.

Two types of scenes were designed for each application. One type of scene was common to a standalone application, a web application, and a virtual reality application, and the second type of scene was ready for augmented reality apps. Both types of scenes included 3D models of the main objects, interior panoramas, or the objects in the form of panoramas for the exterior. The virtual reality scene was enriched with terrain, vegetation and a spherical panorama of the sky and a cylindrical panorama of the distant surroundings obtained through the drones, as you can see in Fig. 1.

For each type of application, it was necessary to create a custom graphical user interface that is based on the need for navigation and object selection in relation to the different types of input devices and imaging techniques used.

Each scene of a particular object is complemented by a number of multimedia objects such as descriptive text, a real object image, as well as sound and eventual

Fig. 1 Scene of the Château in Humenné surrounded by its environment for virtual reality application

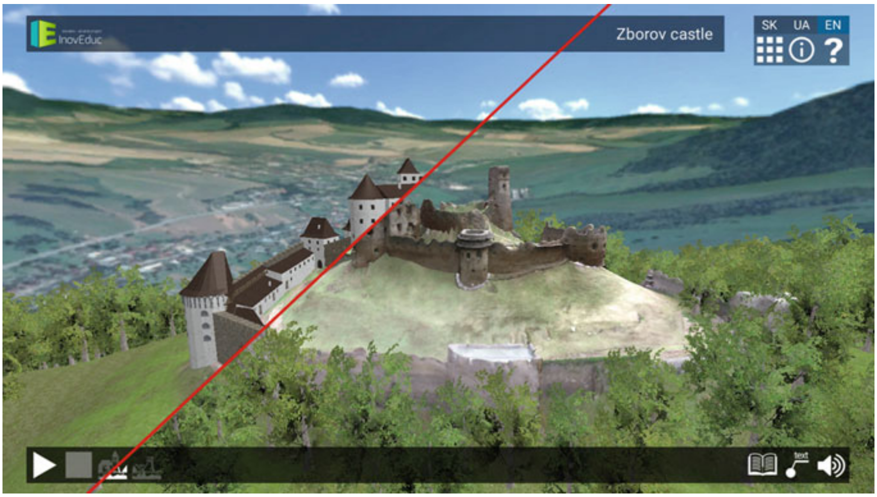

Fig. 2 3D model of ideological reconstruction and ruins of Zborov castle

descriptions directly linked to individual parts of the object in the form of hotspots. Most scenes consist of a 3D exterior model and optional interior panoramas. For some objects, additional features related to the historical development or functionality of the object are added. For example, Zborov Castle contains, besides the photogrammetrically processed current state of ruins, also its ideological reconstruction as shown in Fig. 2. Wooden church in Šmigovec can be virtually dismantled according to individual layers (roof, plaster, tower, tiling…). The railway viaduct in Hanušovce nad Topľou is complemented by an animated 3D model of a historic locomotive and can be let out, which is a reference to the historical event of the end of World War II. The water mill in Vyšná Jablonka is currently located in the Humenné open-air museum, where the source of flowing water is not possible, so this was added in the virtual space and at the same time the animation of the rotation of the water wheel was realized. The church in the Veľká Tŕňa can be seen in three different states, given the historical development of its appearance in different periods. Some other objects are added to some objects. For the Mill from Vyšná Jablonka there is added a wall with a picture of the building layers, for the Wine Cellars in the Veľká Tŕňa are added 3D models of barrels for wine production.

3.1 Virtual Reality Application

When designing a virtual reality application, we suggested that we do not want to offer a full-featured application with storytelling to students, as we assumed the involvement of the teacher in the application. Although the application is not collaborative and is designed for a single user, it is possible to display each scene for the objects separately, which also gives the teacher the opportunity to concentrate the students' attention on the various details in the scene. Within the scene, you can track the location of the user in the space that was specified when calibrating the headset. However, the scale of individual scenes is significantly larger, and since we offer 1:1 object display, it is necessary to ensure that the user moves both in the scene and outside the reserved area. For movement of the user in the scene, we chose the ability to jump positioning through the Oculus touch controller or HTC VIVE controllers through pointing to the terrain. For most objects, the camera in the virtual space is inserted at the level of the average human height above the terrain. To view the ruins of the Zborov and Nevice castles, we placed the camera so that the user sees the objects from the viewpoint, and when changing the position to the terrain, he gets to the appropriate place at a level of about 20 m (in the scene units) above the terrain. We have chosen this approach to test user responses in different scenarios.

An important part of the scenes are panoramas, whether in the form of interior panoramas, or for some scenes, the panoramas are the main view of the content. As part of the design of the system, we have solved the dilemma whether it is necessary to create stereoscopic panoramas, or it will be enough to use the classic panorama without the possibility of perceiving the depth. As it turned out during testing, it is enough for users to use panoramas without stereo, because when changing the scene between the exterior (3D model) and the interior, users do not see the change between views as a major problem. We used hotspots to move between the scene and the spherical panoramas used in the app. As it turned out when testing the app, users, especially younger people, did not have the problem of being aware of the change in the view and the way of navigation in the 3D scene and in panoramas where we had a limited possibility of movement.

Fig. 3 Position of the description text above the controller

Additional information about the objects in the scene is displayed with a text description. Their display is realized after the controller has been directed to the text appears above the controller description of the part of the object so that the position of this description is linked to the position of the controller itself, as you can see in Fig. 3.

3.2 Augmented Reality Application

For apps with augmented reality, we've been forced to optimize dramatically because they are triggered on mobile devices that do not have such high performance, and there is no need to enter all the data for that scene, because in the extended reality, users focus only on that object. That's why we've reduced the terrain and eliminated the vegetation. Because the entire content of the application is stored locally and not dynamically loaded, we also optimized the size of the textures and the shaders used.

The individual scenes are displayed in the application by using the image pattern for tracking the space and determining the global coordinate system of the scene. 3D scenes are displayed above the tracked image without scaling, so scaling is controlled only by changing the device's distance from the tracked image. Testing has shown that this method is most user-friendly. Figure 4 shows the scene in the application.

You can view panoramas in the augmented reality application by clicking on the hotspot in the 3D scene. The panoramas themselves are displayed on the entire area of the device and do not use a tracked image to determine their location in the room,

Fig. 4 3D model of ideological reconstruction and ruins of Zborov castle in the augmented reality application

but they can be viewed using the internal sensors of the mobile devices (accelerometer, gyroscope, magnetometer). As the user rotate, the angle of view changes to part of the panorama. During the development of the application we also tested the possibilities of linking the panorama position with the tracked image so that the user did not lose the context. For these needs, we mapped panoramas on an inverse sphere, the centre of which was above the tracked image. As it turned out, it was not possible to display all parts of the panorama in this way.

4 Results

Utilizing our application for virtual and augmented reality in teaching requires teacher guidance. Teacher provides students with information that is complemented by visual and audio channels through 3D scenes. Within the framework of the implemented project, working methodological sheets were created, which the selected teachers directly participated in. The working methodological sheets are conceived in five cross-cutting themes (civil society, traditional folk culture, history, religion, and ICT) that complement each of the created applications. The individual activities in the working methodological sheets are adapted to accompany students using storytelling to obtain expert information on historical, geographic and factual contexts. In particular, the augmented reality application is used for group activities, and for individual activities, they are applications using virtual reality.

4.1 Mixing VR and AR Together in Education

Within the InovEduc project, applications for virtual and augmented reality have been developed to enable them to engage in the learning process individually or collectively, and at the same time that students as the primary target group of the project are able to use them at home as well. Within the app, the same content is offered in spite of a different approach within the interaction and display modes. With this approach, it is possible to combine different approaches directly in the classroom, independent student interaction in a virtual reality without the teacher having to enter the process or the augmented reality use of the group with the teacher's commentary and the possibility of storytelling. Optionally, separate use of home-based applications, depending on the HW available to the user.

Based on feedback from teachers, such a combination of individual approaches appears to be an appropriate complement to traditional approaches to learning, while the use of multiple application types allows for greater variability in the selection of different learning variants along with methodological worksheets for the individual subjects being taught. The impact of selected technologies on learning experience can be measured individually by the psychological factors, that is, presence, motivation, cognitive benefits, control and active learning as mentioned in Lee, Wong and Fung (2010).

4.2 Testing of the Memorability of the Information by Using AR/VR

An important indicator for education is how to memorize information and how long it is stored in the memory. Therefore, when measuring the impact of using our applications on the teaching process, we have decided to measure just how much information students are able to remember about digitised cultural heritage sites. In the process of remembering, an important factor is the induction of emotion that improves the way the information can be memorized, regardless of whether the emotion is positive or negative. Virtual reality is something new to many users, and immersion itself gives them a positive emotion. In the impact measurement, we created two groups of students. The task of each group was to remember as much of the factual data about the objects. Group A (26 students) worked in a traditional way without the use of VR and AR, and Group B (24 students) used the applications in the classroom. Subsequently, we created a standardized 20-question test and the students had to answer them correctly. This test was carried out immediately after the end of the lesson, followed by one week and one month. The measurement results are shown in Table 2.

The results processed in the graph can be seen in Fig. 5.

The results have shown us that the use of virtual and augmented reality methods is not only a fun way of submitting information but it also affects the memorability

Table 2 Measures of the impact of applications to memorizing facts about objects

Group	% of correct answers immediately	% of correct answers after 1 week	% of correct answers after 1 month
A—without VR/AR	90	76	52
B—with VR/AR	95	83	71

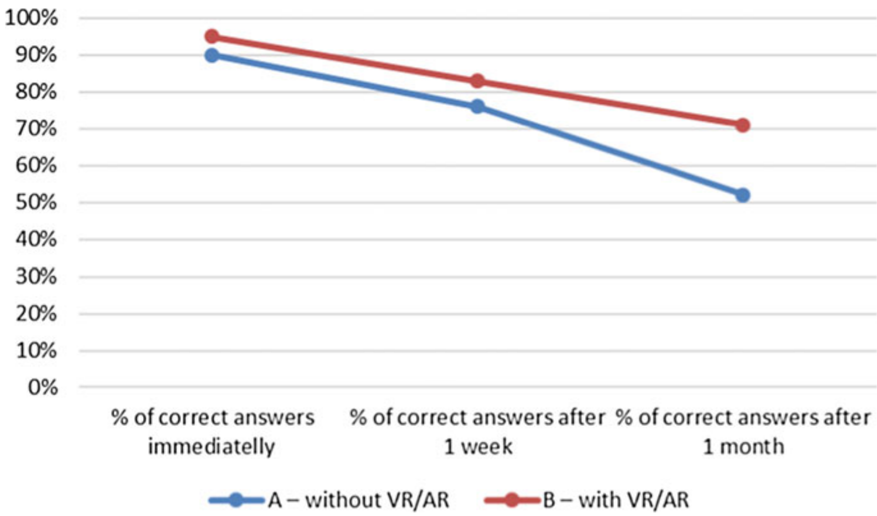

Fig. 5 Graph of the result of the testing

of the information obtained. On the other hand, the biggest obstacles to technology deployment to schools have shown problems with hardware equipment, but in connection with applications for virtual reality and the problem of motion sickness (manifested in about 12% of the tested persons), despite the fact that user tracking in the area by external sensors.

4.3 Applications in the InovEduc Project

The selection of individual cultural heritage objects that were processed into scenes in the InovEduc project was made so that scenes can be used universally not only for education but also for the propagation of these objects on-site or off-site. It was important to create apps that use a variety of technologies to display content, so we've created virtual reality apps, mobile apps for augmented reality, but also standalone and web apps that can show content without the use of special hardware, and it's possible also be used for presentation to a wider audience, not just an individual user.

5 Conclusions

As we have seen in the article, virtual and augmented reality can positively influence the memorability of the information obtained within the learning process. The knowledge gained through this approach is kept longer in the user's memory, assuming that this fact is significantly influenced by the so-called wow effect, when the positive or negative emotion triggered results in the storage of information in the long-term memory as stated by Tyng, Amin, Saad and Malik (2017). Verifying fact, that this is caused by virtual and augmented reality we anticipate as a future work in collaboration with psychologists. The created applications can be used directly in the teaching process, but also in home education.

Moreover, due to the fact that the content itself has been chosen as cultural heritage, other possibilities of utilization such as promotion in tourism and the like are also open. Thanks to the versatility of the processed content and the individual applications created, it is possible to mediate the content on different technology platforms (web, touch panels…) and in different places (on-site or off-site) in various educational, cultural and self-government institutions. In addition, digital technologies can bring new experiences in the visualization of events that cannot be repeated in the real space (for example, the destruction of the railway viaduct in Hanušovce nad Topľou).

Despite the fact that there are still many obstacles to a larger boom in technology, there is evidence of the use of virtual and augmented reality as a good step towards improving the learning process. As stated by Kríž (2017), such learning methods can also be used to reduce barriers between countries. The created applications have the potential for their further development, for example, towards the processing of other topics, such as the history of local transport, mentioned in the article of Štefanovič and Schindler (2016).

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References

Angelopoulou, A., Economou, D., Bouki, V., Psarrou, A., Jin, L., Pritchard, C., et al. (2011). Mobile augmented reality for cultural heritage. *International Conference on Mobile Wireless Middleware, Operating Systems, and Applications* (pp. 15–22). Berlin, Heidelberg: Springer.

Chiang, T. H., Yang, S. J., & Hwang, G. J. (2014). An augmented reality-based mobile learning system to improve students' learning achievements and motivations in natural science inquiry activities. *Journal of Educational Technology & Society, 17*(4), 352.

Dunleavy, M., & Dede, C. (2014). Augmented reality teaching and learning. In *Handbook of research on educational communications and technology* (pp. 735–745). New York, NY: Springer.

Häfner, P., Häfner, V., & Ovtcharova, J. (2013). Teaching methodology for virtual reality practical course in engineering education. *Procedia Computer Science, 25,* 251–260.

Ip, H. H., et al. (2016). Virtual reality enabled training for social adaptation in inclusive education settings for school-aged children with autism spectrum disorder (ASD). In *International Conference on Blending Learning* (pp. 94–102). Cham: Springer.

Kríž, M. (2017). Innovative school education as the way to lower barriers between eastern Slovakia and Zakarpathia. In *Innovative Methods in Education and Research 2017* (pp. 18–22). Prague: Wolters Kluwer. ISBN 978-80-7552-760-8

Lee, K. (2012). Augmented reality in education and training. *TechTrends, 56*(2), 13–21.

Lee, E. A. L., Wong, K. W., & Fung, C. C. (2010). How does desktop virtual reality enhance learning outcomes? A structural equation modeling approach. *Computers & Education, 55*(4), 1424–1442.

Machado, L. D. S., Moraes, R. M. D., Nunes, F. D. L. D. S., & Costa, R. M. E. M. D. (2011). Serious games based on virtual reality in medical education. *Revista Brasileira de Educação Médica, 35*(2), 254–262.

Martín-Gutiérrez, J., Fabiani, P., Benesova, W., Meneses, M. D., & Mora, C. E. (2015). Augmented reality to promote collaborative and autonomous learning in higher education. *Computers in Human Behavior, 51,* 752–761.

Monahan, T., McArdle, G., & Bertolotto, M. (2008). Virtual reality for collaborative e-learning. *Computers & Education, 50*(4), 1339–1353.

Novotný, M., Lacko, J., & Samuelčík, M. (2013). Applications of multi-touch augmented reality system in education and presentation of virtual heritage. *Procedia Computer Science, 25,* 231–235.

Ott, M., & Pozzi, F. (2011). Towards a new era for Cultural Heritage Education: Discussing the role of ICT. *Computers in Human Behavior, 27*(4), 1365–1371.

Pan, Z., Cheok, A. D., Yang, H., Zhu, J., & Shi, J. (2006). Virtual reality and mixed reality for virtual learning environments. *Computers & Graphics, 30*(1), 20–28.

Rillero, P., & Padgett, H. (2012). Supporting deep conceptual learning: Technology can help educators train students' focus away from rote memorization toward deep conceptual learning by building on prior knowledge and making connections between concepts. *THE Journal (Technological Horizons in Education), 39*(9), 37.

Rodriguez, M. B., Agus, M., Bettio, F., Marton, F., & Gobbetti, E. (2015, September). Digital Mont'e Prama: 3D Cultural Heritage presentations in museums and anywhere. In Digital Heritage, 2015 (Vol. 2, pp. 557–564). New York: IEEE.

Štefanovič, J., & Schindler, F. (2016). Education support by research in local transportation history. *Creative and Knowledge Society, 6*(1), 1–12.

Thorsteinsson, G. (2013). Developing an understanding of the pedagogy of using a virtual reality learning environment (VRLE) to support innovation education. In L. V. Shavinina (Ed.), *The Routledge international handbook of innovation education* (pp. 456–470). Oxford: Routledge. ISBN-10, 415682215.

Tyng, C. M., Amin, H. U., Saad, M. N., & Malik, A. S. (2017). The influences of emotion on learning and memory. *Frontiers in psychology, 8,* 1454.

Voľanská, Ľ. (2017). Stories related to the 3D objects in the InovEduc project. In *Innovative Methods in Education and Research 2017* (pp. 11–17). Prague: Wolters Kluwer. ISBN 978-80-7552-760-8

Part V
AR & VR Applications and Immersive Designs

To Have and Vehold: Marrying Museum Objects and Virtual Collections via AR

Ronald Haynes

Abstract The Veholder.org project is aiming for enhanced, innovative museum exhibitions, enabled by collaborative use of Augmented Reality. Complementing physical with relevant 3D virtual objects widens impact of interrelated collections. Objects brought together, from display or storage, provide blended environments for visitors and researchers. Veholder (Virtual Beholder, or Virtual Environment for Holdings and Online Digital Educational Repositories) is developing collaborations between suitable institutions. Early tests at the University of Cambridge are promising, while challenges such as calibration and scaling stress the need for shared solutions to blend collections. Following initial discussions with developers of IIIF, the International Image Interoperability Framework, about standards for digital library sharing of historical manuscripts and other disparate 2D images, we hope that working together can accelerate the process for a standardised approach to sharing 3D images. This could extend the concept of universal digital library viewers to incorporate and integrate 3D and AR images as well.

Keywords Museums · Virtual collections · Blended collections · 360 viewing · 3D scanning · Calibration and real-world scaling

1 Introduction

A visit to a museum is like immersion in an illustrated book, where key concepts have emerged from the textual contents and taken on full form, and suddenly sprung into vibrant full shapes. What we read in books will often draw us to a museum, to see in embodied form the ideas and items described, or to experience more of the material culture and cabinet curiosities which provide content and context for our tales. Conversely, the museum will often suggest further reading and follow up literature to carry forward ideas inspired by and presented in collection

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displays. This interrelation of the primary 2D and 3D aspects of our communications, culture and collections are perhaps the earliest and most extensive clues of what we know about our ancient human ancestors and species relatives. Early humans combined what they crafted with what they collected and conveyed this through drawing and construction, through various means of story-telling, visual representation, and writing.

The Veholder.org project has been working with institutional groups interested in exploring and addressing some challenges with expanding from 2D into 3D imaging, to enable and improve collaborative Augmented Reality and with other museums collections. The project was introduced at the 3rd International AR and VR Conference held 23rd February 2017 in Manchester (www.mmu.ac.uk/creativear/conferences/2017-augmented-and-virtual-reality-conference-2017 [June 19, 2018]), as described in "Eye of the Veholder: AR Extending and Blending of Museum Objects and Virtual Collections" (link.springer.com/chapter/10.1007%2F978-3-319-64027-3_6 [June 19, 2018]). Veholder is a term intended to creatively describe someone who, by virtue of the ability of AR to wed physical and complementary virtual items, becomes a "Virtual Beholder". Veholder also was formed as the acronym for "Virtual Environment for Holdings and Online Digital Educational Repositories".

Although some museums may have previously been reluctant to scan and share objects, with concerns about reducing visits to the museum, the Veholder project represents an AR extension of the idea of special exhibitions and the well-established practice of lending objects from one collection to another. Such special exhibitions regularly increase a museum's attendance, however they also can provide the perfect opportunity to scan and share for future agreed use by the already collaborating museums. In a special event for its Members, the Director of the British Museum hosted the Director of the State Hermitage Museum (St. Petersburg) in a discussion about the role of the encyclopaedic (or universal) museum in the 21st century (www.britishmuseum.org/whats_on/events_calendar/event_detail.aspx?eventId=3906 [June 19, 2018]), as well as the future of museums, their roles and options for collaboration. It was noted that one of the Parthenon Sculptures had been lent to the Hermitage for a special exhibition, as part of their 250th anniversary. Although great lengths were taken during transit to avoid controversy with Greece over the location of the sculptures, such concerns raise questions of combining casting and 3D scanning and printing, along with AR imaging options—concerns which the Veholder project aims to help address.

The project has been developing potential collaborations with suitable groups in Cambridge, where there are multiple museums (www.museums.cam.ac.uk [June 19, 2018]) and research collections, with a project proposal submitted in conjunction with the University of Technology Sydney, for the forthcoming 250th anniversary of Cook's landing at Botany Bay, proposing 3D images and duplicates of expedition artefacts in Cambridge and London. There also have been partnership discussions with the Natural History Museum of Denmark (snm.ku.dk/english [June 19, 2018]), University of Copenhagen, and Cambridge's Museum of Zoology (www.museum.zoo.cam.ac.uk [June 19, 2018]), and Duckworth Collections (www.human-evol.cam.ac.uk/duckworth.html [June 19, 2018])—potentially working together on a pan-primate 3D catalogue.

More recently, we have had initial and promising discussions with a network of developers and implementers of IIIF, the International Image Interoperability Framework (iiif.io [June 19, 2018]), about the interoperability standards they have advanced for the development of digital libraries. We hope that working together, including with the IIIF 3D community group (iiif.io/community/groups/3d [June 19, 2018]), can accelerate the process for a standardised approach to sharing 3D images, as well. This could extend the concept of universal digital library viewers, which they have created and are promulgating, to incorporate and integrate 3D images and ideally AR techniques as well.

2 Issues

While the aims of the Veholder.org project include enabling enhanced AR collaboration between museum holdings, archives and collections, the focus has largely been on images, display and visual technologies. For the future and for more immersive experiences, it is important to consider the wider scope of AR developments, which are attempting to engage us via other senses, in particular through smell, touch, and sound. For example, one approach to AR via the sense of smell is called Cyrano, by oNotes (onotes.com [June 19, 2018]) which is capable of programmable scent scenarios which can be shared between units, and which the producers refer to as the "first digital scent player".

Touch is perhaps even more surprising for AR, and a new prototype tablet called Tanvas (tanvas.co [June 20, 2018]) simulates the feeling of various textures, including choppy, grainy, fine, and wavy (see Fig. 1). The combination of feeling connected with what we are seeing on a screen could be especially powerful for AR, and particularly helpful for interaction with virtual objects, providing a richer experience of the physical characteristics of 3D objects than available to sight alone.

The image (Fig. 1) is of Tanvas, a prototype touchscreen which simulates how things feel, to augment what you see on the screen. Using electrostatic fields to create friction, through touch it can convey textures such as choppy, grainy, fine, and wavy. (johnbiehler.com/2017/01/11/wired-wednesday-favourites-ces-2017 [July 21, 2018])

Smart glasses are being developed with new sensory options for AR, as are tablets, with prototypes available for providing AR with hearing. In particular, Bose smart glasses (www.theverge.com/2018/3/12/17106688 [June 19, 2018]) look like sporty sunglasses, but can be paired with a smartphone to supply directions and commentary about where you are and, to some extent, what you are seeing. They can also deliver great music, channelling sound into the ears without using in-ear plugs. Other audio equipment companies seem interested in this area, and there

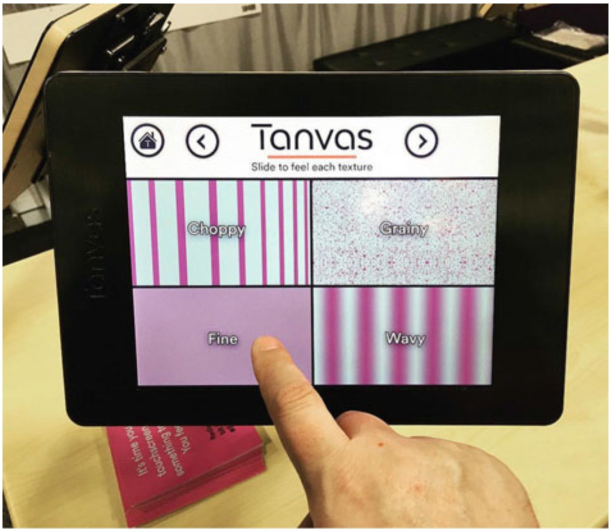

Fig. 1 Image courtesy of John Biehler

should be some combinations of such smart audio with visual technologies for even smarter smart glasses.

Generally, however, there continue to be more developments in the area of sight and displays, including new options for smartphones and smart glasses. And yet, as with other areas of innovation we have a connected challenge of divergent directions and incompatible systems, as well as initially producing technologies focussed almost exclusively on solitary experiences. Thankfully, there are increasing efforts and indications of interest in greater collaboration and commitment to evolving standards.

From the early advances with virtual reality technologies in the mid 1800s, with the explosive expansion of stereographs and viewers, what was crucial to the widespread success was the early setting of a standard. In general, any of the many viewers available could be used to view the hundreds of thousands of stereograph cards produced (see Fig. 2). Those inclined could construct their own viewer, as well. Then, as now, a standard ensured that the viewer and cards would work together, no matter their origin. This legacy has endured, and stereographs from the Victorian era still work as designed and pleasingly well on modern VR and AR systems.

The first image (Fig. 2) shows Sherlock Holmes (Ronald Howard, 1954 TV series, Episode 28) using a stereoscope (archive.org/details/SherlockHolmes1954 [June 19, 2018]). The enormous popularity of stereographs prompted development of options for group sharing. The second image (Fig. 2) is a Kaiserpanorama (www.stadtmuseum.de/ausstellungen/kaiserpanorama [July 22, 2018]), also known as a Fotoplastikon, a Victorian era innovation for communal 3D viewing, precursor to cinema, and still in selective use.

Fig. 2 Images courtesy of Guild Films/Heiko Noack, Stadtmuseum Berlin

While smart glasses for AR use continue to evolve, many projects have been developing around Microsoft Hololens (www.microsoft.com/en-gb/hololens [July 21, 2018]), at the same time that there has been extensive coverage and planning around the well-funded and promising Magic Leap (www.magicleap.com [July 21, 2018]), due for release in 2018. Epson's Moverio glasses (www.epson.co.uk/moverio [July 21, 2018]) have a third generation model designed for multi-person use, particularly in museums (BT-350), as well as a novel release of the multi-person display and frames which can be used to develop or deploy with other smartphones or computer systems (BT-35E).

Among concerns expressed by a number of museums, about AR equipment and other technologies, are questions about affordability, robustness and sustainability. This is why some still prefer to focus on smartphones alone, with the idea that interested visitors can bring their own devices and use a suitably prepared app. Others have been hoping to pair up visitors' smartphones with the AR equivalent of Google Cardboard (vr.google.com/cardboard ([July 21, 2018]). Late 2017 and early 2018 saw some innovators in this area, with two leading examples (see Fig. 3) in the Aryzon AR Headset (www.aryzon.com [June 19, 2018]) and the Haori Mirror (haoritechnology.com/en/col.jsp?id=109 [June 19, 2018])—or Docooler AR Headset, in the UK (www.amazon.co.uk/dp/B07851GG8Q [June 19, 2018]).

Fig. 3 Images courtesy of Shenzhen Haori Technology Co. Ltd./Aryzon B.V.

The first image (Fig. 3) is of the Haori Mirror (marketed in the UK as Docooler AR Headset), with its Bluetooth controller. The second image (Fig. 3) is the Aryzon headset kit. Each has their own apps, can use a wide range of smartphones for viewing, works with a variety of AR and VR resources, and for AR can use an included target to place and anchor an image in local space. Each retails under £50.

As a potentially fruitful complement to smart glasses, or smartphones in headset holders or on their own, there are some recent options available for transparent touchscreen computer displays which can be built into museum cases. These can achieve some of the AR effects without glasses, directly shareable with groups, although of course within a fixed location rather than in a portable mode (see Fig. 4).

The images (Fig. 4) are from a demonstration of an interactive transparent display, using a computer touchscreen forming the main window for exhibiting a book within the cabinet (youtu.be/OeRpeBchZ0s [June 19, 2018]).

While new VR goggles and AR glasses (and novel displays) continue to emerge, along with new and alluring features, there continues to be sufficiently diverse and proprietary platforms to make it difficult to develop for the many format and feature differences. There are helpful approaches to these cross-platform challenges, notably with the widespread developments using the Unity engine (unity3d.com [July 21, 2018]). Yet, there have been understandable concerns about the lack of common ground and of standards, including variations in the use of the terms VR, AR, MR and XR (https://www.forbes.com/sites/charliefink/2017/10/20/war-of-arvrmrxr-words [June, 2018]), which have meant confusion as well as often higher costs of development for those who want to publish VR or AR (or related) content across the many available platforms.

In response, there are recent and high-level movements toward open standards, for development and delivery to be via our web browsers, with Mozilla leading the push for WebXR (blog.mozilla.org/blog/2017/10/20/bringing-mixed-reality-web [July 21, 2018]), built on earlier open standards in order to provide a common programming interface to simply development for both AR and VR devices. Mozilla is also providing the Firefox Reality browser (blog.mozilla.org/blog/2018/04/03/mozilla-brings-firefox-augmented-virtual-reality [July 21, 2018]), designed to help ensure these standards are available for stand-alone VR and AR headsets. WebXR is also being supported by Google (www.vrfocus.com/2018/05/google-introduce-webxr-standard-to-chrome July 21, 2018]) and Amazon (www.zdnet.com/article/aws-sumerian-a-bet-that-enterprise-augmented-and-virtual-reality-will-be-browser-based [July 21, 2018]), and the combined commitments should ensure continued traction for these much-needed development and delivery standards.

3 Procedures

To demonstrate the great potential for AR delivered via smartphones, and to provide initial samples of what options for AR with museum collections might be like, some photographic experiments were carried out to situate and display 3D models in selected physical spaces to produce suitably combined images.

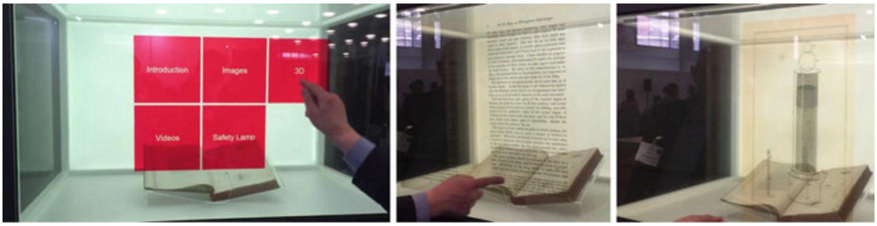

Fig. 4 Images courtesy of Crystal Display Systems Ltd.

The 3D models were selected from among the vast offerings found on Sketchfab (sketchfab.com [June 19, 2018]). The models were displayed using the Sketchfab app in AR mode on a suitable smartphone, with these experiments carried out using a Samsung Galaxy S8. Appropriate physical settings were selected to highlight the AR possibilities.

With 3D models of scans taken from Cambridge and British Museum collections, below are selected representatives of the initial outcomes (see Fig. 5).

4 Results

Following the promising initial samples, the AR photographic experiments progressed to bring together a pair of similar physical and virtual objects, and Sketchfab was again a good source of models, this time from Oxford and further afield (see Fig. 6).

The image (Fig. 6) shows an AR combination of a physical-virtual composite, where the skull on the right is a 3D model of Australopithecus afarensis (Lucy), from the Oxford Natural History Museum collection (skfb.ly/HyJs [June 19, 2018]). The 3D model was scaled and positioned on the physical shelf, alongside the

Fig. 5 Images courtesy of Ronald Haynes/3D models courtesy of Sketchfab. The first image shows a Neanderthal skull model from Cambridge (https://skfb.ly/6yTt9 [June 19, 2018] visually scaled and placed on a tabletop, to produce a virtual-physical composite as an AR test. The second image shows a Cuneiform tablet model from Cambridge (skfb.ly/PySr [June 19, 2018]) above the same tabletop. The third image is of the same tabletop with an Easter Island monolith model from the British Museum (skfb.ly/6srQY [June 19, 2018])

Fig. 6 Images courtesy of Ronald Haynes/3D model courtesy of Sketchfab

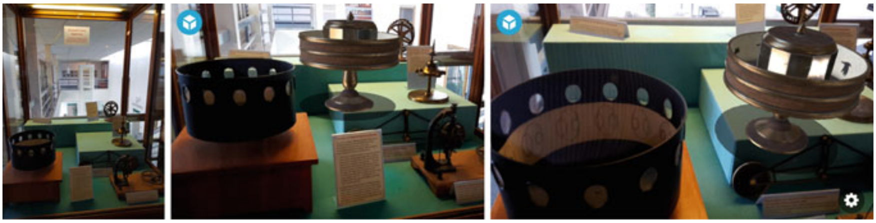

Fig. 7 Images courtesy of Ronald Haynes/3D model courtesy of Sketchfab

physical skull on the left, a modern human skull from the Duckworth Collection in Cambridge (www.human-evol.cam.ac.uk/duckworth.html [June 19, 2018]).

The side-by-side AR skulls experiments were well received and encouraging for additional testing. A next logical step was to attempt to virtually place a suitable 3D model among the physical objects within an existing museum case. A suitable case and objects were located, and once again Sketchfab was a good source of a 3D model, this time a computer-generated one from an independent project (see Fig. 7).

The first image (Fig. 7) shows a display case before any AR experimentation, and in the left-hand corner is a large zoetrope and image strips designed by the physicist James Clerk Maxwell, key apparatus for what is believed to be the first time a moving picture was used for scientific demonstration. The case is part of the Cavendish Laboratory museum collection, in Cambridge (www.phy.cam.ac.uk/outreach/museum [June 19, 2018]). The second and third images include a 3D model of a praxinoscope (skfb.ly/6pQqK [June 19, 2018]), which is scaled and positioned to the right and looking nearly at home alongside its relative the zoetrope.

5 Conclusions

Along with the very promising results of the AR image tests noted, there remain concerns about scaling and image standards. It has been most encouraging to find the great progress which has been made in the digital library and archive world, dealing with the challenges of 2D imaging, including how to address the many difficulties associated with fragmented manuscripts. After meeting developers and community leaders from IIIF, the International Image Interoperability Framework community (iiif.io [June 19, 2018]), it has been very helpful to learn more about their progress and practices. IIIF has defined a set of programming interfaces, based on open web standards, derived from shared use cases, and is also is the community that implements the specifications.

IIIF has had a particular concern for the difficulties surrounding the sharing of historic manuscripts and other often disrupted 2D texts and images, whether due to fragmentation of the originals, or otherwise torn, worn or missing pieces, which at times can be reconstructed by virtually putting the pieces back together. For these challenges, they have created standards for interoperability, and introduced the concept of universal viewers, which can present composite images assembled from local sources and remote links to collaborating systems which are following the IIIF standards and so are compatible. The resulting environment ensures digital library

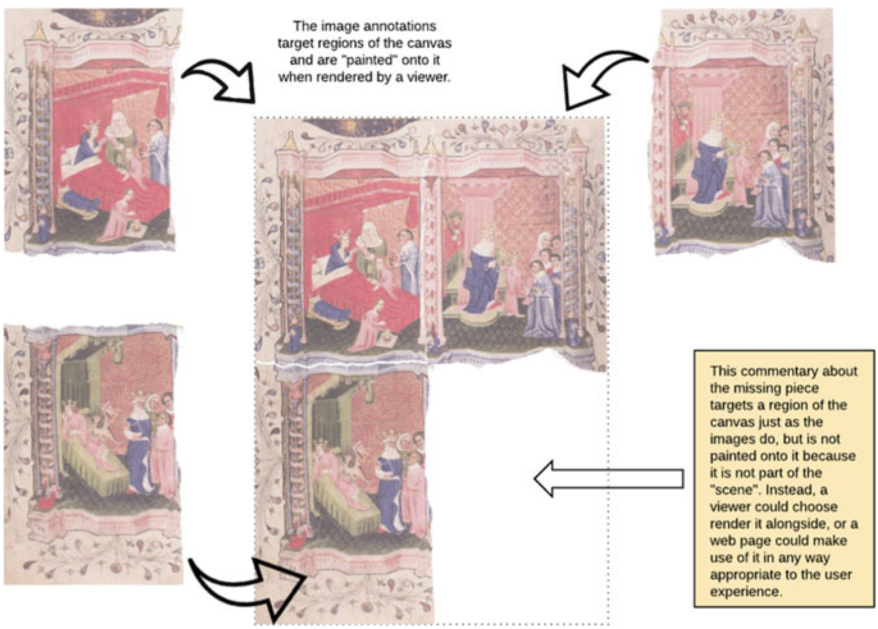

Fig. 8 Image courtesy of Digirati

patrons and researchers can reunite or creatively assemble more of the worlds disconnected knowledge (see Fig. 4).

The image (Fig. 8) is an illustration of how IIIF can help reunite the fragmented and distributed parts of a manuscript (resources.digirati.com/iiif/an-introduction-to-iiif [June 19, 2018]), where existing pieces are presented in the interoperability framework.

It also has been very heartening to find the IIIF 3D interest group (iiif.io/community/groups/3d [June 19, 2018]) and the open and collaborative approach they are taking to clarify interoperability and other challenges with 3D imaging. There is hope that some of the great success with interoperability and universality in sharing 2D materials, in particular through a viewer which can connect and integrate disparate resources, will help guide a similar process for 3D imaging. It is a worth considering ways to be able to bring together digital texts and images, and 3D models in one environment, for instance to enable with one viewer the ability to review da Vinci's notes, to view his illustrations, and to interact with 3D models based on his designs. Similarly, although Darwin's publications and manuscripts are online, the specimens from the Beagle expedition are divided between museums. The same integration in a universal viewer would benefit these and any other areas where image and text are meaningfully connected with 3D objects, and vice versa.

The option to further test and potentially incorporate high-feature smartphones, rather than solely focus on one or more proprietary smart glass models, opens up many more options for the always budget-sensitive museums. The move toward open web standards and increasing adoption of WebXR will also pave the way for greater collaboration, as well as more flexible and sustainable projects. It is hoped that the work with IIIF will also help advance efforts toward standards in 3D imaging, scaling and interoperability, to simplify sustainable collaborations between institutions.

The Veholder project may be best developed in optional phases, to start testing the technology at the soonest, and help build the required collaborations, including:

- Phase I—360-degree live-streaming guided option, with guides to introduce new technology and help blend collection images and concepts.
- Phase II—introduction of 3D scanned images, with guides to introduce the technologies and collections, clarifying any oddities.
- Phase III—initial curated, blended special exhibition, with 3D images suitably scanned and scaled for compatibility across collections.
- Phase IV—development of a larger catalogue of suitably matched 3D images, available for more extensive combinations across collections.

More details of the Veholder project will be found on www.veholder.org.

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References

3rd International AR and VR Conference. (2018, June 19). https://www.mmu.ac.uk/creativear/conferences/2017-augmented-and-virtual-reality-conference-2017.

Aryzon—Augmented Reality powered by your smartphone. (2018, June 19). (https://www.aryzon.com).

Biehler, J. (2017, Jan 11). *Wired Wednesday: Favourites from CES 2017* [Blog Post]. Retrieved July, 2018 from http://johnbiehler.com/2017/01/11/wired-wednesday-favourites-ces-2017.

Cavendish Museum. (2018). *Cavendish Museum*. Retrieved June, 2018 from https://www.phy.cam.ac.uk/outreach/museum.

Conan Doyle, A., Early, C. & Early, J. & Previn, S. (1955). The case of the Jolly Hangman [Television series episode]. In S. Reynolds, *Sherlock Holmes*. First-run syndication. Retrieved June, 2018, from https://archive.org/details/SherlockHolmes1954.

Crane, T. (2017, March). *An Introduction to IIIF*. Retrieved June, 2018, from https://resources.digirati.com/iiif/an-introduction-to-iiif.

Crystal Display Systems. (2017, January 20). *Transparent display boosts interest at museum* [Video file]. Retrieved June, 2018 from https://youtu.be/OeRpeBchZ0s.

Cyrano—Digital Scent Player. (2018, June 19). https://onotes.com.

Dignan, L. (2018, April 3). *AWS Sumerian: A bet that enterprise augmented and virtual reality will be browser-based*. ZDNet. Retrieved June, 2018, from https://www.zdnet.com/article/aws-sumerian-a-bet-that-enterprise-augmented-and-virtual-reality-will-be-browser-based.

Docooler AR Headset. (2018, June 19). https://www.amazon.co.uk/dp/B07851GG8Q

Duckworth Collections. (2016). *Duckworth collections*. Retrieved June, 2018, from http://www.human-evol.cam.ac.uk/duckworth.html.

Epson Moverio. (2018, July 21). https://www.epson.co.uk/moverio.

ferl3. (2018). *neanderthal - 3D model by ferl3 (@ferl3)*. Retrieved June, 2018, from https://skfb.ly/6yTt9.

Fink, C. (2017, October 20). *War of AR/VR/MR/XR words*. Forbes. Retrieved June, 2018, from https://www.forbes.com/sites/charliefink/2017/10/20/war-of-arvrmrxr-words.

Flynn, T. (2014). *Hoa Hakananai'a—Download Free 3D model by The British Museum (@britishmuseum)*. Retrieved June, 2018, from https://skfb.ly/6srQY.

Google Cardboard—Google VR. (2018, June 21). https://vr.google.com/cardboard.

Haori Mirror. (2018, June 19). http://haoritechnology.com/en/col.jsp?id=109.

Haynes R. (2018). Eye of the veholder: AR extending and blending of museum objects and virtual collections. In: T. Jung & M. tom Dieck (Eds.), *Augmented reality and virtual reality. Progress in IS*. Cham: Springer. https://link.springer.com/chapter/10.1007%2F978-3-319-64027-3_6.

Hills-Duty, R. (2018, May 9). *Google introduce WebXR standard to chrome*. VRFocus. Retrieved July, 2018, from https://www.vrfocus.com/2018/05/google-introduce-webxr-standard-to-chrome.

IIIF—International Image Interoperability Framework. (2018, June 19). http://iiif.io.

IIIF 3D Community Group—International Image Interoperability Framework. (2018, June 19). https://iiif.io/community/groups/3d.

Kahney, L. (2018, January 4). *Your smartphone is ready to take augmented reality mainstream*. Retrieved June, 2018, from https://www.wired.co.uk/article/augmented-reality-breakthrough-2018.

Kaiserpanorama - Märkisches Museum. (2018, July 22). https://www.stadtmuseum.de/ausstellungen/kaiserpanorama.

MAACambridge. (2016). *Cuneiform tablet, Ur, Iraq—Download Free 3D model by MAACambridge (@MAACambridge).* Retrieved June, 2018, from https://skfb.ly/PySr.

Magic Leap. (2018, July 21). https://www.magicleap.com.

Microsoft Hololens. (2018, July 21). https://www.microsoft.com/en-gb/hololens.

Museum of Zoology, Cambridge. (2018). *Museum of Zoology, Cambridge*. http://www.museum.zoo.cam.ac.uk.

Natural History Museum of Denmark—University of Copenhagen. (2018). *Natural History Museum of Denmark*. http://snm.ku.dk/english.

Robertson, A. (2018, March 12). *Bose's new augmented reality glasses use sound instead of sight*. The Verge [Online]. Retrieved June, 2018, from http://www.theverge.com/2018/3/12/17106688.

Sketchfab. (2018, June 19). https://sketchfab.com.

Tanvas - TanvasTouch surface haptics. (2018, June 20). https://tanvas.co.

The role of the encyclopaedic museum in the 21st century. (2018, June 21). http://www.britishmuseum.org/whats_on/events_calendar/event_detail.aspx?eventId=3906.

Unity engine. (2018, June 21). https://unity3d.com.

University of Cambridge Museums. (2018, June 19). https://www.museums.cam.ac.uk.

Villalobos, C. (2017). *Praxinoscope!—3D model by Cristian Villalobos (@flowpoly)*. Retrieved June, 2018, from https://skfb.ly/6pQqK

Vrignaud, A. & Bergstrom, L. (2017, October 20). *Bringing mixed reality to the web* [Blog Post]. Retrieved July, 2018 from https://blog.mozilla.org/blog/2017/10/20/bringing-mixed-reality-web.

White, S. (2018, April 3). *Mozilla brings firefox to augmented and virtual reality* [Blog Post]. Retrieved July, 2018 from https://blog.mozilla.org/blog/2018/04/03/mozilla-brings-firefox-augmented-virtual-reality.

Wilson, P., & Mason, B. (2017). *Australopithecus afarensis (Lucy)—3D model by Maritime Archaeology (@maritimearchaeologytrust).* Retrieved June, 2018, from https://skfb.ly/HyJs.

A Tool, not a Toy: Using Virtual Reality to Evaluate the Communication Between Autonomous Vehicles and Pedestrians

Sebastian Stadler, Henriette Cornet, Tatiana Novaes Theoto and Fritz Frenkler

Abstract Although the main market for Virtual Reality (VR) is currently the gaming industry, advantages of using virtual environments in research and development have been already demonstrated e.g. for car industry or urban planning. Especially when no prototype is feasible or available, VR constitutes an advantageous alternative since it allows tests in laboratory conditions with high flexibility and ensured safety for test participants. In the presented study, it is investigated how VR can be used as a tool for Usability Tests to evaluate Human Machine Interfaces (HMI) for communication between autonomous vehicles and pedestrians. Singapore with its regulations and requirements has been selected as reference. Beyond the findings that explicit HMI concepts improve the communication between autonomous vehicles and pedestrians, VR was validated as suitable tool to conduct Usability Tests. Further studies plan to integrate additional case studies as well as improved immersion of test participants within the virtual environment.

Keywords Virtual reality · Usability tests · Human machine interfaces · Autonomous mobility

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1 Introduction

Due to the lack of a driver in level 5 autonomous vehicles[1] (AV), communication between AVs and human road users, like pedestrians, has to be replaced. Human Machine Interfaces (HMI)—for instance, on-vehicle screens with real-time information—are a possible solution (Matthews & Chowdary, 2017). The critical nature of the task (i.e. crossing the street when an AV is approaching) demands visible and comprehensible information in order to ensure pedestrians' safety. Especially in a multicultural environment like Singapore,[2] universal comprehensibility of written information and/or symbols, which constitute the HMI concepts, is a prerequisite. Therefore, the usability of HMI concepts must be tested, as the implementation of such communication without appropriate verification could lead to misinterpretation and thus safety hazards.

However, the autonomous mobility context brings significant obstacles to reliable validation of HMI concepts mainly regarding complexity, effort, and safety. Indeed, in order to create an authentic traffic condition, a physical test bed has to be set up, including e.g. roads, junctions, sidewalks, traffic lights, zebra crossings, and traffic signs. Additionally, both manually driven cars and AVs have to be integrated into the test bed. Test participants, which include drivers, pedestrians, and passengers, also have to be present to create the environment. To ensure a reliable data collection, all these aspects have to work together perfectly—which results in a complex endeavour and leads to great effort regarding time and money spent. Furthermore, AVs raise concerns about the technology's safety (Eng, 2017). Misinterpretation can lead to accidents, as it became visible at the fatal crash caused by a Tesla in self-driving mode (The New York Times, 2016). Therefore, testing the usability of communication between AVs and pedestrians in real-life conditions remains potentially dangerous.

The hypothesis of the presented study is that Virtual Reality (VR) is a suitable tool to test the usability of HMI concepts between AVs and pedestrians as a replacement for tests in real-life conditions. Therefore, the objective is to develop a suitable methodology for Usability Tests within VR in the context of autonomous mobility.

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[1]In contrast to level 0 automation, which means the human driver has to perform all aspects of the driving task, level 5 automation means that humans do not overtake or influence any task in any driving situation, but act solely as passengers (SAE International, 2016).

[2]For the investigation of communication between AVs and human road users, a geographical context is required. Singapore has been selected for this study. Its local regulations and cultural environment will be considered as requirements.

2 Literature Review

2.1 Context: Existing HMI for Communication Between AV and Pedestrians

The focus of this paper lies on communication between AVs and pedestrians, in an ambiguous situation at a one-way street without traffic lights and/or zebra crossing and a potential intention of crossing the road by the pedestrian while an AV is approaching. For this type of communication, a distinction can be made between explicit and implicit communication. While explicit communication implies direct messages exchanged between the road users (e.g. light signals, horn, gestures), implicit communication is linked to indirect messages in which the content is not directly addressed (e.g. a car reduces its speed to encourage pedestrians to cross) (Fuest, Sorokin, Bellem, & Bengler, 2017). Explicit communication occurs between pedestrians and drivers mainly via gaze and/or gestures (Šucha, 2014). Without driver in an AV, this communication has to be provided alternatively in the future.

Multiple car manufacturers proposed HMI solutions for their Level 4 and Level 5 AV concepts, like for instance the Mercedes F 015 (Mercedes, 2015) or the Nissan IDS concept (Nissan, 2015). In order to deal with the missing communication between drivers and pedestrians, on-vehicle displays and/or projection technology are possible solutions to signalize for instance instructions to the pedestrians.

However, comprehensive testing and validation of the results are not published. Some researchers—as Clamann, Aubert, and Cummings (2017) and Benderius, Berger, and Lundgren (2017)—have proposed and tested concepts by using regular cars disguised as autonomous vehicles, with mixed results regarding the interfaces' effectiveness.

With these insights, a method, which is safe and easy to set up, for evaluating the usability of communication concepts between AVs and pedestrians is still lacking.

2.2 Testing Usability

Usability is defined as 'the degree to which something is able or fit to be used' (Oxford Dictionary, 2018). Rubin and Chisnell (2008) define a product or service as truly usable when the user 'can do what he or she wants to do the way he or she expects to be able to do it, without hindrance, hesitation, or questions' and speak of 'absence of frustration in using something'. van der Bijl-Brouwer (2012) studied the link between varying use situations and usability. In the presented context of AV to pedestrian communication, it means that the designed HMI should provide information (e.g., intention and/or instructions) that the user needs in order to successfully complete a task—in this case, crossing a street—and that he/she understands without hesitation or question.

Table 1 Attributes of usability and implications for the study

Attribute	General definition	Context of the study: HMI for AV to pedestrian communication at a one-way street
Usefulness	To which extend a product or service supports the user to reach his/her goal with regard to the willingness from the user's side to use the product or service in the first place	How should be the HMI designed so that the user is supported in his/her intention to cross the road? Is an HMI even needed?
Efficiency	Time, accuracy and degree of completion to reach the user's goal	Is the HMI supporting a faster decision-making for crossing the road?
Effectiveness	To which extent a product behaves as expected	Is the HMI adapted to the situation and the environment e.g. regarding traffic conditions and safety? To which extent can the HMI prevent wrong behaviour from pedestrians?
Learnability	Ability from user's side to operate a product or system considering a certain level of competence to operate the system after a predefined period of time	Are any competences from the user side required to understand the HMI correctly? Is a phase of education necessary to understand the message provided?
Satisfaction	Subjective feelings, perceptions and opinions from user's side to reveal users' satisfaction levels	How does the user perceive the HMI for crossing the road?
Accessibility	Access to the products or services that are needed to reach the goal especially for users with disabilities (e.g. temporary or permanent limited mobility)	Is the HMI understandable for people with disabilities e.g. cognitive disabilities?

Source Based on Rubin and Chisnell (2008)

According to Rubin and Chisnell's definition (2008), to be useful, a product or service should enable usefulness, efficiency, effectiveness, learnability, satisfaction, and accessibility. Table 1 presents the definition of these attributes according to Rubin and Chisnell as well as their implications for the study.

For answering the questions raised in Table 1, several methods and techniques can be used and combined to evaluate the usability of a product or service such as observation of users in real-life environment, surveys, expert interview or classical experiments with large sample sizes and control groups. Considering the advantages and drawbacks of the methods for evaluating usability based on the work of Rubin and Chisnell (2008) as well as van der Bijl-Brouwer (2012), Usability Testing is selected for the presented study.

This method provides empirical data from the observation of representative users while using a product or system. Compared to classical experiments, Usability Tests are more informal, iterative and give qualitative insights of a product's or service's usability. Basic elements that are included in the method are:

(a) The articulation of research questions or test objectives
(b) A representative amount of users (randomly or not randomly chosen)
(c) Representation of actual environment
(d) Observations and Interviews
(e) Quantitative and qualitative data.

However, the representation of actual environment for Usability Tests raises issues in the presented study of AV to pedestrian communication since the conduct of Usability Tests in real-life conditions with AVs and pedestrians is potentially dangerous for the test participants. Moreover, building up a testbed in real-life conditions to test the AV to pedestrian communication would lead to great effort, as well as time and money to be spent.

To tackle safety issues, costs, and time spent, VR is investigated as alternative to Usability Tests in real-life conditions.

2.3 Virtual Reality

VR's major scope of application is the gaming industry. One reason for this is the improved immersion into virtual environments and therefore enhanced experiences. However, it is also used as a tool in industry fields like automotive, construction and military (Berg & Vance, 2017). Deb, Carruth, Sween, Strawdermann, and Garrison (2017) used VR to conduct research in the field of pedestrian safety since it constitutes a safe alternative for test participants. Furthermore, VR is used as a research tool to conduct psychological studies thanks to its capabilities to create laboratory conditions for the experiments and its high flexibility to create immersive environments (Loomis & Blascovich, 1999). Mihelj, Novak, and Beguš (2014) state that VR is used for designing and testing machines and objects, especially when they are very expensive (e.g. power plants) or when they are produced in large quantities (e.g. cars).

Consequently, running Usability Tests in Virtual Reality (VR) environments is proposed as an alternative to real-life tests with the hypothesis that the attributes of usability can be evaluated similarly or even with advantages in regard to real-life tests, for instance, due to the possibility to neglect unintentional factors like the implicit communication of deceleration.

Therefore, the hypothesis is: Virtual Reality is a suitable tool to conduct Usability Tests with a multicultural selection of participants in order to evaluate the most *usable* HMI concept for the communication between AVs and pedestrians in ambiguous situations.

3 Method

3.1 Case Study

The purpose of the presented case study is to measure the usability of HMI display content for the AV to pedestrian scenario: A test person stands on the sidewalk of a one-way street with one lane and without traffic light and zebra crossing. The task is to cross the road as soon as the test person assesses the traffic situation to be safe. In each scenario, an AV that is equipped with an HMI concept approaches the test person. The HMI concepts indicate if it is safe for the test person to cross the road or not. To achieve this, each HMI concept consists of one "Cross" symbol and one "Don't Cross" symbol. The HMI concepts include the commonly understandable red and green colour combination, used at Singapore's traffic lights, in which green is used for indicating that the pedestrian has the right of way (Fig. 1):

- Walking man (a)
- Arrow (b)
- Check (c)
- LED strip (d)
- Traffic light (e)

A control test is made without any HMI concept in order to compare the HMI concepts with the absence of AV to pedestrian communication.

Since the goal is to evaluate the usability of used HMI concepts when applied in the AV to pedestrian scenario and not the display technology itself, a simple screen-like surface is positioned in front of the vehicle, where the content is shown (Fig. 2). Factors like reflections and brightness are neglected. A further controlled variable is the vehicle's deceleration: to avoid that pedestrians decide to cross based on the AV's kinematic cues, the AV's deceleration was disregarded.

In light of Singapore's speed limit regulations for one lane roads, a speed of 50 km/h (v = 13.9 m/s) was selected for the approaching vehicle (Land Transport Authority, 2017).

Initially, an appropriate distance from which the AV starts displaying the information to the user has been calculated (Distance to Zebra, DTZ), which is the product of the factors speed (v) and Time To Collision (TTC) (Eq. 1). TTC

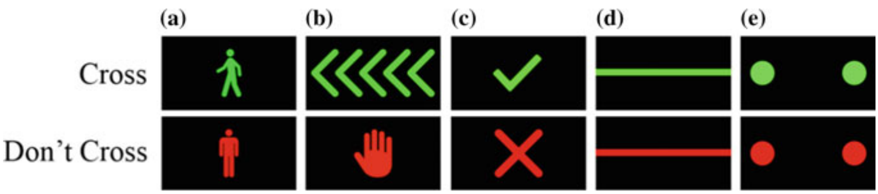

Fig. 1 Concepts tested for HMI content [The HMI concepts to be tested have been developed based on internal workshop sessions and surveys (Theoto, 2018)]

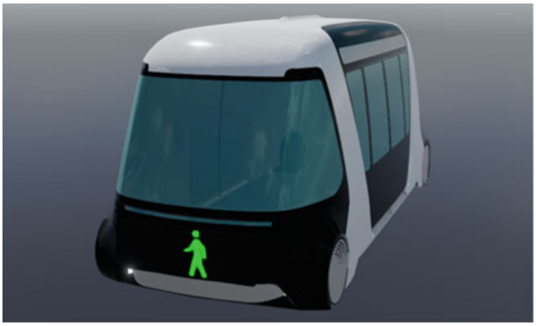

Fig. 2 Basic interface

describes the time it would take for the AV to reach the pedestrian's path if the chosen vehicle speed (v) is kept constant (Schneemann & Gohl, 2016).

$$DTZ = v \cdot TTC \tag{1}$$

TTC is the sum of the minimum perceptual reaction time of 2.5 s, and the average time required to cross a single lane of traffic of 2.7 s (based on Clamann et al., 2017) (2.5 s + 2.7 s = 5.2 s). The TTC of 5.2 s is within the critical gap acceptance interval as observed by Schmidt and Farber (2009): under 3 s, no pedestrian crosses the street, whereas everybody walks with a TTC above 7 s.

Considering a constant speed of the vehicle and a TTC of 5.2 s, the DTZ has been set to 72.2 m (Eq. 2).

$$DTZ = v \cdot TTC = 13.9\frac{\mathrm{m}}{\mathrm{s}} \cdot 5.2\ \mathrm{s} = 72.2\ \mathrm{m} \tag{2}$$

Figure 3 showcases the configuration of the virtual environment. The participant position is delimited with a cross on the virtual sidewalk, and as soon as he/she faces to the right-hand side, the vehicle appears. Other traffic and road users were neglected. This guarantees that all participants face the AV at the same initial spot and under the exact same conditions.

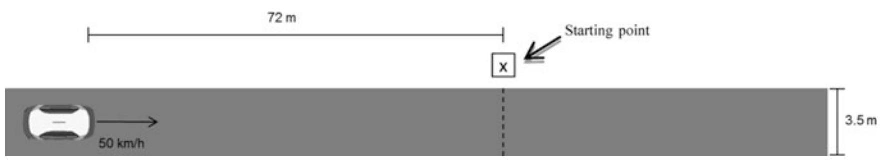

Fig. 3 Configuration of virtual environment

3.2 Test Participants

As one aspect of the scenario lies on a multicultural environment, the chosen quota sample for the recruitment of test participants reflects Singapore's ethnic distribution. Since there is no ethnic data for the large non-resident population (which account for 29.4% of the country's population, i.e. 1.65 million people), the sample is based on the citizens and permanent resident (PR) data (Singapore Statistics, 2017). Therefore, the ethnic composition of the sample is 53.8% Chinese, 10.6% Malay, 5.2% Indian, and 30.4% PRs with other ethnicities.

3.3 Virtual Reality Hardware Setup

The Virtual Reality Laboratory consists of an empty space of up to 4.5 m $\times$ 4.5 m. Tracking devices allow investigating position changes as well as head movement. Test persons get immersed in the virtual scenario with help of a Head Mounted Display (HMD) (i.e. HTC Vive). Input devices allow the test person to interact with the virtual scenario if needed. To deepen the immersion, the test person wears noise-cancelling headphones. Additional hardware is located outside the tracked area.

3.4 Adaptation of Usability Tests Within VR

The Usability Tests within VR focus on the following attributes of usability listed in Table 1: *efficiency*, *effectiveness*, and *satisfaction*. The attributes are chosen due to the fact that the quantitative measures of *efficiency* and *effectiveness* (i.e. reaction time and error rate) can be collected very accurately with the help of VR. *Satisfaction* is chosen in order to get qualitative insights about the test participants feelings and perceptions regarding the HMI concepts.

For the assessment of *efficiency* of selected HMI concepts, reaction times are measured and compared afterwards with the control group. The reaction time is defined as the time it takes from the moment when the test participant sees the AV until he/she starts to cross the road. *Effectiveness* can be derived from an error analysis, in which the amount and type or errors (e.g., the pedestrian crosses when he/she must not) are collected and analysed. The level of *satisfaction* is assessed with qualitative data, collected with questionnaires before and after the Usability Tests.

The procedure for the tests is shown in Table 2.

One test person is tested at a time. Prior to the tests, a first questionnaire is conducted. Then, the participants are introduced to the VR setup with help of a tutorial in order to get familiarized with the technology. After the tutorial, the

Table 2 Procedure of the tests within VR

Procedure	1	2	3	4
Activity	First questionnaire	Tutorial	Usability tests	Final questionnaire
Duration (min)	5	2	10	3

Usability Tests are conducted. Here, the test participant gets the task to cross the street while an AV is approaching. Since there are five HMI concepts that include one symbol for “Cross” and one symbol for “Don’t Cross”, as well as one control group, the test is conducted eleven times per test participant. First of all, the control group without HMI concept is conducted, followed by the five HMI concepts. The sequence of procedure for the HMI concepts is randomized to rule out distorted results caused by the testing order. After the tests, a final questionnaire is conducted in order to get insight into the feelings and perceptions of the test participants.

4 Findings

Overall 18 people participated in the Usability Tests. The ethnic distribution of test participants was: 10 Chinese participants, 2 Malay participants, 1 Indian participant and 5 Participants with other ethnicities.

Figure 4 presents results of the test, i.e. the average decision times for each HMI concept.

The result showed that the decision times differed significantly between the control group and any HMI concept. While the average reaction time for the control group is 4.8 s, the average reaction times for the HMI concepts lie between 2.0 and 3.0 s.

This data proved that the symbolic representations lead to a reduced pedestrians’ reaction time. When HMI concepts were not present, the mean reaction time was significantly larger (4.8 s instead of 2.0–3.0 s), showing that display intention or instructions to pedestrians can help their decision process, at least when no other intention indicators (deceleration, engine sound) are present. However, no significant decision time variation among the different HMI concepts was observed.

Through the collection of error rates, the HMI concepts’ *effectiveness* regarding usability has been evaluated. As Table 3 shows, the test revealed that in 72.2% of the tests the control group led to errors, as test participants crossed the street when the vehicle exercised its right of way and did not stop for the test participants. When the HMI concepts were present, errors occurred only in three out of 90 trials.

This outcome is an indicator of the HMI concepts’ *effectiveness*, as the error rate declined steeply when HMI concepts were present. A comparison among the different HMI concepts was possible, as the “Check” and “LED Strip” were less effective than the other ones.

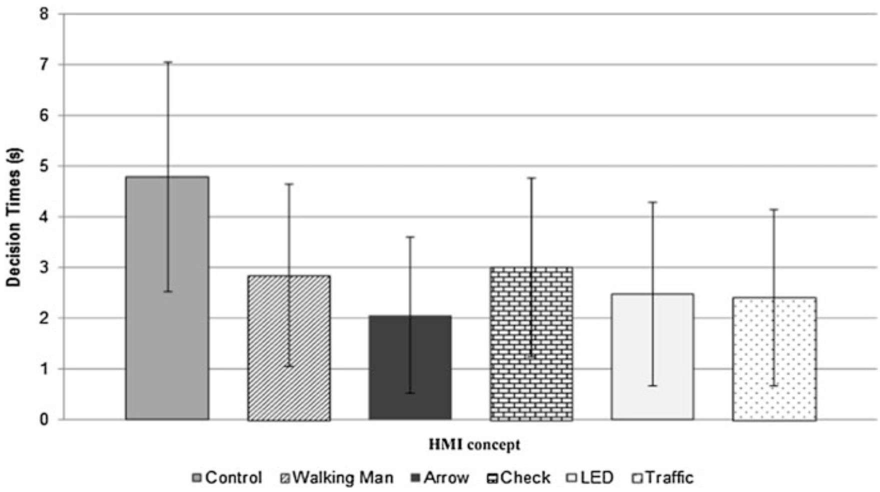

Fig. 4 Comparison between average decision times, in seconds, for the control group and different HMI concepts

Table 3 Error analysis for control group and different HMI concepts

HMI concept	Error frequency (%)
Control	72.2
Walking man	0
Arrow	0
Check	5.5
LED strip	11.1
Traffic	0

Finally, the *satisfaction* was analysed thanks to the questionnaire after the tests. The questions to be answered concerned the subjective cognitive effort for the test participant to complete the task. This question had to be answered for each HMI concept as well as for the control group. In order to get a homogenous outcome, the test participants were asked to indicate the effort on a scale which ranges from −60 (very low effort) to 60 (very high effort). Consequently, negative results indicate a low effort to complete the task. The answers revealed that only the control group's value was distinguishable from HMI concepts, whereas the values of the HMI concepts among one another did not lead to significant differences (Table 4).

Further questions were insightful regarding the perception if the test participant was able to detect the HMI concept (Detection), if the HMI concepts influenced the decision making for crossing the street or not (Influence on crossing), and if the HMI concepts were comprehensible for the test participants. "Yes or No" questions were asked to evaluate aforementioned perceptions. Figure 5 presents the answers

Table 4 Subjective effort to cross the road for the HMI concepts and control group

HMI concept	Indicator of effort
Control group	−22.8
Walking man	−42.5
Arrow	−46.8
Check	−35.4
LED strip	−43.0
Traffic	−42.9

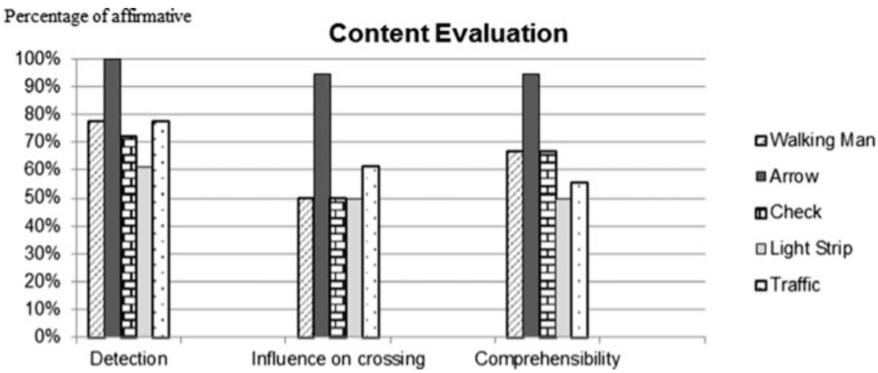

Fig. 5 Results of questions regarding detection, influence on crossing and comprehensibility of HMI concepts

for the questions regarding the possibility to detect the HMI concepts, if the HMI concepts influenced the decision making on crossing the street, and if the HMI concept was understandable for the test participant.

The bars represent the percentage of participants that answered the questions affirmatively. This means for instance that 100% of test participants could detect the HMI concept "Arrow" and 50% of test participant stated that the HMI concept "LED Strip" influenced their decision making on crossing the street. As it is visible in Fig. 5, the "Arrow" HMI concept had the highest rates in all three categories. On the other hand, the "LED Strip", "Check", and "Traffic" HMI concepts were the concepts that influenced least the decision making to cross the street. Furthermore the "LED Strip" and "Traffic" HMI concept were the least comprehensible concepts in the test participants' subjective sense. This qualitative data indicates a higher user *satisfaction* when interacting with the "Arrow" HMI concept than with the other concepts.

5 Discussion

The discussion merges the facts that have been brought to light by the case study regarding the HMI and the more general points about the Usability Tests within VR that have been found out during the development process of the methodology.

Within the presented study, it was possible to demonstrate the need for an explicit HMI for the communication between AVs and pedestrians in ambiguous situations. Indeed, even though the HMI concepts did not have significant differences in terms of *efficiency*, *effectiveness*, and *satisfaction* among one another, the results had significant differences compared to the control group without any explicit HMI concept. This could be highlighted within VR since it was possible to test the explicit HMI concepts in an isolated way without interfering factors like deceleration. In other studies, like the one from Clamann, Aubert, and Cummings (2017), who conducted research on explicit HMI for manually driven cars that were disguised as AVs, deceleration and gap distance were identified as the main indicators for pedestrians to assess traffic situations. We suppose that these indicators interfered with the accurate evaluation of explicit HMI concepts since they constituted unneglectable variables. However, the neglect of these variables was possible within VR and thus the presented method is validated as suitable tool for evaluating communication concepts without interferences.

Furthermore, Pillai (2017) conducted a study of implicit communication (i.e. deceleration behaviour) between AVs and pedestrians at zebra crossings within VR. Beyond the results that a “human-like” driving behaviour from AV’s side improves the interaction with pedestrians, the study revealed that explicit HMI concepts would have been useful for the test participants to further assess the situation correctly. This underlines the necessity for explicit HMI concepts.

In further studies, it is planned to investigate a combination of explicit and implicit communication for better usability for pedestrians. Supplementary development can also accommodate further scenarios in which for instance more than one pedestrian are willing to cross the road, or pedestrians come from different directions.

Regarding the methodology used within VR, the presented study has validated that VR is a suitable tool to conduct Usability Tests for the case study of explicit communication between AVs and pedestrians in ambiguous situations. There are drawbacks in using VR like limited immersion and absence of haptic feedback. However, VR enables high flexibility to create the environment and the scenarios and the tests could be conducted with ensured safety for the test participants. This is aligned with findings from Deb et al. (2017) and Pillai (2017).

As a next step, a benchmark test is planned to be conducted to prove the validity of collected data within VR. In order to do so, a scenario will be created in real-life conditions as well as in VR and afterwards compared regarding congruence of results.

Finally, it will be investigated if the presented methodology can be used for other case studies like for instance how information, related to AV technology (e.g. intention or detection) can prevent anxiety from passengers' side inside an AV for public transport.

6 Conclusion

The present work highlighted the suitability of Virtual Reality as a tool to test usability, particularly in the context of communication between AVs and pedestrians. On the one hand, when no functional AV prototype is available, the method worked as a quick, preliminary validation method for the presented case study. On the other hand, the case study showed that the absence of communication between driver and pedestrian needs to be compensated towards an explicit HMI. Even though there are no significant results about differences of *efficiency*, *effectiveness*, and *satisfaction* attributes among the tested concepts, the VR Usability Tests helped to evaluate and dismiss several alternatives. Regarding the case study, further tests are necessary to evaluate the influence of implicit communication for the decision making of pedestrians in the Av to pedestrian scenario. In order to further validate VR as a suitable tool for the conduct of Usability Tests in general, additional case studies will be selected and additional usability attributes will be focused on.

References

Benderius, O., Berger, C., and Lundgren, V. M., (2017). The best Rated Human-Machine Interface Design for Autonomous Vehicles in 2016 Grand Cooperative Driving Challenge. *IEEE Transactions on intelligent transportation systems, 19*(4), 1302–1307.

Berg, L. P., & Vance, J. M. (2017). Industry use of virtual reality in product design and manufacturing: A survey. *Virtual Reality, 21*(1), 1–17. https://doi.org/10.1007/s10055-016-0293-9.

Clamann, M., Aubert, M., & Cummings, M. L., (2017). *Evaluation of vehicle-to-pedestrian communication displays for autonomous vehicles*.

Deb, S., Carruth, D. W., Sween, R., Strawderman, L., & Garrison, T. M. (2017). Efficacy of virtual reality in pedestrian safety research. *Applied Ergonomics, 65,* 449–460. https://doi.org/10.1016/j.apergo.2017.03.007.

Eng, H. (2017). *Embracing the future of land transportation: Valuing flexibility in design and technology options for autonomous vehicles developments in Singapore*. (Master thesis, Massachusetts Institute of Technology).

Fuest, T., Sorokin, L., Bellem, H., & Bengler, K. (2017). Taxonomy of traffic situations for the interaction between automated vehicles and human road users. In *International Conference on Applied Human Factors and Ergonomics* (pp. 708–719). Springer, Cham.

Land Transport Authority. (2017). *Speed limits*. Retrieved from https://www.onemotoring.com.sg/content/onemotoring/en/on_the_roads/road_safety/speed_limits.html.

Loomis, J. M., & Blascovish, J. J. (1999). Immersive virtual environment technology as a basic research tool in psychology. *Behavior Research Methods, Instruments, & Computers, 31*(4), 557–564.

Matthews, M., & Chowdary, G. (2017). Intent communication between autonomous vehicles and pedestrians. Arxiv preprint arXiv:1708.07123.

Mercedes, (2015). Der Mercedes-Benz F 015 Luxury in Motion. Retrieved from https://www.mercedes-benz.com (22.02.2018).

Mihelj, M., Novak, D., & Beguš, S. (2014). *Virtual reality technology and applications*. Dodrecht: Springer.

Nissan, (2015). Nissan IDS Concept: Nissan's vision for the future of EVs and autonomous driving. Retrieved from http://www.nissan-global.com (22.02.2018).

Oxford Dictionary. (2018). Definition of *usability* in English. Retrieved from: https://en.oxforddictionaries.com/definition/usability (07.02.2018).

Pillai, A., (2017). *Virtual reality based study to analyse pedestrian attitude towards autonomous vehicles*. Aalto University–School of Science.

Rubin, J., & Chisnell, D. (2008). *Handbook of usability testing: How to plan, design, and conduct effective tests*. 2nd edition, Indianapolis: Wiley Publishing Inc.

SAE International. (2016). *Taxonomy and definitions of terms related to driving automation systems for on-road motor vehicles*. Retrieved from www.sae.org (21.08.2017).

Schmidt, S., & Farber, B. (2009). Pedestrians at the kerb: Recognising the action intentions of humans. *Transportation Research part F: Traffic Psychology and Behaviour, 12*(4), 300–310.

Schneemann, F., & Gohl, I. (2016). Analyzing driver-pedestrian interaction at crosswalks: a contribution to autonomous vehicle in urban environments. In *Intelligent Vehicles Symposium (IV)—IEEE* (pp. 38–43).

Šucha, M. (2014). *Road users' strategies and communication: Driver-pedestrian interaction*. In Transport Research Arena, Paris.

The New York Times. (2016). Inside the self-driving Tesla fatal accident. *The New York Times*. Retrieved from https://www.nytimes.com/interactive/2016/07/01/business/inside-tesla-accident.html (23.08.2017).

Theoto, T., (2018). *Human-machine interface design for pedestrians and autonomous vehicles* (Unpublished master's thesis). Technical University of Munich, Germany.

van der Bijl-Brouwer, M., (2012). *Exploring usability—Design for dynamic and diverse use situations*, Ph.D. Thesis, University of Twente, Enschede.

Designing Spatial UI as a Solution of the Narrow FOV of Microsoft HoloLens: Prototype of Virtual Museum Guide

Ramy Hammady and Minhua Ma

Abstract Since the Augmented Reality (AR) headset 'Microsoft HoloLens' released in 2016, the academic and the industrial community witnessed an obvious transformation and changes in the perception of AR applications. Despite this breakthrough, most of the HoloLens users have explicitly reported the narrow field of view (FOV) that crops the virtual augmentation from the viewer's sight to a small window of 34° (Bimber & Bruns in PhoneGuide: Adaptive image classification for mobile museum guidance, 2011). This limitation can result in losing pre-made functions and visuals in the AR application. Therefore, this study introduced attempts to design a spatial UI representing a way around the narrow FOV that HoloLens suffers from. The UI was a crucial part of AR museum system which was evaluated by 9 experts in HCI, visual communication and museum engaging studies. Results showed a positive feedback on the usability of the system and users' experience. This method can help HoloLens developers to extend their applications' functionalities with avoiding missing content.

Keywords Microsoft HoloLens · Field of view · User experience · Usability · Mixed reality · Spatial UI

1 Introduction

Augmented Reality Head Mounted Displays (HMD) and smart glasses are representing a revolution after the use of mobile devices. They started progressing to overcome the limited screens that users can see the blended worlds from. However, the limitation of the hardware and the image processing of the existed AR HMDs reflected a lack of usability and caused cumbersome to users (Hsieh, Jylhä, Orso,

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Gamberini, & Jacucci, 2016). Therefore, the pioneering of Microsoft HoloLens was depicted on providing the opportunity to explore environments with hands-free HMD's capability (Evans, Miller, Pena, MacAllister, & Winer, 2017). It means the device has the mobility feature with being wired with an external device or another controller. Moreover, it provides a content registration by spatial mapping (Coppens, 2017). These distinguished functionalities offer a wide usage of potential application, which subsequently reflects on more exploration on the concept of User Experience (UX) on HoloLens applications.

The spatial 3D user interfaces are commonly used in virtual reality applications (LaViola, 2008). However, in the non-see-through HMDs, users cannot see the physical surroundings (Bowman, Kruijff, LaViola, & Poupyrev, 2004). The privilege of using spatial interface is it not constrains by the typical 2D desktop on mobile screens. Moreover, it open prospects to interact freely in the open space (Billinghurst, Poupyrev, Kato, & May, 2000). According to the spatial mapping feature of HoloLens, AR is perfectly suitable for creating User Interface (UI) for location-aware applications (Höllerer, Feiner, Terauchi, Rashid, & Hallaway, 1999). Thus, the UI could be allocated as a virtual layer in between the user and the physical world in the desired location. HMDs such as Microsoft HoloLens can open prospects of innovative spatial UI with collaborative interactions. The privilege of the collaborative interactions is to involve group of users to interact on the same share UI which reflects positively on content engagement and rich shared experiences.

Interaction with the spatial UI in the see-through HMDs requires a careful consideration to some factors. Some of them relevant to the user performance such as distance to be travelled to interact, size of the potential manipulated object and the length of the user (Bowman et al., 2004). Also, other environmental considerations are needed to take in account such as the of existence of the obstacles, level of activities or movement in the physical environment. User characteristics also should be considered such as the cognitive measures—e.g. the ability to do interactions spatially and the physical considerations such as arm length. Finally, the system considerations—e.g. the frame rate in the real-time (Bowman & Hodges, 1999).

In spite of the uniqueness of holographic lenses of Microsoft HoloLens, the field of view is quite narrow as Bimber and Bruns stated it is 34°. However, Keighrey, Flynn, Murray, and Murray (2017) stated the lens have an FOV of 30° by 17.5°. This limitation of FOV was not satisfactory of HoloLens developers and users (Bright, 2015) as it makes the AR experiences not so immersive. Others claimed it is not suitable for the user's peripheral vision (Hockett & Ingleby, 2016). Also this constrained FOV conflicts with Milgram's definition about the adequacy of see-through displays should be achieved in its FOV (Milgram, Takemura, Utsumi, & Kishino, 1994).

1.1 Related Work

Not many developers have focussed on the development of HoloLens applications yet as it is an emerging piece of technology and due to the expensiveness of its price. However, there are some novel applications that exploited HoloLens in different sectors. For instance, 'HoloMuse' that engage users with archaeological artefacts through gesture-based interactions (Pollalis, Fahnbulleh, Tynes, & Shaer, 2017). Another research utilised HoloLens to provide in situ assistant for users (Blattgerste, Strenge, Renner, Pfeiffer, & Essig, 2017). HoloLens also used to provide magnification for low vision users by complementary finger-worn camera alongside with the HMD (Stearns, DeSouza, Yin, Findlater, & Froehlich, 2017). Even in the medical applications, HoloLens contributed in 3D visualisation purposes using AR techniques (Syed, Zakaria, & Lozanoff, 2017) and provide optimised measurements in medical surgeries(Pratt et al., 2018, Adabi et al., 2017). Application of HoloLens extended to visualise prototype designs (DeLaOsa, 2017) and showed its potential in gaming industry (Volpe, 2015, Alvarez, 2015) and engaging cultural visitors with gaming activities (Raptis, Fidas, & Avouris, 2017).

The literature around UI in optical-see-through HMDs was not discussed frequently. Furthermore, the limitation of the FOV of HoloLens causes challenges in developing the UI and UX for 'hBIM' project, which leads to a rapid disappearance of the content from the user frustum view (Fonnet, Alves, Sousa, Guevara, & Magalhães, 2017). Also in 'Holo3DGIS', the authors stated that their system cannot show the content in the user's visual space (Wang, Wu, Chen, & Chen, 2018). Due to the lack of investigating this problem which is a major concern for HoloLens developers, we were motivated to find a way around to enhance the usability and the user experience.

According to the later literature, this paper we introduce:

1 A method to redesign and restructure a spatial user interface that can find a way around the limitation of the FOV.

2 Exploring the interactions of the designed UI method towards the four categories of outside factors that determined by Bowman's factors (Bowman & Hodges, 1999) which are user performance, environmental consideration, user characteristics and system consideration. This exploration will be measure by experimental evaluation.

Keeping in mind the main aim is to increase the usefulness and immersiveness of the AR application overcoming the hardware limitation.

2 System Overview

In order to manifest our method, it is prior to build a practical prototype and this prototype was constructed for cultural heritage guidance. The application is meant to be developed is a simple, interactive and informative system to guide visitors in museums. This system required from the user to wear Microsoft HoloLens and to explore the virtual content through spatial user interface. These interactions should be occurred with the existence of an exhibited antique in order to superimposed the content of the system as a complementary guidance.

2.1 Functionality

Our goal is construct the most usable UI that is capable to achieve the simplest interactions needed. The user has to interact with a spatialized 3D models, text, images, videos and buttons. The user has to deal with:

1 Doing air-tap or hand gesture on the floating virtual objects such as the virtual replica of the authentic. The user can explore the virtual item in 360° so they can rotate it by dragging to right and left to spit it. The antique should be remains on its position.
2 Interacting with buttons of documentary images and scripts when needed by the visitor.
3 Interacting with a virtual guide represent a character from the same context explaining the exhibited item as a real-time virtual narrator. Also the user has the ability to click on a set of buttons to play/pause/replay to control the narrations' flow.
4 Interacting with small circles working as trigger buttons to reveal information in particular spots in the virtual replica. User can click on it by moving his head straightforward by the gaze point then doing the air-tap.

2.2 System Architecture

The system developments always be constructed by creating 2D and 3D assets.
Development of the system took three stages as depicted in Fig. 1:

1. 2D and 3D assets creation: In order to design a tempting and futuristic spatial UI design, 2D software adopted such as adobe Photoshop and Illustrator. All graphical items were designed and exported as PNG and JPG format which is going to be imported later as texture assets. Then, the 3D assets come to the process by creating the 3D model of the virtual guide using zBrush and Autodesk Maya. After modelling, the 3D designs required high textured

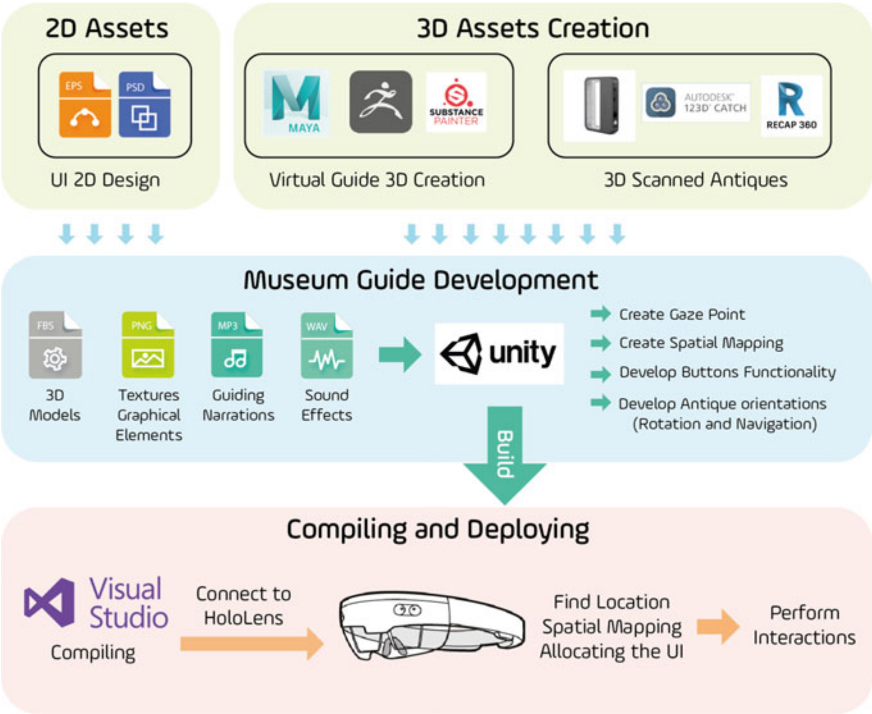

Fig. 1 System architecture

materials so Substance Painter was adopted to accomplish this mission. Acquiring the virtual replica of the authentic piece went through using 3D scanners such as 3D sense and the mobile application '123D Catch'. Then, 3D scanned replica files refined and re-edited by Recap 360°. All 3D files are exported as FBX in order to be imported to Unity3D.

2. Development Phase: All FBX will be imported to Unity3D project accompanied with PNG and JPG files that is considered as the main elements of the UI design. Add to it all; narrations audio files and sound effects libraries. In unity3D, project is created and the UI arranged in the scene and a set of steps are required to develop the system. Firstly, creating the gaze point in order to help the user to aim to the button that needed to be triggered. It usually appears straight ahead at the centre of the user's vision box. Secondly, the spatial mapping is developed to scan the actual location in order to reallocate the designed UI and the virtual guide location next to the actual antique. It is designed to respond to the user's hand gesture wherever interact. Thirdly, adding functionality to the spatial buttons such as images, scripts and controlling the narration flow. Fourthly, applying the navigation and orientation of the virtual replica in order to be controlled and responded by the user.

3. Compiling and Deploying: After building the application from Unity3D, Visual Studio's role is to compile it and deploy it to Microsoft HoloLens through a wired connection to it. Then the headset will be ready for being used. Once the user opens the application, he/she can perform the interaction – hand gesture- to allocate the spatial visuals in the desired location and the virtual guide starts at once.

2.3 UI Design Process

The first idea to design the spatial UI design is to be designed as a half curve and all visuals are surrounding around the user. This approach was adopted in order to make all interactive points more reachable to the user and to ease the way of interactions. As depicted in Fig. 2, the brightened area is what actually the user can see from the whole scene and the semi-blacked area represents the unseen parts of the scene. In reality the blacked area is representing the actual environment without virtual content but the figure is to manifest the problem of missing content due to the narrow FOV.

Unsurprisingly, and due to the limited FOV, what was seen from the HoloLens view port was clipped scenes as depicted in Fig. 3. Because of this uncoherent UI scene, users can not notice the existence of the missing content whether it is in the left or the right side of the user. Therefore, a series of experimental methods are conducted based on Bowman and Hodges (1999) outside factors which was part of their study.

However, there are some other factors were found out aside with previous factors to accomplish the targeted goal. By considering all these factors that integrated with testing interventions, an obvious learning curve was noticed and we

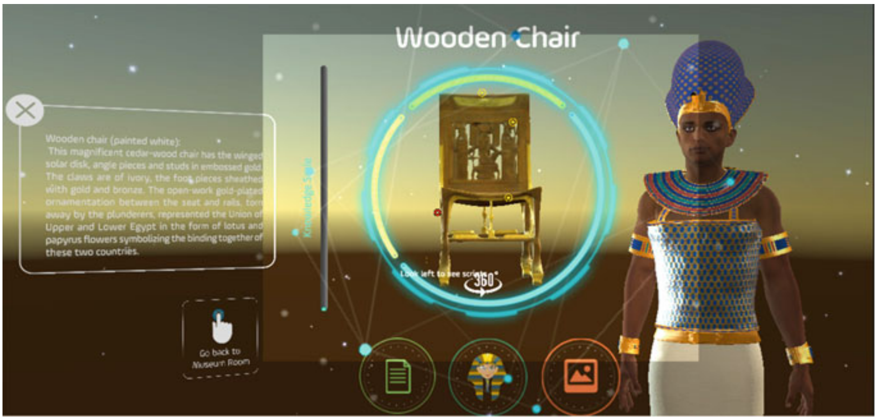

Fig. 2 Spatial UI design as seen from HoloLens

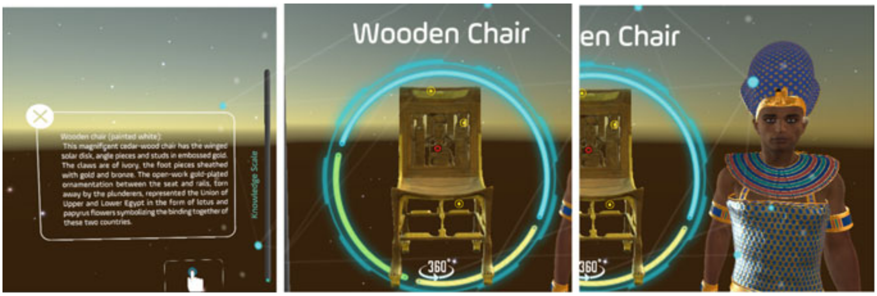

Fig. 3 Cropped scene as the HoloLens user can see

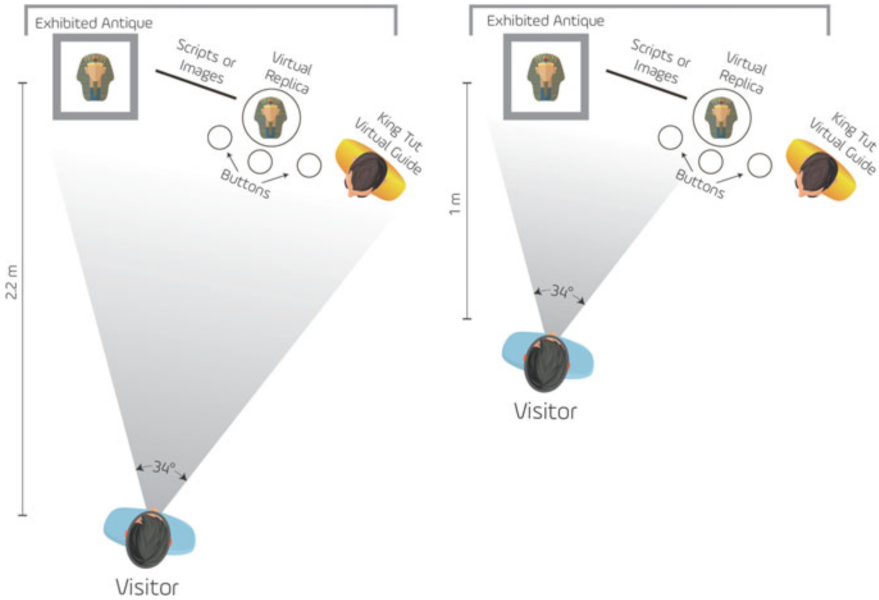

Fig. 4 Visualising the entire seen from different locations

found a solution to enhance the usability and interactivity. Depicted in Fig. 5, the UX principles diagram required for HoloLens UI design.

1. Task characteristics: as described by Bowman & Hodges (1999), they represent all aspects that influence the performance. In our UI prototype, the user has several activities that affect on the way of performing towards it. User has to walk to the UI, aim with his/her head and centre the gaze point then do air-taps. In addition to look around and watch people walking while observing the authentic exhibited item. Moreover, the interactions with the virtual replica requires a dragged hand-gesture to rotate the object. These set of activities require specific attributes to be taken care of:

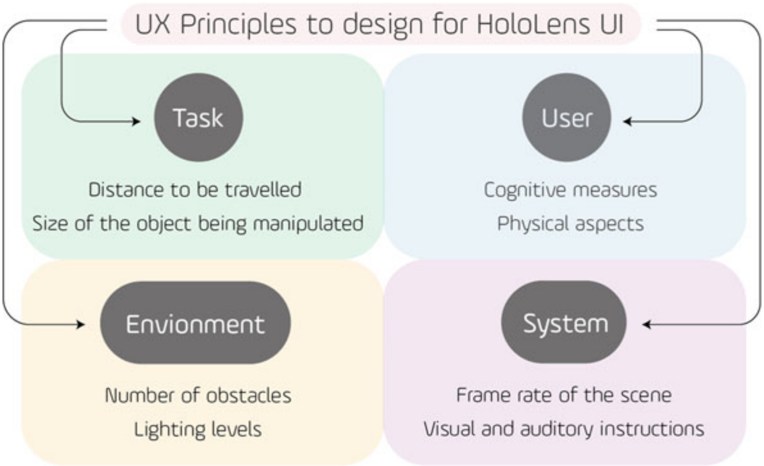

Fig. 5 UX principles for HoloLens UI Design developed from (Bowman & Hodges, 1999)

(a) *Distance to be travelled*: due to the limited FOV, what the user can see is merely quarter of the scene as mentioned before. Moreover, the user has to see the exhibited antique with the UI together. Also, it was calculated the best distance has to be from the UI is 1 m in order to perform a proper hand interaction with the UI. However, in order to see the entire desired scene, the user has to move back 2.2 m to see it as depicted in Fig. 4. The challenge was in the scene triggers that supposed to be so close to the exhibited antique. At the first attempt, we allocated the scene triggers 1 m away from the exhibited item. Unsurprisingly, this attempt results unrecognising the entire scene by the users however, we added a voice command or instructions to look left and right. The second attempt went better than before as we allocated the scene triggers 2.2 m away from the exhibited item. However, the UI was so far and the location of the triggers were not in the desired location but users could see the whole scene. With minor voice and visual instructions, users came closer to interact with the UI and could realize the existence of the whole scene.

(b) *Size of the object being manipulated:* Based on our measurements in the intervened test of our participants, the best distance to do the interaction is 1 m. Moreover, the most appropriate size that our participants felt convenient with is to be over 50 cm height and 50 cm width. It is worthy to mention that most of the participants were exposed to minimal instructions on how to do the air-tap and make the dragging gesture.

2. Environmental characteristics: The environment of using and interacting with HoloLens requires an adequate space. Therefore, we consider the characteristic of the space by involving some variables in the process of interactions.

(a) *Number of obstacles:* While running the application, it was concluded that the user requires an empty area in front of him/her to place the visuals. If some people pass in front of the user, it might change the location of the UI and that's due to the deforming of the spatial mapping of the actual location. So, this problem is commonly in museums, it is expected to have many visitors at the same spot.
(b) *Lighting levels:* It is preferable to display visuals in low levels of lighting conditions and the visuals opacity increases with interior lighting conditions. Sun lights decreases the opacity percentages and the visuals start to lose its opaqueness.

3. User characteristics: All aspects related to the user himself/herself regarding the physical and cognitive attributes.

(a) *Cognitive measures:* Participated group were instructed minimally the way the interact and do the air-tap. During the experimental phases, we noticed different levels of acquiring the interaction skills, which reflects an uneven retention of the instructions. Getting used of the HoloLens interactions takes time with some people and no time with others.
(b) *Physical aspects:* The diversity of the participants' heights were noticed during testing interventions. We designed the visuals are appropriate to 1.70 m for the person's height. However, we noticed that shorter participants tend to look up to the visuals, which is a cumbersome for them and cause pain in their necks after time. Likewise, the participant who their height is longer than 1.70 cm. After several attempts, we were driven to scale the whole UI based on the person's height. Once the scene opened, it calculates the distance between the ground and the camera of the HoloLens. Then, it scales the whole UI based on it. Eventually, it made the participants feel more convenient.

4. System characteristics: All aspects that relevant to the headset or the application developed or the hardware specifications.

(a) *Frame rate of the scene:* It was noticed a rapid streaming of the physical visualisation that combined with the virtual content when the complexity of 3D graphics is in minor levels. On contrary, if the current frame that the user is observing from the HoloLens viewport has loads of complex 3D models, the frame rate will come to 15–20 frame per second. It also could cause lags and delay of rendering the current frame. So, from the spatial design perspective, it is recommended to distribute the complex 3D visuals around the space with adequate room in order to avoid seeing them together in one frame.
(b) *Visual and auditory instructions:* From the UX concepts, the user should be aware of the all visuals that designed to be seen or to be heard. To loose recognising or seeing a visual content from the user cause a lack of user experience. Therefore, we used a 'tag along method', which gives the user a visual clue that points to the location of the virtual content in the space around the object. This method adopted by Fonnet et al. (2017). It ensures that the content is constantly a glace away from the users. We also used

auditory instructions to compensate the visual instructions if there is no room for the later method.

3 Prototype Evaluation

We opted for a field study demanding the involvement and participation of actual users. The aim of the evaluation is to investigate the usability aspect and the other unexplored aspects that might occur during the system usage. The evaluation's nature was a completed simulation of the actual system that could be applied practically in museums.

3.1 Method

We conducted an evaluation in the university library where we invited 9 participants and they are experts in different disciplines such as in Human Computer Interactions (HCI), visual communication and museum engaging studies. The research employed experts to do a discrete evaluation on aspects some of them were common to the participant evaluation and other relevant to their expertise. Worthy to mention that some similar studies employed disciplines' experts to ensure the validity to the evaluation process (Karoulis, Sylaiou, & White, 2006). They were instructed prior the experiment by a brief tutorial on the way of interaction as depicted in Fig. 6. The evaluation method adopted the quantitative method as the

Fig. 6 Participants testing the system

Table 1 Participants demographics

Discipline expertise	Male/ female	Years of experience	Age group
Academic and professional expert in Visual communication and Arts	F	22	45–60
Expert at public engagement in museums	F	7	31–45
Expert in museum curatorship	M	7	25–30
Expert in museum curatorship	F	6	31–45
Expert in museum curatorship	F	4	25–30
Expert in HCI and visual interactions	F	9	31–45
Data manager and responsible for enhancing the museum visitor engagement	F	2	31–45
Expert in museum curatorship	M	10	31–45
Academic and professional expert in museum curatorship	M	8	31–45

research instrument was semi-structured questionnaires that include open questions. These questionnaires were piloted prior the experiment through other experts to make sure the questions are clear and answer the research objectives The quantitative method comprised of two types: textual analysis and numeric analysis. The textual questions were designed based on 1–5 Likert scale. The experiment took from 5–10 min per participant. In Table 1, the demographics of participant is manifested based on their age group, expertise area and years of experience.

3.2 Results

The numeric data in Table 2 represents the measurements of the usability aspect including the experience of interactions and preforming the functions desired. The first question was the lowest positive percentage of respondents were about the convenience of the headset and if it is comfortable during the usage of the prototype or not. As participants stated *"Slightly heavy perhaps"* and another said *"It was a bit heavy on my neck, so I would not want it on too much"*. It is worthy to mention that the headset is 579 g (Microsoft, 2015). The following question wonders if it causes dizziness, or headache, however the responds were highly positive. A participant commented *"The HoloLens was much better than VR headsets, there was no disorientation or loss of the horizon, I was immersed in the location without losing track of my surroundings. Good experience"*. The 3rd question's responses also were quite positive, however a participant *"I was glad to be reminded to look up and down"*. The 4th question was regarding the air-tap and the comments were quite convincing. A participant stated *"I had to learn how to do this—but that was part of the fun"* and another commented "*Yes, after minimal guidance"*. The 5th question was examining the core of our theoretical study and the comments were

Table 2 Usability Aspect

Measure	Strongly agree (%)	Agree (%)	Neutral (%)	Disagree (%)	Strongly disagree (%)	Mean	Std. dev.
I found the headset comfortable to wear	0.0	77.8	11.1	4.3	0.0	3.67	0.707
I did not experience nausea, dizziness, or headache	77.8	22.2	0.0%	0.0	0.0%	4.78	0.441
I could look around the room comfortably	10.6	44.7	38.3%	6.4	0.0%	4.44	1.014
I could do air tap on the virtual objects appropriately	33.3	55.6	11.1	0.0	0.0	4.22	0.667
I could interact with the user interface as I expected	44.4	33.3	11.1	11.1	0.0	4.11	1.054
I could do all functions I desired	33.3	55.6	55.6	11.1	0.0	4.11	0.928

(1 = Strongly disagree to 5 = Strongly agree. N = 9)

progressive as a participant commented *"Much more interactive than anticipated-love that you can more around the scene and look in all directions"*. However, another participant stated *"It is required some time to deal with it"*. The 6th question also examines the main theoretical contribution and the percentage was similar to the previous question. Participants responses regarding this question were all positive as someone stated *"This became easier the move I used the device"* and another commented *"Generally, very easy to use"*.

4 Discussion and Conclusion

This research contributes theoretically by forming the UX principals for HoloLens UI applications as way to overcome the UI problems that stated in the literature. Our experiment was driven due to the formed UX principles in, which can enhance the usability aspect which was affected by the narrow FOV of HoloLens that was stated clearly in the literature. The conducted experiment introduced an empirical evidence through a HoloLens system prototype, which provides strong support for our hypothesis. Hence, this prototype was developed according to the UX principles in order to measure the ability to overcome the FOV UI problem.

Also this paper manifests the system structure with the pipeline of the designed prototype that can be used to guide visitors in museums. This system is featured to have a personalised virtual guide, intractable virtual replica and holographic UI presented aside with the exhibited antique. According to the positive results, the prototype proved its usability and accessibility to a group of experts with different expertise that relevant to the prototype cross-disciplinary nature. The theoretical contribution is quite helping the UX designers and developers to overcome the mentioned problem if they can consider these principles during their pipeline and testing phases. Also the techniques are flexible to be applied to any application has the spatial UI design and intractable floating buttons. The UX model also consider users who has different heights and also consider different environment natures.

Despite the HoloLens enabled us to develop prototypes with genuine AR applications, it still has limitations that should be considered in the future versions of it. For instance, the unstable spatial mapping function was witnessed when someone crossed in front of the user. Also the device is bulky for some users, so they could not able to wear it for long periods which means it is not so much acceptable in museum long tours. Moreover, the real-time rendered frame should not have so much graphics—3D models and textures-, otherwise it could cause lags and delays of real-time rendering.

Enhancing the museum experience through immersive technologies reflects explicitly on the tourism industry. It absolutely encourages visitors to come to museums to experience the technological tool and to enjoy it. Hence, museum managements need to invest time and resources on these vital tools as it might be the next revolutionary gadget in museums that can reshape the mental image of museums.

4.1 Future Work

We seek for adding more usability and enriching the user experience to the system so that we are aiming to add voice recognition and text-to-speech techniques. We still not sure if the voice recognition can practically work with some languages e.g. Arabic language. Also we envision a futuristic AR system that can present visuals beyond the spatial UI and can depict holograms everywhere around the user. That system can consider the user is in the centre of a sphere of interactive worlds. We also aim to include games at specific zones of museums to enrich the level of interactivity and empower the content with contextual interesting stories. These games should have some motivational actions such as exploring and investigation the rooms to discover clues for rewards and reaching milestones. These actions can encourage the physical interactions within the museum context. Hopefully, this expanded system could achieve more aims with newly developed HoloLens or headset with widen FOV.

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References

Adabi, K., Rudy, H., Stern, C. S., Weichman, K., Tepper, O., & Garfein, E. S. (2017). Optimizing measurements in plastic surgery through holograms with Microsoft Hololens. *Plastic and Reconstructive Surgery Global Open, 5*(9 Suppl).

Alvarez, E. (2015). *Microsoft shows off 'Minecraft' built specifically for HoloLens*. Retrieved from https://www.engadget.com/2015/06/15/microsoft-minecraft-hololens/.

Billinghurst, M., Poupyrev, I., Kato, H., & May, R. (2000). *Mixing realities in shared space: An augmented reality interface for collaborative computing.* Paper presented at the Multimedia and Expo, 2000. 2000 IEEE International Conference on ICME 2000.

Bimber, O., & Bruns, E. (2011). *PhoneGuide: Adaptive image classification for mobile museum guidance*.

Blattgerste, J., Strenge, B., Renner, P., Pfeiffer, T., & Essig, K. (2017). *Comparing conventional and augmented reality instructions for manual assembly tasks.* Paper presented at the Proceedings of the 10th International Conference on PErvasive Technologies Related to Assistive Environments.

Bowman, D. A., & Hodges, L. F. (1999). Formalizing the design, evaluation, and application of interaction techniques for immersive virtual environments. *Journal of Visual Languages & Computing, 10*(1), 37–53.

Bowman, D., Kruijff, E., LaViola, J. J., Jr., & Poupyrev, I. P. (2004). *3D User interfaces: Theory and practice*. CourseSmart eTextbook: Addison-Wesley.

Bright, P. (2015). HoloLens: Still magical, but with the ugly taint of reality. Retrieved from https://arstechnica.com/gadgets/2015/05/hololens-still-magical-but-with-the-ugly-taint-of-reality/.

Coppens, A. (2017). *Merging real and virtual worlds: An analysis of the state of the art and practical evaluation of Microsoft Hololens*. *arXiv preprint* arXiv:1706.08096.

DeLaOsa, J. (2017). Ford Designs Next-Gen Cars Using Microsoft's HoloLens. Retrieved from https://www.ecnmag.com/blog/2017/09/ford-designs-next-gen-cars-using-microsofts-hololens.

Evans, G., Miller, J., Pena, M. I., MacAllister, A., & Winer, E. (2017). *Evaluating the Microsoft HoloLens through an augmented reality assembly application.* Paper presented at the Degraded Environments: Sensing, Processing, and Display 2017.

Fonnet, A., Alves, N., Sousa, N., Guevara, M., & Magalhães, L. (2017). *Heritage BIM integration with mixed reality for building preventive maintenance.* Paper presented at the Computação Gráfica e Interação (EPCGI), 2017 24º Encontro Português de.

Hockett, P., & Ingleby, T. (2016). Augmented reality with HoloLens: Experiential architectures embedded in the real world. *arXiv preprint* arXiv:1610.04281.

Höllerer, T., Feiner, S., Terauchi, T., Rashid, G., & Hallaway, D. (1999). Exploring MARS: developing indoor and outdoor user interfaces to a mobile augmented reality system. *Computers & Graphics, 23*(6), 779–785.

Hsieh, Y.-T., Jylhä, A., Orso, V., Gamberini, L., & Jacucci, G. (2016). *Designing a willing-to-use-in-public hand gestural interaction technique for smart glasses.* Paper presented at the Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems.

Karoulis, A., Sylaiou, S., & White, M. (2006). Usability evaluation of a virtual museum interface. *Informatica, 17*(3), 363–380.

Keighrey, C., Flynn, R., Murray, S., & Murray, N. (2017). *A QoE evaluation of immersive augmented and virtual reality speech & language assessment applications.* Paper presented at the Quality of Multimedia Experience (QoMEX), 2017 Ninth International Conference on.

LaViola Jr, J. J. (2008). Bringing VR and spatial 3D interaction to the masses through video games. *IEEE Computer Graphics and Applications, 28*(5).

Microsoft. (2015). HoloLens hardware details. Retrieved from https://developer.microsoft.com/en-us/windows/mixed-reality/hololens_hardware_details.

Milgram, P., Takemura, H., Utsumi, A., & Kishino, F. (1994). Augmented reality: A class of displays on the reality-virtuality continuum. *Telemanipulator and Telepresence Technologies, 2351*.

Pollalis, C., Fahnbulleh, W., Tynes, J., & Shaer, O. (2017). *HoloMuse: Enhancing engagement with archaeological artifacts through gesture-based interaction with holograms.* Paper presented at the Proceedings of the Tenth International Conference on Tangible, Embedded, and Embodied Interaction.

Pratt, P., Ives, M., Lawton, G., Simmons, J., Radev, N., Spyropoulou, L., et al. (2018). Through the HoloLens™ looking glass: Augmented reality for extremity reconstruction surgery using 3D vascular models with perforating vessels. *European Radiology Experimental, 2*(1), 2.

Raptis, G. E., Fidas, C., & Avouris, N. (2017). *Cultural heritage gaming: Effects of human cognitive styles on players' performance and visual behavior.* Paper presented at the Adjunct Publication of the 25th Conference on User Modeling, Adaptation and Personalization.

Stearns, L., DeSouza, V., Yin, J., Findlater, L., & Froehlich, J. E. (2017). *Augmented reality magnification for low vision users with the microsoft hololens and a finger-worn camera.* Paper presented at the Proceedings of the 19th International ACM SIGACCESS Conference on Computers and Accessibility.

Syed, A., Zakaria, A., & Lozanoff, S. (2017). Dark room to augmented reality: Application Of hololens technology for oral radiological diagnosis. *Oral surgery, oral medicine, oral pathology and oral radiology, 124*(1), e33.

Volpe, J. (2015). Disney Infinity might make its way to Microsoft's HoloLens. Retrieved from https://www.engadget.com/2015/07/01/disney-infinity-might-make-its-way-to-microsoft-hololens/.

Wang, W., Wu, X., Chen, G., & Chen, Z. (2018). Holo3DGIS: Leveraging Microsoft HoloLens in 3D geographic information. *ISPRS International Journal of Geo-Information, 7*(2), 60.

Recommender System as the Support for Binaural Audio

David Bernhauer and Tomáš Skopal

Abstract Virtual reality devices nowadays can effectively utilise other senses besides vision, too. The most often used secondary sense is hearing with binaural audio as VR engine. Currently, practical usage of binaural audio as the source of VR is impossible because of the inaccuracy of a general model. On the contrary, measuring the personalised parameters can be time-consuming. Our task was to prove the possibility of reconstruction of the binaural audio parameters in domestic conditions. We have focused on the design of the user interface that can be used independently on the platform. Our proposed browser-based application uses collaborative filtering as a recommender system. We have proven that sound-based navigation in axial plane is possible with 6.6° inaccuracy. The gamification and browser-based implementation make it easier for all people to find the best possible parameters. The resulting profile can be used both with fully VR environment and with semi-VR games.

Keywords Binaural audio · HRTF · Recommender system · Collaborative filtering · Virtual reality

1 Introduction

Virtual reality is currently widespread mostly with just the graphical part of applications. Developers must deal with the inaccuracy of audio component. Currently, there are two most used approaches. Firstly, they can completely ignore

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spatial audio. This variant is suitable for application where the sound has a support role, such as background music or pre-recorded 3D sound. On the other hand, developers want to provide complete immersive experience. In most cases, it is not necessary to have an absolute precise simulation of spatial audio. Binaural audio (with right parameters) can provide the best results. The primary parameter of binaural audio is head-related transfer function (HRTF) which represents the hearing of the user. The usage of pseudo-generic HRTF profile achieves average results across all users.

Some applications, including assistive technology and audio-based entertainment industry, need more precise spatial audio simulation. The audio part of virtual reality should provide high enough precision for navigation in space to substitute for vision. The binaural audio can be used in the same manner. However, HRTF needs to be personalised for every subject. The precise measurement of the personalised HRTF can be time-consuming and uncomfortable.

There are various HRTF databases without the wider practical use. Their primary purpose is to support alternative ways of HRTF reconstruction based on different measurements. Anthropometry is a method based on the relationship between ears and head measurements and HRTF.

It is obvious that some profiles match the user better than other profiles. The simple idea is to find the best HRTF for the user instead of using a generic one. Recommender systems are widely used in business, mostly by e-shops. Specialised recommender systems can suggest results based on content, user ratings or more complicated formulas (including HRTFs).

1.1 Contribution

The main purpose of the work is to analyse possible methods of ranking HRTFs and prove that collaborative filtering can efficiently choose the best matching HRTF. Collaborative filtering can later be switched to another recommender system.

We have looked for a solution that will provide nearly-precise simulation, save the time of the user and be comfortable. We have focused on application that will be easy to use in domestic conditions. It has been our priority to minimise special and expensive device requirements.

2 Physics of Binaural Audio

The principle of binaural audio is based on acoustics. We can model audio space and listener properties. The main idea is to divide the source of sound into small sources. The human ear cannot distinguish the original from the small one near the ear. In the same manner, the camera cannot distinguish the farther silhouette from

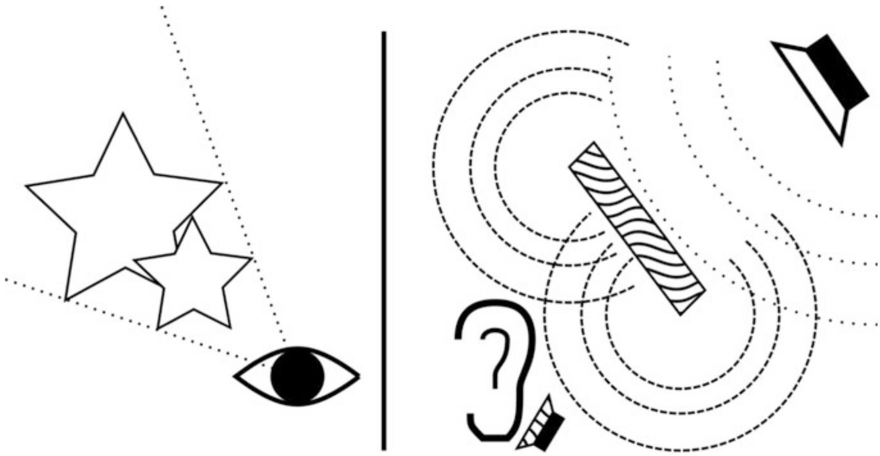

Fig. 1 Camera (left) can be cheated by a smaller closer object. Binaural audio (right) can process the signal in the same manner

the smaller but closer one as shown in Fig. 1. It means that we can replace the original source by the expected signal in ears.

This chapter describes basic principles of spatial audio. Combination of these principles makes binaural audio more realistic. In the end, we can find an overview of current approaches, advantages and disadvantages.

2.1 Basic Principles

The common and most intuitive approach to modelling spatial audio is a simulation of different level of sound. It is obvious that the listener will perceive right-positioned sound louder from the right-side. This fact is called interaural level difference (ILD). Interaural time difference (ITD) compares delay between left and right ear. Both variables directly depend on the head size and shape.

ILD and ITD can be represented as a function of relative position of the source (spherical coordinates), sound and head (shape). Detailed model of the head may not be available for practical use. Moreover, ILD and ITD provide precise sound localisation only in the axial plane. The cone of confusion shows equally distant points as shown in Fig. 2 (right side).

Head-and-torso approach brings another point of view. Torso can provide additional information about the elevation of the sound position. The sound will be reflected from the shoulders as shown in Fig. 2 (left side). The ears will receive the same signal two times. The first signal will determine a set of points in the cone of confusion. The second one will determine the elevation of the source.

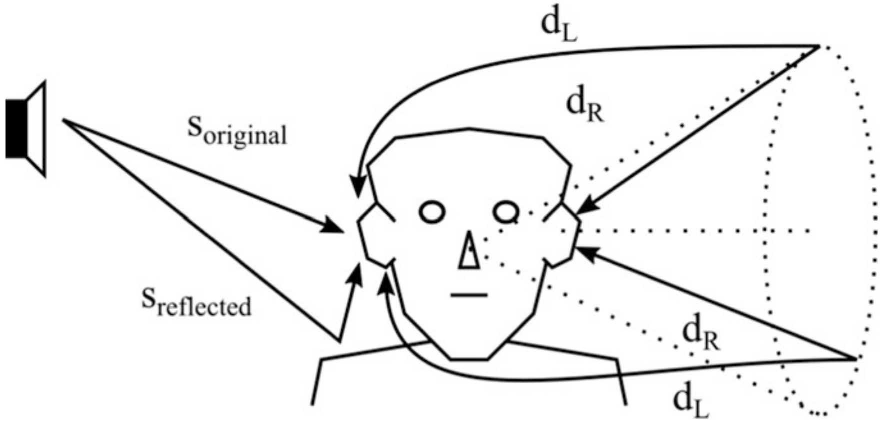

Fig. 2 Head-and-torso reflections with delay (left). Same distance (ITD, ILD) in the cone of confusion (right)

The complexity of the human ear reflects the precision of determining the position of the sound source. Unlike bats, humans cannot map space by echolocation. Even so, they can navigate in space with the support of a navigator. Human ears as the complex device utilise the high number of pinna reflections for sound localisation. These ear details are almost unique for everyone (similar to fingerprint).

Combination of mentioned principles can be generalised as a function of relative position, person and signal. All of these reflections and modifications encode the position of the original sound in head-related impulse response (HRIR). The head-related transfer function (HRTF) is a function that characterises how the final signal is modified. Generally, HRTF is Fourier transform of HRIR.

2.2 Standard Approaches to Retrieving HRTF

In practice, we can divide standard approaches into two categories. The first category is measuring HRTF. Measuring HRTF requires specialised software and hardware including a soundproof room. The basic principle is the same as mentioned above. Microphones can be placed in the ear canal, and HRIR is recorded for every position. Alternative approaches try to deal with the time-consuming process of recording. Time efficiency can be achieved by swapping the microphone for speakers at the expense of discomfort.

Because of unavailability (and other disadvantages) of public HRTF measuring, alternatives are needed. The second approach is modelling the HRTF based on the other properties. Current approaches are discussed in Chap. 3. Our method proposes the possibility of reusing existing HRTF databases for almost precise HRTF retrieval.

3 Related Work

The most accurate method is measuring the HRTF for the particular person. The measuring is time-consuming and uncomfortable. The measuring itself has to deal with inaccuracy caused by noise and imperfections during measuring session. The problems during measuring are discussed in (Plaskota & Pruchnicki, 2014). Measuring is not always the solution to the problem. Especially, measuring HRTF near a subject's head is a little bit problematic, because the loudspeakers used for producing white noise cannot be considered as the point source as written in (Hosoe, Nishino, Itou, & Takeda, 2005).

Another popular method is the reconstruction of the subject's HRTF based on the anthropometry. This approach expects that HRTF depends directly on the geometric model of the head and torso. In this work, we have used CIPIC, one of the open HRTF databases (Algazi, Duda, Thompson, & Avendano, 2001). Some theories work just with the pinna anthropometry. Zotkin et al. (2003) describe the differences between pinna and head-and-torso anthropometry and the consequences.

Current approaches involve modern principles and are based on recommendation. We can find experiments based on autoencoder recommendation and modelling. Luo et al. (2013) used a neural network for recommendation and individualisation of HRTF. The problem of many similar experiments is that the real user is replaced by a virtual one. A virtual user does not have the same qualities as a real one. Yamamoto and Igarashi (2017) bring an experiment with autoencoders and real users. The users subjectively choose the better HRTF. In our work, we show another method of recommendation and testing.

4 Recommendation System

Today's industrial approach involves usage of a general HRTF profile. General HRTF profile can be retrieved by aggregation as an average one. The basic idea is to utilise public HRTF databases. Recommendation of the best HRTF can depend on many factors. It is impossible to recommend precise HRTF because of its uniqueness.

Proposed approach involves a simple recommendation system. Recommendation systems are based on finding relationships (similarity, dependency, complementarity). The recommendation can be used in many fields. Collaborative filtering specialises in finding similarities based on ratings of users.

The principle of collaborative filtering (CF) is finding similarities between persons and objects. If person P_1 likes object O_1, and person P_1 and P_2 are similar, then we can expect that P_2 will like O_1 as shown in Table 1. Similarly, we can define an inverse thesis about objects. The core of the problem is specification of a similarity function.

Table 1 Like-table for CF

Rating	O_1	O_2	O_3	O_4
P_1	Like	Dislike	Like	???
P_2 (similar P_1)	??? (*exp. Like*)	Dislike	Like	Like
P_3 (dissimilar P_1)	???	Like	Dislike	Dislike

The question mark: the user does not rate the object

The tricky part is the word “like”. The user has to rate his relationship to the object. There are many possibilities: yes or no, from 1 to 5, purchase … But, it is sometimes impossible to rate the item. The user cannot decide if one HRTF is better than another one. The next section describes methods how the user can directly rate HRTF profiles.

4.1 User-Related Rating Methods

User’s ranking is essential as the primary input of the collaborative filtering. The aim of collaborative filtering is to find the best matching existing HRTF from a database.

4.1.1 Laboratory Method

The first discussed method focuses on the laboratory approach. The primary target is to provide maximum flexibility for the expert to control the whole testing session. The measured subjects are sitting in the laboratory with the standardised earphones (or headphones) in their ears. The expert randomly or systematically chooses the position of the sound source. The spatial sound is reproduced to subject. The subject will record the assumed position of the source in a simple application or on a sheet. The recommender system will regularly evaluate the error and improve the subject’s HRTF recommendation shown in Fig. 3.

The advantage of this method is the fully controllable environment. The expert can modify any parameter of recommendation system at the time of testing and improve the recommendation. The whole process can be interrupted or restarted in case of any problem. The testing environment provides information about the precision of simulation for different positions. The successful laboratory method combined with measuring the HRTF can provide proof that a recommender system will find the optimal HRTF for the subject. This makes this approach suitable just for experimental purposes.

The disadvantage of this method is in the way of recording the assumed position of the source. The subject is forced to identify the position by hearing, but he records it by sight. This method does not correspond with the localisation of sound

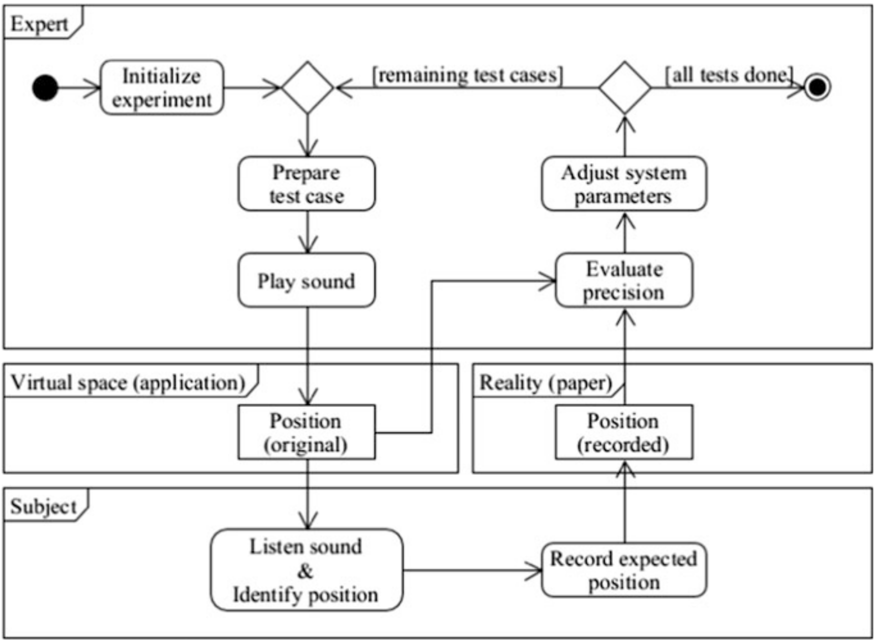

Fig. 3 The activity diagram shows laboratory approach and the problematic difference between virtual (audio) environment and a physical paper sheet

in the real world. It does not allow him to move his head. Secondly, the problem is switching between sight and hearing like switching the lights on and off. The whole experiment can be uncomfortable for the subject. These problems make this method unusable for wide use.

4.1.2 HRTF Reconstruction in Home Conditions

This method is focused on reconstruction in typical home conditions. It assumes standard low-end computer or notebook, low-end headphones and internet connection (optional). The subject will start the application (alternatively open the web application), read the instructions and start the recommendation process shown in Fig. 4.

The user should be able to install an application or open web page. He is placed in the virtual environment and somewhere is a hidden target. The user can rotate the virtual avatar's head with a mouse. If he is sure that he is targeting the source, he will record the position by mouse click. This process is repeated until precision of HRTF is not suitable or time limit exceeded.

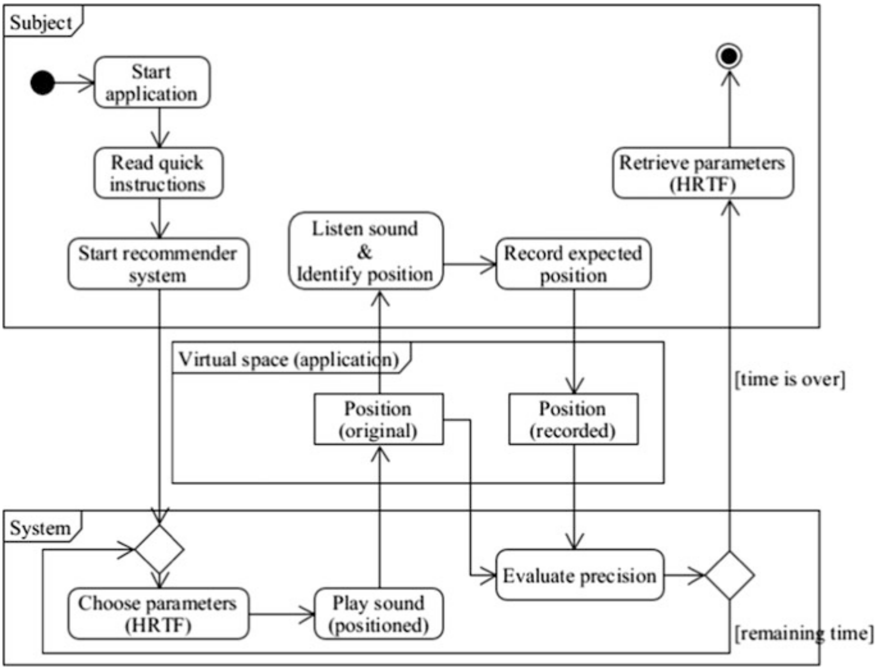

Fig. 4 The activity diagram shows domestic approach. Original sound and recording of the expected position are in the same application

The advantage of this method is wide use in home conditions. It does not require any special hardware requirements. The subject doesn't need to convert audio space to visual space. The whole process is easily understandable to an average user. Adding advanced hardware can improve the recommendation process.

The main problem is the assumption that the subject will follow the instructions. Secondly, there is no expert present. Depending on the implementation, the expert can be connected remotely. Remote control allows him to partially modify the parameters.

4.1.3 VR-Extended Method

The last discussed and analysed method involves usage of virtual reality device. VR device makes wide use more complicated. VR devices are expensive for most people today. On the other hand, it provides different approaches to recording the position of the sound. VR devices should be considered from the long-term view.

Typically, we can use a head tracking device instead of a mouse. Head tracking makes the simulation more traditional. More natural behaviour means more precise HRTF recommendations. VR sets with hand motion tracking device should be more interactive. With this kind of a tracking device, it is possible to test localisation in different positions by pointing the hand only. The subject will get complete VR experience by combining the hand and head motion tracking.

5 Experiment

The experiment of the efficient recommendation of the most personalised HRTF was designed for use in home conditions. The testing web application was implemented in WebGL and WebAudio. Minimum requirements are a low-end computer with a modern browser, internet connectivity and headphones. The process of the experiment is hidden behind the gamification. The player (subject) has to shoot the enemy (source of sound) and maximise the precision and number of hits in 15 min. Firebase was used as a database for the collected data. The Firebase database makes the experiment semi-supervised in real-time.

As the recommender system, we have used collaborative filtering based on similarity of users. Because the number of users will grow and the number of HRTFs will be constant, it would be logical, from a long-term perspective, to base the collaborative filtering on a similarity of HRTFs (Lops, De Gemmis, & Semeraro, 2011). As the HRTF database, we have used CIPIC database, which provides additional data about the 43 original subjects.

Users. 40 users participated in the experiment. 25 of them finished both phases of the experiment. Testers were mostly students of the Czech Technical University in Prague. About 12% of participants were women.

Phases. The experiment was split into two phases. The purpose of the first phase was to get an average precision error with the usage of a pseudo-general HRTF profile. The pseudo-general HRTF profile was simulated by recommending uniformly distributed random HRTFs. The second phase happened after two weeks. Almost every subject completed this phase at home. During the second phase, the HRTFs were recommended by collaborative filtering.

5.1 Results

During the first phase, the subject's precision highly depended on the randomly chosen HRTF. The average inaccuracy was approximately 30°. The subjects acknowledged that they were confused most of the time and they were not able to accurately localise the source of the sound. The average number of hits in 15 min was around 50. Example accuracy during the first phase is shown in Fig. 5.

During the second phase, the subject's precision was at first inaccurate similarly to the first phase, but in the second part (at least last 20% of hits) of the experiment, the average inaccuracy decreased to 6.6°. Nearly all subjects improved over the first

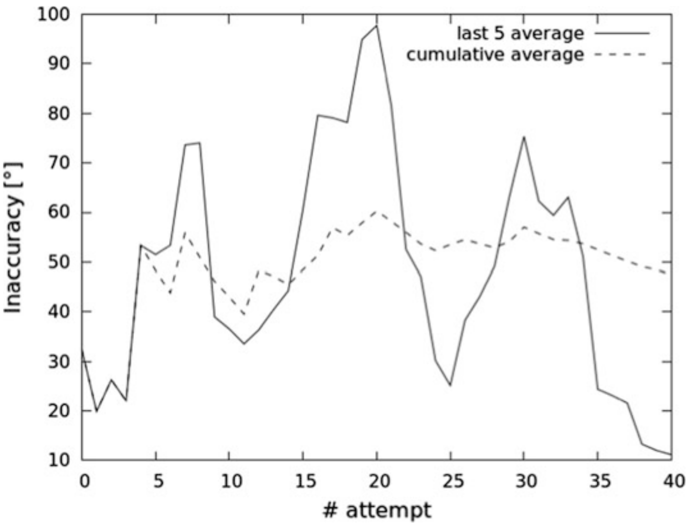

Fig. 5 Subject #16Q6yE inaccuracy during the first phase without individualisation. It can be seen the accuracy is highly dependent on current HRTF profile

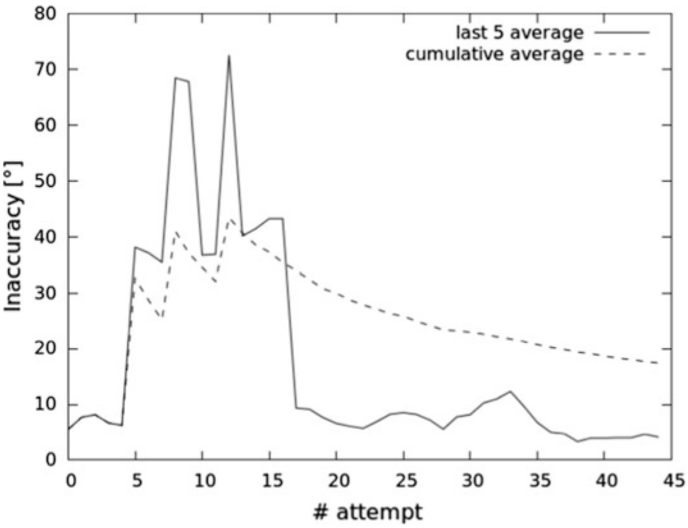

Fig. 6 Subject #16Q6yE inaccuracy during the second phase of collaborative filtering. First 15 shots serve as the best solution searching. Final accuracy is stable

phase, except the subjects that were near the 6.6° limit in the first phase. The average number of hits in 15 min was nearly same. Example accuracy during the second phase is shown in Fig. 6. The final results are presented in Table 2.

Table 2 Average inaccuracy in individual parts of the experiment

Experiment phase	Average inaccuracy	Standard error
Visible target (without crosshair)	5.653°	4.097°
HRTF without individualisation	29.712°	44.256°
HRTF with collaborative filtering	13.995°	17.256°
HRTF with CF, last 20% hits only	6.632°	2.243°

5.2 *Problems*

In contrast with theoretically oriented works, we have focused on problems that cannot be included in probabilistic models. We can observe many different patterns of behaviour during the testing session. Our solution must take these into account. Based on analysis results we have implemented several features to avoid these problems.

The biggest problem with the whole process is human error. As the collaborative filtering is highly dependent on the rating, a wrong rating can result in a wrong recommendation. The wrong recommendation leads to rejection of a potentially perspective solution. In our case, we discard the best and the worst rating as we expect that these outliers can be a statistical deviation. The misclick problem is shown in Fig. 7.

We have predicted that the user will be confused in the front and back direction. This confusion may arise due to many reasons. The primary reason is that the user

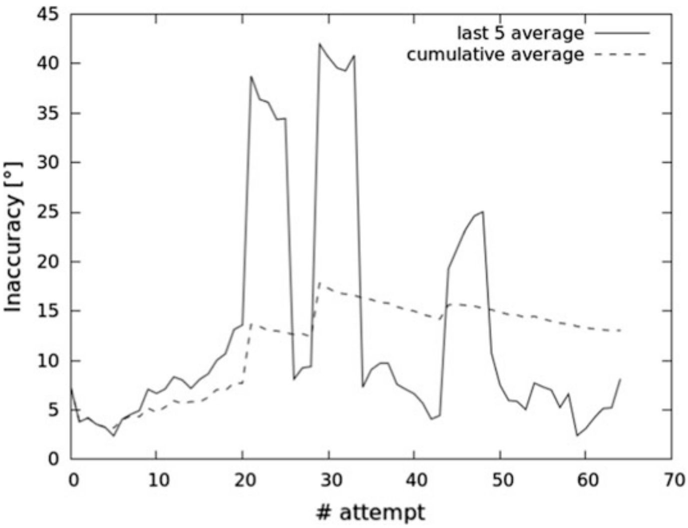

Fig. 7 Subject #L6R7Ep inaccuracy caused by misclick. The peaks represent the misclicks which caused worse accuracy

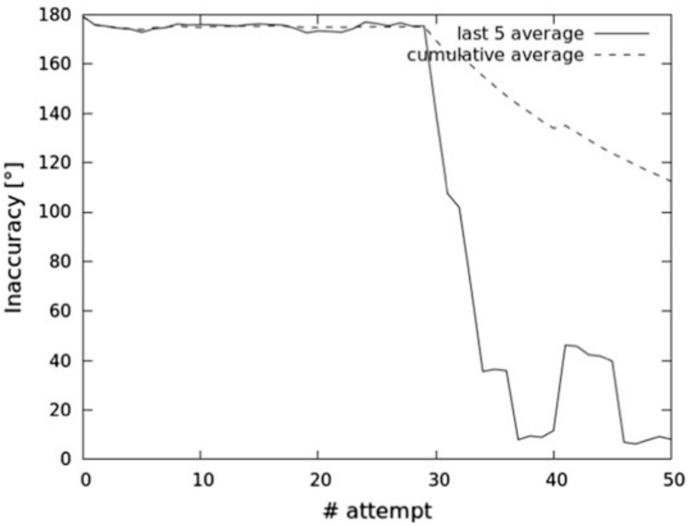

Fig. 8 Subject #LfAp0t inaccuracy caused by disorientation

is not used to orienting themselves with hearing. The different way of localisation may confuse many users at the beginning. The second reason is not being used to the mouse control. Most users move their heads in an attempt to find the source of the sound. The front-back problem is shown in Fig. 8. We have implemented first five rounds with a visible target to make sure that the user understands the controls. The expert was present during the first phase of the experiment. He could notify the user in the case of total disorientation.

Another pseudo-problem during the experiment was caused by several users with good sound perception. These users could adapt to almost every HRTF profile. In this case, it was very difficult to find the best HRTF profile and beat the accuracy of the first phase. Results from both phases were nearly the same.

At last, one of the problems was the sound used for localisation. We have repeated one track again and again. The users were tired after few minutes. In practice, triviality like this can determine the success or failure of this method. Before expanding among the public, we should research further and try to find a generally pleasurable sound.

6 Conclusion and Discussion

Our experiment proved that HRTF recommendation is an efficient way of improving the accuracy of sound localisation. It is possible to get relatively accurate HRTF using a standard computer and modern browser. The average improvement of our approach was 25°. The final accuracy was close to the limit of vision accuracy. The average number of hits was nearly same.

The experiment required precomputed data from the first phase. In practical usage, we can provide it separately. Alternatively, we can extend the testing session to 30 min. First 15 min will use the random recommendation as the exploration of preferences. The other 15 min will be used for collaborative filtering recommendation.

We have to deal with human error. Sometimes the subject may localise sound on the opposite side of space. This phenomenon is due to the fact that subjects are not used to hearing as a primary source for localisation.

Collaborative filtering has proven to be an efficient approach to find the best available HRTF. From the long-term point of view, it is necessary to consider how to improve existing HRTF for better personalisation. This kind of extended personalisation could be based on subject behaviour during the use of the recommended HRTF.

6.1 Binaural Audio for Business Purposes

Currently, there are no many applications using binaural audio. Existing applications only use a general profile. It has just a support role. The biggest problem is that there is no easy way for users to record their HRTF. Precise HRTF recordings are used in assistive technologies. Most of these assistive tools are in experimental phase.

Generator (or recommender system) of HRTFs can be the first step towards allowing users to use a personalised profile. This efficient approach can bring new type of application and game development industry. Augmented and virtual reality application can be extended by binaural audio and provide more realistic simulation. Game industry can easily extend existing games with spatial audio without any additional hardware requirements.

Practical usage will need to define a standardised format for HRTF profiles. HRTF databases can rapidly grow and hold additional information (like anthropometry). The recommender system will improve as the requirements will raise. These changes can help the audio-based assistive tools too.

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References

Algazi, V. R., Duda, R. O., Thompson, D. M., & Avendano, C. (2001). The CIPIC HRTF database. In *2001 IEEE Workshop on the Applications of Signal Processing to Audio and Acoustics* (pp. 99–102). IEEE.

Hosoe, S., Nishino, T., Itou, K., & Takeda, K. (2005, August). Measurement of head-related transfer functions in the proximal region. In *Forum Acusticum* (pp. 2539–2542).

Lops, P., De Gemmis, M., & Semeraro, G. (2011). Content-based recommender systems: State of the art and trends. In *Recommender systems handbook* (pp. 73–105). Boston, MA: Springer.

Luo, Y., Zotkin, D. N., & Duraiswami, R. (2013, October). Virtual autoencoder based recommendation system for individualizing head-related transfer functions. In *2013 IEEE Workshop on Applications of Signal Processing to Audio and Acoustics (WASPAA)* (pp. 1–4). IEEE.

Plaskota, P., & Pruchnicki, P. (2014). Practical aspects of using HRTF measuring device. *Archives of Acoustics, 31*(4(S)), 439–444.

Yamamoto, K., & Igarashi, T. (2017). Fully perceptual-based 3D spatial sound individualization with an adaptive variational autoencoder. *ACM Transactions on Graphics (TOG), 36*(6), 212.

Zotkin, D. Y. N., Hwang, J., Duraiswaini, R., & Davis, L. S. (2003, October). HRTF personalization using anthropometric measurements. In *2003 IEEE Workshop on Applications of Signal Processing to Audio and Acoustics* (pp. 157–160). IEEE.

Virtual Reality References in Design Problem Solving: Towards an Understanding of Affect-Cognition Interaction in Conceptual Design

R. Vimal Krishnan and Prasad S. Onkar

Abstract Empirical studies in cognitive psychology indicate that a typical problem solving activity will involve both affective and cognitive processing. Design problem solving being a creative process is often driven by affective components such as moods, emotions and feelings. This paper demonstrates the dynamics of affective influence on mental imagery processing, a cognitive process involved in producing and modifying visual representations, in the context of conceptual design. This is done by foregrounding the impact of immersive technology such as virtual reality (VR) references through an experimental pilot study. Subjects who received VR references to solve a design problem, demonstrated a markedly different kind of affective engagement as compared to those who received screenshot references. This is reflected in the distinct styles of mental imagery processing and the consequent differences in the produced design solutions, which are presented in the paper as preliminary results.

Keywords Affect · Cognition · Virtual reality · Conceptual design

1 Introduction

Human computer interaction (HCI) is in the wake of a paradigm shift brought about by emerging sociotechnical systems such as wearable devices, voice/haptic interfaces and virtual/augmented/mixed reality setups. This shift has a far reaching impact on the psychological dimensions of users and designers who transact with such technical interfaces. Consequently, research in the field of design and HCI points to an increasing interest in the cognitive and affective sciences. Though a

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considerable amount of work which links cognition, design and HCI has happened, the implications of affective processes is an emerging area of study. Jeon (2017) classifies the major research paradigms concerning affect, design and HCI into four broad categories: emotional design (Norman, 2004), Hedonomics (Hancock, Pepe, & Murphy 2005), Kansei engineering (Nagamachi, 1995, 2002) and affective computing (Picard, 1997).

The role of affect is especially significant in research concerning virtual reality (VR) environments. VR systems are being employed in numerous domains and applications ranging from psychology, neuroscience, scientific visualization, education, sports, cultural heritage and so on. A fundamental aspect of VR which distinguishes it from other media is that it generates an emotionally engaging experience through illusions of "place (presence), plausibility and embodiment." Due to the immersive nature of VR, participants perceive the simulated environment as real and they react emotionally to stimuli contained within the virtual environment (Slater and Sanchez-Vives, 2016). Therefore a VR experience is inherently affective. Research focusing on the hedonistic, social and functional aspects of virtual reality and its implications for commercial sectors such as entertainment and tourism highlights how affective affordances of VR can yield economic benefits (Jung et al. 2018).

The present study focuses on the influence of affective arousal triggered by VR references/mood boards among design students engaged in the conceptual stages of design problem solving.

2 Review of Literature

Design processes bring about the transformation of abstract ideas into concrete forms and solutions (Suh, 1990). A design activity typically involves designers in an iterative process between a design problem and a set of possible solutions (Dorst & Cross, 2001). The conceptual phase of design thus becomes very significant, as designers tend to develop numerous early ideas and solutions in this phase. The significance of various psychological processes activated in designers while they are engaged in the conceptual phase has been a topic of interest for many design researchers.

2.1 Affect, Cognition and Conceptual Design

Literature in the domain of psychology distinguishes cognition and affect as two separate modalities of mental information processing. While cognition denotes a more rational and logical approach to a problem, affect implies aspects such as emotions, feelings and moods. Affective and cognitive processes are deeply linked and influence each other (Zajonc, 1980; Lazarus, 1984; Damasio, 1994; Schwarz and Clore, 2003). Though the influence of cognition on conceptual design has received much attention in design research (Goldschmidt, 1991; Goel, 1995; Suwa, Purcell, & Gero, 1998; Kavakli & Gero, 2001; Hay, Duffy, McTeague, Pidgeon, & Vuletic, 2017), only recently have researchers started to focus on the role of affect in the early stages of design ideation. Empirical studies in the domain of cognitive psychology document the multifaceted nature of affect-cognition interaction. But design research tends to treat cognitive processes in an isolated manner and studies related to the role of affect have largely been confined to the evaluative stages of conceptual design (Kim & Ryu, 2014; Hay et al. 2017). Suwa, Purcell and Gero (1998) in their macroscopic analysis of conceptual design activity, identified four major categories of actions that designers perform: physical, perceptual, functional and conceptual. Through their analysis, they revealed that designers engage in evaluative actions (e-actions) to judge aesthetic aspects of their conceptual sketches and ideations. Such aesthetic judgments are often driven by affective dispositions. There are other studies which show that emotional dimensions can be incorporated into new product designs by understanding emotional reactions of users to existing product designs. The affective user experience data may be used as starting points for an emotion driven design approach (Desmet & Dijkhuis, 2002). In a product design context, Leblebici-Basar and Altarriba (2013) demonstrate that incorporating "emotion" words into design briefs trigger more creative and varied associations. When designers tackle briefs which have emotional words and affective cues, they tend to produce more diverse translations of ideas into embodied forms. Kim and Ryu (2014) report on the relevance of affective heuristics which influence problem solving activities of expert designers. When tackling complex design problems expert designers often take design decisions based on like/dislike dispositions about artefacts and their own design solutions. Expert designers also rely on an "attitude heuristic" to classify existing design options into favourable or unfavourable categories. A favourable or unfavourable attitude to a design option might determine its selection or avoidance which in turn influences subsequent design strategies. The importance of understanding the emotional impact of conceptual sketches made by designers and how such emotions can be transferred to the embodied form of the product has also been documented (Kim, Bouchard, & Ryu, 2012). Lindgaard and Wesselius (2017) also point out new trajectories of design thinking in the context of feeling and embodied cognition. They situate theories of design cognition in the framework of material engagement and indicate that physical dimensions of design such as sketching and the associated feelings triggered by such embodied actions need to be taken into account while theorizing design cognition.

This study attempts to understand the dynamics of affective influence on cognition in a designer oriented manner, especially in the context of employing virtual reality references in conceptual design.

2.2 Affect, Virtual Reality and Conceptual Design

This section discusses research pertaining to affect, virtual reality and conceptual design. Tenneti and Duffy (2006) establish the correlation of various rendering styles, (photorealistic, non-photorealistic and vague rendering styles) with user perceptions and affective responses. They show that specific rendering styles of computer graphics can be employed to convey different kinds of information such as affective, functional and cognitive in order to elicit the appropriate responses from viewers. Model based VR environments could therefore be rendered in a specific style, depending on the kind of affective responses to be elicited from viewers.

The positive implications of utilizing an immersive workflow in an industrial design context have also been documented (Rieuf, Bouchard, Meyrueis, & Omhover, 2017; Rieuf, Bouchard, & Aoussat, 2015). The results of these studies show that using immersive three dimensional sketching environments and virtual reality mood boards can heighten the emotional engagement of designers. This in turn leads to better conceptual designs as designers transfer ideas from "inspiration" to "generation" in a typical design process.

2.3 Research Questions

As mentioned earlier, a typical design activity entails designers traversing back and forth between the problem space and the solution space, modifying both the entities in the process. Several factors influence this recursive movement such as the nature of the design problem/design brief (Rao, Onkar & Mathew, 2017), types of available visual information (Laing & Masoodian 2015, 2016; Laing, Apperley & Masoodian 2017) cultural background, experience levels of designers and their design settings (Lotz & Sharp, 2017), design tools (Rahimian & Ibrahim, 2011; Baskinger, 2008) and so on. Psychological processes of designers also play a huge role in influencing the manner in which they tackle a conceptual design task. Though there have been studies highlighting the various strategies adopted by designers when they solve a problem in the conceptual phase (Kruger & Cross, 2006), the symbiotic interaction of affective and cognitive processes in design problem solving could also be studied.

Clore, Schiller and Shaked (2017) have propounded three principles of affect-cognition interaction: the attribution principle (Affective responses are attributable to specific objects such as cognitive thoughts or external stimuli), the immediacy principle (affect is generated by immediately accessible mental phenomena and affective appraisals of such mental phenomena influence problem solving) and affective processing principle (positive or negative affect are analogous to decision boxes determining "YES/NO" values for cognitive inclinations and thought trajectories.)

The present study extrapolates such theoretical models of affect-cognition interaction to the context of conceptual design. The following hypothesis therefore stems from the need to discuss the role of affect-cognition interaction in a designer oriented manner in the conceptual design stage.

RQ1: Do positively/negatively valenced affective states and high/low arousal levels influence mental imagery processing of design students engaged in conceptual stages of design problem solving?

In addition to the foregoing hypothesis, this study also investigates whether specific tools such as virtual reality references play any significant role in altering the nature of affective engagement among design students. Existing studies on inducement of emotions and memory formations through virtual reality (Genheimer, 2015; Shin, 2018; Schöne, Wessels, & Gruber, 2017) indicate that exposure to VR simulations does result in affective engagement among users and clinical patients. This study attempts to extend these findings to a sample of design students engaged in a conceptual design task.

RQ2: Do VR references/Mood boards influence the affective engagement of design students working on conceptual design ideas?

3 Methodology

3.1 Experimental Pilot Study and Expected Findings

In order to capture the interaction of affect and mental imagery processing of the respondents, a sample problem statement was developed. In addition to this, reference material in the form of screenshots (non VR) and 360° immersive video to be viewed in a mobile based VR device were selected. The respondents, divided as experimental (with VR reference) and control subjects (with non VR reference) were exposed to the reference material before they performed the design task outlined in the problem statement. The pilot study focussed on capturing the affective influence on mental imagery processing in two stages: (a) post exposure to the reference material (VR/non VR) and (b) persistence and influence of affect during problem solving/ conceptual sketching. This enabled the correlation of affective dynamics to the type of reference material. The impact of affect on mental imagery processing during problem solving could also be analysed. Mental imagery processing is a cognitive process which involves the generation, maintenance and transformation of visual mental images (Kosslyn, 1995). Mental imagery processing is analogous to visual perception in that visual representations are internally generated and maintained for further examination. But mental imagery processing is driven by memory and not perceptual sensory inputs. The subsequent impact of the interaction of affect and mental imagery processing on the nature of the produced conceptual designs were also evaluated. To summarise, the study focuses on:

- Measuring positive/negative affective dispositions owing to the type of references/mood boards (VR/non VR).
- Extending theoretical underpinnings of affect-cognition interaction available in cognitive psychology to design contexts.
- Comparing the interaction of affect and mental imagery processing triggered by VR and non VR conditions with regard to differences in the produced conceptual ideas.

3.2 Procedure

A pilot study was conducted with an experimental research design, wherein four master level design students (2 male and 2 female students) with varied backgrounds participated. The experimental subjects received a design brief and a VR reference material to generate conceptual sketches for a graphic design task. The control subjects received the same design brief given to the experimental subjects. But instead of a VR reference material, screenshots gathered from the VR footage were given (Table 1).

The two pairs of respondents had to execute the given design task in a time frame of 30 minutes (excluding time taken to read the brief and exposure time to reference material) by producing conceptual sketches using a digital tablet (WACOM INTUOS) and design software of their choice (Adobe Photoshop/ Illustrator CC Trial Versions). The participants in both the conditions were given the design brief (to be read in 5 minutes). They were then exposed to their respective reference material for a period of 6 minutes. They then had to respond to a PANAS (positive and negative affect scale) questionnaire (Watson, Clark, & Tellegan, 1988) which would indicate the momentary affective tendencies (whether positive or negative) of the participants in relation to the reference material. Subsequently, the respondents performed the design task. The sketching and scribbling activities were recorded through screen capture software (Camtasia Trial Version) (Fig. 1).

3.3 Material

A sample design brief (Fig. 2) was developed which involved the respondents in a graphic design task: to produce conceptual sketches of a logo for a fictitious sky

Table 1 Experimental design of pilot study

Virtual reality reference	R1—male	R3—female
Screenshot reference	R2—female	R4—male

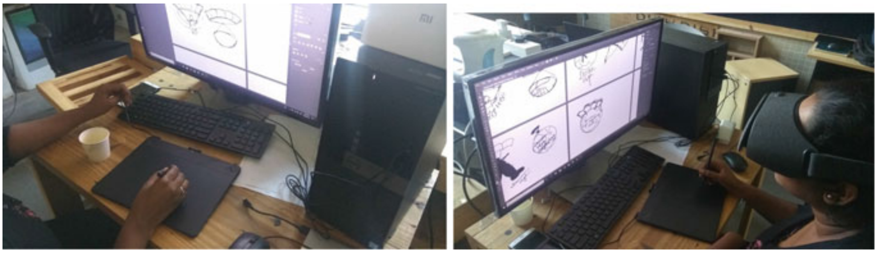

Fig. 1 Design setup

Design Brief

Kindly go through the following information and complete the design task within the given time limit.

Part A

Design Task:

Skydiving is a popular adventure sport practiced all over the world. Owing to high demand for the sport, a sky diving club named "Deccan high" is being launched. The club intends to promote skydiving locally by organizing training programs, sky diving sessions and other such activities. The club is formed by a group of sky diving professionals from all over the world and the aim of the club is to broaden the community of divers by giving exposure to as many enthusiasts as possible.

You are expected to come up with conceptual sketches for a logo of the club. The logo will be an integral part of its brand identity. It will be used in all their promotional material, digital presence points like websites, apps and so on. The logo will be part of collaterals like business cards, apparel, signage and so on.

You are free to produce any number of conceptual sketches and explorations.

Visual references

You will be given certain visual references of sky diving before you start the design task. You must go through the references before starting the design task.

Fig. 2 Design brief

diving club named Deccan High. Two sets of reference material (VR and Non VR) were also selected. The Virtual Reality reference was a 360° virtual reality video of a group of people performing sky diving (Stuykhin, 2016). (User permission obtained through personal communication—email dated 24-02-2018). The video consists of three segments: on ground/take-off, inside aircraft, skydiving/landing. The video was played on a mobile based virtual reality setup (Phone: Redmi Note 3. HMD: MI VR Play 2). The non VR reference material consisted of screenshots gathered from the 360 VR video of the sky diving activity. Screenshots were taken on the basis of two factors: change in video segment and change in primary view (gaze in different directions, addition/subtraction of elements into and out of the frame) of the 360 camera.

The decision to employ open access footage such as Youtube videos was driven by the rationale that designers/design students generally tend to refer to such freely accessible material on the internet in the conceptual design stage.

3.4 Protocol Study

Once the task was completed, the method of think aloud protocol study (Cross, Christiaans, & Dorst, 1996) was employed to capture cognitive/affective processes of the respondents. They produced retrospective verbal protocols by watching video recordings of their sketching activity. An interviewer sought clarifications by asking questions as and when required.

3.5 Data Analysis

A preliminary qualitative content analysis was performed on the video recordings of the verbal protocols. The utterances were organized based on categories of mental imagery processing derived from ontologies of design cognition (Hay et al., 2017) and principles of affect-cognition interaction (Clore, Schiller & Shaked, 2017). Utterances of the respondents which foregrounded the working of the principles of affect-cognition interaction (principle of attribution, principle of immediacy and principle of affective processing) were isolated. They were then analysed to understand the operation of the principles in relation to the given reference material, the interaction of affect and mental imagery processing during problem solving and the subsequent impact of such processes on the produced conceptual designs.

4 Results

Both pairs of respondents successfully produced conceptual sketches for the given task. Figure 3 shows the final design outcomes of the respondents. While three of them explored various iterations (R2, R3, R4) only one respondent (R1) zeroed in on an idea early in the design session and continued to refine it. The PANAS questionnaires indicated that an overall positive affect (mean momentary positive affect = 37.5 and mean momentary negative affect = 17.25) prevailed among respondents irrespective of exposure to either type of reference material.

As indicated in Table 2, the conceptual design task triggered the interaction of affect and mental imagery processing in the given conditions. The results indicate the working of the principles of affect-cognition interaction in distinct ways

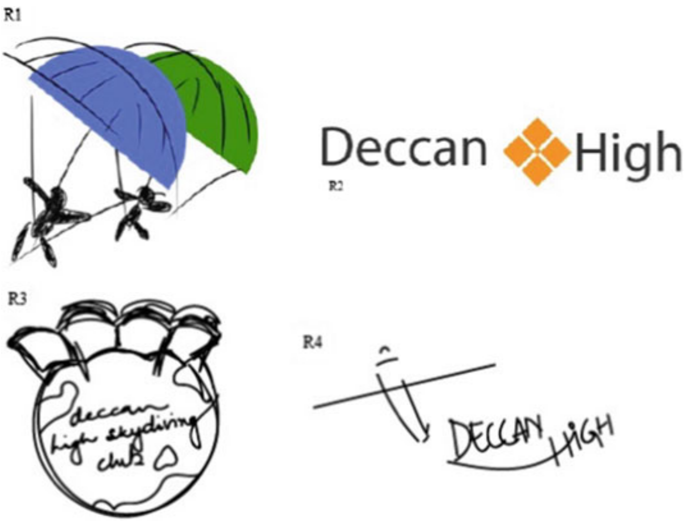

Fig. 3 Final sketches by the four respondents

depending on the experimental condition (experimental/control group). In addition to this, the interaction of these two modalities of problem solving in turn influenced the nature of the final conceptual designs.

4.1 The Operation of Principles of Affect-Cognition Interaction in VR Condition

Respondents who received the VR reference (R1, R3) revealed through their protocols that the central aspect of skydiving was the experience of falling and the need for safety in such a sport. They identified skydiving as an intermediate point between the sky and the ground and they conferred affective value to the image of the parachute as a gear which enables the "safe" experience of thrill. Subsequent explorations involving perspective, typography, symbolism and so on (R3) converged around the identified central aspects mentioned earlier. Though the problem statement triggered the image of the parachute as an iconic symbol for the sport of skydiving, the additional safety aspect (which generates thrill instead of fear) was induced by the VR reference (R1, R3). This indicates that the skydiving VR experience generated some degree of immersion as they witnessed the operation of the parachute in mid-air as compared to the subjects in non-VR condition who saw still images. This clearly indicates the affect-cognition principles at work. Affect was attributed to the safety aspect of the parachute (attribution principle). Affect was generated by immediately accessible mental phenomena such as the thrill of skydiving, the aspect of falling, the need for safety (immediacy principle) and the

Table 2 Preliminary classification of utterances of R3

Verbal protocol and sketch	Cognitive process and principle of affect-cognition interaction
"When I read skydiving, the first thing that came to my mind was that there is a glider or parachute …" "there had to be a view of a person falling or the earth … wherever I have used circle … it would denote the earth … like a top view when the person is falling" 	Generation of mental images + Attribution, immediacy
"The thing that I had in my mind constantly when I was doing any of the iterations is that … I was trying to not make it look like something that would not be like a regular, normal view … I made mental notes of the views I was seeing in the reference" "I used the reference to note the shape of the parachute"; "When I experienced that VR reference the safety bit … was established by that … 	Maintenance of mental images + Attribution, immediacy, affective processing
"I kind of simplified it here…I just kept the parachute…and the name itself…and then just to like bring it all together I added the circular element…" 	Transformation of mental images + Attribution, immediacy, affective processing

momentary positive affect acted as "go" signals (affective processing principle) for the line of thought that the parachute and the aspect of skydiving as a connector of two end points (earth, sky) ought to be included in the logo. This is reflected in the style of mental imagery processing: generation (parachute image, the fall from the sky to the ground by incorporating perspectives such as bird's eye view and coloured depictions of sky and ground), maintenance (parachute as not just an iconic sporting gear but a safety equipment, the fall as a thrilling activity as opposed to being dangerous) and transformation (abstraction of parachute image into logo designs and fusing the parachute image with the two end points which are the sky and ground).

4.2 The Operation of Principles of Affect-Cognition Interaction in Non VR Condition

The respondents who received the non VR references (R2, R4) revealed through their protocols that they explored various ideas for the logo. Form explorations around visual components such as aircraft wings (R2), human figures (R2), typography (R2, R4), skydiving formations (R2) posture of divers (R4), atmospheric elements such as clouds (R4), symbolisms such as images of parachute (R4) were attempted by the respondents. When compared to subjects in the VR condition, the respondents in the non VR condition generated iterations driven by varied aspects as opposed to one or two central aspects. The respondents relied on memories such as sky diving scenes in films (R2), sky diving videos (R4) and also the visual references (screenshots) (R2, R4) to generate solutions. This indicates a markedly different functioning of the affect-cognition principles when compared to the VR group. Since the iterations were influenced by the assessment of the respondents as being feasible for a logo or not, affect was attributed to their own designs as opposed to a central idea or theme (attribution principle). Affect was generated by immediately accessible memories and visual references (immediacy principle) and the momentary positive affect acted as "go" signals (affective processing principle) for the line of thought/iteration which the respondents thought were most feasible for a logo of a skydiving club. This is again reflected in the style of mental imagery processing: generation (images generated around various aspects of sky diving such as aircraft, divers), maintenance (multiple iterations of design concepts based on perceived potential as logo) and transformation (abstraction/fusion of one design iteration into a logo form).

4.3 Indication of Affect-Cognition Heuristic in Conceptual Design

Table 2 denotes a detailed instance of the verbal protocol of R3 in the form of an affect-cognition heuristic.

5 Discussion and Conclusion

In this paper, the role of affect has been understood in a designer oriented manner. The paper details the need to capture affect in protocol studies to get a more comprehensive view of design problem solving processes. The experimental pilot study produced results which illustrate how affect influences cognitive aspects such as mental imagery processing and in turn the nature of ideation and conceptual designs. The impact of using tools such as immersive mood boards and virtual reality references on the affective engagement of designers/design students has also been demonstrated.

The paper foregrounds the interaction of affect and cognition in design problem solving. While existing protocol studies tend to focus mainly on cognitive aspects of design thinking, this study produces preliminary results which show that cognition is not an isolated activity. The salience of affective influence on cognition is much greater and is not confined to evaluation alone. The role played by affect indicates that designing is not driven by cognitive logic alone. These findings could lead to further studies which could offer a holistic view of designer psychology and conceptual design. Such studies could enhance existing theories, models and ontologies of design. The study also shows how incorporating VR reference material into the early stages of design could manipulate the affect-cognition dynamics of a designer. Specific formats of reference material elicit different kinds of psychological responses from designers. Depending on the nature of the problem being addressed, appropriate reference material may be employed to induce different kinds of problem solving modes. Further studies with bigger sample sizes, varied sample population, a broader range of design tasks and more dynamic conditions of experiments will be undertaken to refine the results of the present study.

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References

Baskinger, M. (2008). Cover story pencils before pixels: A primer in hand-generated sketching. *Interactions, 15*(2), 28–36.

Clore, G. L., Schiller, A. J., & Shaked, A. (2017). Affect and cognition: Three principles. *Current Opinion in Behavioral Sciences, 19*, 78–82.

Cross, N., Christiaans, H., & Dorst, K. (Eds.). (1996). *Analysing design activity*. West Sussex: Wiley.

Damasio, A. (1994). *Descartes' error: Emotion, reason and the human brain*. New York: Avon.

Desmet, P. M. A., & Dijkhuis, E. (2003). A wheelchair can be fun: A case of emotion-driven design. In *Proceedings of the International Conference on Designing Pleasurable Products and Interfaces, June 23–26, 2003* (pp. 22–27). Pittsburgh, Pennsylvania, USA. New York: The Association for Computing Machinery.

Dorst, K., & Cross, N. (2001). Creativity in the design process: co-evolution of problem–solution. *Design Studies, 22*(5), 425–437.

Genheimer, H. (2015). *Fear and anxiety in virtual reality: Investigations of cue and context conditioning in virtual environment*. Wurzberg: Springer.

Goel, V. (1995). *Sketches of thought*. Cambridge (MA): MIT Press.

Goldschmidt, G. (1991). The dialectics of sketching. *Creativity Research Journal, 4*(2), 123–143.

Hancock, P., Pepe, A. A., & Murphy, L. L. (2005). Hedonomics: The power of positive and pleasurable ergonomics. *Ergonomics in Design, 13*(1), 8–14.
Hay, L., Duffy, A. H. B., McTeague, C., Pidgeon, L. M., Vuletic, T. (2017). Towards a shared ontology: A generic classification of cognitive processes in conceptual design. *Design Science, 3*(7), 1–42.
Jeon, M. (Ed.). (2017). *Emotions and affect in human factors and human–computer interaction*. Cambridge (MA): Academic Press.
Jung, T., Dieck, M. C., Rauschnabel, P., Ascenção, M., Tuominen, P., & Moilanen, T. (2018). Functional, hedonic or social? Exploring antecedents and consequences of virtual reality rollercoaster usage. In T. Jung & M. C. Tom Dieck (Eds.), *Augmented and virtual reality: Empowering human, place and business* (pp. 247–258). Berlin: Springer. (Progress in IS).
Kavakli, M., & Gero, J. S. (2001). Sketching as mental imagery processing. *Design Studies, 22*(4), 347–364.
Kim, J., Bouchard, C., & Ryu, H. (2012). Emotion finds a way to users from designers: assessing product images to convey designer's emotion. *Journal of Design Research, 10*(4), 307–323.
Kim, J., & Ryu, H. (2014). A design thinking rationality framework: Framing and solving design problems in early concept generation. *Human–Computer Interaction, 29*(5–6), 516–553.
Kosslyn, S. M. (1995). Mental imagery. *Visual Cognition: An Invitation to Cognitive Science, 2*, 267–296.
Kruger, C., & Cross, N. (2006). Solution driven versus problem driven design: strategies and outcomes. *Design Studies, 27*(5), 527–548.
Laing, S., & Masoodian, M. (2015). A study of the role of visual information in supporting ideation in graphic design. *Journal of the Association for Information Science and Technology, 66* (6), 1199–1211.
Laing, S., & Masoodian, M. (2016). A study of the influence of visual imagery on graphic design ideation. *Design Studies, 45,* 187–209.
Laing, S., Apperley, M., & Masoodian, M. (2017). Investigating the effects of client imagery on the ideation process of graphic design. *Design Studies, 53,* 78–98.
Lazarus, R. S. (1984). On the primacy of cognition. *American Psychologist, 39*(2), 124–129.
Leblebici-Başar, D., & Altarriba, J. (2013). The role of imagery and emotion in the translation of concepts into product form. *The Design Journal, 16*(3), 295–314.
Lindgaard, K., & Wesselius, H. (2017). Once more, with feeling: Design thinking and embodied cognition. *She Ji: The Journal of Design, Economics, and Innovation, 3*(2), 83–92.
Lotz, N., & Sharp, H. (2017). The influence of cognitive style, design setting and cultural background on sketch-based ideation by novice interaction designers. *The Design Journal, 20* (3), 333–356.
Nagamachi, M. (2002). Kansei engineering as a powerful consumer-oriented technology for product development. *Applied Ergonomics, 33,* 289–294.
Norman, D. A. (2004). *Emotional design: Why we love (or hate) everyday things*. New York: Basic Books.
Picard, R. W. (1997). *Affective computing*. Cambridge (MA): The MIT Press.
Rahimian, F. P., & Ibrahim, R. (2011). Impacts of VR 3D sketching on novice designers' spatial cognition in collaborative conceptual architectural design. *Design Studies, 32*(3), 255–291.
Rao, M. N., Onkar, S. P., & Mathew D. J. (2017). Evolution of design briefs: Expressions from professional design practice. In A. Chakrabarti & B. Chakrabarti (Eds.), *Research into design for communities* (Vol. 2, pp. 555–566). Singapore: Springer Nature.
Rieuf, V., Bouchard, C., & Aoussat, A. (2015). Immersive moodboards, a comparative study of industrial design inspiration material. *Journal of Design Research, 13*(1), 78–106.
Rieuf, V., Bouchard, C., Meyrueis, V., & Omhover, J.-F. (2017). Emotional activity in early immersive design: Sketches and moodboards in virtual reality. *Design Studies, 48,* 43–75.
Schöne, B., Wessels, M., Gruber, T. (2017). Experiences in virtual reality: A window to autobiographical memory. *Current Psychology* 1–5. https://doi.org/10.1007/s12144-017-9648-y.
Schwarz, N., & Clore, G. L. (2003). Mood as information: 20 years later. *Psychological Inquiry, 14*(3–4), 296–303.

Shin, D. (2018). Empathy and embodied experience in virtual environment: To what extent can virtual reality stimulate empathy and embodied experience? *Computers in Human Behavior, 78,* 64–73.

Slater, M., & Sanchez-Vives, M. V. (2016). Enhancing our lives with immersive virtual reality. *Frontiers in Robotics and AI, 3,* 74. https://doi.org/10.3389/frobt.2016.00074.

Stuykhin, A. [vr360 pro]. (2016, July 13). *SkyDive in 360° Virtual Reality via GoPro / Прыжок с парашютом в 360° градусов* [Video file]. Retrieved from https://www.youtube.com/watch?v=S5XXsRuMPIU&feature=youtu.be

Suh, N. P. (1990). *The principles of design*. Oxford, England: Oxford University Press.

Suwa, M., Purcell, T., & Gero, J. (1998). Macroscopic analysis of design processes based on a scheme for coding designers' cognitive actions. *Design Studies, 19*(4), 455–483.

Tenneti, R., & Duffy, A. (2006). Analysing the emotive effectiveness of rendering styles. In Gero J. S. (Eds.), *Design computing and cognition '06* (pp. 285–304). Dordrecht: Springer.

Watson, D., Clark, L. A., & Tellegan, A. (1988). Development and Validation of brief measures of positive and negative affect: The PANAS scales. *Journal of Personality and Social Psychology, 54*(6), 1063–1070.

Zajonc, R. B. (1980). Feeling and thinking: Preferences need no inferences. *American Psychologist, 35*(2), 151–175.

Intuitive Hand Gestures for the Interaction with Information Visualizations in Virtual Reality

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Abstract The development of virtual reality provides opportunities for immersive information visualizations and therefore it is expected to facilitate the exploration and understanding of data. Hand gesture control enables intuitive interaction and thus it is suggested to amplify the level of immersion further. This paper conducts and experiment to identify a set of intuitive gestures when interacting with an information visualization. Participants are asked to provide hand gestures to given information seeking tasks in an interactive data visualization application in virtual reality that they did not know in advance. The results are analysed and findings with intuitive gestures are communicated and discussed.

Keywords Virtual reality · Human computer interaction · Gesture analysis · Information visualization

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1 Introduction

Companies, which are able to manage and analyse big data, are suggested to gain a competitive advantage (Espinosa & Armour, 2016), but often businesses struggle with data examination (Boyd & Crawford, 2012). Virtual reality (VR) comes with new possibilities for the visualization of such information (Tegarden, 1999) and it is proposed to enable an easier perception and manipulation of data (Donalek et al., 2014). Whereas there are already many examples of visualizing data in VR (García-Hernández, Anthes, Wiedemann, & Kranzlmüller, 2016), interaction in VR as well as the navigation of 3D data visualizations remain to be a challenge and come with several unsolved problems (Brath, 2014; Vultur, Pentiuc, & Lupu, 2016). At the same time, not only the representation but also interaction influences how well data are perceived (Ball, North, & Bowman, 2007; Raja, Bowman, Lucas, & North, 2004). Based on an experiment this paper examines such interactions by observing which gestures participants intuitively use to conduct information seeking tasks in an information visualization in VR.

The paper begins with a literature review about the overlapping domains of VR and information visualization and touchless gesture interaction, specifically, with data. Furthermore, the framework of the Visual Information Seeking Mantra (Shneiderman, 1996) is introduced as a guideline for the tasks examined in the experiment. Then the method of the experiment is explained and the results are presented. Finally, our findings are discussed and implications for future research are proposed.

2 Literature Review

2.1 Information Visualization in Virtual Reality

Managing, analysing and understanding data became a crucial part of valid and successful business decisions (Chen, Chiang, & Storey, 2012). Although more and more complex data is available, businesses often fail to derive valuable information because they struggle with data exploration and discovering patterns (Boyd & Crawford, 2012). Information visualization can be an approach to digest such abstract data in a more understandable way (Bollier, 2010; Van Dam, Laidlaw, & Simpson, 2002). Whereas visualization technologies have been applied in many different areas of business since years (Tegarden, 1999), VR now enables information visualizations in a more immersive way. This could allow users to become part of a virtual environment and ideally would enable them to embody interactions (Teras & Raghunathan, 2015). This allows perceiving and manipulating information in an intuitive and immersive way and could therefore improve data exploration and understanding (Donalek et al., 2014; García-Hernández et al., 2016; Moran, Gadepally, Hubbell, & Kepner, 2015).

VR is already applied in scientific visualizations for the representation of physically based data (Nagel, 2006), such as in the area of genomics (Adams, Stancampiano, McKenna, & Small, 2002), medicine (Shen et al., 2016) or astronomy (Wang & Bennett, 2013) and is reported to have facilitated research processes (Van Dam, Forsberg, Laidlaw, LaViola, & Simpson, 2000). For example, García-Hernández et al. (2016) conclude that scientific visualization in VR leads to "easier understanding and manipulation possibilities for the data, yielding a more efficient and complete analysis" (p. 1). Even though information visualization represents more abstract, processed data (Bollier, 2010), the found benefits for scientific visualization in VR are proposed to be likewise viable for visualizing information in VR (Vultur et al., 2016). Based on a visualization of Twitter data on a 3D model map, Moran et al. (2015) demonstrated, that VR provides an immersive way for information visualization and that "patterns and visual analytics are more efficient when working in a geospatial domain" (p. 6). Various other studies report that visualizing abstract data in VR can improve the analysis process compared to conventional 2D visualizations, for example by reducing errors and faster completion of particular analysis tasks (Alper, Hollerer, Kuchera-Morin, & Forbes, 2011; Cordeil et al., 2017).

2.2 Touchless Interaction with Data

The benefits of exploring data in VR come from its enhanced immersion (Raja et al., 2004; Teras & Raghunathan, 2015). But not only the representation influences perception, also the way a user interacts with such a visualization has an impact on how well information is received (Cabral, Morimoto, & Zuffo, 2005; Kosara, Hauser, & Gresh, 2003). Efficiency and effectivity of human-computer interaction have shown to depend on the used input device (Bachmann, Weichert, & Rinkenauer, 2014). Especially touchless, gesture-controlled input devices are suggested to allow a more intuitive and natural way of interaction with computers (Cabral et al., 2005) and thus could increase the level of immersion (Zocco, Zocco, Greco, Livatino, & Paolis, 2015). With interaction schemes directly based on the experience of familiar movements (Deller, Ebert, Bender, & Hagen, 2006), gesture-based VR applications allow users for example to grab, throw or push objects in VR with hand gestures, as the users is used to from reality ("VR—Leap Motion Gallery," n.d.). Hence gesture-controlled VR applications combine both, a virtual environment and intuitive interaction in one immersive experience and thus could also bring information visualization to a new level.

Although interaction is considered to have a significant impact on how information is perceived, the focus of information visualization research has been mainly on the new possibilities of representation (Yi, ah Kang, & Stasko, 2007). In the related area of touchless navigation, Ball et al. (2007) reported that users not only prefer physical navigation, it has also outperformed other virtual navigation techniques, such as joysticks, in respect to comprehension, speed or orientation.

2.3 The Visual Information Seeking Mantra

Interactions with information visualization systems often require a similar set of tasks to be performed by the users. Shneiderman (1996) published "Visual Information Seeking Mantra" (VISM) framework of seven tasks (overview, zoom, filter, detail-on-demand, relate, history, extract) that are usually necessary to handle data in effective way. He furthermore stated that "Overview first, zoom, filter and then details-on-demand" is a principle that can be found in many visual design guidelines and real life applications. This framework is widely accepted in the area of human-computer interaction and in data visualization applications and has been extended and updated in various studies (Craft & Cairns, 2005).

In their proposal for an updated VISM 2.0, Stauffer, Ryter, Dornberger, and Hil (2016) separated the initial tasks into four main tasks, which are also part of the mantra itself (overview, zoom, filter, detail-on-demand) and three support tasks (relate, history, extract). Additionally, they differentiated the zoom task into zoom-in and zoom-out as these are considered as two different cognitive tasks.

The VISM has been widely referred to by researchers developing new information visualization applications or interaction methodologies (Craft & Cairns, 2005), including the domain of information visualization in virtual environments. Wiss and Carr (1999) compared the elements of their cognitive classification framework for 3-dimensional information visualization with Shneiderman's tasks (Wiss & Carr, 1998) and based an experiment for identifying important factors for the usability of 3D information visualization interfaces on the VISM framework. Other papers apply the VISM guidelines to the visualization of object-oriented software (Maletic, Leigh, Marcus, & Dunlap, 2001) or digital libraries (Borner, 2000) in VR. Whereas the VISM framework seems to have arrived in the discussion about designing virtual environments, no literature could be found that explicitly addresses implications of the VISM on the development of touchless gesture control.

2.4 Research Questions

Seven years after the publication of the VISM, Bederson and Shneiderman (2003) envisioned that computers must become "an extension of the user's body" as information visualization interfaces should "enable users to forget they are using a computer and think only of the important work they are accomplishing". We argue that intuitive gesture control combined with VR could enable such an immersive information visualization.

The positive impact of VR on the understanding of information visualizations as well as the implication of the VISM on VR have been discussed in literature. At the same time, the implications of the VISM on the design of touchless gesture control has not received much attention. Intuitive hand gesture control could further amplify the immersion level (and its benefits) of information visualization in VR and thus should be investigated in greater detail. But are there VISM tasks that can be controlled by intuitive hand gestures? This will be examined based on the following statement:

> Intuitive hand gestures can be used for conducting tasks of the Visual Information Seeking Mantra to handle data in an information visualization application in virtual reality.

Due to the choice of the Force-Directed Graph application (Sect. 3.1) as the platform, for the experiment and with its ensuing limitations outlined in Sect. 3.2, this paper investigates three main VISM tasks. The experiment is based on following research question: What are intuitive gestures to get an *overview,* to *zoom* and to find detailed information (*detail-on-demand*) in an information visualization VR application?

3 Methods

3.1 The VR Application

For observing what gestures participants intuitively and spontaneously apply to interact with data in VR, an experiment based on an existing information visualization application was conducted. To find an application for a specific scope of examining touchless gesture control in VR, all major platforms for VR applications were searched and reviewed. Only a few data visualization apps for VR were available and only one of them could be controlled with gestures: "Force-Directed Graph" (Kinstner, 2016).

Force-Directed Graph is an experimental data visualization demo application created by Zach Kinstner and is available in the Leap Motion community gallery ("VR—Leap Motion Gallery", n.d.). The application visualizes data nodes in the form of a force-directed graph. The data nodes are randomly generated and no own datasets can be imported.

At the time of research, the possible interactions were limited to:

- Pushing and hitting nodes
- Grabbing nodes
- Tapping a node (opens detail menu of node)
- Left hand palm menu (opens main menu)
- Looking around in the virtual space.

The detail menu of the nodes and the main menu furthermore provide various options for manipulation, such as changing the color, size or amount of the nodes. In our experiment, Force-Directed Graph application ran on Windows 10 with an Oculus Rift Consumer Version ("Oculus Rift", n.d.) in combination with a Leap Motion controller ("Leap Motion", n.d.) for detecting the hand gestures (Fig. 1).

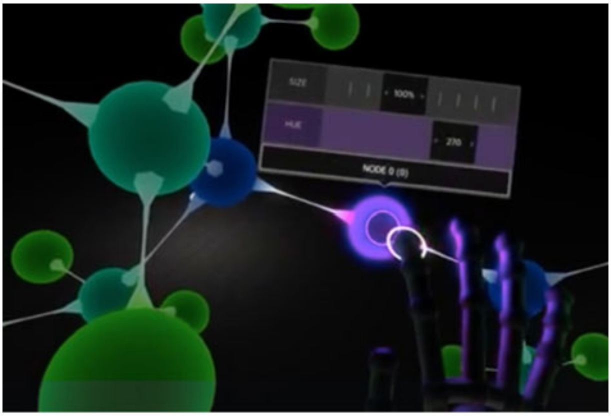

Fig. 1 Screenshot from force-directed graph application

3.2 Assigning VISM Tasks to App Functionalities

VISM-related tasks are especially important for the seeking and understanding of visualized information. Therefore, the experiment aims to test the tasks presented in the VISM 2.0 (Stauffer et al., 2016). Due to the lack of fitting functionalities in the available VR app, it is decided to assess **overview, zoom-in, zoom-out** and **detail-on-demand** tasks and to abstain from an assessment of the *filter* task. The selected tasks are matched with the corresponding application functionalities as shown in Table 1.

As there was no function getting an **overview** of the nodes, the head movements (i.e. looking around) is chosen for evaluating the overview task. This is not directly an overview of the data, as intended in the original VISM framework, although it still represents the related task of getting an overview in a broader sense.

Even though the app offers a **zoom** (i.e. scale) functionality over the main menu, no direct gesture control has been implemented yet for zooming. Nevertheless, it was possible to observe what zoom gestures participants would use intuitively by just pretending that there would be one.

Table 1 VISM 2.0 tasks assigned to the force-directed graph application

VISM 2.0 task	Gesture input (pre-defined)	Visual output (pre-defined)
Overview	Head movement	Overview of data visualization in virtual space
Zoom-in	Select menu/graph/scale (left hand palm)	Zoom in
Zoom-out	Select menu/graph/scale (left hand palm)	Zoom out
Detail-on-demand	Index finger tap select on data node	Opens pop-up window with details about the node

Data nodes can be opened by tapping an index finger, this action visualizes a pop-up window with more detailed information (Fig. 1). This function is used for testing the **detail-on-demand** task.

3.3 Survey and Experiment

The experiment followed a strictly structured survey with a fixed order of questions and tasks. First, demographic questions and the level of experience with VR and gesture based applications were gathered. Then the participants were instructed to look around and acquire the **overview** of the data visualization, and perform basic tasks of pushing and grabbing a data node. This not only allowed them to get used to the virtual environment, it was a chance to make them believe, that the ensuing tasks in fact would result in a feedback if done right. We hypothesized that familiarizing the participants with the environment would result in more authentic and intuitive reactions as it would have been possible in a hypothetical "what if"-scenario.

The experiment then continued with the investigation of the following VISM tasks. The participants could try up to three gestures per task in order to navigate in the virtual environment with the lens of visual information seeking (Sect. 2.3). These were tested with the following commands:

1. *"Find more detailed information of a data node."* ***(detail-on-demand)***
2. *"Get nearer to the node-network by zooming in."* ***(zoom-in)***
3. *"Make the node-net appear smaller by zooming out."* ***(zoom-out)***.

As some experiments were conducted in English and some in German and due to the different knowledge of technical terms, the exact wording had to be varied slightly. The results were collected with an online survey tool and were then exported to SPSS for the analysis. After the experiment, the descriptions of the observed gestures were categorized to get a comparable result.

4 Findings

4.1 Characteristics of Study Participants

The experiment was conducted with a total of 30 participants in the university campus. Most the participants were either students (73%) or academic staff (20%) with a broad variety of backgrounds such as science of education, law, business information systems and others. Mostly participants were in the Age group 18–34 (96.7%) with one participant in the age group 35–54 (3.3%). In the experiment, females had a share of 67%.

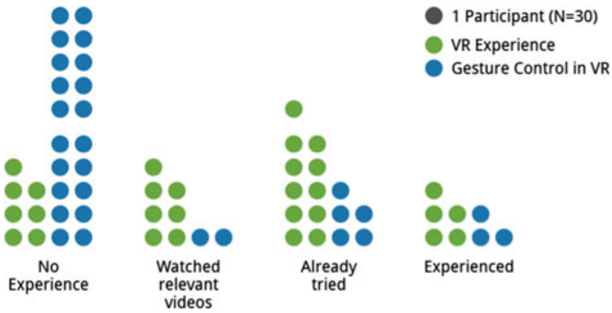

Fig. 2 Distribution of participants' experience with VR and gesture control in VR

As seen in Fig. 2, 23 participants have assigned themselves familiar with VR (i.e. watched relevant videos of VR applications, already tried or experienced). In contrast to VR experience, 20 participants had no experience with gesture control in VR, only 8 participants responded as already tried or experienced.

4.2 Details-on-Demand

Initially, the participants were asked to look around, push and grab a node in order to familiarize with the environment. All participants, sometimes with an operational support of the examiners, completed these tasks successfully. Following the introduction phase to test a details-on-demand task, the participants were told to find detailed information of a data node (Table 2). 80% of the 30 participants managed to find the correct gesture and tapped on a node with an index finger. Another popular attempt was to grab the node with one hand (24% of all trials), although exactly this gesture has already been used in the introductory task.

Table 2 Detail-on-demand task

Most popular gestures[a]	Trial 1	Trial 2	Trial 3	Overall
Tap node	**13 (43%)**	**9 (52%)**	2 (25%)	**24 (44%)**
Grab with one hand	9 (30%)	4 (24%)	0	**13 (24%)**
Other	8 (27%)	4 (23%)	6 (75%)	18 (33%)
n	30	17	8	55

[a]For a clear overview, only the most popular gestures are shown in the tables

Table 3 Zoom-in task

Most popular gestures	Trial 1	Trial 2	Trial 3	Overall
Finger pinch (in)	**10 (33%)**	6 (23%)	1 (5.3%)	17 (23%)
Swim	**10 (33%)**	1 (4%)	1 (5.3%)	12 (16%)
Pull with both hands	4 (13%)	7 (27%)	2 (10.5%)	13 (17%)
Pinch with both hands	1 (3%)	4 (15%)	2 (10.5%)	7 (9%)
Other	5 (17%)	8 (31%)	13 (68%)	26 (35%)
n	30	26	19	75

Table 4 Zoom-out task

Most popular gestures	Trial 1	Trial 2	Trial 3	Overall
Finger pinch (out)	7 (26%)	6 (27%)	1 (13%)	14 (25%)
Swim (backwards)	5 (19%)	1 (5%)	1 (13%)	7 (12%)
Push with both hands	8 (30%)	1 (5%)	3 (38%)	12 (21%)
Pinch (out) with both hands	3 (11%)	3 (14%)	0	6 (10%)
Other	4 (15%)	11 (50%)	3 (38%)	18 (32%)
n	27	22	8	57

4.3 Zoom-In and Zoom-Out

When asked to zoom-in, most of the participants either first tried a finger pinch gesture like the pinch-to-zoom gesture of smartphones (33%) or an arm movement as if they would swim in water (33%) (Table 3). Other trials included pulling the nodes toward oneself or a pinch movement using both hands. Furthermore, also a zoom-out gesture was tested. Often, the participants only half-heartedly tried to find a zoom-out gesture, probably because they already failed to find a with zoom-in gesture before. Usually, the participants tried the opposite gestures of the ones they just tried for zooming-in (e.g. pushing the net away instead of pulling it) (Table 4).

5 Discussion

The conducted experiment demonstrated that there are some intuitive gestures that can be introduced for the VISM tasks, in this case for zoom-in, zoom-out and details-on-demand. To fully test our initial thesis statement, the remaining VISM tasks would have to be tested in further experiments. Especially some of the support tasks might not be transformed into gestures, as they require more flexible and nuanced ways of interaction.

Even though the results based on a sample of 30 participants are not representative, the experiment uncovers some interesting tendencies that will be further discussed. Certain gestures were well more popular and thus intuitive to more participants than others. In particular, tapping on a node to get detailed information (**detail-on-demand**) seemed to be intuitively clear to most of the participants.

An example for a “natural” gesture that people used frequently was the swimming movement for **zooming-in**. Many of the participants tried to literally dive into the data. Another very physical approach was to pull and push the node-net to zoom-in, respectively -out. At the same time, the also very popular finger pinch gesture indicates, that intuition not necessarily represents a physical, “natural” gesture. Pinch to zoom is an abstract gesture widely used on touchscreen devices, which seems to have heavily influenced the intuitive behavior of humans. Unexpected was that people tended to think that tapping a centered node could give access to a menu overview. This is contradictory to the idea that each node represents a separate data point and we could not identify a parallel function in touchscreens or desktop environments.

In addition, the experience from classical computer desktops and smartphones trained the human intuition. As well, science fiction movies might have influenced the participants, as many told us that they would “feel like in Minority Report (Molen, Curtis, Parkes, de Bont, & Spielberg, 2002)”.

The findings of this experiment for gesture intuition is notable, considering that the most intuitive gesture are not always the best gesture from an ergonomic and technical point of view. It might feel very intuitive to dive into data with a swim gesture, however at the same time frequent zooming would turn into an exhausting physical exercise. Other intuitive gesture might be problematic to detect for sensors or could lead to a weak accuracy (Kinstner, n.d.).

6 Conclusion and Future Work

Today’s success of businesses depends on the understanding and manipulation of data. Literature states that information visualization in VR might facilitate the analysis and digestion of data. We suggest, that such VR visualizations could be combined with touchless hand gesture control to create a truly immersive information visualization. Based on an experiment, a set of gestures were identified that participants used to conduct particular tasks based on the VISM framework.

Future research should aim for a better understanding of the influence of gesture control on immersive information visualization, especially in visualizations with higher density than in our experiment. A replication of our experiment should not only be based on a larger sample size, but also a broader set of tasks, including the remaining VISM tasks, and other existing data visualization applications in VR should be examined. Furthermore, it would be interesting to investigate variations between different generations, nationalities or socio-cultural backgrounds. Whereas there are clear benefits of incorporating intuition into the design of gesture interaction, more parameters need to be considered. Only when the interplay of intuition, technical restrictions and ergonomic consequences are well understood, a sustainable gesture standard can be developed.

Touchless hand gesture control for immersive information visualizations in VR is still at its infancy, but it is probable that hand gestures will enable users to "forget they are using a computer and think only of the important work they are accomplishing" (Bederson & Shneiderman, 2003). Thus, these gestures might be part of the future of interactive information visualizations.

References

Adams, R. M., Stancampiano, B., McKenna, M., & Small, D. (2002, November). Case study: A virtual environment for genomic data visualization. In *Visualization, 2002. VIS 2002. IEEE* (pp. 513–516). IEEE.

Alper, B., Hollerer, T., Kuchera-Morin, J., & Forbes, A. (2011). Stereoscopic highlighting: 2d graph visualization on stereo displays. *IEEE Transactions on Visualization and Computer Graphics, 17*(12), 2325–2333.

Bachmann, D., Weichert, F., & Rinkenauer, G. (2014). Evaluation of the leap motion controller as a new contact-free pointing device. *Sensors, 15*(1), 214–233.

Ball, R., North, C., & Bowman, D. A. (2007, April). Move to improve: Promoting physical navigation to increase user performance with large displays. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 191–200). ACM.

Bederson, B., & Shneiderman, B. (Eds.). (2003). *The craft of information visualization: Readings and reflections*. Morgan Kaufmann.

Bollier D. (2010). *The promise and peril of big data.* Retrieved from https://www.emc.com/collateral/analyst-reports/10334-ar-promise-peril-of-big-data.pdf.

Borner, K. (2000, February). Visible threads: A smart VR interface to digital libraries. In *Proceedings of SPIE International Society of Optical Engineering* (Vol. 3960, pp. 228–237).

Boyd, D., & Crawford, K. (2012). Critical questions for big data: Provocations for a cultural, technological, and scholarly phenomenon. *Information, Communication & Society, 15*(5), 662–679.

Brath, R. (2014, November). 3D InfoVis is here to stay: Deal with it. In *2014 IEEE VIS International Workshop on 3DVis (3DVis)* (pp. 25–31). IEEE.

Cabral, M. C., Morimoto, C. H., & Zuffo, M. K. (2005, October). On the usability of gesture interfaces in virtual reality environments. In *Proceedings of the 2005 Latin American Conference on Human-Computer Interaction* (pp. 100–108). ACM.

Chen, H., Chiang, R. H., & Storey, V. C. (2012). Business intelligence and analytics: From big data to big impact. *MIS Quarterly*, *36*(4).

Cordeil, M., Dwyer, T., Klein, K., Laha, B., Marriott, K., & Thomas, B. H. (2017). Immersive collaborative analysis of network connectivity: CAVE-style or head-mounted display? *IEEE Transactions on Visualization and Computer Graphics, 23*(1), 441–450.

Craft, B., & Cairns, P. (2005, July). Beyond guidelines: What can we learn from the visual information seeking mantra? In *Proceedings Ninth International Conference on Information Visualisation, 2005* (pp. 110–118). IEEE.

Deller, M., Ebert, A., Bender, M., & Hagen, H. (2006, July). Flexible gesture recognition for immersive virtual environments. In *Tenth International Conference on Information Visualization, 2006. IV 2006* (pp. 563–568). IEEE.

Donalek, C., Djorgovski, S. G., Cioc, A., Wang, A., Zhang, J., Lawler, E., … & Davidoff, S. (2014, October). Immersive and collaborative data visualization using virtual reality platforms. In *2014 IEEE International Conference on Big Data (Big Data)* (pp. 609–614). IEEE.

Espinosa, J. A., & Armour, F. (2016, January). The big data analytics gold rush: A research framework for coordination and governance. In *2016 49th Hawaii International Conference on System Sciences (HICSS)* (pp. 1112–1121). IEEE.

García-Hernández, R. J., Anthes, C., Wiedemann, M., & Kranzlmüller, D. (2016, March). Perspectives for using virtual reality to extend visual data mining in information visualization. In *2016 IEEE Aerospace Conference* (pp. 1–11). IEEE.

Kinstner, Z. (2016, December). *Devup: Force-directed graph in vr*. [Blog]. Retrieved from https://medium.com/@zachkinstner/devup-force-directedgraph-in-vr-9e6bf3e1a351#.4mcknk25e.

Kinstner, Z. (n.d.). aestheticinteractive/Hover-UI-Kit. Retrieved January 25, 2018 from the Hover-UI Kit Wiki: https://github.com/aestheticinteractive/Hover-UI-Kit/wiki.

Kosara, R., Hauser, H., & Gresh, D. L. (2003). An interaction view on information visualization. In *State-of-the-Art Report. Proceedings of EUROGRAPHICS* (pp. 123–137).

Maletic, J. I., Leigh, J., Marcus, A., & Dunlap, G. (2001). Visualizing object-oriented software in virtual reality. In *Proceedings. 9th International Workshop on Program Comprehension, 2001. IWPC 2001* (pp. 26–35). IEEE.

Molen, G. R., Curtis, B., Parkes, W. F., de Bont, J. (Producers), & Spielberg, S. (Director). (2002). Minority Report [Motion picture]. United States: 20th Century Fox.

Moran, A., Gadepally, V., Hubbell, M., & Kepner, J. (2015, September). Improving big data visual analytics with interactive virtual reality. In *High Performance Extreme Computing Conference (HPEC), 2015 IEEE* (pp. 1–6). IEEE.

Nagel, H. R. (2006). Scientific visualization versus information visualization. In *Workshop on State-of-the-Art in Scientific and Parallel Computing*, Sweden.

Oculus Rift. (n.d.). Retrieved from https://www.oculus.com/rift.

Raja, D., Bowman, D., Lucas, J., & North, C. (2004, May). Exploring the benefits of immersion in abstract information visualization. In *Proceedings of Immersive Projection Technology Workshop*.

Shen, S., Gao, C., Zhao, Y., Lu, H., Shen, Y., Wang, C., … Wang, Y. (2016, June). Development of lower limb rehabilitation evaluation system based on virtual reality technology. In *IEEE International Conference on Real-time Computing and Robotics (RCAR)* (pp. 517–522). IEEE.

Shneiderman, B. (1996, September). The eyes have it: A task by data type taxonomy for information visualizations. In *Proceedings. IEEE Symposium on Visual Languages, 1996* (pp. 336–343). IEEE.

Stauffer, M., Ryter, R., Dornberger, R., & Hil, D. (2016). *A review and extension of the visual information seeking mantra (VISM)*.

Tegarden, D. P. (1999). Business information visualization. *Communications of the AIS*, *1*(1es), 4.

Teras, M., & Raghunathan, S. (2015). Big data visualisation in immersive virtual reality environments: Embodied phenomenological perspectives to interaction. *ICTACT Journal on Soft Computing*, *5*(4).

Van Dam, A., Forsberg, A. S., Laidlaw, D. H., LaViola, J. J., & Simpson, R. M. (2000). Immersive VR for scientific visualization: A progress report. *IEEE Computer Graphics and Applications, 20*(6), 26–52.

Van Dam, A., Laidlaw, D. H., & Simpson, R. M. (2002). Experiments in immersive virtual reality for scientific visualization. *Computers & Graphics, 26*(4), 535–555.

VR—Leap Motion Gallery. (n.d.). Retrieved from https://gallery.leapmotion.com/category/vr/.

Vultur, O. M., Pentiuc, S. G., & Lupu, V. (2016, May). Real-time gestural interface for navigation in virtual environment. In *2016 International Conference on Development and Application Systems (DAS)* (pp. 303–307). IEEE.

Wang, J., & Bennett, K. J. (2013, March). A virtual reality study on Santa Maria Crater on Mars. In *2013 IEEE Virtual Reality (VR)* (pp. 105–106). IEEE.

Wiss, U., & Carr, D. (1998). *A cognitive classification framework for 3-dimensional information visualization*. Luleå tekniska universitet.

Wiss, U., & Carr, D. A. (1999). An empirical study of task support in 3d information visualizations. In *Proceedings. 1999 IEEE International Conference on Information Visualization, 1999* (pp. 392–399). IEEE.

Yi, J. S., ah Kang, Y., & Stasko, J. (2007). Toward a deeper understanding of the role of interaction in information visualization. *IEEE Transactions on Visualization and Computer Graphics*, *13*(6), 1224–1231.

Zocco, A., Zocco, M. D., Greco, A., Livatino, S., & De Paolis, L. T. (2015, August). Touchless interaction for command and control in military operations. In *International Conference on Augmented and Virtual Reality* (pp. 432–445). Cham: Springer.

Part VI
AR & VR Medical Applications

Pulmonary Rehabilitation in Virtual Reality for COPD Patients

Natasha Moorhouse, Timothy Jung, Xin Shi, Farhan Amin, Joanne Newsham and Sarah McCall

Abstract The purpose of this study is to assess the benefits of Virtual Reality (VR) as a form of self-managed Pulmonary Rehabilitation (PR) for patients with Chronic Obstructive Pulmonary Disease (COPD). Qualitative data were collected including one focus group and four one-one interviews at a Health Centre in South Cumbria, and one focus group and two one-one interviews at a General Hospital in West Cumbria. A total of ten patients participated. Data were analysed using thematic analysis. This study is one of the first to investigate VR for PR. The findings contribute to the body of knowledge of VR for rehabilitation, and for PR more specifically. The findings indicate that elderly COPD patients using VR for PR are more compliant to conducting their exercises because VR motivates them and increases their confidence in physical activity and self-management of their condition. Patients demonstrated significant improvements in strength and mobility, and report psychological benefits including satisfaction in achieving their goals and completing milestones within the PR in VR programme. Combining these factors together contributes to an overall improved quality of life for COPD patients. Recommendations for future developments of VR for PR are discussed. Furthermore, this study provides important practical implications for health professionals.

Keywords Virtual reality · Pulmonary rehabilitation · Chronic obstructive pulmonary disease

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1 Introduction

Chronic Obstructive Pulmonary Disease (COPD) has a significant negative effect on patients' quality of life and constitutes a substantial social and economic burden on the UK's National Health Service (NHS) (Ogunbayo et al., 2017). COPD patients with Medical Research Council (MRC) dyspnea (difficulty breathing/ shortness of breath) grade 3 or above (and especially grade 4 and 5) have been shown to have clear exercise intolerance, reduced disease-specific health status, reduced mood status, and reduced self-reported daily physical activities (Bestall et al., 1999). The need for engaging and activating approaches to providing health and social care for people with long-term conditions has been recognised (Singh & Ham, 2006). New technologies, including Virtual Reality (VR), are rapidly impacting on the development of novel rehabilitation interventions in a range of key research areas and subject classification including medicine, computer science, and engineering (Huang et al., 2016). In the field of healthcare research, VR has proven useful and effective because of its customisation, interactivity, and ability to improve learning and rehabilitation rate (Huang et al., 2016; Rose, Nam, & Chen, 2018). When compared to real-world rehabilitation, VR-based Pulmonary Rehabilitation (PR) has been found to be more interesting and less dangerous (Huang et al., 2016), and could assist patients with simultaneously improving balance, coordination, muscle strength, and range of motion while providing physiotherapists with quantitative data (Matijević et al., 2013). However, a thorough exploration and evaluation of VR's use for Pulmonary Rehabilitation (PR) is required (Huang et al., 2016). Therefore, this exploratory study aims to assess the benefits of VR as a form of self-managed PR for elderly COPD patients.

2 Literature Review

2.1 Current Treatments for Pulmonary Rehabilitation

COPD can be defined as "a multi-factorial progressive chronic lung disease that causes obstruction in air flow" (McCarthy, Casey, Devane, Murphy, Murphy, & Lacasse, 2015, p. 1). This obstruction leads to persistent and progressive breathlessness, productive coughing, fatigue, and reoccurring chest infections (Gold, 2014). Patients with very severe COPD experience disabling physical symptoms (e.g. breathlessness), psychological distress, social isolation, and co-morbidity (Bourbeau, 2009; Habraken, Willems, de Kort, & Bindels, 2007; Williams, Bruton, Ellis-Hill, & McPherson, 2007). Physical activity is unpleasant because of air trapping and increased hyperinflation in the lungs, which results in increased breathlessness due to subsequent inefficient breathing (Dias et al., 2013; O'Donnell et al., 2007). This then leads to anxiety, further breathlessness, exacerbation of COPD symptoms, and panic (McCarthy et al., 2015). Therefore, physical inactivity is common in people with COPD, however, this causes muscle de-conditioning and reduces the capacity to engage in physical activity (Bourbeau and van der Palen, 2009; Spruit et al., 2013). Resistive exercises for respiratory muscles and general physical exercises are often involved in the care and treatment and part of a PR program (Dias et al., 2013). PR programmes often include nutrition guidelines, guidelines on medication, as well as physical training methods and respiratory muscle (Zaini & Negrini, 2011). The basic goal of PR is to (1) improve symptoms, (2) restore functional capabilities, and (3) enhance overall quality of life (Sharma & Singh, 2011).

To achieve the goals of the PR program, patients should adhere to the program with monitoring and attendance at least three times per week for several months, however, often patients (especially MRC 3–5) cannot consistently perform PR for professional reasons, limited mobility, and lack of economic motivation to present themselves at the rehabilitation centres as often as necessary (Dias et al., 2013; Holland et al., 2016). In the UK, more than 15 million people have a long-term condition (LTC) and therefore heavily rely on health services, accounting for at least 70% of all NHS spend (NHS, 2017). Home-based (i.e. self-managed) PR provides a viable alternative to clinic-based PR programmes (Liu et al., 2008). Home-based PR programmes represent effective therapeutic intervention approaches for relieving COPD-associated respiratory symptoms, re-establishing and improving functional disability, enhancing participation in everyday life, promoting autonomy, and improving HRQoL (Liu, Tan, Wang, & Chen, 2014; Spruit et al., 2013). Self-management education of COPD patients has been used to help them increase their physical activities and obtain more effective management of their disease (Dinesen, Huniche, & Toft, 2013). Additional benefits include improvements in well-being through enhancement to physical and psychological status, time convenience and flexibility in training, cost effectiveness, and patients feeling stronger and achieving goals (Lahham et al., 2017; Mendes de Oliveria et al., 2010).

Studies have focused on several self-management approaches for COPD including telerehabilitation (i.e. the delivery of rehabilitation through information and communication technologies) using telephone calls (e.g. Dinesen et al., 2013; Holland et al., 2013), comparing video and instruction booklet (e.g. Moore et al., 2012), and mobile applications (e.g. Hardinge et al., 2015; Farmer et al., 2014; Williams, Price, Hardinge, Tarassenko, & Farmer, 2014). For example, Williams et al. (2014) explored the use of mobile health applications with COPD patients aged 50–85 years, and found that patients had increased awareness of the variability of their symptoms following the use of the mobile application. In addition, using the mobile application assisted with their self-management approach regardless of the previous knowledge and experience with mobile applications. Similarly, Farmer et al. (2014) focuses on the use of a mobile telehealth application through an Android tablet. Patients were allocated a tablet for home use and could complete a daily symptom diary and record clinical symptoms using a Bluetooth-linked pulse oximeter. The aim of the trial was to investigate the extent to which a telehealth platform designed to support self-management improves quality of life for COPD patients. The researchers' subsequent study (Hardinge et al., 2015) found patients increased compliance. Moore et al. (2012) compared the effectiveness of home-based PR using two control groups including a video programme and an educational booklet. Their findings suggested that participation in a home exercise video program could benefit people with COPD more so than the educational booklet because there was an improvement in fatigue, emotion, and reduced breathlessness in comparison to the other group (Moore et al., 2012). However, existing telehealth systems often have restricted times of data entry rather than being fitted with individual patient lifestyles, with frequent data errors requiring repeated entry (Hardinge et al., 2015). Moreover, studies have begun to investigate VR for rehabilitation and it is now considered a useful addition to rehabilitation tools in the process of some diseases (Camporesi, Kallman, & Han, 2013; Dimyan & Cohen, 2011; Kwakkel, Kollen, ven der Grond, & Prevo, 2003; Wyller, 1997). Studies have demonstrated its usefulness for home-based rehabilitation (e.g. Rizzo & Kim, 2005; Rizzo et al., 2001), although few studies have explored VR specifically for self-managed PR.

2.2 The Use of Virtual Reality for Rehabilitation

The capacity of VR to create controllable, multisensory, and interactive 3D environments, within which human behaviour can be motivated and measured, offers clinical and assessment treatment options that were not possible using traditional methods (Rizzo et al., 2011). Relevant simulated environments can be created where assessment of cognitive, emotional, and motor problems can take place (Rizzo et al., 2011). The key characteristics of VR including immersion, feedback, and interactivity (Brey, 2008) within the virtual environment are expressed to varying degrees in rehabilitation-specific systems (Levac et al., 2016). In addition, as VR is mobile-based it can be conducted anywhere at any time and it is not limited by the confinements of the patient's home. Indeed, research has found that VR is useful for a wide range of health conditions and clinical applications, including pain management, physical rehabilitation, treatment of anxiety disorders and post-traumatic stress, among many other physical, neurological, and psychological conditions (Powell, Rizzo, Sharkey, & Merrick, 2017). Although virtual rehabilitation has been the focus of considerable research for many years, its use for rehabilitation was limited by the lack of inexpensive, easy-to-use systems that promote the user of valid movement patterns (Levin, Weiss, & Keshner, 2015). More recently, the increase in interest and its use in a variety of clinical and home settings has increased due to the availability of consumer-ready VR hardware and software developments (Levin et al., 2015; Powell et al., 2017).

In the health sector, the aim of emerging technologies such as VR is not to replace clinical expertise and human factors, but rather to provide a set of tools to supplement and support rehabilitation and to empower patients to participate in their own well-being (Powell et al., 2017). Technology-enhanced rehabilitation is beneficial given its ability to individualise treatment programmes dynamically, with either intelligent algorithms which respond to patient performance, or customisable programs which allow clinicians to create individualised treatment plans within VR software (Powell et al., 2017). In addition, health practitioners can access patients' physiological metrics such as breathing, heart rate or activity level during rehabilitation from remote settings, which can then be streamed into the VR system and used to dynamically change the user experience (Powell et al., 2017). The realism of VR environments allows patients the opportunity to explore independently, therefore increasing their sense of autonomy and independence in directing their own therapeutic experience (Kizony, Raz, Katz, & Weiss, 2005). In the UK, an estimated 1.2 million people are living with COPD. This group are mostly aged 40 years and over, with the proportion of COPD patients increasing markedly with advancing age (British Lung Foundation, 2018). Research has found that elderly patients that exercise using VR benefit from improvements in mobility (Bisson, Contant, Sveistrup, & Lajoie, 2007; Maillot, Perrot, & Hartley, 2012), muscular strength of lower limbs (Jorgensen, Laessoe, Hendriksen, Nielsen, & Aagaard, 2013), cognition (mainly of executive functions) (Maillot et al., 2012), balance control (Bieryla & Dold, 2013; De Bruin, Schoene, Pichierri, & Smith, 2010; Pluchino Lee, Asfour, Roos, & Signorile, 2012; Rendon et al., 2012; Szturm, Betker, Moussavi, Desai, & Goodman, 2011), reaction time (Bisson et al., 2007), and fall prevention (de Bruin et al., 2010; Duque et al., 2013; Schoene et al., 2013). Given its benefits, VR could be considered a viable method for rehabilitation, although further investigation is required specifically focusing on its use for PR.

3 Method

3.1 Participant Profile

Ten elderly COPD patients, including 4 females and 6 males aged between 62 and 76, participated in this study. This particular group (MRC 4–5) have significant exercise limitation and are at most risk from COPD exacerbation and subsequent hospital admission (Healthcare Quality Improvement Partnership, 2018), and therefore tend not to attend traditional PR programmes. P1–P10 represents the participant number, which is used for the analysis (Table 1).

Table 1 Participant profile

Participant no.	Age	Gender
P1	75	M
P2	68	M
P3	69	M
P4	73	F
P5	62	F
P6	71	M
P7	76	M
P8	69	F
P9	63	F
P10	63	M

3.2 PR in VR Application

Within the "PR in VR" programme there are eight modules, one for each week of the eight week course. The first module began with an introduction to COPD and the PR in VR programme. Modules two to seven consisted of a set of exercises with instruction in the form of a digital avatar. Throughout those modules patients were provided with information on COPD. The eighth and final module summarised the program and provided patients with an incentive for taking part.

3.3 Experiment

Patients used the PR in VR programme at home for the entire duration of the eight week course. Given that patients could use the programme at their own pace, each patient had reached a different module within the PR in VR programme based on their physical wellbeing and ability to complete the exercises. This meant that some patients had finished all eight modules, while others were repeating certain modules, or had only completed the first module.

3.4 Qualitative Data Collection

Two focus groups and six one-one interviews were conducted in June 2018. The first focus group, consisting of three COPD patients and each of their partners, and four one-to-one interviews were conducted at a health centre in South Cumbria. One of the one-to-one interviews was an update from a patient who participated in the first focus group. The second focus group, consisting of two COPD patients only, and another two one-to-one interviews were conducted at a general hospital in

West Cumbria. The focus groups were conducted by two researchers, one physiotherapist, and one healthcare assistant at both locations. The one-to-one interviews were conducted by one physiotherapist and one healthcare assistant in each location. The physiotherapist and the healthcare assistant at each location had been assisting the patients throughout the course of the eight week programme by visiting patients' homes and communicating via phone and text message. Questions explored patients' PR in VR experience including the benefits and areas for improvement, patient satisfaction and perceptions, immersive learning, the usability of the VR device and application, and future intentions to conduct PR in VR.

3.5 Data Analysis

Thematic analysis was employed to identify emergent themes within the data set. Overall, nine key themes were identified including seven benefits: increased strength and mobility, compliance, motivation, quality of life, improved self-management, satisfaction, and confidence, and two recommendations for improvement: personalisation and technical capabilities.

4 Findings and Discussion

4.1 Benefits of PR in VR

4.1.1 Increased Strength & Mobility

As a result of using the VR application, several patients (P1, P3, P4, P5, P7, P8, P9, P10) reported an *increase in strength*, in particular in their legs, which has had a positive impact on their *mobility* and confidence to conduct daily activities. This is evident as P8 reported, "I know certainly my legs are stronger, I can feel that even just getting up off the chair … I have taken back more control again with things around the house". Similarly, when conducting daily tasks P9 stated, "after using VR, I am less breathless … my recovery time is much quicker". In addition, P1 reported, "I am a lot more flexible, and without the pain", and P5 stated, "my walking distance had improved".

4.1.2 Compliance

According to the findings, PR in VR increases patients' (P1–P10) *compliance* with their exercises. When comparing PR in VR with traditional methods, P9 stated, "VR is more akin to my needs … it fits in more with my routine based on whether I am having a good or bad day". P4 even reported using VR more than once in a day, "I can use it twice a day when I am feeling good. I built myself up and I started using the weights I have at home". In line with this, patients enjoyed the flexibility of completing their exercises using VR at any point throughout the day (P1, P2, P3, P4, P8, P9), "I have done [VR] early in the morning and late at night, around 10 o'clock" (P1). Having said that, P4, P5, and P7 agreed that PR in VR could complement rehabilitation classes at the venue, whereby patients' build up their fitness through VR until they are fit enough to attend the class, which they enjoy for socialising. Finally, when comparing VR to using the exercise booklet at home, P8 stated "I found VR easier than having the booklet at home".

4.1.3 Motivation

As a result of using PR in VR to conduct their exercises more regularly, patients (P1–P5, P7–P10) stated that they are more *motivated* to leave the house, which previously they could only do to a limited degree. "I think I had given up. I decided that the illness had gone so far, I was not going to get better. I was not going to go out again or enjoy life. It has completely reassured me in that way, and given me the energy to get going again" (P8). In addition, knowing that the patient usage and data is being tracked by the health practitioners was an important factor relating to three patients' motivation (P2, P4, P5, P9). For example, P5 stated, "it is nice to know that someone has their eye on you, it helps you along", and P9, "I feel more secure".

4.1.4 Confidence

The majority of patients (P1–P5, P7–P10) discussed having increased *confidence* with conducting daily activities. For example, "it builds up my confidence because I can go out more" (P4), and, "I feel confident enough that I started filling my own flasks again" (P7), which also demonstrates how PR in VR has helped patients gain back more control in their life. In addition, monitoring their own oxygen level and heart rate while exercising was important for increasing patients' confidence while exercising (P2, P5, P6, P8, P9), "it reassured me being able to see my oxygen level and heart rate while I was exercising" (P8). Further, patients that reached the final module where largely interested in accessing a more advanced level or additional programme, therefore, indicating how increased confidence leads to increased motivation and desire to continue with the programme. An example of this is that P2's partner enquired, "now that he has done level eight and he is quite happy doing it, can he have another programme?".

4.1.5 Quality of Life

PR in VR has improved patients' (P1–P10) *quality of life* which is evident given that one patient (P8) had not left the house in seven weeks, however, since using VR the patient is now out socialising and enjoying daily activities. "[I feel] a lot of progression. From sitting on the sofa I have been able to go with my husband for a coffee, go out in the car … it had got me to the stage again where I felt I could go out and go shopping … I can go out more now because I can walk further and I enjoy it more because I feel better. It is motivating to continue" (P4). In addition, patients physical and mental state has improved which motivates them to be more active. In support of this, "I feel better physically and ready to do something, to go somewhere, more active, after I have done my exercises" (P4).

4.1.6 Improved Self-management

For some patients (P1–P5, P8, P9), PR in VR served as a reminder to conduct their exercises more often, more effectively, and made exercising "pleasurable rather than chore-like" (P9), therefore providing patients with increased enjoyment and *better self-management* of their condition. "I think I had forgotten to change positions from being hunched down and not breathing. Now, I sit up, take a deep breath and do the Thai Chi exercises. I noticed I was not doing that before" (P8). Although P1 was conducting exercises prior to using PR in VR, he reported that PR in VR has taught him to conduct the exercises "better and slower". In addition, "it has given me back control to manage my condition. I am confident enough to say that I can manage it" (P8).

4.1.7 Satisfaction

Further, patients (P1, P4, P8, P9) felt a sense of *satisfaction* after completing the modules and consistently exercising and monitoring their health. For example, P9 stated, "[what I enjoyed most is] actually achieving the programme, getting from start to finish because the first two times I couldn't complete it … when I eventually go to the end it made me feel better, I could feel the progress". In addition, P4 stated, "I feel satisfied that I motivated myself to do it. It did help me to do it. I feel satisfied when I sit down and think that's me done for tonight". Further, "what I enjoyed most was knowing that I could get through the exercises. Knowing that my oxygen was not dropping. It was a real achievement for me" (P8), and "when I've finished the Thai Chi I do feel physically and mentally relieved" (P1).

4.2 Recommendations for Future Development

4.2.1 Technical Capabilities

Regarding the usability of the headset, the patients found it fairly easy to use (P1–P10), "I picked it up quickly. It was not difficult to use" (P5). However, the findings indicate that stated that certain *technical capabilities* could be improved. For example, P1–P10 reported the device manufacturing issue whereby the camera moves to the right and takes some time to return to centre. Additional suggestions for future development are a more lightweight VR headset (P4, P5, P8, P9), and "what I want to be able to do is fast forward it and pause it" (P1), which was echoed by P2 and P3 and supported by P4 and P5, as this would allow them to complete the modules at their own pace.

4.2.2 Personalisation

In line with this, given that patients have varying levels of COPD, it is important to provide *personalised programmes* to ensure patients are being challenged based on their ability. This is evident given that P2, P5, and P10 found the modules too easy, "I feel that the first two were too easy" (P5), and require more advanced levels, as this would "make it more attractive and interesting" (P10). In line with this, P1 stated, "for people less breath affected, they might want a harder programme". Further, P4 and P6 found the pace "too slow for me" (P6). Whereas P1, and P3–P5 found the more advanced levels required more practice and enjoyed the flexibility to remain on certain levels, "it is beneficial to have the different levels so I can drop down depending how I feel each day" (P4). In addition, P5 agreed with P4 and added that various exercises within each module would maintain engagement, "I would like two or more routines in each module instead of doing the same thing all the time. For longer than six weeks it would become boring" (P5).

5 Conclusion

The present study aimed to provide initial insights into the benefits of VR for self-managed PR by using an exploratory qualitative technique. The findings offer initial evidence to support VR's potential in this specific context by identifying seven benefits of VR for COPD patients. The majority of patients in this study reported they had not been exercising at home or attending traditional classes, however, some had prior experience with the latter. This study demonstrates how PR in VR increases patients' compliance with their exercises, particularly those that find it difficult to consistently attend traditional classes due to ill health, lack of motivation, suffering from depression, or inconvenience with timing and limitations with transportation. This is because patients benefit from increased motivation, confidence, and significant improvements with their strength and mobility. They are able to better self-manage their condition, and feel psychological benefits such as satisfaction from achieving personal goals and feeling healthier. Together, those factors improve patients' quality of life, therefore, demonstrating the potential of this innovative technology as a credible alternative to traditional PR programmes, particularly for the target group considering their limitations.

6 Theoretical Contribution and Practical Implications

Previous studies (Bisson et al., 2007; Huang et al., 2016; Jorgensen et al., 2013; Kizony et al., 2005; Lahham et al., 2017; Maillot et al., 2012; Mendes de Oliveria et al., 2010; Rose et al., 2018) have addressed the use of VR for rehabilitation and found several benefits including increased compliance, improved self-management, increased mobility and strength, and achieving goals. However, to the best of the researchers' knowledge this is one of the first studies to investigate the benefits of VR for self-managed PR. Furthermore, this study provides important practical implications for healthcare professionals on the benefits of emergent technologies such as VR for PR. This innovation differs from any other self-managed programmes by giving the health practitioners the ability to supervise patients remotely and at scale, and to performance measure delivering Digital Precision Medicine. Therefore, the NHS could benefit from less expenditure on physiotherapists delivering classes in hospital outpatient departments. Indeed, the national shortage of physiotherapists means places are limited and patients are on a long waiting list to attend (NHS Funding, 2018), and during this time patients have reported non-engagement with exercising. PR in VR provides a solution to this problem, and because patients' data is tracked and observed in real-time, this limits the need for regular hospital visits, therefore, reducing costs and time for both the patient and the NHS. In addition, patients could feel more confident knowing their exercises are being monitored.

7 Limitations and Future Research

The first limitation is related to the selected sample. COPD is common among people aged 40 years and above, however, this study employed a sample of patients aged 62 and over. Therefore, future studies could employ a sample with varying demographics (i.e. age range) in order to ensure the findings can be considered relevant to the majority of COPD patients. Furthermore, this study outlines only the exploratory qualitative phase and future studies will provide statistical evidence to support the benefits of VR for self-managed PR in order to advance this research area.

References

Bestall, J. C., Paul, E. A., Garrod, R., Garnham, R., Jones, P. W., & Wedzicha, J. A. (1999). Usefulness of the Medical Research Council (MRC) dyspnoea scale as a measure of disability in patients with chronic obstructive pulmonary disease. *Thorax, 54*(7), 581–586.

Bieryla, K. A., & Dold, N. M. (2013). Feasibility of Wii Fit training to improve clinical measures of balance in older adults. *Clinical Interventions in Aging, 8,* 775–781.

Bisson, E., Contant, B., Sveistrup, H., & Lajoie, Y. (2007). Functional balance and dual-task reaction times in older adults are improved by virtual reality and biofeedback. *CyberPsychology & Behaviour, 10,* 16–23.

Bourbeau, J. (2009). Activities of life: The COPD patient. *COPD, 6,* 192–200.

Bourbeau, J., & van der Palen, J. (2009). Promoting effective self-management programmes to improve COPD. *European Respiratory Journal, 33*(3),461–463.

Brey, P. (2008). Virtual reality and computer simulation. In K. Einer, K. Himma, & H. T. Tavani (Eds.), *The handbook of information and computer ethics* (pp. 361–384). Hoboken: Wiley.

British Lung Foundation. (2018). Chronic obstructive pulmonary disease (COPD) statistics. *British Lung Foundation.* Accessed on July 25, 2018 https://statistics.blf.org.uk/copd.

Camporesi, C., Kallman, M., & Han, J. J. (2013). VR solutions for improving physical therapy. In *Virtual reality (VR)* (pp. 77–78). IEEE.

De Bruin, E. D., Schoene, D., Pichierri, G., & Smith, S. T. (2010). Use of virtual reality technique fort he training of motor control in the elderly. Some theoretical considerations. *Gerontology and Geriatric Medicine, 43,* 229–234.

Dias, F. D., Sampaio, L. M., da Silva, G. A., Gomes, E. L., do Nasciment, E. S., Alves, V. L., et al. (2013). Home-based pulmonary rehabilitation in patients with chronic obstructive pulmonary disease: A randomized clinical trial. *International Journal Chronic Obstructive Pulmonary Disease, 8,* 537–544.

Dimyan, M. A., & Cohen, L. G. (2011). Neuroplasticity in the context of motor rehabilitation after stroke. *Nature Reviews Neurology, 7*(2), 76–85.

Dinesen, B., Huniche, L., & Toft, E. (2013). Attitudes of COPD patients towards tele-rehabilitation: A cross-sector case study. *International Journal of Environmental Research and Public Health, 10*(11), 6184–6198.

Duque, G., Boersma, D., Loza-Diaz, G., Hassan, S., Suarez, H., Geisinger, D., et al. (2013). Effects of balance training using a virtual-reality system in older fallers. *Clinical Intervention in Aging, 8,* 257–263.

Farmer, A., Toms, C., Hardinge, M., Williams, V., Rutter, H., & Tarassenko, L. (2014). Self-management support using an internet-linked tablet computer (the EDGE platform)-based intervention in chronic obstructive pulmonary disease: Protocol fort he EDGE-COPD randomised controlled trial. *British Medical Journal Open, 4,* 1–8.

Global Initiative for Chronic Obstructive Lung Disease. (2013). Global strategy for the diagnosis, management, and prevention of chronic obstructive pulmonary disease. Accessed on July 25, 2018 http://www.goldcopd.org/uploads/users/files/.

Gold. (2014). *Global strategy for the diagnosis, management, and prevention of chronic obstructive pulmonary disease*. Global initiative for chronic obstructive lung disease (pp. 1–44).

Habraken, J. M., de Willems, D. L., Kort, S. J., & Bindels, P. J. E. (2007). Healthcare needs in end-stage COPD: A structured literature review. *Patient Education and Counseling, 68,* 121–130.

Hardinge, M., Rutter, H., Velardo, C., Shah, S. A., Williams, V., Tarassenko, L., & Farmer, A. (2015). Using a mobile health application to support self-management in chronic obstructive pulmonary disease: A six-month chort study. *BMC Medical Informatics & Decision Making, 15*(46), 1–10.

Healthcare Quality Improvement Partnership. (2018). National COPD Audit Programme. Pulmonary rehabilitation: An exercise in improvement. National Report 2018. *Healthcare*

Quality Improvement Partnership. Accessed on July 25, 2018 https://www.hqip.org.uk/wp-content/uploads/2018/04/COPD-National-report-2018-Pulmonary-rehabilitation-an-exercise-in-improvement.pdf ().

Holland, A. E., Mahal, A., Hill, C. J., Lee. A. L., Burge, A. T., Cox, N. S., … McDonald, C. F. (2016). Home-based rehabilitation for COPD minimal resources: A randomised, controlled equivalence trial. *Thorax,* 1–9.

Holland, A.E., Mahal, A., Hill, C.J., Lee, A., & Burger, A.T., et al. (2013). Benefits and costs of home-based pulmonary rehabilitation in chronic obstructive pulmonary disease - a multi-centre randomised controlled equivalence trial. *BMC Pulmonary Medicine, 13*(57), 1–7.

Huang, Y., Huang, Q., Ali, S., Zhai, X., Bi, X., & Liu, R. (2016). Rehabilitation using virtual reality technology: A bibliometric analysis, 1996–2015. *Scientometrics, 109,* 1547–1559.

Jorgensen, M. G., Laessoe, U., Hendriksen, C., Nielsen, O. B., & Aagaard, P. (2013). Efficacy of Nintendo Wii training on mechanical leg muscle function and postural balance in community-dwelling older adults: A randomized controlled trial. *Journal of Gerontology A Biological Sciences and Medical Sciences, 68,* 845–852.

Kizony, R., Raz, L., Katz, N., & Weiss, P. L. (2005). Video-capture virtual reality system for patients with paraplegic spinal cord injury. *The Journal of Rehabilitation Research and Development, 42*(5), 595–608.

Kwakkel, G., Kollen, B. J., ven der Grond, J., & Prevo, A. J. H. (2003). Probability of regaining dexterity in the flaccid upper limb—Impact of servery of paresis and time since onset in acute stroke. *Stroke, 34*(9), 2181–2186.

Lahham, A., McDonald, C. F., Mahal, A., Lee, A. L., Hill, C. J., Burge, A. R., … Holland, A. E. (2017). Home-based pulmonary rehabilitation for people with COPD: A qualitative study reporting the patient perspective. *Chronic Respiratory Disease,* 1–8.

Levac, D., Glegg, S. M. N., Sveistrup, H., Colquhoun, H., Miller, P. A., Finestone, H., et al. (2016). A knowledge translation intervention to enhance clinical application of a virtual reality system in stroke rehabilitation. *BMC Health Services Research, 16*(557), 1–11.

Levin, M. F., Weiss, P. L., & Keshner, E. A. (2015). Emergence of virtual reality as a tool for upper limb rehabilitation: Incorporation of motor control and motor learning principles. *Physical Therapy, 95*(3), 415–425.

Liu, X., Tan, J., Wang, T., & Chen, J. (2014). Effectiveness of home-based pulmonary rehabilitation for patients with chronic obstructice pulmonary disease: A meta-analysis of randomized controlled trials. *Rehabilitation Nursing: The Official Journal of the Association of Rehabilitation Nurses, 39*(1).

Liu, W. T., Wang, C. H., Lin, H. C., Lee, K. Y., Lo, Y. L., Hung, S. H., et al. (2008). Efficacy of a cell phone-based exercise program for COPD. *European Respiratory Journal, 32*(3), 651–659.

Maillot, O., Perrot, A., & Hartley, A. (2012). Effects of interactive physical-activity videogame training on physical and cognitive function in older adults. *Psychology and Aging, 27,* 589–600.

Matijević, V., Secić, A., Masić, V., Sunić, M., Kolak, Z., & Znike, N. (2013). Virtual reality in rehabilitation and therapy. *Acta Clinica Croatica, 52*(4), 453–457.

McCarthy, B., Casey, D., Devane, D., Murphy, K., Murphy, E., & Lacasse, Y. (2015). Pulmonary rehabilitation for chronic obstructive pulmonary disease. *Cochrane Database of Systematic Reviews, 23*(2).

Mendes de Oliveria, J. C., Studart Leitão Filho, F. S., Malosa Sampaio, L. M., Negrinho de Oliveira, A. C., Pastrello Hirata, R., Costa, D., & Donner, C. F. (2010). Outpatient vs. Home-based pulmonary rehabilitation in COPD: A randomized controlled trial. *Multidisciplinary Respiratory Medicine, 5*(6), 401–408.

Moore, L., Hogg, L., & White, P. (2012). Acceptability and feasibility of pulmonary rehabilitation for COPD: A community qualitative study. *Primary Respiratory Journal, 21*(4), 419–424.

NHS Funding. (2017). Physiotherapy. *NHS.* Accessed July 25, 2018 https://nhsfunding.info/symptoms/physiotherapy/.

O'Donnell, D. E., Aaron, S., Bourbeau, J., Hernandez, P., Marciniuk, D. D., Balter, M., et al. (2007). Canadian thoracic society recommendations for management of chronic obstructive pulmonary disease—2007 update. *Canadian Respiratory Journal, 14,* 5B–32B.

Ogunbayo, O. J., Russell, S., Newham, J. J., Heslop-Marshall, K., Netts, P., Hanratty, R., et al. (2017). Understanding the factors affecting self-management of COPD from the perspectives of healthcare practitioners: A qualitative study. *Primary Care Respiratory Medicine, 54,* 1–9.

Pluchino, A., Lee, S. Y., Asfour, S., Roos, B. A., & Signorile, J. F. (2012). Pilot study comparing changes in postural control after training using a video game balance board program and 2 standard activity-based balance intervention programs. *Archives of Physical Medicine and Rehabilitation, 93,* 1138–1146.

Powell, W., Rizzo, A., Sharkey, P., & Merrick, J. (2017). Innovations and challenges in the use of virtual reality technologies for rehabilitation. *Journal of Alternative Medicine Research, 10*(1).

Rendon, A. A., Lohman, E. B., Thorpe, D., Johnson, E. G., Medina, E., & Bradley, B. (2012). The effect of virtual reality gaming on dynamic balance in older adults. *Age and Aging, 41,* 549–552.

Rizzo, A. A., Buckwalter, J. G., Bowerly, T., Humphrey, L. A., Neumann, U., van Rooyen, A., et al. (2001). The virtual classroom: A virtual reality environment for the assessment and rehabilitation of attention deficits. *Revista Española de Neuropsicologia, 3*(3), 11–37.

Rizzo, A., & Kim, G. J. (2005). A SWOT analysis of the field of Virtual Reality rehabilitation and therapy. *Presence, 14*(2), 119–146.

Rizzo, A., Parsons, T. D., Lange, B., Kenny, P., Buckwalter, J. G., Rothbaum, B., et al. (2011). Virtual reality goes to war: A brief review of the future of military behavioural healthcare. *Journal of Clinic Psychology in Medical Settings, 18,* 176–187.

Rose, T., Nam, C. S., & Chen, K. B. (2018). Immersion of virtual reality for rehabilitation—Review. *Applied Ergonomics, 69,* 153–161.

Schoene, D., Lord, S. R., Delbaere, K., Severino, C., Davies, T. A., & Smith, S. T. (2013). A randomized controlled pilot study of home-based step training in older people using videogame technology. *PLoS One, 8,* e57734.

Sharma, B. B., & Singh, V. (2011). Pulmonary rehabilitation: An overview. *Lung India, 28*(4), 276–284.

Singh, D., & Ham, C. (2006). Improving care for people with long-term conditions: A review of UK and international frameworks. Health Services Management Centre.

Spruit, M. A., Singh, S. J., Garvey, C., ZuWallack, R., Nici, L., Rochester, C., et al. (2013). An official American Thoracic Society/European Respiratory Society statement: Key concepts and advances in pulmonary rehabilitation. *American Journal of Respiratory and Critical Care Medicine, 188*(8), 13–64.

Szturm, R., Betker, A. L., Moussavi, Z., Desai, A., & Goodman, V. (2011). Effects of an interactive computer game exercise regimen on balance impairment in frail community-dwelling older adults: A randomized controlled trial. *Physical Therapy, 91,* 1449–1462.

Williams, V., Bruton, A., Ellis-Hill, C., & McPherson, K. (2007). What really matters to patients living with chronic obstructive pulmonary disease? An exploratory study. *Chronic Respiratory Disease, 4,* 77–85.

Williams, V., Price, J., Hardinge, M., Tarassenko, L., & Farmer, A. (2014). Using a mobile health application to support self-management in COPD: A qualitative study. *British Journal of General Practice, 64*(624), 392–400.

Wyller, T. B. (1997). Disability models in geriatrics: Comprehensive rather than competing models should be promoted. *Disability and Rehabilitation, 19*(11), 480–483.

Zaina, F., & Negrini, S. (2011). EJPRM systematic continuous update on Cochrane reviews in rehabilitation: News from July to December 2011. *European Journal of Physical and Rehabilitation Medicine, 47*(4), 601–605.

Exploring Surgeon's Acceptance of Virtual Reality Headset for Training

Libi Beke Hen

Abstract Understanding user intention to accept or reject a new technology is a key factor in implementation and success of new system technology in an organization (Gahtani & King, 1999). The purpose of this study was to explore surgeon's acceptance of Virtual Reality Headset (VRH) as a surgical simulator. The Unified Theory of Acceptance and Use of Technology (UTAUT) model was applied to explore the factors that affected surgeon's acceptance. A structured questionnaire was conducted to capture information from international surgeons. The result explain 52% of variance associated with Behavioural Intention ($R2 = 0.521$), the three constructs of UTAUT model: Performance Expectancy (PE), Social Influence (SI) and Effort Expectancy (EE) have a significance and the biggest impact on surgeons behavioural intention to use the Virtual Reality Headset, therefore organizations must take into account the following: (1) emphasize the usefulness of the software (2) consider surgeon's psychological aspects. (3) The system must be easy to use.

Keywords Virtual reality headset · Simulator · Surgical training · UTAUT · Technology acceptance

1 Introduction

Medical science is continuing to break new boundaries, while surgical training is still somewhere behind; new technology innovation such as Virtual Reality (VR) simulators can offer the answer to this actual gap. The simulation is defined as an environment that simulates a segment of reality, and allows the student to control the variables of the same reality (Eshet & Hammer, 2006).

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VR are computer based simulators with a designed software, it provides a real physical feeling and a real interaction of clinical situations (Gardner & Raemer, 2008). While VR simulator have the significant advantage to develop learner skills and improve quality of healthcare over traditional methods (McGaghie et al., 2015), it is not surprising to see iteration of VR in surgical education, it gives surgeons the possibility to train outside of the Operation Room (OR) in a safe environment with an interactive and realistic model. VR is at the forefront of innovation for digital learning.

In this study, the author has introduced a new surgical simulator that haven't been used yet in the health care environment. The training tool is a new VRH called: HTC Vive.

HTC Vive was released to the market in April 2016, "VIVE is a first-of-its-kind VR platform developed by HTC and Valve for total immersion in virtual worlds. Using a Headset and wireless controllers, the learner can explore and interact with VR experiences, apps and games that blur the line between imagination and reality" (HTC Vive, 2017).

With the financial sponsorship of Johnson and Johnson medical devices company, the author and her colleagues used Johnson and Johnson surgical procedure on Knee replacement and created an application supported by the HTC Vive. The surgeon is able to step inside surgical virtual OR (Fig. 2), explore proper surgical steps and "see" the virtual patient. He can assemble the instruments, use them on the virtual patient and also receive a direct feedback while using it.

As they wanted to evaluate VRH as a potential learning tool and identify the best ways to implement it, according to Al-Gahtani and King (1999) the key factor in implementation and success of new system technology is the ability to predict and identify user's acceptance. In order to better understand what factors influences user acceptance of new technology, researchers have suggested different models examining the factors contributing to individuals in the acceptance of Information Technology (IT).

Nowadays, different publication studies are exploring VRH as a training tool in a wide range of subjects such as: Driving simulation for accident prevision (Taheri, Matsushita, & Sasaki, 2017), student's behavioural intention to use VRH in learning (Shen, Ho, Kuo, & Loung, 2017), and recent study by Pulijala et al. 2017 explore the effectiveness of VRH in surgical training on surgical resident.

The motivation to conduct this research was the lack of empirical support assessing surgeon's intention to use VRH. The author has used the "Unified Theory of acceptance and use of technology" (UTAUT) model (Venkatesh, Morris, G. Davis, & F. Davis, 2003) to develop a structural model of surgeon's acceptance of VRH simulator, data was collected from orthopaedic surgeons from all over the world with different level of surgical experience from age 30–65. The author has made an empirical contribution to the UTAUT research by conducting the first research on surgeon's acceptance of VRH as educational simulator.

The key research question that the study was designed to explore is: What critical success factors/determinant will influence surgeon's intention to use VRH simulator? Next: Are Surgeons willing to use the VRH simulation for training purpose? Do surgeons perceive the VRH simulation to be free of effort?

Finally: Do surgeons perceive the VRH simulation to be useful as part of the training experience?

The findings of this study provide a useful guidance to health care professional trainers, medical devices industry and hospitals, assessing the integration of VRH simulator such as HTC Vive in their organizations, and help them to understand the critical success factors that influence surgeons accepting the VRH as an educational tool.

2 Literature Review and Hypothesis

2.1 Theoretical Framework

2.1.1 Unified Theory of Acceptance and Use of Technology (UTAUT)

Venkatesh et al. (2003, 2008) compared empirically the eight models of technology acceptance; each of this model explore user behaviour by using variety of factors, Venkatesh et al. have unified and integrated the four core determinants of intention and usage of new technology system based on the similarity of the eight models into new theory names as: "Unified Theory of acceptance and use of technolog" (UTAUT), this theory aimed to integrate all the factors that were known to affect the user adoption into one model. UTAUT presented by it researchers as the final model incorporates what is known and provides an infrastructure guideline for future research in the context of the acceptance and adoption of technology by users (Venkatesh et al., 2003). Respectively, the validity and reliability of this model for adoption of technological systems have been shown in numerous studies and in different contexts. (Oye, Iahad, & Rahim, 2014). A group of determinates that influence the adoption of new information technology by the user can be divided into two groups of factors; The first group consists of beliefs about the system. For example, determinates: 'perceived usefulness' (PU) and 'perceived ease of use' (PEOU) of the system represent the user belief about the system (Davis, 1989). A second group of factors that influence the acceptance of the information system includes; social factors associated with the user social environment so call "social influence" (Holden & Krash, 2010). Different studies examining the role that these factors play in using the system and the finding shows: users tend to use the system more when they believe that people who they care about, or people who have an impact on their behaviour, think they need to use the system (Lu, 2014; Williams, Rana, & Dwivedi, 2015).

The UTAUT model (Venkatesh et al., 2003) as indicated in Fig. 1, hold four key constructs that influence behavioural intention to use a technology: (1) Performance expectancy (PE)—"the degree to which an individual believes that using the system

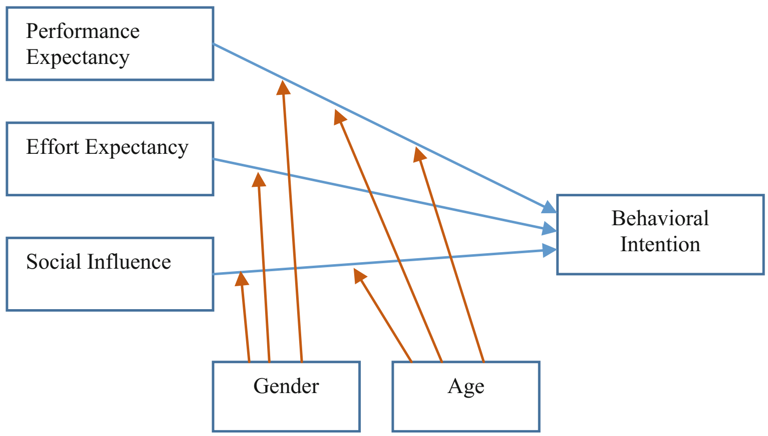

Fig. 1 Structural model of hypothesis

will help him or her to attain gains in job performance". (2) Effort expectancy (EE)—"the degree of ease associated with the use of the system". (3) Social influence (SI)—"the degree to which an individual perceives that important others believe he or she should use the new system". (4) Facilitating conditions (FC)—"the degree to which an individual believes that an organizational and technical infrastructure exists to support use of the system" (Venkatesh et al., 2003, pp. 447–453). As the model, has been tested empirically, three key constructs of the predictors were found as directly determinants of user intention and usage, (1) Performance expectancy (PE) was found to be the strongest predictor at all points for both mandatory and voluntary setting in Venkatesh et al. (2003) study. Performance Expectancy (PE) in the UTAUT model captures the nations of: perceived usefulness, motivation, job-fit, advantage and outcome expectations. (2) Effort expectancy (EE) in the model is similar to perceived ease of use and (3) Social influence in previous models is such as social form and subjective norm, were found also having significant influence on behaviour indentation to use the system but slightly less since it was significant only for the first period of usage. The fourth and last predictor (4) Facilitating conditions (FC) represented organizational support, which has no significant direct impact on initiation to use the information system but had significant direct impact on the actual use of the system. Finally, gender, age, experience and voluntariness of use, were posited as moderating the impact of the four predictors on usage intention as indicated in UTAUT model Venkatesh et al. (2003).

2.1.2 Advantages of UTAUT

Unlike TAM that explain 40% of the user acceptance of new technology, UTAUT model explain over 70% of variance of usage behaviour (Holden & Karsh, 2010). Hence, we can conclude that UTAUT is explaining more factors influencing BI.

As well, it combines all eight base models into one unified model (Venkatesh et al., 2003, pg. 425).

If we compare UTAUT to TAM, UTAUT includes the social influence which is a very important component in today environment, the impact of social media in our daily lives is enormous, it become an integral part of our daily activities. TAM is a simple model and we cannot except from such a simple model that was created in the beginning of the nineties were social media was in it very beginning, to explain decisions on acceptance of technology in a wide range of technologies like we have today.

Since UTAUT is the most up to date technology accepted theory that merge with other theories, the author has chosen to use it in her study.

2.2 Hypothesis

The research model is illustrated in Fig. 1 consistence with UTAUT model. The study criterion variable is surgeon's acceptance of VRH simulator for training, which is surgeon's intention to use and trained with VRH given the opportunity.

Consistence with UTAUT model, the hypotheses will be presented in two relationship categories; one has a direct influence (the independent variables) on behaviour intention (the dependent variable), and the second category has indirect influence on the behaviour intention to use the new technology by moderating the impact of the independent variables.

As the system, haven't been utilized yet, the actual usage behaviour cannot be measured. In consistence with Venkatesh et al. (2003) study (UTAUT) the Behaviour Intention (BI) will be used to predict actual use and the measurement of use will not be applied.

2.2.1 Direct Influence -the Influence of Performance Expectancy (PE), Effort Expectancy (EE) and Social Influence (SI) on Behavior Intention (BI)

As stated by Venkatesh et al. (2003) "Performance Expectancy (PE) is the strongest predictor determinant of behavioural intention".

H1. The greater the Performance Expectancy (PE), the greater will be surgeon's acceptance of the VRH simulator. In other words, PE will have a significant positive influence on behavioural intention to use the VRH.
Effort Expectancy (EE) is similar to 'ease of use' from the original TAM, it means that the expected use will be free of effort (Davis, Bagozzi & Warshaw 1989). Complicated technology that required a- lot of effort will discourage HCP to use it, on the other hand, technologies that perceived to be easy will have higher intention to be used (Holden & Krash, 2010) the effect of EE on BI among Health Care

Professionals was found to be positively associate with BI. (Anja, Heiko, & Ulrich, 2014).

H2. The lower the Effort Expectancy (EE), the greater will be surgeon's acceptance of the VR simulator. In other words, EE will have a significant positive influence on behavioural intention to use the VRH.

Social Influence (SI) is define as the perception of an individual that important others believe he or she should be using the new technology. The influence of SI on BI is significant positive in early stages of experience and affect intention under mandatory situations (Venkatesh et al., 2003).

Although in this study the setting is voluntary, the technology is tested in a very early stage of experience and consequently the propose hypothesis is:

H3. The greater the Social influence (SI), the greater will be surgeon's acceptance of the VR simulator. In other words, SI will have a significant positive influence on behavioural intention to use the VRH.

Facilitating condition is define as the degree to which individual believe he or she has the organizational and technical support to use the new technology and that the support is design to remove barriers to use (Venkatesh et al., 2003).

Although this study is not measuring the actual use;

H4. Facilitating conditions will not have a significant influence on Behavioural Intention to use the VRH. In other word, FC will not directly affect acceptance of the VR.

2.2.2 Indirect Influence—The Influence of the Moderating Variables on the Independent Variables

Venkatesh et al. (2003) have identified in their study four key moderating variables: age, gender, experience and voluntariness. The influence of the moderating variable on the independent variable is presented in

H5. The influence of Performance Expectancy (PE) on behavioural intention will be moderated by age.

H6. The influence of Effort Expectancy (EE) on behavioural intention will be moderated by age.

H7. The influence of Social Influence (SI) on behavioral intention will be moderated by age.

H8. Gender will have no moderated effect on surgeon's acceptance of VRH.

3 Data and Methodology

In this study setting VRH named: HTC Vive was used. HTC vive was released in April 2016.

The hardware (Fig. 2) is containing two Lighthouse base stations for tracking the user movements, two controllers for user interactions and the Headset for immersive experience. To run the experience, a solid PC must be provided. With very high-resolution image given by the Vive Headset, a natural and convenient feeling is displayed, the user can look up and to the side with his eyeballs rather than by moving his entire head. The user can move around his 'real-world' environment without removing the Headset. The Headset is very light since it is the computer that handles all the heavy graphics.

The lighthouse base stations are tracking the motions and the users can move freely in the room what helps the users feel like he can explore the space. The controllers are designed to behave as the user's hands and are interacting with the virtual world—a haptic feedback integrated in each controller, it helps to let the user know when he has completed the correct action.

The author and her colleagues have created an application supported by the HTC Vive which allow the surgeon to enter a surgical virtual environment—(Fig. 3)—this medical environment is a virtual Operation Room (OR) allowing the surgeon to

Fig. 2 HTC Vive hardware (HTC Vive, 2017)

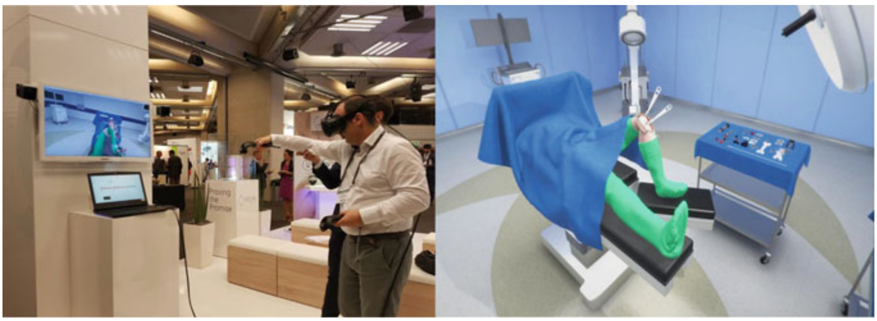

Fig. 3 Left: surgeon in a congress trying the VR simulator using HTC Vive. The screen in the background shows the same sequence as appears to the user in the VR glasses (right)

perform a full operational procedure and "see" the virtual patient. He can assemble the instruments, use them on the virtual patient and also receive a direct feedback while using it.

The surgical procedure presented on the software is a full knee replacement training—open surgery, the trainee can perform the all procedure and learn all the technical steps. Appropriate guidance is provided in order to stimulate the learning mechanism; which tool to pick up from the surgical table and how to place it correctly while using it. For the trainee, this environment giving the feeling like he is inside the real OR, he can move around and even adjust the lights on the patient knee.

4 Method

Johnson and Johnson Medical Devices Company, have sponsored the author to travel and attend two big Scientific congresses (Fig. 3), one is the EKS (European Knee Society) 750 surgeons from all over the world, and the second is EFORT (European Federation of National Associations of Orthopaedics and Traumatology) 10,000 surgeons from around the globe. In the form of these congresses, the author has presented the VRH system as an exhibitor.

As mentioned in previous section, the application presented by the VRH system is a medical simulator for knee replacement.

The VRH simulator attracted a lot of attention and surgeons were coming voluntarily requesting to try this new technology. At the time of the actual use, the author has been guiding each participant on the procedure and acted as a trainer. By the end of the experience (proximity of ten minutes, since the software was designed to stop after ten minutes for exhibition purposes) the study was presented and asked the surgeon for his agreement to answer the questionnaire.

In addition to the congresses, the author has attend a Johnson and Johnson course and met with the orthopaedic department of Saint Jean hospital in Brussels.

The course target audience were; experience surgeons who are using the knee replacement product and procedure. The author presented her study following with the experience; similarly, to the data collection method in the congresses, the questionnaire was handled to the surgeon after trying the VRH simulator.

Data was collected from March 2017 through June 2017, from all above sources. A total of 111 surgeons, have participated in the study. All 111 participants received the questionnaire, 4 responses had to be discarded due to invalid data entries, the sample comprised a total of 107 participants. 95% of the responses were male and aged between 30 to 40 years old (46%) (see Table 1). As the software was developed to support the knee replacement product training, no bias has occurred in group selection.

A structured questionnaire was conducted to capture information from the surgeons. All UTAUT predictors, i.e., Performance Expectancy (PE), Effort Expectancy (EE), Social Influence (SI), Facilitating Conditions (FC) and Behavioural Intention

Table 1 Demographic profile of the sample (N = 107)

Variable	Content	N	%
Gender	Male	102	95
	Female	5	5
Age	30–40	49	46
	41–50	22	21
	51–60	32	30
	>60	4	4
Involved in training	Yes	79	74
	No	22	21
Previous experience with VR	Yes	31	29
	No	76	71

(BI) were measured by used multi item, 5-point Likert-type scales [(1) Strongly disagree, (2) Disagree, (3) Neutral, (4) Agree, (5) Strongly Agree]. The questionnaire is presented in Appendix I. All items were sourced from the original UTAUT model with a small adaptation to the study settings.

The author collected data on age, gender, year of practice, degree of interest in new technology, degree of involvement in training and development and asked if the participant had previous VRH experience. Furthermore, the author and her colleagues were keen to know if the surgeon will recommend VRH training to other surgeons and if he could think in investing into VRH, therefor, two questions were added at the end of the questionnaire.

5 Analysis and Results

Same as in the original UTAUT study (Venkatesh et al., 2003) partial least squared (PLS) was used to analyse the data and SmartPLS as software.

Structural Equation Model (SEM) is examining relationship among variables while including two sub models in the structure such as: Inner model and Outer models. The Inner model is also known as the structural model and should specifies the relationship between the constructs (PE, EE, SI, FC) to Behaviour Intention and to actual use. The Outer model is also known as the measurement model which specifies the relationship between the constructs and gives an overview on how the constructs are measured.

PLS is useful for Structural Equation Model (SEM) as it focusses on the analysis of the variance and it has been proven to be a good analysis technique for small sample size. (Wong, 2013).

Most of the items (indicators) found to be reliable as the loadings were above the recommended 0.7, except items EE3 and SI2 (Table 2), Indicator EE3 was measured in a reversed way, to test the attention of the responders, hence, before import

Table 2 Model's reliability and validity

Construct (latent variable)	Indicators	Loadings	Composite reliability (CR)	Average variance extracted (AVE)
Performance expectancy (PE)	(PE1) Using the virtual reality would enhance my effectiveness on the job	**0.888**	**0.861**	**0.676**
	(PE2) I would find the virtual reality useful for training	**0.709**		
	(PE3) Overall, I believe that the virtual reality is easy to use	**0.858**		
Effort expectancy (EE)	(EE1) Learning to use the virtual Reality simulator is easy for me	**0.874**	**0.858**	**0.671**
	(EE2) Overall, I believe that the virtual reality is easy to use	**0.878**		
	(EE3) It takes too long to learn how to use the virtual reality to make it worth the effort	***0.690***		
Social influence (SI)	(SI1) My management supports new technology in training	**0.866**	**0.795**	**0.568**
	(SI2) I would use Virtual Reality simulator if my friends and colleagues use it	***0.641***		
	(SI3) Hospitals and industry partners encourage surgeons to use VR simulators	**0.736**		
Facilitating conditions (FC)	(FC1) I know the resources necessary to use virtual Reality	**0.733**	**0.847**	**0.651**
	(FC2) I have a technical team in the hospital that can assist me with virtual reality difficulties	**0.777**		
	(FC3) I feel comfortable introducing a virtual reality simulator in my hospital now	**0.902**		
Behavioral intention (BI)	(BI1) I intend to use virtual reality again, given the opportunity	**0.900**	**0.915**	**0.782**
	(BI2) I predict I would use the virtual reality, given the opportunity	**0.880**		
	(BI3) I can imagine using virtual reality regularly for training purposes	**0.872**		
Age*PE	Age*PE1	**0.757**	**0.784**	**0.573**
	Age*PE2	***0.407***		
	Age*PE3	**0.989**		
Age*EE	Age*EE1	**0.748**	**0.858**	**0.669**
	Age*EE2	**0.817**		
	Age*EE3	***0.674***		
Age*SI	Age*SI1	**0.777**	**0.817**	**0.599**
	Age*SI2	**0.711**		
	Age*SI3	**0.849**		

to SmartPLS the indicator was reversed to fit the Likert format similar to the other indicators (=6—response value), this might be the reason for unreliable item. However, EE3 and SI2 were retained since the loading is very close to 0.7.

Composite Reliability (CR) was used to evaluate how well constructed are measured by their items (indicators), all CR values in the model are larger than 0.7 (Table 2), therefor, a high level of internal consistency reliability have been demonstrated among all constructs.

Convergent validity was assessed by evaluating Average Variance Extracted (AVE), it is found that all the AVE values exceed 0.5 (Table 2), so convergent validity is confirmed.

Discriminant Validity was assessed according to Fornell and Larcker (1981), when the square root of AVE in each construct (latent variable) is larger than the correlations between the constructs then discriminant validity exists.

Looking at the inner model path coefficient it is suggested that Performance Expectancy (PE) has the strongest effect on Behavioural Intention (0.469), followed by Social influence (SI) (0.233), and last Effort Expectancy (0.155). Facilitating Conditions had the lowest effect on Behaviour Intention (0.023). For PE, EE and SI the hypothesis path relationship is statistically significant. However, the hypothesized path relationship between FC and BI is not statistically significant. This is because its standardized path coefficient (0.023) is lower than 0.1. Thus, we can conclude that: PE, EE and SI are moderately strong predictors of BI, but FC does not predict BI directly. Furthermore, this finding supports the author hypothesis path relationship, and consistent with the original UTAUT model where FC has no relationship with Behavioural Intention, hence, it was excluded from the final calculation.

Bootstrapping (1000 resample) was used to measure the path significance, testing the inner and the outer model present the result of testing the hypothesis, using two tailed T-statistic, with significance level of 5%. The model was controlled for age as a moderator.

As expected and confirmed by author's earlier finding from PLS-SEM results, 3 out of the 4 constructs relationships were found significant. The model explains 52% of variance associate with Behavioural Intention ($R2 = 0.521$) and 5 hypotheses out of 8 were accepted. Table 2, describe the correlation coefficient, the T-value and the P-value that associate with each relationship in the model. The result support H1 and confirm that Performance Expectancy (PE) has a positive and the strongest impact on surgeon's acceptance ($t = 3.984$, $p = 0$). H2 and H3 were supported and show a significant direct effect of Social Influence (SI) ($t = 2.132$, $P < 0.05$) and Effort Expectancy (EE) ($t = 1.997$, $p < 0.05$) on behavioural Intention (BI). H4 was supported as Facilitating Conditions (FC) was found not significant ($t = 0.256$, $p > 0.05$) and confirm the hypothesis and UTUAT original model, FC does not influence surgeon's BI.

Age was tested as a moderator and did not have a significant effect on PE and EE but did have a significant effect on SI, therefore H5 and H6 were rejected but H7 was accepted. H8 was not tested with consideration to the skewness of the gender distribution.

5.1 Implications and Limitations

UTAUT model was not originally designed to evaluate Health Care Professionals (HCP) acceptance, nevertheless, this study supported the finding of the original model: with 52% of variance explaining BI. Furthermore, PE, EE and SI were found to be statistically significant predictors of surgeon's acceptance of VRH, and FC was found not significant predictor of BI.

If Surgeons perceive the VR simulator as useful, it is most likely to increase their intention to use it, in other words: surgeons will accept the technology when it is considered to be useful to his or her practice. As PE was found to have the strongest impact on BI it is consistent with the finding of Holden and Krash (2010), Li et al. (2013), Williams et al. (2015), Chau and Hu (2002) and many other studies.

To conclude; the critical success factor that influence surgeons accepting the VRH as an educational tool are: (1) Performance Expectancy is a key, emphasize the usefulness and design the software to bring direct benefits to the surgeons in the form of improved effective process. (2) Social Influence has an important role consider surgeons psychological aspects. Increasing the driving force of peer colleagues to use the VR may affect surgeon's behaviour, and will increase their willingness to use the new technology. (3) Effort Expectancy is crucial, time to learn a new system has a consequence on the intention to use. The system must be easy to use. Convincing surgeons that VRH simulator such as HTC Vive is low effort will be important to ensure they see advantages in using the technology.

In this study, some limitation should be considered: the sample was only targeted orthopaedic surgeons on a voluntary basis. The software presented on the VR hardware was only focused on the knee replacement procedure, since it was developed by Johnson and Johnson. These limitations may have affected the study findings, as the result cannot be generalized to other professional groups.

This study has provided a useful contribution to the UTAUT studies and to the medical devices industry as it is the first study on VRH acting as a surgical training simulator, targeting surgeons from all over the world.

Considering the importance of nurses in the OR a future study on HTC Vive acceptance by nurses is suggested. Moreover, future study can investigate other professional groups. With the same study setting a future study is suggested by examining all UTAUT moderating effects and the actual use. The actual use can be examined as soon as the HTC Vive simulator will be integrated in the organizations. Besides, other setting than voluntary can be compered.

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References

Al-Gahtani, S. S., & King, M. (1999). Attitudes, satisfaction and usage: Factors contributing to each in the acceptance of information technology. *Behavior and Information Technology, 18* (4), 277–297.

Anja, N., Heiko, G., & Ulrich, H. (2014). Why do they resist? Examining the salient factors of physicians' it adoption behaviour. In *PACIS 2014 Proceedings*. Paper, 223. http://aisel.aisnet.org/pacis2014/223.

Chau P. Y. K., & Hu P. J-H. (2002). Investigating healthcare professionals' decision to accept telemedicine technology: an empirical test of competing theories. *Information and Management, 39*, 297–311.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly, 13*(3), 319–340.

Davis, F. D., Bagozzi, R. P., & Warshaw, P. R. (1989). User acceptance of computer technology: A comparison of two theoretical models. *Management Science, 35*, 982–1003.

Eshet, Y., & Hammer, R. (2006). *Designing computer-based learning environments, reader* (pp. 357).

Fornell, C., & Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research, 18*(1), 39–50.

Gardner, R., & Raemer, D. B. (2008). Simulation in obstetrics and gynecology.

Holden, R. J., & Karsh, B.-T. (2010). The technology acceptance model: Its past and its future in health care. *Journal of Biomedical Informatics, 43*(1), 159. https://doi.org/10.1016/j.jbi.2009.07.002.

HTC Vive. (2017). Hardware HTC Vive.

Li, J., Talaei-Khoei, A., Seale, H., Ray, P., & MacIntyre, C. (2013). Health Care Provider Adoption of eHealth: Systematic Literature Review. *Interactions Journal Medical Research, 2* (1), e7.

Lu, J. (2014). Are personal innovativeness and social influence critical to continue with mobile commerce? *Internet Research, 24*(2), 134–159.

McGaghie, W. C., Issenberg, S. B., Cohen, E. R., Barsuk, J. H., & Wayne, D. B. (2015). Does simulation-based medical education with deliberate practice yield better results than traditional clinical education? A meta-analytic comparative review of the evidence. *Academic Medicine: Journal of the Association of American Medical Colleges*, *86*(6), 706.

Oye, N. D., Iahad, N. A., & Rahim, N. A. (2014). The history of UTAUT model and its impact on ICT acceptance and usage by academicians. *Education and Information Technologies, 19*(1): 251–270. Retrieved from http://store.steampowered.com/app/358040/HTC_Vive/.

Pulijala, Y., Ma, M., Pears, M., Peebles, D., & Ashraf, A. (2017) Effectiveness of immersive virtual reality in surgical training—A randomized control trial. *Journal of Oral and Maxillofacial Surgery*, ISSN 0278-2391, https://doi.org/10.1016/j.joms.2017.10.002. Retrieved from http://www.sciencedirect.com/science/article/pii/S0278239117312508.

Shen, C. W., Ho, J. T., Kuo, T. C., & Loung, T. H. (2017). Behavioral intention of using virtual reality in learning. In *Proceedings of the 26th International Conference on World Wide Web Companion* (pp. 129–137).

Taheri, S. M., Matsushita, K., & Sasaki, M. (2017). Virtual reality driving simulation for measuring driver behavior and characteristics. *Journal of Transportation Technologies,* (7), 123–132.

Venkatesh, V., & Bala, H. (2008). Technology acceptance model 3 and a research agenda on interventions. *Decision Sciences, 39*(2), 273–315.

Venkatesh, V., & Davis, F. D. (1996). A model of antecedents of perceived ease of use: Development and test. *Decision Sciences, 27*(3), 451–481.

Venkatesh, V., & Morris, M. G. (2000). Why don't men ever stop to ask for directions? Gender, social influence and their role in technology acceptance and usage behavior. *MIS Quarterly, 24,* 115–139.

Venkatesh V., Morris M., Davis G., & Davis F. (2003). User acceptance of information technology: Toward a unified view. *MIS Quarterly, 27,* 425–478.

Venkatesh, V., Sykes T. A., & Zhang, X. (2011). Just what the doctor ordered: A revised UTAUT for EMR system adoption and use by doctors. In *Proceedings of the 44th Hawaii International Conference on System Sciences—2011.*

Williams, M. D., Rana, N. P., & Dwivedi, Y. K. (2015). The unified theory of acceptance and use of technology (UTAUT): A literature review. *Journal of Enterprise Information Management, 28*(3), 443.

Williams, M. D., Rana, N. P., Dwivedi, Y. K., & Lal, B. (2011). Is UTAUT really used or just cited for the sake of it? A systematic review of citations of UTAUT's originating article. In *19th European Conference on Information Systems,* Helsinki.

Wong, K. K. K. (2013). Partial least squares structural equation modelling (PLS-SEM) techniques using SmartPLS. *Marketing Bulletin, 24,* 1–32. Available on http://marketingbulletin.massey.ac.nz.

Wong, K. K. K. (2016). Technical note: Mediation analysis, categorical moderation analysis, and higher-order constructs modeling in partial least squares structural equation modeling (PLS-SEM): A B2B example using SmartPLS. *Marketing Bulletin, 26,* 1–22. Retrieved from www.scopus.com.

Evaluation of Virtual Reality in Orthopaedic Training—A Pioneering Pilot Study

Ronnie Davies, Natasha Moorhouse, Timothy Jung, Saleem Mastan and Bibhas Roy

Abstract This study aimed to evaluate the effectiveness of VR for surgical training and identify the user requirements for surgical training VR applications. Nine orthopaedic surgical trainees were recruited. A multimodal approach was employed using three elements of data collection. This included measurements of head movement while experiencing VR, followed by a survey, and then a one-to-one interview. During the survey and interviews, three key areas were investigated including the technical quality of the VR material, VR usability, and the VR user experience. The VR application design provided surgical trainees with detailed imagery as well as rich information, allowing them to apply theory to practice during remote virtual training. However, several recommendations to improve the quality of the video, the usability, and the user experience are offered. Moreover, the findings suggested a positive educational impact of the VR application, although further evidence is required. Theoretical contributions and avenues for further research are offered together with the implications for practice.

Keywords Virtual reality · Surgical training · Simulation · User experience

1 Introduction

The use of Virtual Reality (VR) has been shown to be of benefit for surgical skills. However, it seems that simulators and three-dimensional (3D) learning for orthopaedic surgery seem to lag behind other disciplines (Johns, 2014). In the past two

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decades, there has been limited research into whether orthopaedic simulators have a role to improve practice, and even fewer studies exploring how this can be validated (Rambani, Ward, & Viant, 2014). Currently, neither simulators nor VR immersive videos are available to a large population of orthopaedic trainee surgeons or fully-qualified surgeons. The majority of simulated teaching comes from courses which need to be self-initiated. Surgical videos provide close-up snapshots of operations, but lack the real-life field of view that is crucial for learning how to operate. For example, in arthroscopic (keyhole) surgery, the view is often of the inside of the joint (from the viewpoint of the camera inside the joint), but it is important to simultaneously see where incisions and instruments are placed outside the patient. There seems to be a shift towards the use of surgical VR. The previous conventional teaching of ‘see one, do one, teach one’ seems to be an inefficient method of learning, with no guarantee of there being a varied case mix, quality of quantity. There is also a growing focus on competency based medical education, which fits in with the restrictions of junior doctor working times. Simulation, and VR in theory, provides trainees to practice and view technical skills in an environment which is safe and does not put the patient safety at risk (Akhtar, Chen, Standfield, & Gupte, 2014). VR immersive videos can now be obtained using 360° cameras which allows procedures to be viewed with a wide field of vision in the operating theatre. Furthermore, detailed operative field views from a secondary camera can be superimposed to provide greater clarity for some parts of the operation. This technology is accessible using standard VR headsets and the trainee’s own mobile phone.

This study explores the effectiveness of VR training for orthopaedic surgeons and identifies several user requirements for surgical training VR applications. The results can be used to optimise the delivery of VR training in surgery. This paper begins with a review of the literature focusing on two separate agendas: (1) the current use of VR in medical and surgical training, and (2) the user experience of VR applications specific to medical and surgical training. The methods and methodologies are then outlined which includes a preliminary intervention and both qualitative and quantitative methods and gathering of head movement data. The VR application design provided surgical trainees with detailed imagery as well as rich information, allowing them to apply theory to practice during remote virtual training. However, several recommendations to improve the quality of the video, the usability, and the user experience are offered which will aid in future development. The findings suggested a positive educational impact of the VR application, although further evidence is required. Finally, the discussion and conclusions are presented followed by the theoretical contribution and practical implications.

2 Literature Review

2.1 VR in Medical and Surgical Training

Laparoscopic surgery is technically demanding and requires specific psychomotor abilities and skills that are different from those required in conventional training (Figert, Park, Witzke, & Scwartz, 2001) and difficult to obtain in the operating room (Scott et al., 2000). The skills required include altered tactile feedback, different eye-hand co-ordination, translation of 2D image to a 3D working area, and the fulcrum effect (Gallagher, McClure, McCuigan, Crothers, & Browning, 1999). Acquiring the skills to become competent is associated with a long learning curve, and extensive training is required in order to be able to move instruments within the operative field safely and effectively (Alaker, Wynn, & Arulampalam, 2016). However, learning such skills can be inefficient, time consuming, and may pose safety concerns for patients (Gallagher, McGuigan, & McClure, 2001). Traditionally, residents have been trained in classic apprenticeship format, practicing basic surgical and laparoscopic skills in the operating room (Yiannakopoulou, Nikiteas, Perrea, & Tsigris, 2015), however, it is now unacceptable to train this way because it exposes patients to potential risk (Alaker et al., 2016). Therefore, learning technical and non-technical skills outside the operating room has become an essential part of surgical training (Nagendran, Gurusamy, Aggarwal, Loizidou, & Davidson, 2013; Seymour, Gallagher, Roman, O'Brien, Bansal, Anderson et al., 2002), and current methods include physical box training and video training while more recent research has begun to investigate VR training and VR simulation training.

VR simulation trainers digitally recreate the procedures and environment of laparoscopy (Buckley, Nugent, Ryan, & Neary, 2012). In comparison to 2D videography, VR provides an enhanced visual overview of the procedures being performed and offers a more realistic experience as if the trainee is in the operating room. Research has indicated that training in VR simulators could improve the technical skills of surgical trainees (Nagendran et al., 2013). The use of simulation training in education has been recognised for some time and in medical education it has taken a variety of settings (Gorman, Meier, & Krummel, 1999). Simulation is the replication and modelling of real-life situations for training, testing, and other purposes such as scenario planning and design verification (H. R. H. Patel & B. P. Patel, 2012). It can be any educational program or technology that removes the actual patient from the equation to allow novice learning and skill mastery to occur in a low-stress, high-feedback environment, while protecting the patient from procedural inexperience (H. R. H. Patel & B. P. Patel, 2012). Hence, VR simulators provide basic skills training without supervision in a controlled environment that is free of pressure of operating on real patients (Yiannakopoulou et al., 2015). The skills obtained through VR simulators are transferable to the operating room (Yiannakopoulou et al., 2015). In addition, VR simulators produce objective measures of performance, allow for real-time feedback to trainees, and is a safe, ethical, and repeatable alternative for early-stage surgical trainees to acquire technical skills for laparoscopic surgery (Nagendran et al., 2013). Therefore, in addition to physical box trainers and video trainers, VR simulation has become increasingly used for surgical training.

Researchers have begun to compare the benefits of VR training for medical and surgical training with traditional methods (e.g. Alaker et al., 2016; Gurusamy, Aggarwal, Palanivelu, & Davidson, 2009; Huber et al., 2017; Nagendran et al., 2013; Yiannakopoulou et al., 2015). For instance, Gurusamy et al. (2009) conducted a large systematic review exploring the effectiveness of VR training for laparoscopic training in comparison with video trainer training, no training, standard laparoscopic training or different methods of VR training in surgical trainees with limited or no previous experience. The authors concluded that residents who were trained with VR perform surgery faster than those with conventional training and is at least as effective as video trainer training (Gurusamy et al., 2009). Through a meta-analysis, Alaker et al. (2016) found that VR simulation is significantly more effective than video trainers and at least as good as box trainers. Similarly, Nagendran et al. (2013) found that VR training decreases the operating time by an average of ten minutes, and improves the operative performance of surgical trainees with limited laparoscopic experience when compared with no training or with box-trainer training. Similar reviews have also explored shoulder arthroscopic VR (e.g. Müller, Ziegler, Bauer, & Soldner, 1995; Sutherland, Bresina, & Gayou, 1994). However, it is unknown whether the impact of the decreased time and improvement in operative performance on patients and healthcare funders in terms of improved outcomes or decreased costs (Nagendran et al., 2013). Therefore, further well-designed trails and low risk of bias and random errors that assess the impact of VR training on clinical outcomes are required (Nagendran et al., 2013).

2.2 VR User Experience

In order for any VR training programme to be effective, it needs to demonstrate acceptability, validity, reliability, and reproducibility in the real life operating environment (Buckley et al., 2012). One key element in the design of any VR system is generating a realistic sense of immersion, which is the technology objective aspect of VR (Gorman et al., 1999; Mestre, 2018). Optimal interpretation of the graphical images enables a fuller understanding of the virtual environment, and this experience is enhanced by high-resolution display devices viewed through a Head Mounted Display (HMD) (Burt, 1995; Coleman, Nduka, & Dazi, 1994; Gorman et al., 1999; Vince, 1995). To further enhance the sense of immersion, other sensory cues such as auditory and haptic can be added and there is considerable evidence demonstrating that more sophisticated VR technology results in increased presence (Bãnos et al., 2004; Diemer, Alpers, Peperkorn, Shiban, & Mühlberger, 2015; Gorman et al., 1999; Martin, Gonçalves, Branco, Barbosa, & Melo, 2017). Another important element in the design of virtual environments is interactivity because it allows the user to navigate, and can be achieved through hand tracking devices, motion coupled HMDs, and motion-tracking bodysuits (Burdea, 1996; Coyle & Thorson, 2001; Gorman et al., 1999; Jin, 2009; Keller & Block, 1997; Klein, 2003; Li et al., 2001; Steuer, 1992). The highly visual and interactive nature of VR has proven to be useful in understanding complex 3D structures and for training in visuospatial tasks (Hoffman & Vu, 1997). This recognition has meant there has been an increasing interest in developing VR-based applications for surgical education and training for over a decade (Gorman et al., 1999), and according to Alaker et al. (2016), the incorporation of VR into surgical training curricula is now necessary. For surgical trainees, the development of low-cost VR surgery using more affordable headsets (e.g. Google Cardboard and Google Daydream) is vital (Riva & Wiederhold, 2015), given that desktop VR applications require expensive HMDs and high specification computers that are likely unaffordable for this target market (Pulijala, Ma, Pears, Peebles, & Ayoub, 2018). Given that VR experiences are increasingly used for surgical training (Khor et al., 2016), a framework to build effective VR solutions is required (Pulijala et al., 2018). Therefore, this study aims to determine the specific user requirements, usability, and design factors of VR for surgical training as a preliminary phase to developing a framework to build effective VR solutions in this specific context.

3 Method

3.1 Study Design

A pilot study is a requisite step in exploring a novel intervention or an innovative application of an intervention (Leon, Davis, & Kraemer, 2011). Therefore, a pilot study was conducted to evaluate the feasibility of recruitment, assessment procedures, methods, and implementation of the novel intervention to be used in a subsequent larger scale study (Leon et al., 2011). In collaboration with Mativision, a VR content provider, a surgical video of a keyhole shoulder operation was recorded and developed into a VR mobile application. The viewing technology required for the intervention included a mobile phone inserted into a VR headset to view the surgical training video, and another mobile phone housed with the application Sensor Play to measure gyroscopic data. The mobile phone inserted into the headset was provided by each participant.

To evaluate the effectiveness of VR for surgical training, this preliminary study employed a multimodal approach using three elements of data collection including measurements of head movement while experiencing VR, followed by a survey, and then a one-to-one interview. The interviews were conducted by an upper limb consultant in June 2018 and lasted between fifteen and twenty-five minutes. This included five minutes to watch the video and between ten and twenty minutes to complete the survey and for further discussion. The developed survey comprising of 32 questions using Likert Scale (strongly disagree—strongly agree) was divided into three domains: (1) technical quality of the material, (2) usability and (3) user experience. Qualitative data was required to gather data from open-ended questions that could not be measured quantitatively from the survey.

3.2 Sample and Participant Profile

The population is Orthopaedic surgical trainees in the UK. From this population, nine participants from the North West were recruited at the end of their formal compulsory teaching. Participants were all males aged between 26 and 40 years old and represented a typical trainee orthopaedic demographic. Out of the nine participants, six were senior orthopaedic trainees and the remaining three where junior trainees committed to surgery, but not necessarily orthopaedic surgery. All participants were trailing the VR application for the first time. The VR application was appropriate for both levels of trainees because depending on their level of knowledge, each trainee will draw on a different skill from the VR application (e.g. focusing on the specific details of the task at hand, or gaining knowledge on the environment). To recruit participants, the upper limb consultant asked for nine volunteers to take part in the study at the end of the weekly teaching session. Nine trainees volunteered and took part in the data collection.

3.3 Intervention

For the intervention, each participant watched one five-minute 360° video on shoulder arthroscopy in VR. The shoulder arthroscopy video was filmed for the purpose of this study. In order to achieve this, one 360° camera was located near the primary operator for the duration of the surgery. Recording the surgery in 360° allowed the participant trainees to rotate their heads to explore the complete field of view. Two picture-in-picture screens were overlaid onto the video to provide more in-depth viewings and educational information. This included (1) a focused view of the operation and (2) a PowerPoint presentation with narration of the operation. Once the participant had trailed the VR surgery, both written and verbal feedback was obtained using the survey and interview, respectively.

3.4 Data Collection

During the qualitative and quantitative data collection, three main elements were explored. The first is technical quality of the material. This includes ensuring the intricate details of the 360° video are sufficient for surgical training, and whether the video is viewable from a logistical and practical point of view. The second is usability, which explores the ease of use of the VR HMD, navigating the application, and learning from the 360° video and the picture-in-picture overlays. Finally, the user experience investigated the level of immersion achieved by the VR application, and its impact on educational outcomes. More specifically, a comparison between VR and previous methods (e.g. watching videos) was made in order to draw out recommendations to improve the overall user experience. This was important because if the user experience is inadequate, then the longevity of VR for surgical training would not be maintained. Together with the qualitative and quantitative data, head movement data was measured. Gyroscopic data was recorded on a mobile phone, which was attached to the back of the participant's head.

3.5 Data Analysis

A total score was calculated for each participant survey. From the initial survey score, it was evident that there was a consensus with the points that participants scored higher than others, which demonstrated areas that required further discussion and development, and those areas that were particularly effective. Therefore, the interview questions were used for the purpose of expanding on the survey outcomes only. To investigate the technical quality of the material, an example of the questions asked is, "*Was the quality of the video adequate for learning a procedure?*". An example of the usability questions include "*How comfortable was wearing the headset?*", and for the user experience, "*Can you tell me how the experience could be improved?*". The interview data was reviewed and a general consensus gathered in order to further support the discussion on the survey data. To analyse the gyroscopic data, the radian data files were exported from the mobile application to Excel, which demonstrated the calibration from each participant's resting head movement. It was important to measure the head movement data because often surgical videos are recorded by attaching a camera to the light above the operation, and it is important for the light to be focused directly on the subject. With VR, this could mean that the user is looking down which could put a lot of pressure on the user's neck and cause discomfort. Therefore, it was important to evaluate whether the angle on the VR video recording was appropriate for the user to have a comfortable neck position while using VR.

4 Results

4.1 Interview and Survey Data

4.1.1 Technical Quality of Material

The findings demonstrate that the quality of the VR 360° video was compatible and worked well with their mobile phones. The detail in the 360° video was clear enough to provide a sufficient view of the operating theatre ("*[The video] provided a good overview of the whole operating theatre*", and, "*It was good to see the arthroscopic view and which portals were being used at the same time, which other videos lack*"). However, when displaying the intricate steps of the operations, improved graphics and video quality is required ("*[The detail view] was very grainy and I couldn't make out much*", and, "*I think the video quality was worse than Vumedi*"). The picture-in-picture video of the surgical field improved the detail of the important steps, however, this was subject to the resolution of the mobile phone used. The tutorial that was recorded using PowerPoint and displayed as picture-in-picture was perceived as useful in helping the participants orientate to the video and navigate the software ("*I wouldn't have managed without the training video at the start*"). Several participants felt that the position of the picture-in-picture could have been improved largely because it led to them looking down towards the ground which may become uncomfortable for prolonged periods ("*[To improve the experience] made sure the arthroscopy view is easy to see…not too high*"). Additional suggestions with regards to content include a "*clear narration of what's happening*" and "*3D view of the shoulder*".

4.1.2 Usability

VR is advantageous given that it can be accessed remotely and from any location, which is attractive for this particular group of participants as expressed in the interviews. However, this is reliant upon the trainee having the appropriate equipment to view the VR 360° videos including a VR headset and mobile phone housing the surgical training application. Participants reported an average of a 20–30% drop in battery capacity during the viewing of the tutorial and a 5 min video. Hence, the usability limitations include having access to a VR headset, which may be centralised, and the reported drop in phone battery capacity after only five-minutes usage ("*Battery life [would stop me using VR]. It killed my phone*"). However, this could be overcome by providing trainees with a VR headset and mobile phone, rather than relying on participants using their own. Therefore, a recommendation to improve the experience was to provide a phone charger or the ability to charge the phone while using VR. An additional usability barrier is the limited number of videos readily available in VR at the moment ("*having the [VR] goggles*" and "*not enough videos*"). The weight of the VR headset was considered suitable ("*Not as heavy as it looks*") and several participants felt comfortable wearing the headset once they had gravitated towards wearing it ("*I felt a bit disorientated at first…I forgot I was wearing it after the video started*"). However, others suggested that the headset could be made more comfortable for those wearing glasses, which indicates the need for an improved focusing function ("*It pushed my glasses into my face which wasn't great*").

4.1.3 User Experience

The VR application was well received from all participants, however, recommendations to improve the user experience were provided. The system usability score (SUS) was 47, placing this technology in the lower 10th percentile rank of systems. This was largely due to a rather difficult user interface, which was evident given that participants reported issues navigating within the app to find the appropriate video, along with difficulties controlling the videos (e.g. stop/play/rewind) ("*[The VR application] is not very intuitive…it needs a rewind button*", and, "*I would like to jump forward to skip parts [of the video]*"). Five-minutes was considered a reasonable amount of time for VR surgical training videos. It was suggested that videos exceeding fifteen minutes would be too long to be used frequently, and therefore could reduce usage and acceptance ("*I wouldn't wear it for more than 15 min*"). In addition, VR was considered more enjoyable than watching videos ("*[VR is] much more fun than a normal video*"), and allowed participants to have more control over the area of the video they were focusing on ("*It was up to me what I looked at, not the cameraman*", and, "*I liked being able to look around and focus on more than just the arthroscopic view*"). This is largely because of the immersive nature of VR in that participants felt like they were present in the operating theatre ("*I felt part of the operation*"). Participants also felt that a more detailed picture-in-picture with waypoints to jump to certain parts of the operation would help with the learning, rather than treating it as a linear video. As a revision tool before any practical procedure the junior may undertake, it was clear that this 360° video could be effective in providing a more detailed insight along with a clear explanation with the parallel PowerPoint presentation, when compared with a 2D video. This rich provision of multimodal information was widely accepted as a benefit over standard 2D videos.

4.2 Head Movement Data

Regarding head movement data, objective head movements showed that 88% of the time the head was in a neutral position or was looking slightly up (10–30°) towards the detailed view. Extremes of movement were generally avoided and when interviewed, participants felt comfortable and were not physically fatigued after viewing.

5 Discussion and Conclusion

The aim of this study was to investigate the effectiveness of VR for surgical training and identify the user requirements for future VR applications in the field. Overall, this study demonstrated the importance of high quality resolution displays when developing VR surgical training applications, particularly when displaying the intricate steps of the operation. Although this is preliminary research, the findings indicated the effectiveness of VR as a training tool for surgical trainees compared with previous methods. More specifically, the design of the VR application used for this study provides trainees with detailed imagery as well as rich information, allowing them to apply theory to practice during remote virtual training. A limitation with regards to the usability is the trainee surgeons having access to VR hardware. Several improvements were suggested to develop user-friendly VR surgical training applications. This study suggests that VR could improve educational outcomes for surgical trainees, although further research into the effectiveness of VR as a means of training is required.

6 Theoretical Contribution and Practical Implications

This preliminary study demonstrates several benefits of VR for surgical training with specific focus on trainee orthopaedic surgeons. The findings could be useful for VR developers in designing and developing effective VR surgical training and medical applications. Traditional teaching methods have been effective, however, given that emergent technologies such as VR provide important benefits in comparison to traditional methods, it is important that health practitioners take advantage of such technologies. The ideal future scenario for a surgeon to train would be a complete VR simulation using near to real human tissue, without causing any patient harm. The use of immersive technology such as VR for learning in healthcare has scope for further progression to improve surgeon education and familiarity with a procedure before the trainee operates on a patient. A drawback of VR training is the cost involved (Bashir, 2010). In particular, substantial time and costs are required for VR simulator training (Yiannakopoulou et al., 2015), therefore, this will likely be applicable for similar VR applications developed for this study.

7 Limitations and Future Research

A limitation of this study is the recruitment of a small sample of trainees at two levels of training and from one training institute within the UK. Residents, novice surgeons, and surgeons at various levels of expertise are required to learn basic skills, to be trained in basic and advanced laparoscopic procedures or to be trained in rarely encountered situations, therefore, the effectiveness of VR training should be evidenced for different levels of human behaviour (Yiannakopoulou et al., 2015). Another limitation of this study is that the gyroscopic data did not provide data on eye-tracking. Indeed, eye-tracking is important for future VR developments in the medical field because the unique feature of VR in comparison to 2D videos is that trainees can have a full immersive view of the operating theatre in 360°. Therefore, evaluating eye-tracking is important to determine whether trainees, particularly junior trainees, are taking advantage of the 360° element and viewing the surrounding environment. Although this study aimed to evaluate the educational impact of immersive learning, the data was limited. There is no standardised format to assess whether VR has a positive effect on surgical education, and future research is required to assess the educational impact of this technology on surgical training. For instance, future studies could evaluate whether immersive VR learning experiences results in higher retention for trainees in comparison to previous methods. This preliminary study provides a basis on which future studies will aim to develop a new methodology for evaluating VR training.

References

Akhtar, K. S. N., Chen, A., Standfield, N. J., & Gupte, C. M. (2014). The role of simulation in developing surgical skills. *Current Reviews in Musculoskeletal Medicine, 7,* 155–160.

Alaker, M., Wynn, G. R., & Arulampalam, T. (2016). Virtual reality training in laparoscopic surgery: A systematic review & meta-anaysis. *International Journal of Surgery,* 85–94.

Bãnos, R. M., Botella, C., Alcañiz, M., Liano, V., Guerreo, B., & Rey, B. (2004). Immersion and emotion: Their impact on the sense of presence. *Cyberpsychology Behaviour, 7,* 734–741.

Bashir, G. (2010). Technology and medicine: The evolution of virtual reality simulation in laparoscopic training. *Medical Teacher, 32*(7), 558–561.

Buckley, C. E., Nugent, E., Ryan, D., & Neary, P. C. (2012). Virtual reality—A new era in surgical training. In Eichenberg, C. (Ed.), *Virtual reality in psychological, medical and pedagogical applications.* IntechOpen (pp. 140–166).

Burdea, G. (1996). *Force and touch feedback for virtual reality*. New York, NY: Wiley.

Burt, D. E. (1995). Virtual reality in anaesthesia. *British Journal of Anaesthesia, 75,* 472–480.

Coleman, J., Nduka, C. C., & Darzi, A. (1994). Virtual reality and laparoscopic surgery. *British Journal of Surgery, 81,* 1709–1711.

Coyle, J., & Thorson, E. (2001). The effects of progressive levels of interactivity and vividness in web marketing sites. *Journal of Advertising, 15,* 65–77.

Diemer, J., Alpers, G. W., Peperkorn, H. M., Shiban, Y., & Mühlberger, A. (2015). The impact of perception on presence and emotional reactions: A review of research in virtual reality. *Frontiers in Psychology, 6,* 26.

Figert, P. I., Park, A. E., Witzke, D. B., & Schwartz, R. W. (2001). Transfer of training in acquiring laparoscopic skills. *Journal of the American College of Surgeons, 193,* 533–537.

Gallagher, A. G., McClure, N., McGuigan, J., Crothers, I., & Browning, K. (1999). Virtual reality training in laparoscopic surgery: A preliminary assessment of minimally invasive surgical training virtual training (MIST VR). *Endoscopy, 31,* 310–313.

Gallagher, A. G., Ritchie, K., McClure, N., & McGuigan, J. (2001). Objective psychomotor skills assessment of experienced, junior, and novice laparoscopists with virtual reality. *World Journal of Surgery, 25*(11), 1478–1483.

Gorman, P. J., Meier, A. H., & Krummel, T. M. (1999). Simulation and virtual reality in surgical education. *The Archives of Surgery*, *134*.

Gurusamy, K. S., Aggarwal, R., Palanivelu, L., & Davidson, B. R. (2009). Virtual reality training for surgical trainees in lapaoscopic surgery. *Cochrane Database System Review, 1*.

Hoffman, H., & Vu, D. (1997). Virtual reality: Teaching tool of the twenty-first century? *Academic Medicine, 72,* 1076–1081.

Huber, T., Paschold, M., Hansen, C., Wunderling, T., Lang, H., & Kneist, W. (2017). New dimensions in surgical training: Immersive virtual reality laparoscopic simulation exhilarates surgical staff. *Surgical Endoscopy, 31,* 4472–4477.

Jin, S. A. A. (2009). The roles of modality richness and involvement in shopping behaviour in 3D virtual stores. *Journal of Interactive Marketing, 23,* 234–246.

Johns, B. D. (2014). *The creation and validation of an augmented reality orthopaedic drilling simulator for surgical training* (Ph.D. thesis). University of Iowa.

Keller, P. A., & Block, L. G. (1997). Vividness effects: A resource-matching perspective. *Journal of Consumer Research, 24,* 295–304.

Khor, W. S., Baker, B., Amin, K., Chan, A., Patel, K., & Wong, J. (2016). Augmented and virtual reality in surgery—The digital surgical environment: Applications, limitations and legal pitfalls. *Annals of Translational Medicine, 4,* 454–464.

Klein, L. R. (2003). Creating virtual product experience: The role of telepresence. *Journal of Interactive Marketing, 17*(1), 41–55.

Leon, A. C., Davis, L. L., & Kraemer, H. C. (2011). The role of interpretation of pilot studies in clinical research. *Journal of Psychiatric Research, 45*(5), 626–629.

Li, H., Daughert, T., & Biocca, F. (2001). Impact of 3-D advertising on product knowledge, brand attitude, and purchase intention: The mediating role of presence. *Journal of Advertising, 31*(3), 43–57.

Martins, J., Gonçalves, R., Branco, F., Barbosa, L., & Melo, M. (2017). Multisensory virtual experience model for thematic tourism: A port wine tourism application proposal. *Journal of Destination Marketing & Management, 6,* 103–109.

Mestre, D. R. (2018). *Immersion and presence*. 1–10.

Müller, W. K., Ziegler, R., Bauer, A., & Soldner, E. H. (1995). Virtual reality in surgical arthroscopic training. *Introduction to Journal of Image Guided Surgery, 1*(5), 288–294.

Nagendran, M., Gurusamy, K. S., Aggarwal, R., Loizidou, M., & Davidson, B. R. (2013). Virtual reality training for surgical trainees in laparoscopic surgery. *Cochrane Database of Systematic Reviews, 8*.

Patel, H. R. H., & Patel, B. P. (2012). Virtual reality surgical simulation in training. *Expert Review of Anticancer Therapy*, *12*(4), 417+.

Pulijala, Y., Ma, M., Pears, M., Peebles, D., & Ayoub, A. (2018). An innnovative virtual reality training tool for orthognathic surgery. *International Journal of Oral Maxillofacial Surgery, 47,* 1199–1205.

Rambani, R., Ward, J., & Viant, W. (2014). Desktop-based computer-assisted orthopedic training system for spinal surgery. *Journal of Surgical Education, 71,* 805–809.

Riva, G., & Wiederhold, B. K. (2015). The new dawn of virtual reality in healthcare: Medical simulation and experiential interface. *Studies in Health Technology & Informatics, 219,* 3–6.

Scott, D. J., Bergen, P. C., Rege, R. V., Laycock, R., Tesfay, S. T., Valentine, R. J., … Jones, D. B. (2000). Laparoscopic training on bench models: Better and more cost effective than operating room experience? *Journal of the American College of Surgery, 191,* 272–283.

Seymour, N. E., Gallagher, A. G., Roman, S. A., O'Brien, M. K., Bansal, V. K., Andersen, D.K., et al. (2002). Virtual reality training improves operating room performance: Results of randomised, double-blinded study. *Annals of Surgery, 236*(4), 458–464.

Steuer, J. S. (1992). Defining virtual reality: Dimensions determining telepresence. *Journal of Communication, 42,* 73–93.

Sutherland, C. J., Bresina, S. J., & Gayou, D. E. (1994). Use of general purpose mechanical computer assisted engineering software in orthopaedic surgical planning: Advantages and limitations. *Computerised Medical Imaging and Graphics, 18,* 435–442.

Vince, J. (1995). *Virtual reality systems*. Reading, MA: Addison-Wesley Publishing Co.

Yiannakopoulou, E., Nikiteas, N., Perrea, D., & Tsigris, C. (2015). Virtual reality simulators and training in laparoscopic surgery. *International Journal of Surgery, 13,* 60–64.

Part VII
VR and Media

Towards the Essence of Cinematic VR: Embracing New Technologies to Define a Medium

Sarah Jones

What is the essence of VR, its inner spirit, the cultural motor that propels the technology?
(Michael Heim, The Metaphysics of Virtual Reality, 1994).

Abstract Heim is concerned with the essence of Virtual Reality; the meaning behind the technology. These philosophical questions are not new. Heidegger, McLuhan and Heim are all influential in bringing together ideas about experience and technology that can be applied in a new way to immersive media. Coyne (1995) later brought the thinking together drawing on Heim's idea that new realities and worlds would unfold within virtual reality. He urged us to take a Heideggerian approach that would value the technology in a new way, not bound or limited by previous constraints of what it is. As Heidegger explored the relationship with technology to be one that when experienced is able to freely develop to discover a true sense of meaning, McLuhan argued that the meaning can be found in the characteristics of the medium, not simply by the content (1964). This work is situated at the intersection between these philosophical approaches, media and technology to define a new genre of immersive media. It provides an introduction to the essence of immersive media, one where cinematic VR is no longer classed within film studies. Through an analysis of experiences that have been cited as defining the medium and pushing the boundaries of what is expected, new approaches are defined. Through a playful, experimentation approach, lessons in creating are documented to inform future forms of immersive experiences. This is no longer rooted in any one practice but, as Pimentel and Teixeira noted, merging all forms into VR, through simulation and stimulation, it's the "emergence of a new holistic art experience of the mind" (1993:240).

Keywords Cinematic VR · Media · Immersive technologies

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1 Introduction

People come to the Oasis for all the things they can do. They stay for all the things they can be. Ready Player One (film)

In the virtual world depicted by Spielberg in Ready Player One (2018), it is a world that allows for maximum opportunities and maximum personalities. The Oasis is virtual reality for those living in 2045. This is not a futuristic thought. Developments in immersive technologies allow for a range of interdisciplinary applications. Studies have shown the possibilities of responding to alien objects as if they are part of one's body (Botvinick & Cohen, 1998) or believing that another body is one's own (Petkova & Ehrsson, 2008; Slater, Spanlang, Sanchez-Vives, & Blanke, 2010). Other multi-sensory work has been used to demonstrate ultra-reality within art spaces (Ikei, Abe, Hirota, & Amemiya, 2012) and to develop work within memory studies (Dinh, Walker, Hodges, Song, & Kobayashi, 1999; Lehmann & Murray, 2005). The varied approaches have allowed virtual reality to permeate many aspects of life from training to education to entertainment and are spread across academic research.

With the advancement in technology and accessibility placing considerable value on an industry estimated to be worth 40 billion dollars by 2020 (Orbis, 2017), it is time to review how we think about the technology. With a rush to flood the medium with applications and content, fundamental questions about what we learn, how we use and how the technology can transform thoughts and behaviours need to be addressed. These ideas have roots in philosophical traditions of Heideggerian thoughts (1975) and further developed by Heim asking "What is the essence of VR, its inner spirit, the cultural motor that propels the technology?" (1993). In later literature, Lanier noted that "the most important thing about technology is how it changes people (2010).

In this chapter, these questions will be interrogated to challenge how we think about immersive technology to define a new medium. The approach is at the intersection of scholarly traditions in philosophy, media and technology and applied to recent practice.

2 The Essence of Immersive Media

The importance of defining immersive media begins with the provocation that 360° media and cinematic virtual reality is not *situated* within film studies, nor games studies. The call is to use the approach of philosophy, media and technology to create the future form, rather than developing an existing media practice.

When we look at how media has developed throughout history, clear categories emerge from the first printing press (1440), the typewriter (1870) the telephone (1876), the radio (1895), the television (1925). It is a lot later that computer programme technologies were developed with the Collossus in 1943 and the microchip in 1958. In 1960s, the first developments in simulations and virtual environments began to take place with Morgan Heilig and the Sensoramna in 1960 and Ivan Sutherland building the first headset, harnessed to the ceiling, in 1968. Augmented reality with virtual 3D objects imposed on real ones started being developed in 1990 with the first augmented reality theatre production by Julie Martin in 1994. Despite this and Nintendo releasing the Virtual Boy in 1995, the technology plateaued and it didn't become publicly accessible until the current wave emerging in 2014. With this distinct timeframe for the technology emerging, it is clear how it forms a space in itself, rather than being aligned simply with film or television. Immersive media is distinct. It is not part of the gaming culture. Neither is it part of film culture.

Literature in the field of immersive media is limited. Since the current wave of the technology emerged with the acquisition of Oculus by Facebook in 2014 and the accessibility of cardboard headsets in the same year, there has been a rise in research in the field of study but it is still limited. Traditionally scholarly work has focused on the areas of computer science (Burdea Grigore & Coiffet, 1994), education (Byrne & Furness, 1994) and health (Haluck & Krummel, 2000) but a new field of study is emerging (Jones, 2017; Mateer, 2017).

It is critical to extend ideas and research to early stages of the emergence of the technology, particularly in the eighties and the nineties. It is at this time that significant research studies were being carried out and the conceptualisation of important notions. Presence is one of the defining features of immersive media and one that needs to be drawn out and understood. The notion of *presence*, which is a term that has multiple, contested scholarly origins. However, in the context of these varying definitions, the concept of presence discussed here is informed by Pimentel and Teixeira (1993), who describe the suspension of all disbelief in the world and believing that the mediated world is, in fact, not mediated as the condition of being present (Lombard & Ditton, 1997). It draws upon film theory (Ferri, 2007) and the origin of its term in literary theory by Coleridge, connecting engagement and suspension of judgment.

Place is also an important feature in capturing a sense of presence in an experience. Slater, Pérez Marcos, Ehrsson, and Sanchez-Vives, (2009) argued for Place Illusion (PI) as one of two illusions necessary for an experience to be conducive to gaining presence. He argues that PI is how the world is perceived, with the second necessary illusion being Plausibility, relating to what is perceived, suggesting that the scenario being depicted is actually happening. The illusions are binary and are either experienced or not, "you cannot partially get an illusion" (2009:11). With emerging technology, creating a sense of Place Illusion is achievable but the questions rely on Plausibility to believe that this is happening at that specific time. Place and Plausibility Illusions are developed by Skarbez, Brooks, and Whitton, (2017) with the emphasis on virtual embodiment as bring critical to achieving presence with 90% of participants surveyed citing the importance of this. The findings developed notions from De La Peña et al. (2010) where presence was cited as being the combination of Place, Plausibility and the Virtual Body. Although De La Pena's work is situated within immersive journalism, this conflicts with the majority of factual storytelling approaches within immersive media, where there is no virtual body (Jones, 2017). Often this is the distinction between cinematic VR with 360° spherical cameras and CGI where limitations in technology often restrict embodied presence.

To develop the technology to its full potential, it is useful to understand arguments that immersive media, as a practice, should be developing a distinct form of media and this may not use Place Illusion to create presence. Should the virtual world experienced be one that is distinct, not like reality but one deep in our imagination? This forms the arguments provided by Lanier (2017) beginning with the early emergence of technology when he argued that VR was like a Cyberdelic Experience (Barlow, 1990). This wasn't an attempt to link experience to psychedelic ones but rather because "it is as challenging to describe to the uninitiated" (in Barlow, 1990). In more recent works, Lanier has expressed concern that the potential of VR is being diminished, asking "What happened to the dream of improvising reality? Shared lucid dreaming? I mean, what's the point of just making a flashier type of movie or video game?" (2017:6). This approach is at conflict with the elements of presence required in Slater and De La Pena's work. There is no sense of relatability or plausibility in the environment and yet what Lanier argues is a world beyond conceived reality. In developing this line and applying it to cinematic VR, the argument here is that presence can still be found in this world and disbelief suspended. It is when we reach this point that we begin to see new practices emerging. As Lanier concludes, "this thing we seek, it's a way of being that isn't tied just to our given circumstances in the world" (2017:3).

The field of immersive media is not new. It has evolved through decades of thought and work around story, narrative and computer science. Through applying previous theoretical ideas that were limited to computer generated virtual environments, the work can be applied in a new context. Walser's idea of the 'spacemaker' (1991) and Laurel's definitive work on *Computers as Theatre* (1991, 2013) provide ideas of how we can locate presence within immersive storytelling. Laurel suggests theatre is a powerful metaphor to create virtual worlds: "at the theatre we relax our psychic boundaries to become engaged with the action, feel empathy with the characters and struggle with the problems enacted on the stage" (Pimentel & Teixeira, 1993:156).

3 Immersive Media at the Intersection of Philosophy, Media and Technology

The questions behind the technology were raised by Heim in 1994, asking:

> What is the essence of VR, its inner spirit, the cultural motor that propels the technology? (Michael Heim, The Metaphysics of Virtual Reality, 1994).

These philosophical questions are not new. The technological influence from a phenomenological perspective of experience and discovery guides the thinking on what the crucial parameters of immersive media are. Phenomenology allows for the understanding of the impact of technology on experience and consciousness (Borgmann, 1987; Dreyfus, 1992; Heidegger, 1977). Heidegger, Macquarrie, and Robinson, (1962) began to explore humanity's relationship with technology as something that is experienced when it is able to freely develop to discover a true sense of meaning, with Merleau-Ponty (2013) analysing where our philosophy is developed by the experience of bringing truth into being. This approach seeks to articulate the essence of technology, where much deeper perspectives of immersive media can be developed as the technology advances. Heidegger explains that the essence of technology is nothing technological, arguing for a return to the beginning, before technological advances (Dreyfus, 1992; Heidegger 1977). The technology does not make sense in itself so we need to understand what the technology is revealing to us, or disclosing to us, to fully understand its meaning and place in society (Heidegger 1977:2).

As Heidegger describes:

> Whoever builds a house or a ship or forges a sacrificial chalice reveals what is to be brought forth, according to the perspectives of the four modes of occasioning. This revealing gathers together in advance the aspect and the matter of ship or house, with a view to the finished thing envisioned as completed, and from this gathering determines the manner of its construction. Thus what is decisive in techne does not lie at all in making and manipulating nor in the using of means, but rather in the aforementioned revealing. It is as revealing, and not as manufacturing, that techne is a bringing-forth

In this approach, these ideas are applied to the practice of storytelling, and how new forms of technology permit new story forms to emerge, along with new patterns of experiencing the world and the stories it has to tell. A simple example may be found in a recent virtual reality piece by Marshmallow Laser Feast, which it titled 'Treehugger' (2016). In this work, the immersive experience asks the viewer to step inside the trunk of a tree and to experience its anatomy from within, which makes manifest a completely different way of viewing the object of tree. The experience from within is no less real or truthful from the view we have when looking upon a tree and, indeed, it may add an additional layer of reality to our comprehension of what a tree entails.

This example helps to realise more recent philosophical debates within the field. Debates around consciousness have asked questions concerning the meaning of virtual reality and how we think about our relationship to it. From the idea of cyberspace acting as a virtual world to understand cultures, illuminating "the magical reality of all human narratives" (Pesce, 1997:12) to questioning the provocation itself, asking 'why do we feel the need to create something when we seem to have so little understanding of why the natural exists?' (Gigliotti, 1997:40). Chalmers has furthered the debate about the reality of virtual reality, arguing that it is in fact a form of reality itself (2017). Attributing the value to life in virtual world as almost equivalent to that in non-virtual worlds, this line of argument creates a foundation in which we can place value on immersive media to create genuine experiences that hold value and create knowledge.

The philosophical ideas can be drawn out further through scholarly work in media and technology, particularly in McLuhan's writing on media and his argument that the "medium is the message" (1964). It is deliberately a paradoxical statement but one where McLuhan argues that when analysing a medium we shouldn't look at its content but at the inherent characteristics of a medium itself. To draw out the argument, McLuhan cites the example of a lightbulb; it doesn't have the same level of content that a newspaper or television has but still it is a medium that has a social effect, as "a light bulb creates an environment by its mere presence" (1964:8). For McLuhan, the focus must be on the form that communication is being delivered in, what is being communicated is less important.

So throughout history, what has been communicated is less important than the particular form that the communication has been delivered in. The emphasis on the visual within the printed medium, or oral cultures within speech mediums and television and radio unifying people to encourage participation (Heydon, 2017; Levinson, 2003). With this approach, it's the technology that transfers the message that changes us and changes society. This is the idea that Lanier continues to come back to, arguing in 2010 that the most important thing about a technology is how it changes you (Lanier 2010:4).

These perspectives allow us to think differently about immersive media, questioning what it is that reveals itself through the medium, drawing on both Heideggerian thought and McLuhan. Heim argued that there were seven elements that constitute the idea and essence of virtual reality (1993:108–127);

1. Simulation refers to the modern computer graphics and sound effects that can create such a high degree of realism.
2. Interaction refers to electronic representations that people perceive as virtual reality by their interacts with them.
3. Artificiality refers to a world that is largely of human construct.
4. Immersion refers to the computer-generated sensations to which a man can immerse his sensory perceptions to simulate reality.
5. Telepresence refers to the capacity of computer technology to replace human presence by robotic presence.
6. Full-body immersion refers to the latest technology that allows human body to interact with graphics on a computer screen.
7. Networked communications refers to communication that can go beyond verbal or body language to take on magical, alchemical properties.

Situating Heideggerian thought within the emerging technological form, Heim argues that if an experience has these seven constituents, it will lead to a philosophical experience (1993:36). It strengthens the argument that the focus should be on the revealing of the technology, rather than the technology itself.

Placing the value within the technology when it is not bound or limited by previous constraints of what it is forms Coyne's arguments (1995). Through this, new realities and worlds unfold within virtual reality. Coyne argues that the taking a different approach can have merit. In appreciating that claims that using VR reveals something new about the world doesn't work if we think about truth as disclosure. Nor does it work if we think solely about perception. However, we can find new meanings if we look at it through different metaphors. As he argues,

> In appreciating that using VR is not like operating puppets, we see that we are not constrained (as though by strings), that we can achieve something other than entertainment, that the puppets can change identity to become the people operating them. The VR experience is not like walking through a building—we can fly through it, pass through walls, and shrink and expand the building around us (1994:71)

Through these approaches of philosophy, media and technology and look at them through immersive media, the discovery is the essence of virtual reality, rooted fundamentally in presence, leading to a philosophical experience.

4 Immersive Media in Practice

A number of experiences have been analysed to apply the above concept of immersive media. The experiences based on peer-review and curated collections at Tribeca and Sheffield DocFest Alternate Realities. These run in April and June respectively and for this study offered exploration of work that is seen as defining and the best in the field of study. The Alternate Realities section at Sheffield DocFest (2018) showed 27 interactive and immersive projects including films, games and web projects. At Tribeca (2018), immersive, interactive and emerging technological works are situated within the StoryScapes and Tribeca Immersive strands. 25 projects were shown. The work is selected by a jury, curated by leading professionals in the immersive media. It is designed to show the best work at this present time. Four projects have been selected for analysis, based on the fact that they were shown at both festivals. This study draws on techniques and audience engagement with the experiences to gain an understanding of how the industry is progressing and where new techniques and methods are being realised.

Terminal 3

PROJECT CREATOR: Asad J. Malik
COUNTRY: USA Pakistan
YEAR: 2018
DURATION: 12 min

The Day the World Changed (https://sheffdocfest.com/films/6564)

PROJECT CREATORS: Gabo Arora, Saschka Unseld
COUNTRY: USA Japan
YEAR: 2018
DURATION: 10 min

Vestige (https://sheffdocfest.com/films/6566)

PROJECT CREATORS: Aaron Bradbury, Paul Mowbray
COUNTRY: UK France USA
YEAR: 2018
DURATION: 15 min

This is Climate Change: Feast and Famine (https://sheffdocfest.com/films/6585)

PROJECT CREATOR(S): Danfung Dennis, Eric Strauss
COUNTRY: USA Somalia Brazil Greenland
YEAR: 2018
DURATION: 18 min

Empathy-driven media has dominated cinematic VR in the past few years (Jones, 2017) with the idea that VR is to show how one can 'walk in someone else's shoes'. As Mandy Rose stated in an iDocs overview of Sheffield, "I wish we could get past this preoccupation with walking in the shoes of another, seeing through the eyes of another" (iDocs, 2018). This can be aligned to Coyne's thinking about not replicating a world but looking at it through a new lens, something that Lanier has developed insisting that virtual reality should be creating different worlds and different realities not replicating what we have (2017).

Terminal 3 is an interactive, augmented-reality documentary, using holograms and personalised experiences to drive forward the experience. Six participants of Muslim descent were filmed with Depthkit technology. In the experience, the participant takes on the role of a customs office and interrogates the suspects. The experience lasts for fifteen minutes with the questions for the interrogation appearing within the field of vision. The voice triggers responses. Fernando (Guardian 2018) tried the experience at Sheffield DocFest;

> It puts me in the position of authority—do I choose the tough questions or the softer ones? At the end I'm asked to decide whether to let her into the country or detain her further.

The experience uses the Hololens, Microsoft's augmented reality (AR) glasses. The fictional airport is created around you and the encounters become more personal as the experience develops. What is interesting, in an artistic statement of the work, is the photorealism of the person that you are interrogating. They initially appear like a 'digital ghost' and then depending on the questions that you ask, they can gradually appear more lifelike (Ha in TechCrunch 2018).

The creator, Malik, maintains there is no specific message that is being promoted but instead it is about illustrating the enormous variety of personalities, backgrounds and viewpoints among people who may or may not identify themselves as Muslims, but "who the world would identify as Muslims". This develops the work on Shameful Conquest (2017), a post-Brexit experience, where no political message is being articulated, it's just an experience of life post-Brexit.

The difference with this project comes in the utilisation of AR as a means of storytelling and this extends the practice of immersive media into a new genre. With augmented reality placing digital objects in your environment, the interaction takes you one step further, "*Terminal 3*'s power comes from forcing you to share your physical space with the holograms" (Schwab, 2018, CoDesign)

The responses online from the audience signified the transformative nature that this type of experience had:

> Kudos to @AsadJMalik (https://twitter.com/AsadJMalik) Terminal 3 was one of the most subtle on the surface and profound upon analysis experiences at the Sheffield Doc/Fest Alternative Realities Exhibition this year, #SheffDocFest (https://twitter.com/hashtag/SheffDocFest?src=hash)
>
> David Tames (@cinemakinoeye)

> I've never cried in a VR/AR experience, but I had the honor of going through #Terminal3 (https://twitter.com/hashtag/Terminal3?src=hash) at #Tribeca2018 (https://twitter.com/hashtag/Tribeca2018?src=hash) and I cried for a solid 2 minutes at the end. So, so powerful. And as I'm reflecting, writing about my experience for a class—I find myself crying again as I tell the story.
>
> Such a powerful, powerful experience. Using voice was brilliant, to put people in such an uncomfortable position. It makes me realize how easy it is to disassociate from your body, clicking buttons on a controller—but how much harder it is to dissociate from your own voice.
>
> Rogue Fong (@__roguef)

> Incredible experience that leverages the power of AR, presence, and embodiment.
>
> Helen Situ. @helensitu

***The Day the World Changed** was created in partnership with Nobel Media and Nobel Peace Prize Laureate and the International Campaign to Abolish Nuclear Weapons. It is one of many experiences that have been supported and developed by third-sector organisations, developing the arguments for empathy-driven content (Jones, 2017). The experience uses first-hand testimonies of the victims and survivors of atomic bombs and nuclear arms testing. It brings this together with data visualisations and 3D scanning and photogrammetry. It is the most like the empathy driven content that previously dominated the field, unsurprising as the creator is Gabo Arora (Clouds Over Sidra 2015). Arora is known for his work with VRSE and the United Nations so is well versed on developing immersive media that helps to change understandings;*

> This experience uses virtual reality's strengths in a way that makes viewers have a more visceral relationship with what is usually just a rational engagement with numbers, this time focusing on one of the most urgent issues of today
>
> Arora (2018)

Although agency is limited in the experience and it follows a directed narrative, there is an element of the VR experience infiltrating the environment around the participant. Within the space, the participant can interact with objects recovered from the site. This looks at the development of situating experiences in an environment to deepen the sense of presence, something that has been a focus of literature within immersive theatre (Alston, 2013; Laurel, 2013; Zaunbrecher, 2011). These studies have been influential in the development of exhibiting work but also through increasing presence through environment. In response to the work at Shef Doc Fest, Julie Lennox noted the increase in utilising the environment to enhance the experience and asked, “is this perhaps some indication that creators are realising we need something more than the virtual experience?” (Stevenson, 2018).

The use of capturing testimonies from survivors is interesting and raises further research questions about the role that immersive media could play in capturing memories and digital archives or places and environments, which is an area for further research (Koller, Frischer, & Humphreys, 2009).

The audience responses contained less positive terms than The Terminal and were also limited in number. However the aims and objectives of the experience do appear to be met in some of the engagement. Saschka Unseld, the project’s co-creator, had stated on the project’s website, “we want this to be an unwavering, uncomfortable experience for people”. Feedback from participants said,

> #TheDayTheWorldChanged (https://twitter.com/hashtag/TheDayTheWorldChanged?src=hash) Disturbing experience, yet so real about Hiroshima and the consequences by @gaboarora (https://twitter.com/gaboarora)
>
> Daniela Băicoianu: @DaniiAlina

Ideas being ahead of the technological limitations other reports suggested the experience was too chaotic in user design, complicating the message and hindering the opportunity for presence. These concerns have dominated literature with arguments in co-creation with participants when working toward user experience (Kohler, Fueller, Matzler, Stieger, & Füller, 2011) and utilising applications like teleportation to reduce motion sickness (Hong, 2017). Other researchers have produced frameworks based on focus group studies to understand the design process for immersive experiences, taking into account the ease of discovery, the visual input in the field of view, limiting gestures and hand movements and ensuring that the design gives the user a clear focus as too much multi-tasking can become overwhelming (Spillers & Mortensen, 2018).

The user experience of The Day The World Changed seems at conflict with the last criteria for virtual reality design, according to participant testimonial. Julia Scott Stevenson, researcher at University of West of England found it to be;

> a great example of trying to do too much—both in terms of tools and experience. There were so many different elements that didn’t hang together very well: a lot of mismatched visual content, the interaction with some items that triggered audio was a bit clunky, and the blue dots coming out of our hands at the end were quite confusing as to what they were for and how much control we had over them.
>
> Scott-Stevenson (2018)

The strength of this type of experience still lies in the idea of empathy and the sense of understanding how other people live.

> Experiencing together with many others #TheDayTheWorldChanged (https://twitter.com/hashtag/TheDayTheWorldChanged?src=hash) by @NobelPrize (https://twitter.com/NobelPrize) @nuclearban (https://twitter.com/nuclearban) @gaboarora (https://twitter.

com/gaboarora) @saschkaunseld (https://twitter.com/saschkaunseld) & @igaln (https://twitter.com/igaln) I achieved a sensation of doing something right.

Captain Strange @KapoStrano

The words "doing something right" are typical in analysis of empathy-driven immersive experiences (Jones, 2017). However, the depth of reaction and discussion in online forums is not to the same extent as Terminal 3, which involves much of an active experience. There is much more excitement around the development of the technology and new ideas signifying a potential audience fatigue with this genre (Moeller, 2018).

This is Climate Change *is part of a series of experiences, produced by Participant Media and Condition One. They focus on climate change and looks at how human life and actions are destroying the planet. The first episode looked at glaciers in Greenland, moving to the Amazon rainforest, wildfires in California and famine in Somalia. It follows a traditional VR documentary style with the same techniques and film grammar that we are becoming familiar with (Mateer, 2017). Like Arora above, the intention of this docs-series was to feel the story and experience it, rather than watching as a detached observer (Hardarwar, 2018).*

We are getting to a place where VR is a stream of conscious experiences. We need to get out of the way as filmmakers to allow these raw experiences to be told. It is heartbreaking to see how climate is affecting people in #ThisIsClimateChange (https://twitter.com/hashtag/ThisIsClimateChange?src=hash),

@Danfung (https://twitter.com/Danfung) & #EricStrauss (https://twitter.com/hashtag/EricStrauss?src=hash)

Again, an analysis of social content was limited. Participant's experiencing This Is Climate Change may have had a transformative experience, but didn't promote this in online forums. What is sourced is restrained, although full of praise.

Just saw #thisisclimatechange (https://twitter.com/hashtag/thisisclimatechange?src=hash) at the Tribeca Film Festival. Awesome virtual experience. Check it out. #EarthDay (https://twitter.com/hashtag/EarthDay?src=hash)

Tanya Morgan @MemphisMorgan

Vestige is also a non-fiction experience, based on the personal experience of Lisa Elin, following the death of her husband Eric. It is similar in style and tone to Notes on Blindness (2017) taking the participant through her mind to witness memories. It takes a multi narrative approach, with memories coming together. Creators used volumetric capture of two actors who played Lisa and Eric. More than 15 h of audio interview was captured of Lisa remembering her husband and the times they spent together. Like Notes, it is the audio that drives the experience.

Analysis of participants online all pointed to the emotional power of the piece and the difference in how the technology was used in a way that couldn't have been told by any other medium.

> Me experiencing one of the most emotional VR projects I've seen so far @sheffdocfest (https://twitter.com/sheffdocfest) Vestige is awesome and a must see! #vestigevr (https://twitter.com/hashtag/vestigevr?src=hash) #sheffdocfest (https://twitter.com/hashtag/sheffdocfest?src=hash) #vr (https://twitter.com/hashtag/vr?src=hash)
>
> Anne Doncaster: @IMMDesigns

> Vestige made me really cry, and the animation was beautiful, but at the end, I was left wondering whether the monologue could have been delivered in some other way.
>
> Scott-Stevenson (2018)

From the analysis of participants responses, there is a clear correlation between those that are embracing the technology in new or different ways as gaining a deeper response. This could simply be down to the audience seeing something new, pointing to a need to continue to experiment and engage with different technologies to develop the medium.

The experiences above are often being created through triggers of personal experiences. Although this is often the case of personal-focused documentaries, in other media practice, ideas are increasingly being developed through social media and crowdsourcing (Simula & Vuori, 2012; White, 2010). The triggers for both The Terminal and Vestige were personal experiences of the directors (Asad J. Malik, The Terminal) and the protagonist (Lisa in Vestige).

5 Conclusion

This chapter focuses on the intersection of immersive media between philosophy, media and technology, understanding how a distinct form of presence can be manifested. Through a methodology to analyse this approach through recent practice, it is clear that none of the selected works could be experienced in any other form, other than virtual reality. However, the two pieces of work that were more traditional documentary style and both empathy-driven (This Is Climate Change, The Day the World Changed), provoked less of a response and also used the technology in a more limited capacity.

The focused experiences all bring elements together that demonstrate that intersection of philosophy, media and technology. If we don't treat it or define the medium differently, we simply end up with 'walking in someone else's shoes' filmic practice, that doesn't always justify why it needs to be in VR. To develop the technology, the boundaries need to be explored to understand how it is different and how we can be changed by it.

In early studies on virtual reality, Pimentel and Teixeira (1993) encouraged the use of VR as a form of art where artists, through simulation, will "merge together all art forms" (1993:240). Through doing this, it would become an art experience of the mind. It's something drawn on in more recent literature by Ryan (2015) acknowledging that VR has the potential to be "total art", in a way that no other medium has achieved.

It is Heim and Lanier that offer closing thoughts that have influenced this work and my future projects. With emergent media, the big picture can get lost, in what Heim describes as the rush for content to fill the new medium. It is down to artists to guard the visionary aspects and nurture it in its infancy (1995:66). It is a warning to "not lose itself in the thrill of the content", the idea reiterated by Lanier on many occasions. A question that remains prominent at the end of this thesis, posited earlier,

> What happened to the dream of improvising reality? Shared lucid dreaming? I mean, what's the point of just making a flashier type of movie or video game? (2017:6).

Experiences

Terminal 3

PROJECT CREATOR: Asad J. Malik
COUNTRY: USA Pakistan
YEAR: 2018
DURATION: 12 min

(https://www.beggarkings.com/terminal3/)

The Day the World Changed (https://sheffdocfest.com/films/6564)

PROJECT CREATORS: Gabo Arora, Saschka Unseld
COUNTRY: USA Japan
YEAR: 2018
DURATION: 10 min

(https://www.thedaytheworldchanged.world)

Vestige (https://sheffdocfest.com/films/6566)

PROJECT CREATORS: Aaron Bradbury, Paul Mowbray
COUNTRY: UK France USA
YEAR: 2018
DURATION: 15 min

(http://vestige-vr.com)

This is Climate Change: Feast and Famine (https://sheffdocfest.com/films/6585)

PROJECT CREATOR(S): Danfung Dennis, Eric Strauss
COUNTRY: USA Somalia Brazil Greenland
YEAR: 2018
DURATION: 18 min

(https://www.beggarkings.com/terminal3/).

References

Alston, A. (2013). Audience participation and neoliberal value: Risk, agency and responsibility in immersive theatre. *Performance Research, 18*(2), 128–138.

Barlow, J. P. (1990). *Being in nothingness*. Electronic manuscript. Published in Mondo 2000.

Borgmann, A. (1987). *Technology and the character of contemporary life: A philosophical inquiry*. University of Chicago Press.

Botvinick, M., & Cohen, J. (1998). Rubber hands 'feel' touch that eyes see. *Nature, 391*(6669), 756.

Burdea Grigore, C., & Coiffet, P. (1994). *Virtual reality technology*. London: Wiley-Interscience.

Byrne, C., & Furness, T. A. (1994, June). Virtual reality and education. In *Exploring a new partnership: Children, teachers and technology* (pp. 181–189).

Chalmers, D. J. (2017). The virtual and the real. *Disputatio, 9*(46), 309–352.

Coyne, R. (1995). *Designing information technology in the postmodern age: From method to metaphor*. MIT Press.

De la Peña, N., Weil, P., Llobera, J., Giannopoulos, E., Pomés, A., Spanlang, B., … Slater, M. (2010). Immersive journalism: Immersive virtual reality for the first-person experience of news. *Presence: Teleoperators and Virtual Environments, 19*(4), 291–301.

Dinh, H. Q., Walker, N., Hodges, L. F., Song, C., & Kobayashi, A. (1999, March). Evaluating the importance of multi-sensory input on memory and the sense of presence in virtual environments. In *Proceedings IEEE Virtual Reality, 1999* (pp. 222–228).

Dreyfus, H. L. (1992). *What computers still can't do: A critique of artificial reason*. MIT press.

Fernando, S. (2018). *Virtual truth: Face to face with immersive documentaries*. https://www.theguardian.com/film/2018/jun/15/virtual-reality-vr-film-making-documentaries-face-to-face-sheffield-docfest.

Ferri, A. (2007). *Willing suspension of disbelief: Poetic faith in film*. New York: Lexington Books.

Gigliotti, C. (1997). What is consciousness for? In R. Ascott (Ed.), *"Preface" in consciousness reframed: Abstracts*. Newport, Wales: CAiiA, University of Wales College.

Ha, A. (2018). *Thisyear's Tribeca film festival uses AR and VR to explore music-making and empathy*. https://techcrunch.com/2018/04/28/tribeca-terminal-3-ok-go/?guccounter=1.

Haluck, R. S., & Krummel, T. M. (2000). Computers and virtual reality for surgical education in the 21st century. *Archives of Surgery, 135*(7), 786–792.

Hardarwar, D. (2018). https://www.engadget.com/2018/04/22/this-is-climate-change-vr/?guccounter=1.

Heidegger, M., Macquarrie, J., & Robinson, E. (1962). *Being and time*. Malden, MA: Blackwell.

Heidegger, M. (1977). *The question concerning technology, and other essays*. New York: Harper & Row.

Heim, M. (1994). *The metaphysics of virtual reality*. Oxford University Press.

Heydon, J. (2017). Finding McLuhan: The mind/the man/the message. *Canadian Journal of Communication, 42*(3).

Hong. (2017). https://medium.com/inborn-experience/how-to-design-for-virtual-reality-66d62e88791.

Ikei, Y., Abe, K., Hirota, K., & Amemiya, T. (2012, September). A multisensory VR system exploring the ultra-reality. In *18th International Conference on Virtual Systems and Multimedia (VSMM)* (pp. 71–78). IEEE.

Jones, S. (2017). Disrupting the narrative: Immersive journalism in virtual reality. *Journal of Media Practice, 18*(2–3), 171–185.

Kohler, T., Fueller, J., Matzler, K., Stieger, D., & Füller, J. (2011). Co-creation in virtual worlds: The design of the user experience. *MIS quarterly*, 773–788.

Koller, D., Frischer, B., & Humphreys, G. (2009). Research challenges for digital archives of 3D cultural heritage models. *Journal on Computing and Cultural Heritage (JOCCH), 2*(3), 7.

Lanier, J. (2010). *You are not a gadget: A manifesto*. Vintage.

Lanier, J. (2017). *Dawn of the new everything: Encounters with reality and virtual reality*. New York: Henry Holt and Company.

Laurel, B. (1991). *Computer as theatre: A dramatic theory of interactive experience*. Reading: Addison-Wesley.

Laurel, B. (2013). *Computers as theatre* (2nd ed.). Reading: Addison-Wesley.

Lehmann, S., & Murray, M. M. (2005). The role of multisensory memories in unisensory object discrimination. *Cognitive Brain Research, 24*(2), 326–334.

Levinson, P. (2003). *Digital McLuhan: A guide to the information millennium*. Routledge.

Lombard, M., & Ditton, T. (1997). At the heart of it all: The concept of presence. *Journal of Computer-Mediated Communication, 3*(2).

Mateer, J. (2017). Directing for cinematic virtual reality: How the traditional film director's craft applies to immersive environments and notions of presence. *Journal of Media Practice, 18*(1), 14–25.

McLuhan, M. (1964). *Understanding media. The extensions of man*. New York.

Merleau-Ponty, M. (2013). *Phenomenology of perception*. Routledge.

Moeller, S. D. (2018). Compassion fatigue. In *Visual global politics* (pp. 87–92). Routledge.

Orbis. (2017). *Virtual reality marketplace*. http://www.orbisresearch.com/reports/index/virtual-reality-vr-marketplace-vr-technologies-companies-solutions-devices-components-applications-and-services-2018–2023.

Pesce, M. (1997). Ritual and the virtual. In R. Ascott (Ed.), *"Preface" in consciousness reframed: Abstracts*. Newport, Wales: CAiiA, University of Wales College.

Petkova, V. I., & Ehrsson, H. H. (2008). If I were you: Perceptual illusion of body swapping. *PLoS ONE, 3*(12), e3832.

Pimentel, K., & Teixeira, K. (1993). *Virtual reality through the new looking glass*.

Ryan, M.-L. (2015). *Narrative as virtual reality 2: Revisiting immersion and interactivity in literature and electronic media*. JHU Press.

Scott-Stevenson, J. (2018). *Alternate realities at Sheffield DocFest*. http://i-docs.org/2018/06/15/alternate-realities-at-sheffield-doc-fest/.

Simula, H., & Vuori, M. (2012). Benefits and barriers of crowdsourcing in B2B firms: Generating ideas with internal and external crowds. *International Journal of Innovation Management, 16*(06), 1240011.

Skarbez, R., Brooks, F. P., Jr., & Whitton, M. C. (2017). A survey of presence and related concepts. *ACM Computing Surveys (CSUR), 50*(6), 96.

Slater, M., Pérez Marcos, D., Ehrsson, H., & Sanchez-Vives, M. V. (2009). Inducing illusory ownership of a virtual body. *Frontiers in Neuroscience, 3,* 29.

Slater, M., Spanlang, B., Sanchez-Vives, M. V., & Blanke, O. (2010). First person experience of body transfer in virtual reality. *PLoS ONE, 5*(5), e10564.

Spillers, F., & Mortensen, D. (2018). *Less is (also) more in virtual and augmented reality design*. https://www.interaction-design.org/literature/article/less-is-also-more-in-virtual-and-augmented-reality-design.

Walser, R. (1991). The emerging technology of cyberspace. In S. K. Helsel & J. Roth (Eds.), *Virtual reality: Theory, practice, and promise*. Westport, CT: Meckler.

White, L. (2010). Facebook, friends and photos: A snapshot into social networking for generating travel ideas. In *Tourism informatics: Visual travel recommender systems, social communities, and user interface design* (pp. 115–129). IGI Global.

Zaunbrecher, N. J. (2011). The elements of improvisation: Structural tools for spontaneous theatre. *Theatre Topics, 21*(1), 49–60.