Progress in IS

Timothy Jung
M. Claudia tom Dieck *Editors*

Augmented Reality and Virtual Reality

Empowering Human, Place and Business

Springer

Progress in IS

More information about this series at http://www.springer.com/series/10440

Timothy Jung · M. Claudia tom Dieck
Editors

Augmented Reality and Virtual Reality

Empowering Human, Place and Business

Springer

Editors
Timothy Jung
Faculty of Business and Law
Manchester Metropolitan University
Manchester
UK

M. Claudia tom Dieck
Faculty of Business and Law
Manchester Metropolitan University
Manchester
UK

ISSN 2196-8705 ISSN 2196-8713 (electronic)
Progress in IS
ISBN 978-3-319-64026-6 ISBN 978-3-319-64027-3 (eBook)
DOI 10.1007/978-3-319-64027-3

Library of Congress Control Number: 2017947444

Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer International Publishing AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

International Augmented and Virtual Reality Scientific Committee

Preface

Organised by the Creative Augmented and Virtual Reality Hub at Manchester Metropolitan University, the 3rd International Conference on Augmented and Virtual Reality took place on the 23rd of February 2017 and brought together leading researchers and industry professionals from the area of augmented reality (AR) and virtual reality (VR). The conference theme of "Empowering human, place and business" invited speakers from various disciplines to share their experiences of these new and exciting technologies.

Paper presented focused on the areas of AR and VR in tourism, business, marketing & storytelling, health & defence, retail & fashion and design & development. We hope that this edited book will serve as a valuable source for future research and inform businesses about latest developments in the areas of AR and VR.

Manchester, UK

Dr. Timothy Jung
Dr. M. Claudia tom Dieck

Contents

Part I
Augmented and Virtual Reality in Tourism

Identifying Tourist Requirements for Mobile AR Tourism Applications in Urban Heritage Tourism

Dai-In Han and Timothy Jung

Abstract While research for the employment of information and communication technology in urban tourism settings has been conducted for many years, studies to apply Augmented Reality (AR) to enhance the tourist experience have emerged in recent years. This paper aims to investigate tourist requirements for the development of mobile AR tourism applications in the urban heritage tourism context. Qualitative research incorporating two research stages were conducted in Dublin. The first stage included 26 pre-experience interviews with international tourists to explore tourist requirements, while the second stage was conducted in form of 5 focus groups including a total of 49 participants. The data was analysed through thematic analysis to compare and contrast research outcomes. The findings suggest that tourists would consider using mobile AR tourism applications, if meaningfully designed. Therefore, the user interface should be designed intuitively, while content was regarded the dominant factor for tourism purposes. The study outlines tourist requirements for mobile AR tourism applications, contrasting them to themes in mobile computing identified in preceding studies to confirm previously identified requirements and explore newly emerging elements and tourist perceptions that have developed in alignment with modern technology. Limitations and recommendations for further research are provided.

Keywords Mobile augmented reality · Urban heritage tourism · Tourist requirements · Dublin

---

D.-I. Han (✉)
Academy of Hotel and Facility Management,
NHTV Breda University of Applied Sciences, Breda, Netherlands
e-mail: han.d@nhtv.nl

T. Jung
Faculty of Business and Law, Manchester Metropolitan University,
Manchester, UK
e-mail: t.jung@mmu.ac.uk

T. Jung and M.C. tom Dieck (eds.), *Augmented Reality and Virtual Reality*,
Progress in IS, DOI 10.1007/978-3-319-64027-3_1

1 Introduction

As short trips to urban destinations have been increasing in popularity (Gospodini 2004), maintaining the inflow of tourists especially for heritage sites has become a challenge for a number of destinations. In alignment with technological developments, the implementation of ICTs in the tourism industry was argued to support the sustainability of urban heritage sites and increase their competitiveness in the global market. As a result, it is crucial to investigate how modern technology can be implemented meaningfully to enhance the tourist experience. Augmented Reality (AR) has become an area of interest for tourism, as it is able to overlay digital information in the immediate environment. This makes it an ideal tool to provide information in unknown locations if it can be developed meaningfully. Although research and public interest in AR for wearable devices has increased significantly (Siluk 2015), it is crucial to clearly understand requirements for current mobile AR-ready handsets before investigating forthcoming technology. While a number of studies to implement AR in tourism have been conducted, initial research has largely focused on functionalities (Fritz et al. 2005; Reitmayr and Schmalstieg 2003), while recent studies are shifting towards enhancing the tourist experience (Jung et al. 2015; Leue et al. 2015). Nonetheless, studies exploring requirements of AR applications from a tourist perspective are still limited. Therefore, this study will investigate tourist requirements for mobile AR tourism applications in the context of urban heritage tourism to design beneficial applications for tourists and encourage repeated use.

2 Definition of Augmented Reality

Augmented Reality (AR) has been researched and implemented in various industries such as gaming and retail and has gained increasing interest in the tourism industry in recent years (Nicas 2016). While many attempts have been made to provide a common definition, it was argued that AR is still regarded a developing technology, and therefore has not yet reached its full potential. As a result, the definition of AR has undergone a number of modifications depending on the context or method of implementation (Van Krevelen and Poelman 2010). Nonetheless, Stone et al. (2009) formulated base criteria to be included in AR that have been universally accepted. AR should therefore include a conjunction between the virtual and real environment, be able to interact with the immediate surrounding and register and connect real and virtual objects. Building on this concept, Rouse (2015) defined AR as the integration of digital information with live video on the user's environment in real time. Tourism has long been argued to be one of the logical adaptors of AR due to its ability to share and exchange location-based information in the immediate surrounding (Pang et al. 2006). Klubnikin (2016) in addition claimed that tourism applications were already the 7th most downloaded type of mobile apps, which could greatly facilitate the early adoption of AR-type applications in this industry.

3 AR Applications in Urban Heritage Tourism

Early studies of AR in tourism have largely focused on the functionalities and technical aspects, such as GPS-based AR technology to overlay information in the tourists' immediate environment (Feiner et al. 1997; Rekimoto 1997). Some of the implemented examples of AR in the tourism industry include the 'GUIDE' project by Grossmann et al. (2001) as well as developments by Davies et al. (2005), both of which are mobile AR systems providing location-based information. Since then, a number of researchers argued that AR was able to greatly benefit the tourism industry if it was meaningfully implemented (Hariharan et al. 2005). Subsequent studies attempted to expand on this idea by not only providing location-based information, but developing an application that could serve as a computerised tourist guide which tourists could interact with (Höllerer and Feiner 2004; Pang et al. 2006). In the urban heritage context, AR was seen as a potential tool to overcome the physical boundary of heritage attractions. Since AR is using the digital space to provide additional value, it was argued to support the sustainability of heritage sites. Pang et al. (2006) developed a case of an urban tourist guide application in Vienna, which was able to guide tourists to points of interest (POI) using GPS coordinates. Pang et al. (2006) expanded on the original idea of GPS-based AR, but included social functionalities that enabled the user to generate and share information with peers. In recent years, a number of studies have been conducted exploring the enhancement of the tourist experience using AR through handheld as well as wearable devices (Chung et al. 2015; Jung et al. 2015; Leue et al. 2015). Particularly in the urban heritage environment, AR has been studied to enhance the museum experience by reinterpreting the tourist product (Damala et al. 2008). In this regard, a number of studies have been conducted to examine the acceptance of tourists using handheld as well as wearable devices in the urban heritage context (Jung and Leue 2015). It was found that tourists generally had a positive response on the use of AR for the enhancement of the urban heritage tourism experience. Challenges were noted for AR applications in the outdoor environment, such as in the application 'Paris, Then and Now', in which tourists are able to 'time-travel' and experience sights of Paris how it used to be 100 years ago, for 2000 spots around the city. Uncontrollable external factors, such as changing weather conditions and people in the immediate surrounding would provide issues in the interaction. Fritz et al. (2005) argued that the tourism industry required continuous development and implementation of technology in order to attract visitors and stay competitive in the global market. However, regarding mobile AR applications, it was pointed out that AR systems still required improvement to create meaningful tourist experiences (Lee et al. 2015; tom Dieck and Jung 2015). Nonetheless, as mobile technology is being developed rapidly, it is crucial to understand tourist requirements in order to utilise functionalities such as AR in a meaningful way to encourage repeated use.

4 User Requirements in Mobile Computing

Since identification of requirements for AR applications in the literature was limited, the mobile computing context was regarded to provide the closest indication of requirements that could be aligned with mobile AR applications. The requirements created a knowledge base for the design of interview questions and were contrasted to primary research outcomes. This could determine which requirements were still valid and identify emerging requirements for mobile AR applications in the urban heritage tourism context. 'Simplicity' referring to the user interface (UI) was repeatedly noted in the literature as a key requirement (Dantas et al. 2009; Gebauer et al. 2010; Gafni 2008; Karahasanović et al. 2009; Ngai and Gunasekaran 2007; Pulli et al. 2007). It was argued that the UI should be easy to navigate and understandable for anyone. Required information should be promptly accessible and relevant to the user (Delagi 2010; Dinh et al. 2013; Herskovic et al. 2011; Kenteris et al. 2009; Wang and Liao 2007).

Therefore, content should be 'context-aware' to provide relevant information instantly (Dantas et al. 2009; Delagi 2010; Dinh et al. 2013; Gebauer et al. 2010; Herskovic et al. 2011; Karahasanović et al. 2009). This would avoid the overload of information, as large amounts of irrelevant content was believed to result in a slow down of the software (Delagi 2010; Dinh et al. 2013; Gafni 2008; Gebauer et al. 2010; Kenteris et al. 2009; Pulli et al. 2007; Wang and Liao 2007). In contrast, 'personalised content' was largely expected of mobile applications to access information efficiently (An et al. 2008; Gafni 2008; Herskovic et al. 2011; Karahasanović et al. 2009; Kenteris et al. 2009; Swallows et al. 2007; Wang and Liao 2007). Future applications should be accessible regardless of time and place, as users were increasingly mobile (Delagi 2010; Dinh et al. 2013; Gebauer et al. 2010; Herskovic et al. 2011; Kenteris et al. 2009; Wang and Liao 2007). 'Privacy' was furthermore regarded as a key requirement that would continue to be relevant for future applications (Dantas et al. 2009; Delagi 2010; Dinh et al. 2013; Gafni 2008; Herskovic et al. 2011; Karahasanović et al. 2009). 'Social functions' were revealed to be increasingly significant, as a large number of users were using social platforms such as Facebook and Twitter on a daily basis (An et al. 2008; Herskovic et al. 2011; Karahasanović et al. 2009). A number of studies additionally outlined reliability issues of mobile applications, which were largely performance-based, but could also be determined by the provision of reliable and trustworthy information (Dantas et al. 2009; Dinh et al. 2013; Herskovic et al. 2011; Kenteris et al. 2009; Wang and Liao 2007). Table 1 shows the identified user requirements in the mobile computing context.

Table 1 User Requirements in the Mobile Computing Context

Requirement	Authors
Simplicity	Dantas et al. (2009), Gafni (2008), Gebauer et al. (2010), Karahasanović et al. (2009), Ngai and Gunasekaran (2007), Pulli et al. (2007)
Relevant and updated information	Delagi (2010), Dinh et al. (2013), Gafni (2008), Herskovic et al. (2011), Kenteris et al. (2009), Wang and Liao (2007)
Speed	Delagi (2010), Dinh et al. (2013), Gafni (2008), Gebauer et al. (2010), Kenteris et al. (2009), Pulli et al. (2007), Wang and Liao (2007)
Safety and security (Privacy)	Dantas et al. (2009), Delagi (2010), Dinh et al. (2013), Gafni (2008), Karahasanović et al. (2009)
Accessibility	Delagi (2010), Dinh et al. (2013), Gebauer et al. (2010), Herskovic et al. (2011), Kenteris et al. (2009), Wang and Liao (2007)
Social functions	An et al. (2008), Herskovic et al. (2011), Karahasanović et al. (2009)
Personalisation	An et al. (2008), Gafni (2008), Karahasanović et al. (2009), Kenteris et al. (2009), Herskovic et al. (2011), Swallows et al. (2007), Wang and Liao (2007)
Power efficiency	Delagi (2010), Kenteris et al. (2009)
Context-awareness	Dantas et al. (2009), Delagi (2010), Dinh et al. (2013), Gebauer et al. (2010), Herskovic et al. (2011), Karahasanović et al. (2009)
Reliability	Dantas et al. (2009), Dinh et al. 2013, Herskovic et al. (2011), Kenteris et al. (2009), Wang and Liao (2007)

5 Methods

For the purpose of this study, Dublin was selected as research site representing an urban heritage tourism context. To identify tourist requirements, two separate qualitative research were conducted. The initial interviews were regarded as 'pre-AR experience study', while the second qualitative research was seen as 'post-AR experience study'. Due to the limited research in this context at the time of study, an inductive research method was considered suitable for this research. According to Creswell (2007), qualitative data collection is the preferred research method to explore unknown areas. The research population was selected as international tourists visiting Dublin. Therefore, it was aimed to incorporate the main market segments according to the 2010 Annual Report of Failté Ireland in the sample, including tourists from France, Germany, Spain, USA and the UK. The first research stage was conducted in two separate interview sessions including tourists from Ireland (n = 4), UK (n = 8), USA (n = 3), Germany (n = 4), France (n = 3) and Spain (n = 2) through a convenience sampling method. The research was conducted in two city center hotels in Dublin. The majority of research participants were female, while most interviewees were students and young professionals the age group of 22–30. As participants had limited knowledge of AR at the time of study, three AR application samples were provided including text, image and video overlays as well as a GPS-based AR application sample. Nonetheless, it was crucial that participants had absolute freedom to answer the interview questions to their own discretion, as the aim of the first research phase was the initial identification of tourist requirements. All interviews were digitally recorded for transcribing and analysing purposes. Two pilot interviews were conducted prior to the data collection to assess the clarity and expected responses of interview questions. A total of 26 tourist interviews were conducted in February and April 2013, with interviews ranging from 15.30 min to 48.19 min. The first research stage was designed in form of semi-structured interviews to identify tourist requirements and contrast them to user requirements identified in the literature of mobile computing to investigate whether newly emerging requirements were evident for mobile AR tourism applications in the urban heritage tourism context. Additionally, it aimed to establish an understanding of tourists' user behavior of mobile tourism applications.

A second qualitative research was conducted in form of focus groups, as suggested by Adami (2005) and Halcomb and Andrew (2005). For the purpose of data completeness and trustworthiness of findings, it was suggested that conducting focus groups in addition to interviews was more inclusive compared to using the same data collection method for a second study (Lambert and Loiselle 2008; Plack 2006). After the initial investigation of tourist requirements, a mobile AR application demonstrator was developed based on the requirements identified in the tourist interviews. This allowed the investigation of tourist requirements in focus groups after experiencing a potential mobile AR tourism application in the urban heritage tourism context. A total of five focus groups were conducted with nine to ten participants per group from November 4–6, 2013. The semi-structured focus group questions were designed to encourage discussion among participants with regards to the mobile AR tourism application demonstrator and for the identification of tourist requirements after the experience. Tourists from the young British market were selected as the target population for the focus groups, as a target market for mobile AR tourism applications was still largely undefined and dependent on the context of implementation (Bulearca and Tamarjan 2010). The young market was considered suitable for the study purpose, as they were generally believed to have a high exposure to modern technology. Furthermore, as the aim was the investigation of tourist requirements, it was crucial that participants did not have to go through a learning process on how to interact with the mobile application, but could instead focus on application requirements. In addition, Bulearca and Tamarjan (2010) argued that consumers between 18 to 30 years would be the first market to be targeted by AR applications. As a result, most focus group participants were from the population of the British young market and between 21 to 29 years old. Two application demonstrators were prepared. One was based on story-telling image enhancements inside of the General Post Office (GPO) in Dublin, while another was prepared outdoors using GPS-based AR to project information on the immediate surrounding. Participants were equipped with three mobile devices and given fifteen minutes to experience both applications before the focus groups were conducted. All focus groups were digitally recorded and lasted an average of 25 min. The interview and focus group data was analysed using thematic analysis, which was argued to be one of the most commonly utilised analysis methods of qualitative studies (Boyatzis, 1998). After identifying themes from the literature, they were compared and contrasted to the requirements from the initial tourist interviews to provide an updated list of themes, which was used to develop the mobile AR application demonstrator. In the subsequent 'post-AR experience study', themes were confirmed and modified after tourists experienced the demonstrator and analysed by contrasting them to requirements identified in the tourist interviews.

6 Findings and Discussion

The semi-structured interviews and focus groups were designed to identify tourist requirements for mobile AR tourism applications in the context of urban heritage tourism. The following will discuss themes that emerged as tourist requirements from the interviews and focus groups by contrasting them to the literature. Overall, a large number of user requirements that were identified in the literature in the context of mobile computing were still significant for today's mobile applications. As a majority of them was applicable for mobile devices in general and not context specific, they reoccurred in the primary research of this study.

6.1 Simplicity

In the tourist interviews, it was found that designing a simple user interface in mobile AR tourism applications was crucial, as a large number of consumers had never been in touch with AR functions. To encourage fast adoption, it was revealed that a 'step by step' guide could be useful that would guide the tourist through the initial interaction with the application. However, it was pointed out that interaction with future mobile applications required to be increasingly natural to reduce the need for a learning process. While 'Ease of use' was largely discussed in the literature as a crucial theme (Choi and Lee 2012; Dantas et al. 2009; Gafni 2008; Gebauer et al. 2010; Pulli et al. 2007), tourist interviews as well as focus groups showed that 'simplicity' and 'ease of use' were largely expected in mobile applications. The focus group findings further revealed a shift in the wording of 'simplicity' to 'intuitive', arguing that natural interaction was key in future mobile applications. Schinke et al. (2010) recommended in this regard that intuitive design would facilitate the rapid adoption by users. Choi and Lee (2012) similarly argued that applications that did not require a learning process would encourage repeated use. This could specifically be achieved for mobile AR applications, as they were based on currently used handheld mobile devices. Similar adoption rates are expected after a wide adoption of wearable computing, as consumers would already be familiar with utilising such devices on a daily basis. Morrison et al. (2011) further revealed that using mobile AR applications had to be non-disturbing for the user as well as for people in close vicinity, which was confirmed in the tourist interviews. It was found that using AR to project information in the immediate surrounding disclosed practical issues that will be further discussed in 'Privacy and Security'.

6.2 Information Filter

'Personalisation' was previously identified as a crucial user requirement in mobile computing (Huang and Bian 2009; Xu et al. 2008) and confirmed in the tourist interviews as well as focus groups, as participants argued that tourists were not all interested in the same content. In order to avoid information overload and provide relevant information for the user, being able to filter and tailor the information according to the tourist's needs was regarded crucial. Limiting augmented information was previously revealed to have been discussed in motor vehicles, as it was debated how much information would be suitable for drivers to avoid distraction (van Krevelen and Poelman 2010). Alternatively, Marimon et al. (2010) proposed a user interface that would project additional information on request, while keeping the initial content to a minimum. With regards to content type, focus group participants argued that one of the most important content to provide in mobile AR tourism applications in the urban environment was information on public transportation. While current tourism applications are able to offer this type of information, it was not yet mentioned in the literature. However, it can be seen that public transportation is increasingly important, as current map-based applications are able to include information on public transportation options to reach certain POIs. However, it needs to be acknowledged that focus group participants were from the British young market. Therefore, the need for information on public transportation might have been more dominant compared to other market segments that would have more disposable income available on their travels.

6.3 Social Function

A social aspect was regarded an increasingly expected feature in mobile applications. Not only for tourism applications, but also for gaming, social elements are believed to encourage repeated use and enjoyment while using mobile applications. Roberts (2013) therefore suggested linking tourism applications to established social media platforms that would enable users to share and comment on peer-generated content, which was confirmed in the tourist interviews. It was argued that tourists were using social platforms such as Facebook and Twitter on a daily basis, and therefore being able to access them through the tourist application would greatly enhance convenience and encourage its use. In contrast to the findings from the literature (Dantas et al. 2009; Gafni 2008), primary research particularly from focus groups revealed that privacy concerns in this regard were not considered a key requirement anymore. Focus groups participants argued that using social media to share content had gotten people used to publicise private information. Furthermore, it was revealed that sharing and seeing peer-generated content would be beneficial for potential visitors that were looking for first-hand information, which could also encourage positive word-of-mouth for the tourist attraction and destination. The interviews findings revealed that reviews and ratings by other tourists were highly valued before visiting a destination, confirming literature outcomes (Johnson et al. 2012). Gretzel and Yoo (2008) investigated the impact of reviews and ratings on the buying decision and suggested that it would greatly facilitate the decision making process of tourists, particularly for single travelers and women. While interview participants argued that their own research was equally important, many interviewees nonetheless suggested including a functionality to review and comment on tourist attractions. Similarly, Johnson et al. (2012) argued that users were often influenced by peer reviews not only for tourism products, but also for tangible products. Therefore, Gretzel and Yoo (2008) recommended including such functionalities in mobile tourism applications in order to encourage user engagement with the application.

6.4 Privacy and Security

'Privacy' has long been argued to remain a key requirement in the literature (Dantas et al. 2009; Delagi 2010; Dinh et al. 2013; Herskovic et al. 2011; Karahasanović et al. 2009; Mallat et al. 2009). However, tourist interview and focus group outcomes showed contradicting findings. The majority of participants in the interviews and focus groups argued that secure systems and procedures were established by companies and trustworthy. Therefore, tourists generally did not have any concerns regarding data privacy. While privacy was still argued to be important, it was not considered a key requirement for mobile AR tourism applications. Nonetheless, tourists argued that for the purpose of mobile transactions, privacy was seen to be necessary for secure payments. While studies conducted a few years ago still regarded privacy as a key requirement (Zoellner et al. 2009), online information transparency and peer-generated content has since been widely adopted. However, with the development of wearable technology, privacy issues seemed to be at the forefront of discussion once more (Mallat et al. 2009). Therefore, Carmigniani et al. (2011) suggested designing AR interactions in a way that would not violate other people's privacy in the immediate surrounding. While privacy concerns seemed to be decreasing, mobile AR applications on handheld devices posed a practicality issue during the interaction. After focus group participants experienced the mobile AR tourism application demonstrator, it was pointed out that a key concern was 'security' while using the mobile device outdoors in uncontrolled environments.

The impracticality of pointing the device camera at certain POIs for an extended period of time to access information was believed to induce risks of theft. As an alternative solution, focus group participants suggested designing the application in a way that would allow storing of information without having to continue holding the device at a designated angle.

6.5 Navigation

With regards to in-app navigation systems, tourist interview and focus group outcomes suggested a map-based navigation system similar to Google Maps. As tourists were familiar with using Google Maps (Shi et al. 2010), it was argued that navigation in unknown environments was a key requirement for tourism applications. While applications such as TripAdvisor that would provide reviews and ratings of tourist attractions were optional, tourist interviewees revealed that maps were among the mostly used applications for tourists, as people were constantly requiring way-finding assistance to POIs. In this regard, focus group participants claimed that a map-based functionality was an expected requirement for any future tourism applications involving new technology such as AR. The benefit of map-based applications was revealed to be the possibility to pinpoint the user's location and provide clear way-finding instructions. However, similar to literature findings (Gafni 2008), tourists argued that information on such map-based applications should be personalised and provide an information filtering option to avoid information overload while being guided.

6.6 Language

Interview and focus group participants were increasingly concerned about the convenience for international tourists. Therefore, including language functionalities in future mobile applications were regarded a key benefit for a large number of tourists. These could be developed in form of translating functions to instantly translate signs, words and phrases, or through offering the application in various languages. Focus group participants argued that international travel was becoming more affordable. As a result, future applications should be usable for a wider demographic market. While language options were mentioned in the literature before (Gannes 2013; Marimon et al. 2010; Schinke et al. 2010), they were not discussed to a great extent. However, primary research outcomes revealed that there is an increasing need to investigate the implementation of multiple language options in future mobile tourism applications. In this regard, tourist interviewees suggested a translating option as the most convenient language function for international tourists, as it would not require downloading or carrying a separate dictionary. Instead, phrases and words could be tailored to a specific tourism context or interest. Applications such as 'Word Lens' that can instantly translate languages were being developed for Google Glass (Gannes 2013). However, such functions are still limited and require further investigation to be meaningfully adopted in daily life. Nonetheless, it could revolutionise the way people interact with their surroundings, particularly for tourism purposes.

6.7 Information Quality

Literature findings as well as primary research outcomes revealed that content was the most influential and benefitting element in mobile tourism applications (Damala et al. 2008). Mobile AR tourism applications have been developed in various contexts that supported this view. Bruns et al. (2007) developed a mobile AR application in the museum context that would provide an interactive experience through the use of multimedia, while Huang et al. (2009) suggested a mobile AR application that would enable the virtual reconstruction of heritage sites in outdoor environments to provide an enhanced view of the past for the user. Zoellner et al. (2009) claimed that for such applications in the urban heritage context, it was crucial that the provided information was scientifically accurate in order to be beneficial for tourists. Van Krevelen and Poelman (2010) agreed, saying that the quality and accessibility of information was the key determinant for the success of mobile AR applications. Olsson and Salo (2011) further added that content should be personalised and relevant for the user, while assuring a smooth interactive experience. Morrison et al. (2011) similarly stated that future AR applications needed to be developed in alignment to each specific context to be beneficial for users. This would further facilitate the projection of information relevant to the user (van Krevelen and Poelman 2010). While content was considered key in the literature and by research participants, tourists noted that regularly maintaining the application to assure a smooth user experience was crucial to encourage regular use by tourists. This was particularly applicable for updating accessible content to project latest changes in the environment. Application maintenance was claimed to highly influence the user's perception of the application and a lack of it could be detrimental for the adoption of new applications (Gafni 2008). It was revealed that the importance of AR as functionality in mobile tourism applications was secondary to its content, and therefore regarded merely a tool that would serve as content communicator in the application. Therefore, content quality was confirmed to be the crucial determinant for mobile AR tourism applications. Nonetheless, it was pointed out that a suitable balance between content and function was necessary to provide a memorable user experience. Increasing the amount of available content was argued to pose a risk of exponentially increasing the size of the application. Therefore, to avoid long downloading times of the application, Internet access was revealed to be crucial.

6.8 Accessibility

The instant access of information has become increasingly important, as consumers have become more mobile, and therefore require information to be accessible independent of time and space (Dinh et al. 2013). However, tourist interview and focus groups participants claimed that Wi-Fi access in urban destinations was still too limited to be accessed anywhere at the tourists' convenience. While urban heritage destinations such as Dublin provide a free Wi-Fi service accessible for tourists, it was argued that such would provide limited speeds and access points, and therefore could not be utilised meaningfully. Instead, some tourists revealed to buy roaming packages before the trip that would grant access to the Internet at their convenience. Focus group participants agreed claiming that limited Internet access was a major issue for the young tourist market, as instant access of information was frequently required during a trip. Tourist interview participants therefore suggested providing an offline option in tourism applications that would not depend on the Internet to access content. However, Papagiannakis et al. (2008) pointed out that an offline application design would ultimately increase the size of the application depending on the amount of available content. Furthermore, Munch (2010) argued that such options would increase the loading time and could result in performance issues for the application. Therefore, it was discouraged particularly for tourism applications, as content in tourism applications was regarded a crucial selling point. Additionally, it was emphasised that mobile AR tourism applications required a network connection to instantly provide relevant information. Papagiannakis et al. (2008) further claimed that access to a stable Internet connection was crucial for mobile AR applications, as it would influence the speed of the application. While tourists had a split opinion whether or not to pay for Internet access during their trip, all participants agreed that Internet access was crucial for tourists to instantly search for information. Hill et al. (2010) and Zoellner et al. (2009) therefore claimed that limited Wi-Fi access would result in a negative impact on user adoption of mobile AR applications. Nonetheless, both alternatives would require constant monitoring and updated content to assure a continuous user benefit and enhanced user experience through the application.

7 Conclusions, Limitations and Recommendations

The study was conducted in the context of urban heritage tourism, selecting Dublin as the research site. While wearable devices are increasingly studied and developed for the consumer market recently (Curtis 2015), this study was based on handheld mobile devices that were considered the mobile standard of the time of study. While it can be seen that industry and academics are increasingly shifting to investigate wearable devices for tourism purposes (Leue et al. 2015), it was regarded significant to examine tourist requirements for mobile AR applications based on current devices before moving to the wearable market. On the one hand, wearable devices were not yet widely implemented, limiting the adoption of potential users, on the other hand, tourist requirements identified in this study were largely of generic nature and therefore regarded transferable to wearable devices respectively. Furthermore, Curtis (2015) claimed that it was still unknown when wearable devices would be widely adopted to provide a platform for AR use cases. However, it was regarded to have high potential in the tourism industry, as wearable AR technology was able to replace the handheld screen, opening more opportunities for the tourism industry (Orland 2015). Adoption of wearable AR would not only depend on the content and interaction with the application as proposed in this study, but are expected to largely depend on social norms respectively, as studies in the area of 'Fashnology' indicate (Chuah et al. 2016; Rauschnabel et al. 2016). Nonetheless, it remains crucial that mobile AR tourism applications are able to enhance the tourist experience in a meaningful way to encourage repeated use. Therefore, the study outcomes are believed to add to the current knowledge of implementing AR in the urban heritage tourism context and valuable for further research in the area of mobile application development for tourism purposes.

The study revealed that 'simplicity', which was regarded a key requirement in the literature for many years, was reworded to 'intuitive interaction'. In comparison, literature studying the Technology Acceptance Model (TAM) describes 'simplicity' as 'perceived ease of use', referring to the human-computer interaction (Davis 1989). According to the study outcomes, mobile AR applications should focus on a UI design that would enable tourists to interact with the application naturally without having to go through a learning process. While the TAM model further outlines the importance of 'perceived usefulness' (Venkatesh et al. 2012), research outcomes revealed in this regard that accessible content should be personalised and user-relevant to facilitate the access to required information and avoid information overload. It was expected that this would also positively influence application speed and performance. In addition, tourists largely expected implementing a social function in mobile AR tourism applications. Similar indications were noted in the TAM literature, suggesting that social and cultural factors influenced user's acceptance of new technology (Lewis et al. 2003). As privacy was not regarded a key requirement any longer, sharing information was generally seen as beneficial for tourism applications. In contrast, security issues were regarded a higher priority due to the impractical interaction with current mobile AR-ready handheld devices. While using AR applications was believed to potentially provide new opportunities such as for navigating purposes, regular maintenance of content was crucial to increase trustworthiness and encourage repeated use of the application. Particularly for new developments of AR applications, reliable and updated content was revealed being a key determinant of quality. Therefore, mobile AR tourism applications required being accessible independent of time and space. This demanded a stable and sufficient Internet access to provide requested information instantly.

An Internet dependent mobile AR tourism application was argued to be more beneficial for tourists, despite requiring an active and stable Internet connection, due to the instant provision of information. In addition, it would allow reducing the size of the application, which would positively impact on the speed and user interaction, providing an enhanced tourist experience.

This study has a number of limitations and recommendations for further research. While this research was designed in two stages including a pre- and post-experience study in form of interviews and focus groups, it needs to be acknowledged that both methods are of qualitative nature. Therefore, the study proposes a limitation to generalise its findings. Furthermore, interview participants had limited knowledge of AR at the time of study. Therefore, AR examples were provided to support the understanding of interviewees. Although it was attempted to ensure that participants had as much freedom as possible to answer questions, occasional explanations were required to assist the understanding of AR. Nonetheless, a second research stage was conducted to reduce this limitation. Finally, the limitation in the sample population needs to be acknowledged, as the majority of research participants were female and in the age group of 22–30. A more balanced sample could have provided a modified list of requirements particularly including various age groups.

The research outcomes suggest that tourists are increasingly expecting methods to access information instantly. While this study provides an indication of tourist requirements for mobile AR tourism applications in urban heritage tourism, further research is recommended for the implementation of information and communication technology for the enhancement of the tourist experience. Therefore, it is suggested that demographic segments are explored separately, as tourists are increasingly looking for a tailored tourist experience. Dublin was selected as the study context for this research. However, comparative studies investigating other urban heritage sites would provide an insight into the reliability of findings as well as potentially identify additional requirements. In particular, contrasting urban heritage sites in Europe to Asia could reveal new insights, as cultural differences are expected to influence the way tourists interact with their devices and their surroundings. As studies are increasingly conducted on the adoption and usefulness of wearable AR devices, further studies for user requirements using wearable devices are required. In this regard, it is recommended to investigate not only generic content and function requirements, but in alignment with consumer behavior in a variety of contexts. Although this study was based on handheld mobile devices, a trend towards exploring wearable computing for the consumer market could be observed. While wearable devices have not yet been widely adopted, it is believed that the awareness and adoption of AR will increase significantly with the further development and utilisation of wearable technology.

References

Adami, M. F. (2005). The use of triangulation for completeness purposes. *Nurse Researcher, 12*(4), 19–29.

An, Y., Lee, S., & Park, Y. (2008). Development of an integrated product-service roadmap with QFD: A case study on mobile communications. *International Journal of Service Industry Management, 19*(5), 621–638.

Boyatzis, R. E. (1998). *Thematic analysis and code development—Transforming qualitative information*. Thousand Oaks: Sage.

Bruns, E., Brombach, B., Zeidler, T., & Bimber, O. (2007). Enabling mobile phones to support large-scale museum guidance. *Multimedia, IEEE, 14*(2), 16–25.

Bulearca, M., & Tamarjan, D. (2010). Augmented reality: A sustainable marketing tool? *Global Business and Management Research: An International Journal, 2*(2/3), 237–252.

Carmigniani, J., Furht, B., Anisetti, M., Ceravolo, P., Damiani, E., & Ivkovic, M. (2011). Augmented reality technologies, systems and applications. *Multimedia Tools and Applications, 51*(1), 341–377.

Choi, J. H., & Lee, H. J. (2012). Facets of simplicity for the smartphone interface: A structural model. *International Journal of Human-Computer Studies, 70*(2), 129–142.

Chuah, S. H. W., Rauschnabel, P. A., Krey, N., Nguyen, B., Ramayah, T., & Lade, S. (2016). Wearable technologies: The role of usefulness and visibility in smartwatch adoption. *Computers in Human Behavior, 65,* 276–284.

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 Behaviour, 50,* 588–599.

Creswell, J. W. (2007). *Qualitative inquiry and research method: Choosing among five approaches*. Thousand Oaks: Sage.

Curtis, S. (2015). *Has Google glass failed?* The Telegraph. Retrieved November 2016, from http://www.telegraph.co.uk/technology/google/11350810/Has-Google-Glass-failed.html.

Damala, A., Cubaud, P., Bationo, A., Houlier, P., & Marchal, I. (2008). *Bridging the gap between the digital and the physical: Design and evaluation of a mobile augmented reality guide for the museum visit.* Paper presented at the 3rd international conference on Digital Interactive Media in Entertainment and Arts, Athens, Greece.

Dantas, V. L. L., Marinho, F. G., da Costa, A. L., & Andrade, R. M. (2009). *Testing requirements for mobile applications.* Paper presented at the 24th International Symposium Computer and Information Sciences, Guzelyurt, Northern Cyprus.

Davies, N., Cheverst, K., Dix, A., & Hesse, A. (2005). *Understanding the role of image recognition in mobile tour guides.* Paper presented at the 7th international conference on Human computer interaction with mobile devices & services, Salzburg, Austria.

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

Delagi, G. (2010). *Harnessing technology to advance the next-generation mobile user-experience.* Paper presented at the IEEE International Solid-State Circuits Conference Digest of Technical Papers (ISSCC), San Francisco, CA, USA.

Dinh, H. T., Lee, C., Niyato, D., & Wang, P. (2013). A survey of mobile cloud computing: Architecture, applications, and approaches. *Wireless communications and mobile computing, 13*(18), 1587–1611.

Feiner, S., MacIntyre, B., Höllerer, T., & Webster, A. (1997). A touring machine: Prototyping 3D mobile augmented reality systems for exploring the urban environment. *Personal Technologies, 1*(4), 208–217.

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

Gafni, R. (2008). Framework for quality metrics in mobile-wireless information systems. *Interdisciplinary Journal of Information, Knowledge, and Management, 3,* 23–38.

Gannes, L. (2013). *Next Google glass tricks include translating the world from your eyes,* All Things Digital. Retrieved November 2016, from http://allthingsd.com/20131119/new-google-glass-apps-will-translate-the-world-from-your-eyes-and-other-tricks/.

Gebauer, J., Shaw, M. J., & Gribbins, M. L. (2010). Task-technology fit for mobile information systems. *Journal of Information Technology, 25*(3), 259–272.

Gospodini, A. (2004). Urban morphology and place identity in European cities: Built heritage and innovative design. *Journal of Urban design, 9*(2), 225–248.

Gretzel, U., & Yoo, K. H. (2008). Use and impact of online travel reviews. *Information and communication technologies in tourism*. 35–46.

Grossmann, M., Leonhardi, A., Mitschang, B., & Rothermel, K. (2001). A world model for location-aware systems. *Informatik, 8*(5), 22–25.

Halcomb, E. J., & Andrew, S. (2005). Triangulation as a method for contemporary nursing research. *Nurse Researcher, 13*(2), 71–82.

Hariharan, R., Krumm, J., & Horvitz, E. (2005). *Web-enhanced GPS*. International Symposium on Location-and Context-Awareness. 95–104.

Herskovic, V., Ochoa, S. F., Pino, J. A., & Neyem, H. A. (2011). The Iceberg effect: Behind the user interface of mobile collaborative systems. *Journal of Universal Computer Science, 17*(2), 183–201.

Hill, A., MacIntyre, B., Gandy, M., Davidson, B., & Rouzati, H. (2010). *Kharma: An open kml/html architecture for mobile augmented reality applications.* Paper presented at the 9th IEEE International Symposium on Mixed and Augmented Reality (ISMAR). 233–234.

Höllerer, T. H., & Feiner, S. K. (2004). Mobile augmented reality. In H. Karimi & A. Hammad (Eds.), *Telegeoinformatics: Location-based computing and services*. London: Taylor & Francis.

Huang, Y., & Bian, L. (2009). A bayesian network and analytic hierarchy process based personalized recommendations for tourist attractions over the internet. *Expert Systems with Applications, 36*(1), 933–943.

Huang, Y., Liu, Y., & Wang, Y. (2009). *AR-view: And augmented reality device for digital reconstruction of yuangmingyuan*. Paper presented at the international Symposium on Mixed and Augmented Reality.

Johnson, P. A., Sieber, R. E., Magnien, N., & Ariwi, J. (2012). Automated web harvesting to collect and analyse user-generated content for tourism. *Current Issues in Tourism, 15*(3), 293–299.

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,* 75–86.

Jung, T., & Leue, M. C. (2015). Enhancing the visitor experience through wearable augmented reality: A case study of Manchester art gallery. In M. Sigala, E. Christou, & U. Gretzel (Eds.), *Social media in travel, tourism and hospitality: Theory, practice and cases*. Oxon: Routledge.

Karahasanović, A., Brandtzæg, P. B., Heim, J., Lüders, M., Vermeir, L., Pierson, J., et al. (2009). Co-creation and user-generated content—Elderly people's user requirements. *Computers in Human Behavior, 25*(3), 655–678.

Kenteris, M., Gavalas, D., & Economou, D. (2009). An innovative mobile electronic tourist guide application. *Personal and Ubiquitous Computing, 13*(2), 103–118.

Klubnikin, A. (2016). *Tourism apps are primed to reshape the app industry,* Tech.Co Retrieved November 2016, from http://tech.co/tourism-apps-primed-reshape-app-indusry-2016-01.

Lambert, S. D., & Loiselle, C. G. (2008). Combining individual interviews and focus groups to enhance data richness. *Journal of Advanced Nursing, 62*(2), 228–237.

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*. 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*. New York: Springer.

Lewis, W., Agarwal, R., & Sambamurthy, V. (2003). Sources of influence on beliefs about information technology use: An empirical study of knowledge workers. *MIS quarterly,* 657–678.

Mallat, N., Rossi, M., Tuunainen, V. K., & Öörni, A. (2009). The impact of use context on mobile services acceptance: The case of mobile ticketing. *Information & Management, 46*(3), 190–195.

Marimon, D., Sarasua, C., Carrasco, P., Álvarez, R., Montesa, J., Adamek, T., Romero, I., Ortega, M., & Gascó, P. (2010). MobiAR: Tourist experiences through mobile augmented reality. *Telefonica Research and Development.* Barcelona, Spain.

Morrison, A., Mulloni, A., Lemmelä, S., Oulasvirta, A., Jacucci, G., Peltonen, P., et al. (2011). Collaborative use of mobile augmented reality with paper maps. *Computers & Graphics, 35*(4), 789–799.

Munch, C. (2010). *Effect of website speed on users,* Munchweb. Retrieved November 2016, from http://munchweb.com/effect-of-website-speed.

Ngai, E. W. T., & Gunasekaran, A. (2007). A review for mobile commerce research and applications. *Decision Support Systems, 43*(1), 3–15.

Nicas, J. (2016). *Augmented reality moves forward with investments, products,* The Wall Street Journal. Retrieved November 2016, from http://www.wsj.com/articles/augmented-reality-moves-forward-with-investments-products-1452026393.

Olsson, T. & Salo, M. (2011). *Online user survey on current mobile augmented reality applications.* Paper presented at the 10th IEEE International Symposium on Mixed and Augmented Reality (ISMAR), Basel, Switzerland.

Orland, K. (2015). *Epic's Tim Sweeney: Augmented reality will replace traditional screens,* Arstechnica. Retrieved November 2016, from http://arstechnica.com/gaming/2015/07/epics-tim-sweeney-augmented-reality-will-replace-traditional-screens/.

Pang, Y., Nee, A., Ong, S., Yuan, M., & Youcef-Toumi, K. (2006). Assembly feature design in an augmented reality environment. *Assembly Automation, 26*(1), 34–43.

Papagiannakis, G., Singh, G., & Magnenat-Thalmann, N. (2008). A survey of mobile and wireless technologies for augmented reality systems. *Computer Animation and Virtual Worlds, 19*(1), 3–22.

Plack, M. M. (2006). The development of communication skills, interpersonal skills, and a professional identity within a community of practice. *Journal of Physical Therapy Education, 20*(1), 37–46.

Pulli, P., Zheng, X., Antoniac, P., Hickey, S., Manninen, T., Martikainen, O. & Kuroda, T. (2007). *Design and development of mobile services platform for senior citizens.* Paper presented at the 13th International Conference on Concurrent Enterprising (ICE 2007).

Rauschnabel, P. A., Hein, D. W., He, J., Ro, Y. K., Rawashdeh, S., & Krulikowski, B. (2016). Fashion or technology? A fashnology perspective on the perception and adoption of augmented reality smart glasses. *i-com, 15*(2), 179–194.

Reitmayr, G. & Schmalstieg, D. (2003). *Location based applications for mobile augmented reality.* Paper presented at the Proceedings of the Fourth Australasian user interface conference on User interfaces.

Rekimoto, J. (1997). Navicam: A magnifying glass approach to augmented reality. *Presence: Teleoperators and Virtual Environments, 6*(4), 399–412.

Roberts, J. J. (2013). *One year after facebook integration, instagram relies on design by data,* Gigaom. Retrieved November 2016, from http://gigaom.com/2013/11/06/one-year-after-facebook-integration-instagram-relies-on-design-by-data/.

Rouse, M. (2015). *Augmented Reality,* WhatIS.com Retrieved November 2016, from http://whatis.techtarget.com/definition/augmented-reality-AR.

Schinke, T., Henze, N., & Boll, S. (2010). *Visualization of off-screen objects in mobile augmented realit*. Proceedings of the 12th international conference on Human computer interaction with mobile devices and services. 313–316.

Shi, X., Sun, T., Shen, Y., Li, K., & Qu, W. (2010). Tour-guide: Providing location-based tourist information on mobile phones, *Computer and Information Technology (CIT).* 2397–2401.

Siluk, S. (2015). *Microsoft to roll out hololens to developers in coming year,* Sci-tech Today. Retrieved November 2016, from http://www.sci-tech-today.com/story.xhtml?story_id=0110015BAKJ2.

Stone, R., Bisantz, A., Llinas, J., & Paquet, V. (2009). Augmented multisensory interface design (AMID): A human-centric approach to unisensory and multisensory augmented reality design. *Journal of Cognitive Engineering and Decision Making, 3*(4), 362–388.

Swallows, D., Yen, D. C., & Tarn, J. M. (2007). XML and WML integration: An analysis and strategies for implementation to meet mobile commerce challenges. *Computer Standards & Interfaces, 29*(1), 97–108.

tom Dieck, M. C., & Jung, T. (2015). A theoretical model of augmented reality acceptance in urban heritage tourism. *E-review of Tourism Research, 5,* 1–13.

Van Krevelen, D. W. F., & Poelman, R. (2010). A survey of augmented reality technologies, applications and limitations. *International Journal of Virtual Reality, 9*(2), 1.

Venkatesh, V., Thong, J. Y., & 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.

Wang, Y. S., & Liao, Y. W. (2007). The conceptualization and measurement of m-commerce user satisfaction. *Computers in Human Behavior, 23*(1), 381–398.

Xu, D. J., Liao, S. S., & Li, Q. (2008). Combining empirical experimentation and modeling techniques: A design research approach for personalized mobile advertising applications. *Decision Support Systems, 44*(3), 710–724.

Zoellner, M., Keil, J., Drevensek, T., & Wuest, H. (2009). *Cultural heritage layers: Integrating historic media in augmented reality.* Paper presented at the 15th International Conference on Virtual Systems and Multimedia. 193–196.

How can Tourist Attractions Profit from Augmented Reality?

Eleanor E. Cranmer, M. Claudia tom Dieck and Timothy Jung

Abstract The benefits, value and potential of Augmented Reality (AR) are widely researched. However, the value of AR is most commonly discussed in relation to enhancing the tourist experience, rather than generating revenue or economic returns. Although AR promises to add value to the visitor experience and generate associated benefits, the financial implications and revenue model for AR implementation remain uncertain and therefore too much of a financial risk for most tourist organisations, typically Small to Medium Sized Enterprises (SMEs) characterised by limited funding. Thus, using the case of UNESCO recognised Geevor Tin Mine Museum, in Cornwall, UK, this study identifies ways in which tourism organisations can profit from AR implementation. Fifty semi-structured interviews with Geevor stakeholders, analysed using content analysis reveal a number of ways AR can be introduced to increase revenue generation and profits, therefore filling a gap in research and minimising the risk for managers and practitioners considering AR implementation.

Keywords Augmented reality · Tourism · Revenue model · Business model

1 Introduction

Throughout the 20th Century the emergence of new adaptive and interactive technologies changed the tourism industry completely (Buhalis and Law 2008). Technologies have revolutionised travel behaviours, such as decision making and

E.E. Cranmer (✉) · M. Claudia tom Dieck · T. Jung
Faculty of Business and Law, Manchester Metropolitan University, Manchester, UK
e-mail: e.cranmer@mmu.ac.uk

M. Claudia tom Dieck
e-mail: c.tom-dieck@mmu.ac.uk

T. Jung
e-mail: t.jung@mmu.ac.uk

T. Jung and M.C. tom Dieck (eds.), *Augmented Reality and Virtual Reality*,
Progress in IS, DOI 10.1007/978-3-319-64027-3_2

information searching (Wang et al. 2014), transforming traditional business channels and value networks (Buhalis 2003; Livi 2008). To remain competitive and financially viable, it has been argued tourist organisations must pursue new ways to provide enhanced (Neuhofer et al. 2014; Tussyadiah 2014), enriched and unique experiences (Yovcheva et al. 2013), while offering value adding services (Garcia-Crespo et al. 2009).

For decades, tourism has been considered a tool to stimulate and improve the economy (Ko and Stewart 2002), thus in the modern age, this has progressed to include the adoption of, and investment in new technologies. It is now advised organisations that fail to adopt modern technologies, such as Augmented Reality (AR), will not remain attractive and competitive (Han et al. 2014; Tscheu and Buhalis 2016). Hereby, it is argued future competitive advantages are built around the effective use of technologies that add value to the tourist experience (Carlsson and Walden 2010; Cranmer et al. 2016; Deloitte 2013).

AR has gained much research attention within tourism, for its proven ability to enhance the tourist experience (Garcia-Crespo et al. 2009; Leue et al. 2015), adding value (Cranmer et al. 2016), and creating unique and memorable experiences (Yovcheva et al. 2013). It is widely acknowledged AR creates richer, more immersive content enhancing user's interaction with and perception of the world and thus presents many opportunities to enhance experiences. However, despite many studies exploring and reporting the value of AR, the majority fail to identify and determine its financial benefits and economic potential. Therefore, in contrast to expectations, the adoption and integration of AR has been much slower than predicted (Chung et al. 2015). It is argued one reason for this is the absence of research identifying how AR can be introduced to improve profit potential and create revenue streams. Research is yet to bridge the gap between technological potential and actual value adding economic benefits. Therefore, this study attempts to progress understanding about how tourist organisations can implement and profit from AR by providing new insight, which will reduce the risk associated with AR technology adoption, and help mangers and practitioners to better understand ARs financial value, benefits and potential.

2 Literature Review

2.1 Augmented Reality in Tourism

Technology has had a profound effect on tourism, strengthening the need for organisations to find new ways to increase their presence and therefore competitiveness (Tscheu and Buhalis 2016). Proliferation of technology, and increased smartphone ownership has revolutionised the way tourists' access and explore information (Jung et al. 2015). Tourists, now demand 'info-cultural-tainment' experiences, combining leisure, entertainment, culture, education and sociability

(Palumbo et al. 2013). As a result, an increasing number of tourist attractions have begun to explore the use of AR to enhance visitor interactions with, and perceptions of their real-world environment (Roesner et al. 2014). Research praises AR for its ability to allow tourists with limited knowledge of an area to naturally and realistically experience it (Chung et al. 2015; Martínez-Graña et al. 2013), providing tailored and personalised information (Kounavis et al. 2012; Kourouthanassis et al. 2015) and enhance the tourist experience (Kounavis et al. 2012; Marimon et al. 2014).

A study by Palumbo et al. (2013) found AR increases visitor numbers and provides organisations with more scope to reach wider audiences (Chung et al. 2015; Kennedy-Eden and Gretzel 2012). Moreover, Chung et al. (2015) identified AR offers destinations and attractions a way to differentiate themselves and increase competitive advantage. In addition to this, it is argued simply that technology attracts tourists (Lashkari et al. 2010), because it offers added value to the user (Kounavis et al. 2012), facilitating seamless exploration of their surroundings (Yovcheva et al. 2013), thus extending their learning experience (Yuen et al. 2011). As well as this, implementing AR introduces many marketing opportunities, allowing destinations to come to life, giving visitors a better understanding of what to expect and therefore aiding in decision-making and planning processes (Yovcheva et al. 2013). Many of these findings imply AR could have a positive economic benefit, such as increasing competiveness and therefore, visitors numbers. But, the majority fail to articulate ARs positive profit potential, by failing understand how potential can be translated into economic value. Hence, the financial implications of AR remain too unclear and therefore present too much risk for tourism SMEs.

As a result, contrary to expectations, adoption of AR has been slower than anticipated (Chung et al. 2015), although, it is still argued adopting and investing in modern technologies is a necessity for attractions to remain competitive (Tscheu and Buhalis 2016; Jung et al. 2015) and economically sustainable (Cranmer et al. 2016). The tourism industry currently lacks a framework or model to aid practitioners and managers to effectively implement AR. Research exploring Business Models (BMs) and Revenue Models (RM) for AR in tourism is scarce, and is currently delaying widespread adoption, implementation and exploration of ARs full potential (Cranmer and Jung 2014). To provide insight and progress one step closer to meaningful and wide scale adoption of AR in tourism, this study will identify how ARs potential can be translated into economic value.

3 Augmented Reality Revenue Model

BMs play a crucial role in helping secure and expand competitive advantage (Johnson et al. 2008), telling the story of how organisations intend to create and sustain profits (Magretta 2002). BMs focus on creating value and capturing returns from that value (Chesbrough 2007). Stakeholder collaboration is vitally important to successfully implement new technologies (Al-Debei and Avison 2010), especially in the tourism context which is characterised by large and complex networks (Livi 2008). However, the economic value of AR for tourism is undefined, and as a result, organisations remain unsure how to implement the technology to add value to the visitor experience while generating economic return. The potential to add value by implementing AR is widely researched, but, the majority of studies explore ARs value from a visitor perspective, rather than how it can be adopted to generate profit or create additional revenue. An AR RM is currently missing from research, despite the fact it has been argued “a better business model often will beat a better idea or technology” (Chesbrough 2007, p. 12).

In a study exploring the value creation process of AR at Cultural Heritage (CH) sites, earning profits was identified as the most important outcome of AR implementation from a developers perspective, and “varying business models are currently available on the market” (Tscheu and Buhalis 2016, p. 612). However, no AR specific BMs in a tourism context have been identified within existing research and it remains a clear BM for AR is yet to crystallise (Cranmer and Jung 2014; Kleef et al. 2010).

Nevertheless, Inoue and Sato (2010) propose several potential ways to generate revenue from AR. However, these mainly adapt existing BMs, and are not designed for AR and more specifically the tourism context. On this note, Kleef et al. (2010, p. 4) stated “value is the key concept of a business model, it is what a business trades with its customers”, but suggested in the case of AR, the value is likely to be non-financial. In the context of tourist organisations, often SMEs faced with limited budgets, Tscheu and Buhalis (2016) suggested shared RMs are most suitable, but they do not outline or define how this could work in reality. Therefore, this study will attempt to explore potential RMs for AR implementation, using the case of UNESCO recognised, Geevor Tin Mine Museum, Cornwall.

Geevor is a publically funded organisation, and face increasing pressure to secure additional revenue streams whilst improving the visitor experience and modernising its appeal. Although each CH site is different (Tscheu and Buhalis 2016), the study will identify potential AR RMs, with the aim of providing practical guidelines for practitioners and managers to identify how AR could be implemented to generate financial returns.

4 Methods

Geevor was used as a case study to understand the ways in which stakeholders perceived AR could be introduced to improve the visitor offer, while generating revenue. Stakeholder analysis was performed, identifying five stakeholder groups; 9 of Geevors internal stakeholders (G), 6 Tourist Bodies (B), 3 Tertiary groups (T), 2 local Businesses (L) and 30 Visitors (V). In total, 50 semi-structured interviews were conducted with members of these groups, between March 2015 and February 2016. Due to the exploratory nature of the study, a semi-structured interview approach allowed the freedom to add to and extend questions (Saunders et al. 2012), providing more flexibility and increasing the quality of data (Gillham 2005).

Sampling is often chosen on the basis of employing methods that source respondents to best meet the overall aims of research. Importantly, "the sample must be appropriate and comprise participants who best represent or have knowledge of the research topic" (Elo et al. 2014, p. 4). Therefore, different sampling methods were employed; non-probability sampling was used to interview all stakeholder groups except visitors, where it was more practical to employ convenience sampling. Prior to interviews respondents were shown a short AR video demonstration and provided with an AR information sheet, to ensure their knowledge of AR was proficient to adequately participate in the interview. All interviews were recorded and transcribed and data were analysed using content analysis.

Regarding the profile of visitors, the majority (60%) identified themselves as 'very much' or 'much' with regard to their technical savviness, suggesting they are regular users of technologies such as smartphones and tablets, and 83% owned a smartphone (and those who did not often said they had a tablet). With regard to all other stakeholders, Table 1 demonstrates internal, tertiary, bodies and business stakeholder profiles including their organisation, position, and prior understanding of AR.

Table 1 Stakeholder respondent profile

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

5 Findings

5.1 Secondary Revenue Generation

Stakeholders strongly believed AR could be used to generate secondary revenue, through increased spend both on-site and in the local area, resulting from increased customer retention. It was considered the more time visitors spent on site, using and enjoying AR, the more likely they would be to spend money, such as staying to enjoy lunch in the café or having afternoon tea. In this way, LB1 hoped AR would encourage visitors to "come to Geevor for the day…I am trying to get double sale or tripe sales". It is believed AR would give visitors more to do, while enhancing their experience and therefore enjoyment. In turn this would increase the time they spent on site and thus likelihood to visit the café for refreshments.

Similarly, with regard to the on-site shop, stakeholders suggested AR would increase visitors' engagement and understanding of the exhibits, therefore increasing their likelihood to purchase items, such as books in the shop to continue and improve their learning experience. It was considered AR would help strengthen the connection between the museum experience and the products for sale in the shop. G7 for instance commented "in the mineral gallery…you could have one small notice saying many of these specimens can be seen and purchased in the shop". In this way, it was considered AR would link directly to the on-site businesses, encouraging visitors to go in, instead of bypassing them. LB2 extended this further, suggesting advertising products throughout the museum experience would not only help drive traffic, retain customers and increase sales, but also increase awareness and interest in local traditions and customs. Stakeholders felt if used in this way would be particularly beneficial during low season when the site is quietest, to help combat issues associated with seasonality and customer retention. However, it was acknowledged AR would have to be subtle, careful not to interfere with, or detract from the exhibits.

Stakeholders identified one of Geevors challenges is that visitors underestimate the scale, scope and range of activities offered and often spend longer on site than anticipated. Thus, using AR, G8 and B2 felt people would be more likely to stay even longer because they would appreciate the scale of the attraction. B2 summarised "it is about eating more, drinking more and spending more" suggesting AR would extend visitors dwell time. Equally, B4 pointed out that AR would extend the visitor offer, and likelihood for visitors to spend longer on site, which increases the perception of value for money and therefore again increase their likelihood to spend more in the café and shop. Likewise, B2 claimed if more visitors are coming, staying longer and spending more money it will create a positive change, and increase revenues. These ideas are also mirrored by V22 who said as a visitor, if the experience is more engaging it would increase the likelihood of spending longer on site.

5.2 Marketing Tool

The marketing potential and merits of AR are much discussed within literature, however the use of AR to increase profits has not been previously examined. 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. Thus, also attracting more visitors who would spend more at Geevor and locally (T2). In this way, AR could give Geevor competitive edge, while helping to attract less specialist and more generalist audiences as well as appeal to younger target groups. Importantly, B5 recognised that if you are doing something for younger markets, you are also doing something to benefit older markets, because they “share the same barriers”.

Stakeholders acknowledged simply offering AR would be valuable and drive visits from individuals interested in trying the new technology. In this way, AR could therefore help “seal the deal”, influencing and confirming visitors’ decision to go to Geevor. B1 suggested AR would attract more visitors, anticipating a good visitor experience thinking “oh that sounds a bit different, I am going to try that out”. B1 and G2 perceived, this would have a significant impact on word-of-mouth marketing and recommendations, in turn attracting more people to visit. This is exemplified by V3, V4, V25 and V28 who all claimed they would recommend Geevor, if the AR app provided an enhanced experience.

One of Geevors’ key challenges is a lack of funding, therefore if AR had the potential to demonstrate site advancement, innovation and improvement indirectly attracting funders, this would be extremely valuable to Geevor (B3, LB2). In addition, B2 identified the benefit of AR is that it would offer the media something “new” to promote. B5 and G3 also thought AR would increase visitors’ likelihood to share their experiences on social media platforms, which would again raise Geevors profile and attracter wider audiences. T2 noted that society is used to instant sharing, and AR should inspire photo sharing, or what people thought of the experience to inspire higher visitor numbers “based on new visits rather than repeat visits”. G3 adds this would help increase Geevors online marketing presence. Although T2 raised concern that if some sort of AR experience was available pre-visit, it may have a negative impact and discourage people from actually visiting, because they would feel they had seen it all. But, nevertheless recognised AR would be a good way to potentially increase site engagement and drive visits. AR would however be effective at providing a “wow” factor (G2) incorporated into marketing materials to increase visitor numbers.

5.3 AR Free or Fee

A number of considerations arose during interviews. One of the main debates centred around the best and most effective RM to introduce AR at Geevor.

Stakeholders were of two minds about whether AR should be offered for free, as part of Geevor trying to better the visitor experience or alternatively whether AR be offered as an extra, at an additional fee to the entry cost. Even among stakeholders who felt AR should be charged at a fee, the amount varied. Out of 30 visitors interviewed, just over half said they would be willing to pay between £1 and £5 to use AR, believing it would make the visit more interesting, entertaining and educational. Although, no ideal cost for AR was identified. Some visitors claimed to have paid for audio guides at other attractions, so paying to use AR would be no different. Most stakeholders agreed that audio guides prove visitors' willingness to pay to have "a bit more information at their fingertips" (B1) and thus would make sense to have a fee attached. However, it was also proposed that the fee could vary at different times of the year and for different target segments.

On the other hand, just under half of visitors argued they would not be willing to pay a fee to use AR, and it should be offered free as part of Geevor trying to deepen and broaden the visitor experience, bettering itself. Of these, some suggested however, that if the entry fee increased slightly to cover the costs of AR it would not cause concern. One of the main reasons visitors objected to paying a fee for AR is worry about Geevor becoming too expensive for families, as well as visitors feeling they have to use AR because they have paid for it. This clearly shows that there is no agreement about costs involved in using AR at CH attractions thus, proper research is required to ensure that visitors' willingness to pay is fully understood and appropriate strategies adopted.

5.4 *Own or Loan Devices*

Another debate arising from interviews related to AR pricing structure; whether visitors should have their own devices or if Geevor would provide devices for visitors to loan. Yet, irrespective of the choice made, both could potentially generate revenue. Firstly, if visitors used their own devices Geevor could introduce a charge to download the AR application. Secondly, if Geevor loaned devices to visitors, they could demand a hire fee and deposit. However, both options introduce financial implications, such as buying and maintaining enough devices to loan to visitors. Equally both options have barriers, for example if visitors used their own devices, it would be based on the assumption all visitors have an AR enabled device, that is fully charged, has enough memory, sufficient connectivity and power to efficiently run the AR application. Visitors without their own AR capable devices would miss out on the experience.

On the other hand, if Geevor were to loan devices, stakeholder recognised the long-term commitment and investment it would involve and issues surrounding security and preventative measures to ensure devices are returned. However, deposit schemes, pre booking devices and tracking devices were proposed by stakeholders as a resolution to such barriers. Visitors largely favoured the idea of loaning devices, claiming they would be willing to pay more to hire a device because it would enhance their experience. Whereas if visitors had to use their own devices, paying to pay to download AR it was considered less favourable.

6 Discussion and Conclusions

The aim of this study was to explore and understand potential ways AR can be implemented to generate profit. Despite the many benefits AR presents to tourist organisations such as Geevor, its adoption still involves too many uncertainties and therefore financial risk. Therefore, this study aimed to improve understanding by revealing how AR can be adopted to generate revenue, by identifying a number of ways potential AR RMs. However because the study is conceptual, although it identifies potential profit generation methods, using these methods to earn profit is yet to be researched. Nonetheless, the study bridges a gap within current research. At present, the majority of AR studies identify the potential of AR to add value and enhance experiences, rather than generate profitable and financial value. This study adds to the existing pool of knowledge by exploring financial implications of AR adoption. Fundamentally, business is concerned with creating value and capturing returns from that value (Chesbrough 2007). Although value does not have to be financial, for tourist organisations such as Geevor, it is important investment into and adoption of technologies both enhance the tourist experience and generate revenue (Jung et al. 2015), and earning profits is often considered the most important outcome of AR implementation (Tscheu and Buhalis 2016).

This study reveals a number of potential ways tourist organisations can adopt and implement AR to generate profit. Since this is an underexplored area, the majority of findings have not been previously identified in literature. However, some overlaps with existing research are apparent; for instance stakeholders considered just by offering AR technology, it would broaden and attract wider audiences. This is confirmed by Lashkari et al. (2010) who found technology itself attracts tourists. Similarly, stakeholders identified a number of potential secondary benefits arising from AR implementation that would contribute to increased profits; such as adding value to the visitor experience, increasing and extending the learning experience, as well as providing entertainment and sociability. Such benefits of AR have been previously identified in literature (e.g. Chung et al. 2015; Kounavis et al. 2012; Palumbo et al. 2013), but this study extends understanding identifying how these benefits can contribute to increase profit generation. Stakeholders perceived if visitors have a better experience using AR, they are likely to stay longer on site which would increase their likelihood to spend more money in the café or make a purchase in the shop. In turn, this would create a better reputation for Geevor, broadening the target market, while attracting more visitors, increasing ticket sales and use of local infrastructure, as well as creating more money to invest back into the area. Although previous studies such as Yovcheva et al. (2013) discuss the marketing potentials of AR, they do not examine how it could generate revenue.

Again, interview findings extend understanding; suggesting AR would raise the profile of the site and Cornwall as a tourist destination, increasing visitor numbers, creating a good reputation for the area and enhancing competitiveness.

In addition to this, interviews revealed two debates, firstly should AR be offered free or for a fee? Secondly, should visitors bring their own devices or should Geevor loan AR enabled devices? There was a divide of opinion and although no clear answer was established, the study generates questions that require answers if, and before, AR is to be successfully and sustainably implemented by tourist organisations. For many SMEs, the pressure to adopt and invest in modern technologies increases daily (Han et al. 2014; Jung et al. 2015; Tscheu and Buhalis 2016), but at present there remain too many uncertainties and therefore financial risk. The creation and examination of such 'own or loan', 'free or fee' debates create platforms for discussion and demonstrate the need for further research, as well as providing questions for mangers and practitioners considering AR adoption to answer. Therefore, not only does this study extend the existing pool of knowledge and move AR one step closer to meaningful implementation by outlining potential profit generation. It also provides both practitioners and managers with a number of considerations and potential paths to pursue to implement AR to generate a profit, thus minimising financial risk.

This study has a number of limitations and recommendations for future research. The findings are based solely on a case study of Geevor Tin Mine Museum, therefore minimising their generalisability. Nonetheless, the study identified a number of potential ways to implement AR within tourist organisations to generate profit, however the findings are in no way complete and it is recommended further studies are conducted and the financial outcomes of actual implementation reported. Nevertheless, the study provides insight, of which provide a greater understanding of ARs profit generating potential, thus offering managers and practitioners to learn from and share from the findings.

References

Al-Debei, M., & Avison, D. (2010). Developing a unified framework of the business model concept. *European Journal of Information Systems, 19*(3), 359–376.

Buhalis, D. (2003). *Etourism: Information technology for strategic tourism management*. Harlow: Financial Times Prentice Hall.

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.

Carlsson, C., & Walden, P. (2010). Supporting tourists at the Bomarsund Fortress with a mobile value service. *Journal of Information Technology Theory and Application, 11*(1), 43–56.

Chesbrough, H. (2007). Business model innovation: It's not just about technology anymore. *Strategy & Leadership, 35*(6), 12–17.

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

Cranmer, E., & Jung, T. (2014). *Augmented Reality (AR): Business models in urban cultural heritage tourist destinations*. Paper presetned at Pacific Council on Hotel, Restaurant and Institutional Education (APacCHRIE), Kuala Lumpur.

Cranmer, E., Jung, T., tom Dieck, M. C., & Miller, A. (2016). *Implementing augmented reality to increase tourist attraction sustainability*. Paper presetned at ARVR Innovate, Dublin Ireland.

Deloitte. (2013). *Tourism: Jobs and gorwth: The economic contribution of the tourism economy in the UK*. Retreived July 2014, from http://www.deloitte.com/assets/Dcom-UnitedKingdom/Local%20Assets/Documents/Industries/THL/uk-thl-the-economic-contribution-of-tourism.pdf.

Elo, S., Kääriäinen, M., Kanste, O., Pölkki, T., Utriainen, K. & Kyngäs, H. (2014). Qualitative content analysis, *Sage Open, 4*(1), 4–12.

Garcia-Crespo, A., Chamizon, J., Rivera, I., Mencke, M., Colomo-Palacios, R., & Gomez-Berbis, J. (2009). SPETA: Social Pervasive e-tourism Advisor. *Telematics and Informatics, 26*(3), 306–315.

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

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

Inoue, K., & Sato, R. (2010). *Mobile augmeneted reality business models*. Retreived October 2013, from http://www.perey.com/MobileARSummit/Tonchidot-MobileAR-Business-Models.pdf.

Johnson, M., Christensen, C., & Kagermann, H. (2008). Reinventing your business model. *Harvard Business Review, 86*(2008), 50–59.

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.

Kennedy-Eden, H., & Gretzel, U. (2012). A taxonomy of mobile applications in tourism. *E-Review of Tourism Research, 10*(20), 47–50.

Kleef, V., Noltes, J., & Spoel, S. (2010). *Success factors for augmented reality business models*. Retreived August 2014, from https://www.interactief.utwente.nl/studiereis/pixel/files/indepth/KleefSpoelNoltes.pdf.

Ko, D.-W., & Stewart, W. P. (2002). A structural equation model of residents' attitudes for tourism development. *Tourism Management, 23*(5), 521–530.

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

Kourouthanassis, P., Boletsis, C., Bardaki, C., & Chasanidou, D. (2015). Tourists responses to mobile augmented reality travel guides: The role of emotions on adoption behavior. *Pervasive and Mobile Computing, 18*(1), 71–87.

Lashkari, AH., Parhizkar, B., & Mohamedali, MA. (2010). Augmented reality tourist catalogue using mobile technology. *IEEE, 1*(1), 112–125.

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

Livi, E. (2008). *Information, technology and new business models in the tourism industry*. Retreived October 2014, from http://www.gcbe.us/8th_GCBE/data/Elena%20Livi.doc.

Magretta, J. (2002). Why business models matter. *Harvard Busienss Review, 80*(2002), 86–87.

Marimon, D., Sarasua, C., Carrasco, P., Alvarez, R., Montesa, J., Adamek, T., et al. (2014). Mobi AR: Tourist experiences through mobile augmented reality. Retrevied November 2014, from http://www.researchgate.net/publication/228979424_MobiAR_Tourist_Experiences_through_Mobile_Augmented_Reality.

Martínez-Graña, A., Goy, J., & Cimarra, C. (2013). A virtual tour of geological heritage: Valourising geodiversity using Google earth and QR code. *Computers & Geosciences, 61*(12), 83–93.

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

Palumbo, F., Dominci, G., & Basile, G. (2013). *Designing a mobile app for museums according to the drivers of visitor satisfaction*. Retreived November 2–14, from http://www.wseas.us/e-library/conferences/2013/Dubrovnik/MATREFC/MATREFC-24.pdf.

Roesner, F., Kohno, T., & Molnar, D. (2014). Security and privacy for augmented reality systems. *ACM, 57*(2014), 88–96.

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

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

Tussyadiah, I. (2014). Expectation of travel experiences with wearable computing devices. In Z. Xiang & I. Tussydiah (Eds.), *Information and communication technologies in tourism 2014* (pp. 539–552). Cham: Springer.

Wang, D., Xiang, Z., & Fesenmaier, D. (2014). Smartphone use in everyday life and travel. *Journal of Travel Research, 55*(1), 52–63.

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: Springer.

Yuen, S., Yaoyuenyong, G. & Johnson, E. (2011). Augmented reality: An overview and five directions for AR in education. *Journal of Educational Technology Development and Exchange. 4*(1), 119–140.

An Ethical Perspective of the use of AR Technology in the Tourism Industry

Jessica Saoud and Timothy Jung

Abstract AR technology is a technology which uses the technique of adding digital content over the real world using computers and electronic glasses. As AR technology could be the next technological revolution, now is the time for ethicists to be more proactive in regards to the undoubtedly new ethical implications that will follow. This proposal aims to highlight the importance of developing an ethical framework specifically in regards to AR. It focuses on the merge of the physical and digital world that AR technology brings, and certain ethical aspects in regards to identity and communication, in relation to gamification and wearable computers. The methodology draws in numerous Information and Computer Ethics frameworks in order to compare, contrast and create new links. The pressure on universities to provide market-oriented courses and temptations of businesses to provide profitable products has forced ethical aspects to take the side bench, however previous research has shown that corporations that do include ethical considerations are more successful in the long run.

Keywords Ethics · Augmented reality · Tourism industry

1 Introduction

According to Moor (2005, p. 111), "[t]he emergence of a wide variety of new technologies should give us a sense of urgency in thinking about the ethical (including social) implications of new technologies". Although there has been a steady rise in the interest of Information and Computer Ethics (ICE), this area is still very much under-researched even with the sharp rise of new technological paradigms and devices.

J. Saoud (✉) · T. Jung
Faculty of Business and Law, Manchester Metropolitan University, Manchester, UK
e-mail: jessica.saoud@stu.mmu.ac.uk

T. Jung
e-mail: t.jung@mmu.ac.uk

T. Jung and M.C. tom Dieck (eds.), *Augmented Reality and Virtual Reality*,
Progress in IS, DOI 10.1007/978-3-319-64027-3_3

This proposal aims to emphasize the importance of ethical discourse in regards to technology, with an emphasis on Augmented Reality (AR) technology within the tourism industry, mainly in the areas of education and heritage preservation (Guttentag 2010). Through the analysis of literature relevant to AR, tourism and ethics, and an evaluation of several ethical frameworks and approaches such as ACTIVE Ethics, ETICA approach and Bernd Stahl's approach of interpreting emerging technologies, the proposal aims to highlight the need for a multi-level interdisciplinary approach towards ICE. The methodological approach therefore includes an in-depth research of ICE in order to develop interview questions aimed at industry professionals and surveys aimed at industry professionals and tourists.

According to Viseu (2003), William Mitchell's book 'City of Bits' (1999) interpreted the connection between the physical and the digital world by providing two phases of this relationship; The first phase, initiated with the rise of personal computers, involves the "physical (being) pushed into the digital", where the web, "the world of bits" (Viseu 2003, p. 17), is a "lean-forward medium…where users are (actively) engaged" (Nielsen 2008, p. 1). The second phase is one of ""functionality without virtuality", where the digital is being pushed into the physical, creating artefacts whose 'digitality' is hidden" (Viseu 2003, p. 17).

Augmented Reality (AR) technology is an emerging technology that "deeply changes the perceiving subject and the perceived object" as it "[introduces] new objects in our world" (Liberati and Nagataki 2015, p. 136). This sort of 'power' that comes along with this new technological 'tool' raises many ethical issues as the "changing settings and practices that emerge with new computer technology may yield new values, as well as require the reconsideration of old values" (Brey 2000, p. 15).

According to Moor's (2005) argument, ethical issues increase as the technology increases through its development stages, and Brey (2012) agrees that "current ethics…is insufficiently equipped to address the revolutionary changes…brought about with new and emerging technologies" (p. 15). According to Dechesne Warnier and Van Den Hoven (2013) the social and moral values need to be considered as AR technology is a socio-technical system embedded in social structures. This is because it creates a type of cyberspace, a new "social world…global simulated environment accessible by an almost 'transparent' neural interface" (Shields 2003, pp. 51–52).

AR technology is an emerging technology that has already been put to use by several IT companies worldwide in order to create technological artefacts for different purposes. The technology itself has been on the rise from the late 1990s (Viseu 2003), however as predicted by James Moor in 2001[1] and Ivan Sutherland in 1968,[2] new technological artefacts such as wearable computers are being tested and produced. A device ironically made popular because of its under-rated introduction

[1]"Computing devices themselves may tend to disappear into our clothing, our walls, our vehicles, our appliances, and ourselves" (Moor 2001, p. 89).

[2]A "head-mounted three dimensional display" (Sutherland 1968).

is the Google Glass, a wearable computer powered by Android (Houghton 2013), others include Microsoft's HoloLens and Meta's Space Glasses. Recent news suggest a rumour that Carl Zeiss AG (The "German optics powerhouse") and Apple may work together to produce AR glasses (Rogowsky 2017).

AR—a subdivision of Mixed Reality (MR) (Heimo et al. 2014)—is defined by Danado et al. (2003) as "a technology that allows the superimposition of synthetic images over real images, providing augmented knowledge about the environment in the user's vicinity" (Jung et al. 2015, p. 76). It relies on the "fusion between computer-generated information and 'real world' information… (to provide) new ways to interact with the 'real world'" (Viseu 2003, p. 20).

Ethics has been a key philosophical discipline since Socrates' time, it is a study carried through by "systematic theoretical reflection" of the "moral spiritual practice of individuals and communities…" (Maxim 2014). Its main concern is the essence of 'Good', which is an investigation of "the practical moral life", hence why ethical analysis deals with issues such as "freedom and responsibility (and) autonomy and heteronomy", as it perceives the "world as a whole…a synthetic conceptualized theoretical discourse" (Maxim 2014).

2 Literature Review

The following theoretical literature review is developed according to similar themes that have been found throughout the relevant literature—mainly in journals such as *Ethics and Information Technology* and *Journal of Information*, *Communication and Ethics in Society*. Beginning with a discussion regarding the concept of AR technology, the review will follow with opinions and views of authors who critically assess the possible impact of this technology, scientifically and philosophically. The main ethical issues discussed will be in regards to an individual perspective—Identity—and a social perspective—Communication. However, because these concepts are inter-related, they will be explained together in relation to two AR technologies—wearable computers and gamification.

2.1 Augmented Reality Technology

AR technology is the technique of "adding and supplementing digital content over real world using computers" (Heimo et al. 2014, p. 1). As stated above, it is a subdivision of Mixed Reality (MR) "which stands for mixing computer generated content – a virtual world – into real world" (Heimo et al. 2014, p. 1). Viseu (2003) explained that they provide the "wearers instantaneous and constant access to information" (p. 20) such as "replacing a building with a virtual one that has existed in the same location but was demolished years ago" (Heimo et al. 2014, p. 2).

Floridi (2008) applied a new term for "the world of data, information and knowledge…a new environment, the infosphere…" (p. 28).

Arguably this seems to be true, as "almost everyday papers report on new ethical problems or dilemmas created by computer technology" (Moor 2005, p. 117). Moor 2005, Brey 2012, Floridi 2008 have all argued in favour of ethical emphasis in regards to technology development, stating that we need ethical approaches that are better informed concerning new technologies and their social consequences. Although there has been a rise in the interest in ICE, Tae Wan Kim's and Kevin Werbach's (2016) article pointed that ethics is still under-theorized, because "the technological novelty and rapid adoption of the practice have outstripped careful consideration" (p. 161). Additionally, according to Søraker (2016) the games industry evolves on a pace faster than the research conducted by academics, as the latter requires more time to produce accurate results. Furthermore, Brey (2000) highlighted that there is a need for "conceptual clarification" as he reflected Moor's point (1985), by stating that "the changing settings…that emerge with new computer technology may…require the consideration of old values" (Brey, 2000, p. 126). Richard Sclove (1995) added more emphasis and analysed them as "elements of social structures" (Brey 2000, p. 126) as they "help define or regulate patterns of human interaction" (Sclove, p. 11), additionally according to Lurie and Mark (2016) as "software systems affect the way people act and interact…the system ultimately has an effect on values and social norms" (p. 425).

According to Viseu (2003) augmentation involves "a synergy with the body" (p. 17), as the "interaction between individual agents and the social system in which they are embedded" begins to change. AR artefacts alter "the way in which the world is experienced [as] they mediate the wearer's engagement with the world, more intimately then before" (p. 24). These technological artefacts, once "considered (universal) tools" (Viseu 2003 p. 20) because of their logical malleability (Viseu 2003; Moor 2001, 2005; Bao and Xiang 2006), are "no longer…tools and will become 'technological companions'".

According to Moor (1985) "computer operations…to most people, are hidden from view beyond their comprehension" (p. 272). According to Mitchell (1999), this "functionality without virtuality", is now extending as both the "artefacts [and] digitality [are] hidden" (Viseu 2003, p. 17). Viseu (2003) argued that the "relationship between the physical and digital worlds is changing" (p. 17) as the world seem to be shifting from VR simulation projects ("Replication and Separation") to AR augmentation projects ("Connectivity and responsiveness") (Viseu 2003, p. 18). She includes that although the relationship between those two worlds is dynamic as it is "constantly being re-designed and re-conceived… [T]ension… exists between those two worlds" (Viseu 2003, p. 18). This tension and mediation discussed by Viseu will be further explained in the next part of the literature review.

2.2 The Physical and Digital World

According to Huizinga (1949) "the merge between the real and the virtual creates a 'magic circle' whose rules supersede the norms of reality" (Kim and Werbach 2016, p. 159). And according to Taylor (2009) "the boundary of [this] magic circle is not always clear-cut; the "real" and "virtual" cannot always be easily separated" (Kim and Werbach 2016, p. 159). This is because the augmentation "of the physical through the digital… [creates] a new entity with its own specificities" (Viseu 2003, p. 22) according to De Kerckhove (1995).

Although Floridi's explanation of the infosphere suggests an ontological framework that is different from the real world, Capurro (2008) suggests a re-ontology of the "nature of the infosphere" because Floridi (1999) discusses humans simply as a "bundle of information" (p. 53) and the infosphere as "non-natural environment…[a] hyperreality…separated from…[the] "life world" (Capurro 2008, p. 170). Floridi's view of the "Digital Divide (DD)" suggests a dualistic approach towards explaining the mediation of real world and digital world information, as opposed to a twofold approach whereby the user, according to Viseu (2003) becomes a "hybrid actor…hosts the computational device [and] simultaneously affects and [is] affected by both realities" (p. 18). What if, instead of "de-ontologizing" the infosphere as Capurro suggest, we simply change perspective and begin to look at the human body as the new dynamic infosphere?

This new internal-external infosphere will unsurprisingly have "implications for **identity** and self-expression" (Jones 2016, p. 41) as **communication** will not necessarily be made using our usual biological features, facial expressions, voice, etc. The "autonomous agency of ICTs (may require us) to rethink our own autonomy and thus our identity…a possibility that our view of ourselves will change" (Stahl 2016, p. 150).

2.3 Identity and Communication

For the sake of this specific proposal, identity and communication will be analysed in regards to two AR technologies, one being gamification artefacts and wearable computers. McBride (2014) analysed identity as "concern[ing] a person's concept of who they are, the moral and social beliefs they embrace and how they relate to others" (p. 32). Fearon and Latini (1999 and 2000) explained that identity "works at a personal and social level" because according to Perry (2010) "our conception of self is an internal cognitive function in which through…knowledge we build up a picture of who we are" (McBride 2014, p. 33).

Social processes such as learning (Acquiring knowledge) requires communication (Pejoska et al. 2016). "What happens when two people talk? They engage in a kind of dance. Their volume and pitch fall into balance and they fall into physical and conversational harmony" (Gladwell 2000). Bjorn Myskja explains that "non-verbal communication…may be essential to trust-building" as the "bodily presence in the encounter appears to be essential for understanding the relation of trust" (Ess and Thorseth 2008, p. 206). However online communication acquires a "disembodied" character which can "degrade human communication" (Wolf et al. 2016, p. 220). According to McLuhan (1962) "the shift from oral and tactile cultures to a literature cultures [allowed the individual to gain] a sense of perspective and individualism, but lost a sense of identification with the world and his/her community" (Viseu 2003, p. 24).

2.4 *Gamification and Wearable Computers*

Gamification is "the use of elements and techniques from game design in non-game contexts" (Kim and Werbach 2016, p. 157). It "maintains the context of the physical environment during the game-like activity" (Kim and Werbach 2016, p. 159). An example of gamification using AR technology is "Pokémon GO", a game that "allows players to search for Pokémon, fictional animals derived from the internationally recognized Pokémon franchise. The game uses geolocation to create augmented reality…gaming scenarios for players" (Wagner-Green et al. 2017, p. 35). According to Barfield and Caudell (2001), wearable computers, are "fully functional, self-powered, self-contained computer(s) that [are] worn on the body… [and] provides access…and interaction with information" (p. 6).

Both of these AR technological artefacts can have a profound effect on the user. According to Anderson and Rainie (2012) "Digital games can…easily lead to cognitive [and therefore] behavioural manipulation". Sicart (2015) argued that "gamification…diminishes self-reflection…[and] interferes with human flourishing by introducing an artificial set of motivators" (Kim and Werbach 2016) (Catching the Pokémon fictional characters for example). The player may "develop a fictional moral psychology" (Bartel 2015, p. 292)[3] as he/she can only act within the limits of the game in order to win, "just as an actor can play the part of a villain" (Bartel 2015, p. 292), whether he endorses the actions or not. It arguably shapes "actions without conscious rational consideration" (Kim and Werbach 2016, p. 164), such as war games which include killing innocent "people". Games like these show a "moral indifference to fundamental human values like the sanctity of life" (Kim and Werbach 2016, p. 160), and individual privacy. Using Pokémon GO once again as the example, several articles were published about players being found in inappropriate locations such as cemeteries and mass-reflection cemeteries (such as Auschwitz), a cliff (from where a user fell and passed away), a delivery room, funerals, police stations and residential car parks. Not one, but two rather disturbing

[3]"An individual's moral psychology is made up of all the cognitive apparatus – the concepts, decision-making, strategies, heurists and affects – that are employed in her moral decision-making" (Bartel 2015, p. 291).

videos display a stampede of hundreds of users walking almost without any conscious while staring at their phones towards a "rare Pokémon", in New York's city Central Park and Taiwan.[4]

In regards to wearable computers, these can create a "reduced sense of shared experience" (Wolf et al. 2016, p. 220) between users and non-users. This is not the first time social and psychological separation concerns in regards to technology have been brought into light. According McLuhan (1962, 1964, 1988) argued that "the human psyche and social complex is affected every time a new technology is introduced…[as] a change in the ratio of senses..[is].. accompanied by a reduction" (Viseu 2003, p. 24). As the body's nature is changing and we are "augmenting ourselves through this new digital prosthesis, what is being lost?" (Viseu 2003, p. 24). Another factor that can lead to a separation is psychological, as "traditionally people in the same physical space shared similar…not identical Local Space of Observations (LSO)" however, now if only one of two people owns a wearable computer, "neither can assume similar LSOs…bringing different psychological perspectives" (Wolf et al. 2016, p. 219). This raises the question as it "becomes easier and more convenient to communicate with individuals that are equipped with wearable computers, are all those who can't afford it or don't know how to use it, going to be excluded [from groups and certain social gatherings?]" (Viseu 2003, p. 24).

2.5 *AR and Tourism*

"Heritage sites have huge amounts of information. However, it can be difficult to present this information in a compelling way" (Kysela and Storkova 2014, p. 929). Certain data visualizations that AR can achieve such as "replacing a building with a virtual one that has existed in the same location but was demolished years ago" (Heimo et al. 2014, p. 2), allows a more "physically embodied construct of learning" (Pejoska et al. 2016, p. 475) and hence more personally fulfilling learning experiences.

According to tom Dieck et al. (2016), using AR applications "within art galleries…has a number of benefits" (p. 1) as according to Cucchiara and Del Bimbo (2014, p. 76) it has the potential of "seeing what your eyes cannot reach…" (retrieved from tom Dieck et al. 2016, p. 1); it provides information about the paintings that otherwise would not have been known or been easily accessible. "AR is particularly valuable to the tourism industry because it can create an interactive learning environment…and increase social awareness of the immediate surrounding" (Jung et al. 2015, p. 76). This brings out a positive effect as according to Bligh and Crook (2015), Boys (2011) "learning theories commonly neglect spatial context" (Pejoska et al. 2016, p. 475). AR applications have been "developed for

[4]https://www.youtube.com/watch?v=MLdWbwQJWI0 and (Bellware 2016).

education in natural sciences", however "applications for history and related tourism remain outside the main concern of developers" (Kysela and Storkova 2014, p. 929). From a positive perspective "only those who are familiar with the past can understand the presence and create a successful future…history can again become a play…and search for new information" (Kysela and Storkova 2014, p. 929), however there are concerns that teachers wouldn't teach effectively because they wouldn't know whether the students are paying attention or not (Choudhury et al. 2016).

3 Proposed Methods

According to Himma and Tavani (2008) "The field of information/computer ethics…is becoming one of the most important fields of applied ethics" (Kernaghan 2014, p. 296). Applied ethics is "concerned with the study of morality in particular domains of human practices" (Brey 2000). For Van Den Hoven (1997), it involved the application of existing moral theories and principles to context-specific scenarios. The relationship between ethics and IT goes back to the 1940s for what is now called Information and Computer Ethics (ICE). Computer ethics was developed in the 1970s and in the 1990s Luciano Floridi introduced Information Ethics. Because we are now entering a domain on the basis that users will be receiving information from wearable computers, I will be using the term ICE as Professor Norbert Wiener's examination of ethical issues in relation to technology, AI, robotics, etc. at it seems relevant to the task at hand.

The methodology will begin with Moor's three stages of a technological revolution, and follow with an advantage that AR technology has in relation to technological revolutions. Certain epistemological issues that arise from the use of AR technology will then be analysed. In order to evaluate the process of arriving to the best methodology in regards to the research of ethics in AR, certain IT ethical frameworks will be analysed in summary beginning with Value Sensitive Design, followed by the ETICA project, ACTIVE ethics, RRI in regards to forecasting approach, ethical technology assessment and anticipatory technology ethics (ATE). Finally, Simon Jones' ethical analysis framework will be analysed. The analysis is in this order as each framework becomes more scientific and less speculative, as the anticipatory technology ethics will combine all the strong aspects of the previous frameworks, and Simon Jones' framework will also work well with ATE.

According to Moor (2005) a technological revolution does not appear fully developed as it matures in stages, however its impact and integration into society will be major. Whether AR technology is going to be "revolutionary" in the sense of having "significant social impact" is not yet definite, however Moor's stages of a technological revolution are relevant as AR technology is going through the first one. The three stages are the introduction stage, permeation stage and power stage. In the introduction stage "the earliest implementation of the technology are esoteric…only a few people are aware…but some are fascinated…integration into society will be normal". The permeation stage is when "the technological devices are standardized…more conventional…number of users grow…special training classes…cost of application drops…demand for its use increases". The final stage —the power stage—is when "many understand how to use it…integration into society is major" (Moor 2005, p. 112). Identifying these three stages is the initial step of an ethical research framework of AR. However, instead of perceiving AR solely as revolutionary, Moor's stages should only apply as a guide, as Popper (1945) "argued for what he called piecemeal social engineering, rather than revolutionary social change…to proceed in small or limited steps and to learn from trial and error" (van de Poel 2016, p. 670). This will help in applying a pro-active approach in the aim to "reduce uncertainty in the early phases of technological development" (van de Poel 2016, p. 669) as according to the European Group on Science and Governance (2007) "we are in an unavoidably experimental state" (van de Poel 2016, p. 671). Because the full impact of AR technology is not yet clear, one epistemological issue faced is "the problem of uncertainty concerning future devices, applications, uses and social consequences of emerging technology" (Brey 2012) as according to Sollie (2007, p. 299) "the unpredictable nature of societal processes stem from social, economic, and cultural dynamics" (p. Another is the issue of agency, according to Moor 2004; Dechesne et al. 2013; Wolf et al. 2016; Kim and Werbach 2016 "developers bear responsibility" in regards to the usage of the technology, however "developers of the technology can only to a lesser extent be expected to anticipate values and social consequences of the use of technology" (Dechesne et al. 2013, p. 178). This could be as according to Holland (2011) there are "relatively low levels of moral judgement skills amongst computing students in higher education, regardless of level, and despite exposure to computer ethics in the curriculum" (Jones 2016). This proves that an ethical map or moral theory needs to be constructed in order to provide "normative guidance to both scholars and practitioners" (Kim and Werbach 2016, p. 161), as "teaching ethical theory is an essential part of teaching computer ethics" (Staehr 2002, p. 15). Value Sensitive Design (VSD), an approach constructed in the 1990s holds that "potential computer-ethics issues would be preventable if…attention is directed at the very beginning to avoi(d) harm to human values" (Kernagahan 2014, p. 302). Such values include democratic values, ethical values, people and professional values. It focuses on the "social" aspect of this socio-technical system (Dechesne et al. 2013). The ETICA approach (Ethical Issues of Emerging ICT Applications), focuses on the "ethical assessment of emerging ICTs" (Brey 2012). It is a good starting point as it provides an abstract and general framework towards ethical analysis. Bernd Stahl (2011) provided graphic discourses of ethical issues in regards to emerging technologies. The defining features that he included of AR technology are physical immersion, synthetic sensory stimulation, mental immersion of the user and interactivity. Table 1 below features certain relevant social and socio-technical implications of emerging ICTs from Brey's analysis:

The table provided above and theoretical analysis given in Stahl's research led to another graphic analysis in which he provided certain categorisation of ethical issues, below are certain examples from the one originally constructed:

Table 1 Brey's analysis of socio-technical implications of emerging ICTs

Emerging ICTs			
Pervasiveness	Power over users	Natural interaction	Direct link between humans and machines
Embedded	Control over your body and mind	Context-aware	Augmentation
Synthetic sensory stimulation	Stimulate parts of the brain	Interactivity	Motor function
Virtualisation of resources	Dehumanising factors	Mental immersion of the user	Adaptive

- Technical enablers
- Uncertainty of outcomes
- Ethical theories
- Conceptual Issues
- Role of humans
- Perceptions of technology
- Social consequences (ex. nature of society, culture, responsibility, ownership, sustainability)
- Impact on individual (Treatment of humans, privacy, security, autonomy, identity)

ACTIVE ethics was formed as a new version of the model PAPA which stands for Privacy, Accuracy, Property and Accessibility. It is also a form of virtue ethics which stands for Autonomy, Community, Transparency Identity, Value and Empathy. "The possession of virtues enables actors to make reasoned decisions in the face of ethical dilemmas" (McBride 2014). The analysis of such issues along with rules-based approaches such as codes of conduct will assist in developing new policies as according to Kant "laws are necessary to practice being moral" (Ess and Thorseth 2008). According to the European Commission (2000, p. 3) "Europe needs smart, sustainable and inclusive growth" (Stahl 2011, p.151). Innovation in technology is an important aspect of the Digital Agenda for Europe (Stahl 2011), which leads to Responsible Research and Innovation (RRI). "Ethical study of emerging technologies is an important prerequisite for responsible innovation" (Brey 2012, p. 307). Forecasting studies, "the uses and social consequences of" technological devices is comprised of futures studies and technology assessment. Futures studies is "the field that aims to study possible or probable futures" (Brey 2012, p. 307) and includes approaches such as the Delphi method which relies on "consultation of experts in various fields". Technology assessment is the study of "new technology on industry". The ethical technology assessment (eTA) "provides indicators of negative ethical implications at an early stage of technological development" by the "form of a continuous dialogue rather than a single evaluation at a specific point in time" (Palm and Hansson 2006, p. 543) This is more relevant as "ethics is an ongoing and dynamic enterprise" (Moor 2005, p. 118).

Brey's ethical approach is the anticipatory technology ethics (ATE) approach. He breaks down his analysis into three stages, the technology, the technological artefact and the application level. "Various objects of ethical analysis are defined" at different levels. He initially applied the forecasting method o the technological level, where "understanding of the technology is because acquired from engineers". Similar to the ETICA project, at the identification stage "description of the technology ae cross-references with ethical values". "Ethical issues are either inherent, consequential, or pertaining to specific risks". In regards to the technology level for example, an inherent issues is the manipulation of DNA and in regards to the artefact level, a video game could be degrading human beings. Consequential relate to the consequences of the technology or artefact. The application level deals with different issues, namely "intended use, unintended consequences for users and unintended consequences of non-user stakeholders". He then includes a "design feedback stage…responsibility assignment stage and governance stage". This entire approach is a "full-blown approach to RRI".

While this methodology is extensive and includes elements from almost all the ethical approach mentioned (VSD, ACTIVE and ETICA), an additional framework can be added in order to get stronger results. Simon Jones (2016) recommended five stages that need to be completed in order to reach a result of ethical analysis:

- Identify a particular ethical dilemma.
- Analysis of specific technologies and the social context of their design deployment and use.
- Values and principle at stage are identified in order to understand the "bigger picture".
- Consideration of laws.
- Practitioner moment whereby the implications are followed through for professional practice.
- Assessment and evaluation of potential solutions

During the initial levels the theoretical aspects of the projects can be done through secondary research, however the steps after will require working alongside scientific experts and also social scientists (Brey 2000). Primary research will be in the form of surveys and interviews directed at industry professionals (software developers and IT businesses) in order to understand their priorities and align them with context-specific ethical issues. Whether the final result is reached by building a more comprehensive framework or checklist will be more clear as the research continues.

4 Limitations and Further Research

Forecasting studies can be speculative without a comprehensive and systematic global ethical system (Brey 2012). According to Jones (2016) there is no stand-alone theory that will be comprehensive enough to tackle every single modern ethical dilemma. However, as mentioned previously ethical studies is a "dynamic enterprise that continually requires reassessment of the situation." (Moor 2005, p. 118) and "the target is to achieve a breakthrough in introducing new principles and concepts, to create a new beginning" (Bao and Xiang 2006, p. 43). What if, Moor's According to Brey 2000, Moor 2005, Jones 2016, a multi-dimensional framework is needed to build a comprehensive framework. More research can be conducted in regards to the ontology of Information Ethics and Communication Ethics, AR Reality bioethical issues, AR Tourism, AR Education, AR Health, etc. Additionally, a look into Husserl's phenomenology in regards to horizons (Inner, Outer and World) and how traditional and technological glasses mediate our perception will also assist in building a clearer picture in regards to the wide application of AR technology. This area is very much under-researched and could allow a revival of philosophy and philosophical ethics specifically as the world moves into new forms of interaction and sensory enhanced spatial locations.

5 Conclusion

"[T]he emergence of a wide variety of new technologies should give us a sense of urgency in thinking about the ethical (including social) implications of new technologies" (Moor 2005, p. 111). We need to be more proactive and less reactive in doing ethics, as technologies such as gamification and AR are still "under-theorized…" (Kim and Werbach 2016). The aim was to highlight how a merge between the physical and digital world will create a "magic circle" where the rules are not the same, requiring changes or perhaps additions to our ethical concepts and moral codes. Identity and Communication were the concepts analysed in regards to ethical studies and were related to AR technology by analysing the inter-dependent relationship between the concepts and two AR technologies, wearable computers and gamification technology. The methodology discussed with Moor's three stages of a technological revolution and epistemological issues that arise from the use of AR technology. Certain IT ethical frameworks were analysed in summary beginning with Value Sensitive Design, followed by the ETICA project, ACTIVE ethics, RRI in regards to forecasting approach, ethical technology assessment, anticipatory technology ethics (ATE) and Simon Jones' ethical analysis framework will be analysed. "The temptation to improve the statistical side of business…could overcome the more ethical actions", however "corporations promoting their ethical actions tend to fare better than corporations that do not" (Heimo 2014). Philosophers and industry professionals need to find common ground in order for moral theories to be developed exclusively to the subject/object at hand, and be proactive instead of reactively trying to fix avoidable accidents.

References

Anderson, J., & Rainie, L. (2012). *The future of gamification. Retrieved from PewResearch Internet Project.* Retrieved February 2017, from http://www.pewinternet.org/2012/05/18/the-future-of-gamification/.

Bao, Z., & Xiang, K. (2006). Digitalization and global ethics. *Ethics and Information Technology, 8,* 41–47.

Barfield, W., & Caudell, T. (2001). Basic concepts in wearable computers and augmented reality. *Fundamentals of Wearable Computers and Augmented Reality, 162,* 3–26.

Bartel, C. (2015). Free will and moral responsibility in video games. *Ethics and Information Technology, 17*(205), 285–293.

Bellware, K. (2016). Rare Pokemon Sparks Massive Stampede In Taiwan, *The Huffington Post.* Retrieved January 2017, from www.huffingtonpost.com.au/2016/08/23/rare-pokemon-sparks-massive-stampede-in-taiwan/?utm_hp_ref=au-pokemon+go.

Brey, P. (2000a). Method in computer ethics: Towards a multi-level interdisciplinary approach. *Ethics and Information Technology, 2*(2), 125–129.

Brey, P. (2000b). Disclosive computer ethics. *ACM SIGCAS Computers and Society, 30*(4), 10–16.

Brey, P. (2012). Anticipating ethical issues in emerging IT. *Ethics and Information Technolog, 14,* 305–317.

Choudhury, N., Venkatesh, T., Bhattacharya, S., & Sarma, S. (2016). Avabodhaka: A System to Analyse and Facilitate Interactive Learning in an ICT Based System for Large Classroom. *Procedia Computer Science, 84*, 160–168.

Cucchiara, R., & Del Bimbo, A. (2014). Visions for augmented cultural heritage experience. *IEEE, 2*(1), 47–82.

Dechesne, F., Warnier, M., & Van Den Hoven, J. (2013). Ethical requirements for reconfigurable sensor technology: A challenge for value sensitive design. *Ethics and Information Technology, 15*(3), 173–181.

Ess, C., & Thorseth, M. (2008). Kant and information ethics. *Ethics and Information Technology, 10*(4), 205–211.

Floridi, L. (2008). Information ethics: A reappraisal. *Ethics and Information Technology, 10*(2), 189–204.

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

Gladwell, M. (2000). *The tipping point: How little things can make a big difference.* Boston: Little Brown.

Heimo O. I., Kimppa, K. K., Helle, S., Korkalainen, T., & Lehtonen, T. (2014). *Augmented reality —Towards an ethical fantasy?* Paper presented at IEEE International Symposium on Ethics in Science, Technology and Engineering. Chicago, USA.

Houghton, S. (2013). Google glass: Release date, news and features. Retrieved January 2017, from http://www.techradar.com/reviews/gadgets/google-glass-1152283/review.

Huizinga, J. (1949). *Homo ludens: A study of the play-element in culture*. London: Routledge and Kegan Paul.

Jones, S. (2016). Doing the right thing: Computer pedagogy revisited. *Journal of Information Communication and Ethics in Society, 14*(1), 33–48.

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,* 75–86.

Kernaghan, K. (2014). Digital dilemmas: Values, ethics and information technology. *Canadian Public Administration, 57*(2), 295–317.

Kim, T. W., & Werbach, K. (2016). More than just a game: Ethical issues in gamification. *Ethics and Information Technology, 18*(2), 157–173.

Kysela, J., & Storkova, P. (2014). Using augmented reality as a medium for teaching history and tourism. *Proceda—Social and Behavioural Sciences, 175,* 926–931.

Liberati, N., & Nagataki, S. (2015). The AR glasses “non-neutrality”: Their knock-on effects on the subject and on the giveness of the object. *Ethics and Information Technology, 17*(2), 125–137.

McBride, N. K. (2014). ACTIVE ethics: An information systems ethics for the internet age. *Journal of Information Communication and Ethics in Society, 12*(1), 21–44.

Moor, J. H. (1985). What is computer ethics? *Metaphilosophy, 16*(4), 266–275.

Moor, J. H. (2001). The future of computer ethics: You ain’t seen nothin’ yet! *Ethics and Information Technology, 3*(2), 89–91.

Moor, J. H. (2005). Why we need better ethics for emerging technologies. *Ethics and Information Technology, 7*(3), 111–119.

Nielson, J. (2008). *Writing style for print vs. web*. Retrieved January 2017, from https://www.nngroup.com/articles/writing-style-for-print-vs-web/.

Palm, E., & Hansson, S. O. (2006). The case for ethical technology assessment (eTA). *Technological Forecasting and Social Change, 73*(5), 543–558.

Pejoska, J., Baueters, M., Purma, J., & Leinonen, T. (2016). Social augmented reality: Enhancing context-dependent communication and informal learning at work. *Brtish Journal of Educational Technology, 47*(3), 474–483.

Rogowsky, M. (2017). *‘Wear’ to now? Apple’s vision for the future may be coming into focus*. Retrieved January 2017, from http://www.forbes.com/sites/markrogowsky/2017/01/10/new-rumor-suggests-apples-augmented-reality-future-may-be-coming-into-focus/#6d3ca3461b33.

Sclove, R. (1995). *Democracy and technology*. New York: Guilford.

Shields, R. (2003). *The virtual*. London: Routledge.

Sollie, P. (2007). Ethics, technology development and uncertainty: An outline for any future ethics of technology. *Journal of Information, Communication and Ethics in Society, 5*(4), 293–306.

Søraker, J. H. (2016). Gaming the gamer?—The ethics of exploiting psychological research in video games. *Journal of Information, Communication and Ethics in Society, 14*(2), 106–123.

Staehr, L. J. (2002). Helping computing students develop a personal ethical framework. *IEEE Technology and Society Magazine, 1,* 13–20.

Stahl, B. C. (2011). IT for a better future: How to integrate ethics, politics and innovation. *Journal of Information Communication and Ethics in Society, 9*(3), 140–156.

Sutherland, I. (1968). *A head-mounted three dimensional display.* Paper presented at Fall Joint Computer Conference, Los Alamitos.

Taylor, T. L. (2009). *Play between worlds: Exploring online game culture*. Cambridge: MIT.

tom Dieck, M. C., Jung, T. H., & tom Dieck, D. (2016). Enhancing art gallery visitors’ learning experience using wearable augmented reality: Generic learning outcomes perspective. *Current Issues in Tourism,* 1–19.

van de Poel, I. (2016). An ethical framework for evaluating experimental technology. *Science and Engineering Ethics, 22*(3), 667–686.

Viseu, A. (2003). Simulation and augmentation: Issues of wearable computers. *Ethics and Information Technology, 5*(1), 17–26.

Wagner-Greene, V. R., Wotring, A. J., Castor, T., Kruger, J., Dake, J. A., & Mortemore, S. (2017). Pokémon GO: Healthy or harmful? *American Journal of Public Health, 107*(1), 35–36.

Wolf, M. J., Grodzinsky, F. S., & Miller, K. W. (2016). There’s something in your eye: Ethical implications of augmented visual field devices. *Journal of Information Communication and Ethics in Society, 14*(3), 214–230.

Augmented Reality Adoption by Tourism Product and Service Consumers: Some Empirical Findings

Azizul Hassan, Erdogan Ekiz, Sumesh S. Dadwal and Geoff Lancaster

Abstract There are evidences that, tourist adopt Augmented Reality (AR) for purchasing tourism products and services. Few holiday operators make this technology available for their customers. Arguably, AR as innovative technology supports tourists in pre, during and post-holiday mode and offer them better experiences. As far as, AR turns into an important research area, very few known studies are conducted. Thus, on the empirical ground, this study aims to bring out factors of AR adoption by tourists. Findings classify two different factor sets: positive factors of AR adoption by tourists and negative factors of not adopting AR by tourists. Innovativeness and user-friendliness features appear as the dominant reasons and positive factors of AR adoption by tourists while availability issue and technological issue appear as the negative factors of not adopting AR by tourists. This research offers some theoretical and managerial implications and thus a unique contribution to the limited knowledge of responsible factor studies of AR adoption by tourists.

Keywords Augmented reality · Adoption · Tourists

A. Hassan (✉)
Cardiff Metropolitan University, Cardiff, UK
e-mail: m.hassan15@outlook.cardiffmet.ac.uk

E. Ekiz
King Abdulaziz University, Jeddah, Saudi Arabia
e-mail: erdogan.ekiz@gmail.com

S.S. Dadwal
University of Ulster, London Campus, London, UK
e-mail: dadwal.ss@googlemail.com

G. Lancaster
London School of Commerce, London, UK
e-mail: geofflancs@gmail.com

T. Jung and M.C. tom Dieck (eds.), *Augmented Reality and Virtual Reality*,
Progress in IS, DOI 10.1007/978-3-319-64027-3_4

1 Introduction

Augmented Reality (AR) is arguably becoming popular among tourism product and service consumers. This growth of AR is rather an example where innovative technological advancements are fueled by the unprecedented acceptance of the Internet. The adoption of AR is the positive outcome of wearable and handheld devices. Thus, AR adoption is sharply facilitated by wearable and handheld devices. There are some factors that allure tourism product and service consumers to adopt AR. Some of these factors are positive that supports the adoption of AR tourism product and service consumers where some factors are negative that lead to not adopting AR. However, from the consumption context, AR can hardly be featured as the most trouble-free and updated technology. Thus, there is a necessity to outline these positive and negative factors of AR adoption by tourism product and service consumers. Based on theoretical suppositions of both AR specific and general theories of technology acceptance/adoption, this research aims to bring out the key factors of AR adoption by tourism product and service consumers. This study then determines a series of factors appear into two distinct forms: positive factors and negative factors. AR as a valid research topic is explored in some relevant research works: AR application in museums, parks and heritage sites (Jung et al. 2015); tourism education (Hassan and Jung 2016); visitor management in tourism destinations (Hassan and Ramkissoon 2017); tourism marketing (Hassan and Rahimi 2016; Dadwal and Hassan 2015); tourism destination promotion (Hassan and Shabani 2017). However, a knowledge gap exists in the particular research area of positive and negative factor determination of AR adoption by tourism product and service consumers. This research area is yet to draw attention of researchers and scholars to contribute to narrow the identified knowledge gap justifying to conduct this research. This study along with the other on-going research (Hassan et al. 2017) is a constructive contribution to the limited literature of factor determination of AR adoption.

2 Literature Review

Literature studies show that, AR as an innovative technology has found its place mainly in scientific research. However, this is also evidenced that, AR is valid research topic both in the tourism industry and tourism literature but rather in a very narrow space. There are also evidences that, AR is adopted by tourism product and service consumers. On the contrary, there are also evidences that, AR as a technology has some issues that hinder its wider adoption.

2.1 AR and its Adoption in the Tourism Industry

In real time, AR integrates digital information with the user's environment (Dadwal and Hassan 2015). Both AR and VR are arguably adopted by tourists if they are attached to specific tourism product or service offers. In terms of feature analysis, AR offers a bit dissimilarity with Virtual Reality (VR). AR uses the present environment and overlays newer information on top of it where VR creates a fully artificial environment. The growth of both VR and AR is the result of Global Positioning System (GPS) that is made compatible with Smartphone devices to support and enhance AR usability. The unprecedented development of mobile telephone and handheld computing technologies result more adoption of AR. Also, increasing use of Smartphone expands the scope of AR adoption by tourism product and service consumers. They can access AR in Smartphone devices where this technology can direct them to local tourism amenities with the support of GPS. In the most recent time, AR as an innovative technology experiences popularity for its capacities to offer enhanced and positive experiences with the support of mobile, handheld and wearable devices (Jung et al. 2015). This popularity dates to the historic background of AR. According to Henderson and Feiner (2007), the development of AR is initiated in 1990. Boeing researcher Thomas Caudell notifies that, Augmented Reality illustrate head-mounted displays that the electricians used to apply to assemble complex wiring works. The very early commercial use of AR as a technology was the yellow 'first down' line. This line appeared in 1998 in televised football games. Accordance to Layar (2016), Google glass is probably the most notable and well-known example that brought AR for use by the general consumers. This glass is also accepted by tourism service and product consumers. In later stage, the use of AR expands to many other areas as: healthcare, public safety, marketing and tourism.

2.2 AR Adoption Factors Generated from AR Specific Theories

AR specific theories are very limited in number making the sufficient factors determination difficult. According to Rauschnabel and Ro (2016), ease of use, functional benefits and social norms are some factors of AR adoption where Chung et al. (2015) believe that, technology readiness, visual factor of AR and situational factor are few factors. Factors as personalised service, content, system quality affect users' intention and satisfaction are identified by Jung et al. (2015). In addition, Leue et al. (2014) find out high quality information, enjoyable features and content, perceived benefits, cost benefits and innovativeness. On the other side, tom Dieck and Jung (2015) identify personal innovativeness as factor of AR adoption. In principle, AR specific theories are largely indebted to conventional technology acceptance theories as (Table 1):

Table 1 The summary of Technology Acceptance Theories

1. The Diffusion of Innovations theory (Rogers 1962)	2. The Technology Acceptance Model (Davis 1986, 1989; Davis et al. 1989); with derivatives, as:
	i. The Technology Acceptance Model 2 (TAM 2) (Venkatesh and Davis 2000);
	ii. The Technology Acceptance Model 3 (TAM 3) (Venkatesh and Bala 2008);
	iii. The Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al. 2003);
	iv. The Task Technology Fit (Goodhue and Thompson 1995);
	v. The *Technology Readiness Index* (TRI) (Parasuraman 2000); *and*
	vi. The Technology Readiness and Acceptance Model (TRAM) (Lin et al. 2005; Walczuch et al. 2007)

2.3 Reasons of AR Adoption Generated from Existing AR Literature

To find out reasons and positive factors of AR adoption and negative factors of not adopting AR adoption tourism product and service consumers, researchers are diverse in their arguments because of limited AR literature. Few of such literature studies claim that tourism product and service consumers adopt AR for purchasing a tourism product or service. However, the exact reasons and positive factors of AR adoption and negative factors of not adopting AR adoption still remain unclear and unexplored. However, researchers have determined few reasons and positive factors of AR adoption.

Researchers opine that, reasons for AR adoption are diverse. According to Smith (2010), there are two such reasons as: first, AR can ensure success in new marketing campaigns; and second, easier access of AR through handheld/mobile computing devices. Larkin (2011) defines the reasons of AR adoption as: similarity with Virtual Reality (VR); user perception enhancement in a real-world environment; more opportunities generation for marketers; and information displaying or messaging is user-friendly. Hopkins (2009) argues that, the reasons to adopt AR are: it is simple and a user can adopt AR easily by turning on the Smartphone/computing device or pressing a button. AR is beneficial as users can see space and people around them by using the 'sensed' mobile device. Also, AR can offer location-based information for general users. Spillers (2009) defines several specific reasons of AR adoption as: this technology is mobile phone device supported; capable to enhance mobile device user-experience; able to meet customer expectations by using mobile phone or computing device; AR is simple, helpful and offers convenient just-in-time information. On the other side, Sykes (2013) argues that, AR technology is adopted because, AR delivers design interactive experiences; AR is supported by mobile phone devices and AR is capable to create place-based interactions.

Jackson (2014) believes that, AR is adopted for a series of reasons as: AR ensures a better return from business enterprises; AR combines traditional retail experiences with e-Commerce; AR introduces stronger and active branding campaigns; AR helps to navigate and cover wider areas of a business organisation; AR ensures both brand trust and brand loyalty; AR adoption offers more information to improve shopping experience; AR visualises real-time product or service catalogue; AR creates more selling opportunities with 3D product view support; AR positively supports customers; AR allures and encourages potential customers to buy more services and products. Johnson (2015) states some reasons to adopt AR as: AR has capacities to be merged with digital and print media; AR is an interactive technology to help tourist attractions, destinations and museums; AR obviously helps navigation and transportation; AR offers better retail experiences and AR is compatible with Google glasses. Also, Lord (2012) believes that, AR is supportive to Google Glass. In addition to this, Lord (2012) believes that, there are some reasons to adopt AR as: AR is friendly and fully compatible with Smartphones; AR can produce geo-location based information; AR is not a gimmick and thus replaces gimmicky apps and on top of all reasons, AR is an elusive app.

From an industrial context, the reasons to adopt AR are more application focused. A number of reasons are identified by Total Immersion (2016) as: AR is a virtual support for industries; AR appears with elaborated real-time information of relevant business areas; AR offers immediate benefits to industrial users; AR technology delivers unforgettable experiences to its customers promoting brand image; AR can create interests in consumers to purchase a product or service; AR is interactive and offers both relevant information and direction to purchase a product or service; AR turns a general user into an active user of a product or service. On the other side, Augment (2016) spots some reasons to adopt AR as: AR is capable to make eye-catching presentations and advertisements; AR assists in interactive learning; AR is user-friendly that requires less expensive and portable learning materials; AR holds a better or higher retention rate and AR nurtures intellectual capacities of the customers. Pauley (2016) believes that, AR is a sort of experiential marketing. Pauley (2016) determines some reasons to adopt AR as: AR is massively expanding with the support of 3D touchscreen technologies; AR allows customers getting a solid position in a business environment that is immersive; AR offers memorable experience for the customers; AR is an innovative and high-tech technology to ensure digital interactivity for the customers; AR transforms complex information into easier and more accessible for customers; in principle, AR is a futuristic technology that makes a product or service as eye-catching; finally, AR makes visual contents to be translated into many other languages and making them more accurate and consistent.

2.4 Positive Factors of AR Adoption Generated from Existing AR Literature

Researcher like Smith (2010) identifies uniqueness or difference, personalisation and increased content as positive factors of AR adoption tourism product and service consumers. Also, interactivity capacities with viral loop of AR is also defined as the positive factor of AR adoption (Smith 2010). Another researcher Hopkins (2009) identifies few positive factors of AR adoption as: improved mobile usability, redefined mobile technology experience, revolutionised experience, interface technique and enriched usability. Regarding positive factor identification of AR, the contribution of Larkin (2011) is notable as some key factors are emerged as: better personal experience, interactivity advantage, a new media platform, a new virtual sphere, a new sphere of opportunities, social media compatible, virality and visualised catalogue.

2.5 Negative Factors of not Adopting AR from Existing AR Literature

In terms of negative factors of not adopting AR by tourists, researchers show some specific factors that can be termed as negative. According to Larkin (2011), uncertainty about fully taking off is the key negative factor. Also, Andy (2014) argues that, poor performance on low spec mobile device, integration failure, limited scope of image recognition and gimmick are some negative factors where Pauley (2016) identifies technological similarity as the basic negative factor. Hopkins (2009) argues that, unexplored capacities of AR, privacy issue and restricted use for general people, narrow contents of AR are some major negative factors of not adopting AR. On the other side, researcher like Dribble (2014) opines that, disturbed binocular vision of depth perception, cartoonish image, limited use in movies, glitchy imaging, problematised object recognition and conflict with animation, disturbed compatibility with Smartphones are some negative factors of not adopting AR by tourism product and service consumers.

3 Methodology

3.1 Cases Under Investigation

Three holiday operators are selected as cases for this research as: Virgin Holidays, Kuoni Travel and Thomson Cruises. One of the key reasons for such case selection is that, customers of these holiday operators are given access to AR. Virgin Holidays, Kuoni Travel and Thomson Cruises have evidences to support their customers by making innovative technologies as AR readily available. These three holiday operators also have a considerable customer base from diverse backgrounds. Virgin Holidays, Kuoni Travel and Thomson Cruises bring AR in their marketing campaigns.

Butler (2013) informs that, Virgin Group formed Virgin Holidays in 1985 in the United Kingdom having it's headquarter in the 'Galleria' in Crawley. Owned by Sir Richard Branson, this company is considered as one of the most successful long-haul scheduled tour operators based in the UK. Virgin Holidays also has partnership with more than 100 retail operators including Sainsbury's, Tesco, Debenhams, House of Fraser, Morrison's and many others. Virgin Holidays employs Aurasma, one of the most updated AR providers for bringing holiday retail experience to their customers. This holiday operator launches an app that allows customers for researching holiday destinations and thus making purchases (Virgin 2016). Technologically, this AR app functions on the brochure after placing on a specific destination. This app is said to be the first of its kind that is made available on iPhone for free downloading. After opening this app, a loading screen greets the viewer and allows them to see Virgin Holiday retail interiors. Users are then directed to AR functions and can browse holiday destinations and latest product or service offers. This app is activated by using the iPhone's in-built camera after the device is positioned at a specific place. For example, if the device is placed on the cover of a brochure, the brochure is seemed to have opened with a video of that specific destination on the screen. The customer is then moved to a specific destination when it is made lively. This is supported by sound and movement that are otherwise impossible in a conventional 2D brochure.

Anandan (2009) notifies that, the operational headquarter of Kuoni Travel is in Dorking after acquisition of Challis and Benson Limited in 1966. However, Kuoni Travel is originally established by Alfred Kuoni in 1906 in Zurich (Bywater 2001). After its establishment, Kuoni Travel is expanded within diverse geographical locations in the world turning it into a global brand. At present, this is world's one of the leading travel companies with more than 11000 employees and has business operations in resorts, hotels, package holidays, tailor-made holidays, cruise liners and many others. Kuoni Travel is the United Kingdom's leading tourism operator that has applied AR in its press advertising and magazines. Kuoni Travel is collaborated by Aurasma, an AR specialist that made AR available for Kuoni Travel customers. Kuoni Travel customers can view Kuoni Travel service or product offers on their Smartphone or iPad. This technology is supported by AR with image recognition technology. Online displays and advertisements of Kuoni Travel are made artistic and lively. Considering customer demands, Kuoni Travel website creates more than 240 diverse messages for its customers. These messages appear during the time customers are live on Kuoni Travel website for a booking holiday or making a tourism product or service purchase. AR app of Kuoni Travel aligns with a brand slogan '*Requested by you…Crafted by Kuoni Travel*' a part of this holiday company's integrated marketing campaign (Kuoni Travel 2016). The application of AR by Kuoni Travel manages to grab attention of increased number of customers with more sales.

Thomson Cruises is operated by Thomson that offers cruises across Europe with ships from Royal Caribbean International, Louise Cruise Lines and Holland America Line. Thomson Cruises was founded in 1973 and primarily entered the cruise market in the same year. However, suffering from rising fuel price issue this venture is terminated in initially in 1976. Later in 1995, Thomson reinitiated this cruise line. This is currently part of the TUI Group as a UK based cruise holiday operator. According to Cruise Market Watch (2017), in 2015, the world-wide cruise holiday industry is calculated as a US$39.6 billion industry (a 6.9% increase from 2014) carrying 22.2 million passengers (a 3.2% increase from 2014) where the market share of Thomson Cruises in 2015 is 1.8% of this industry and 1.3% of these passengers. This brand of Thomson Cruises with other TUI owned travel operators is expected to be phased out in 2018 and will operate under the single name of TUI. Mann and Ibrahim (2005), Thompson and Martin (2005) believe that, Thomson Holidays became the pioneer in business-to-business online shopping in 1981. Thomson launched its first Internet site for their Portland Holidays brochure on 19 October, 1995 (Debbage and Ioannides 2005). There is evidence that, Thomson Cruises applies AR for their customers. According to Thomson (2017), Thomson Cruises introduces AR brochures considering the sharp rise of holiday bookings using Smartphone, tablet or handheld computing devices. Thomson Cruises finds a unique way for bringing its ships alive and showcase the life aboard. To do this, an innovative technology as AR is embedded in its conventional brochure pages to modernise its customers' research experiences. Supported by AR, few photographs as seen on the latest Thomson Cruises' brochure brings to life having 6 films. Such films present classy gourmet dining and entertainment selections on board. These also highlight the Platinum offers on board Thomson Celebration and Thomson Dream followed by introduction of the Customer Operations Director of Thomson. For accessing such hidden footage, tourism product and service consumers are required to download the free Aurasma App as available from the Google Play and App Store. Then they have to search for, select and follow Thomson Cruises. By placing the Smartphone, tablet or handheld computing devices over specific images as recognisable through an icon on the brochure, the ships come alive. This offers tourism product and service consumers a real feel for their desired holiday that they wish to book. Thomson UK is headquartered in Luton of England. In the most recent time, Thomson is doing online business as well for retaining a major share in the high-street travel agency business (Canwell and Sutherland 2003; Needle 2004).

3.2 Research Design

To generate primary data, 20 face-to-face interviews are conducted supported by open-ended and informal discussion with target respondents. A semi-structured questionnaire is used for the purpose. Respondent selection is based on purposive sampling because of the nature of this research. For interview, respondents having prior knowledge in AR and loyalty for the selected holiday operators are selected.

This is to avoid risks of lack of knowledge about an innovative technology as AR. Adoption of this technology require specialised knowledge that general tourism products and service consumers might not have and thus purposive sampling is followed. The respondent profile is followed:

3.3 Data Collection

Main sample respondents of this research are customers of three selected holiday operators (i.e.: Virgin Holidays, Kuoni Travel and Thomson Cruises) are the respondents. These sample respondents are identified through careful selection and purposive sampling. In this research, careful attention is paid to respect business policy secrets and sensitive data are not disclosed of any of the 3 holiday operators. However, for the sake of keeping business policy secrecy, the researcher is not granted to make face-to-face visits with any official of the 3 holiday operators. The researcher is not allowed to access to the head office of any of these holiday operators to conduct formal or informal interviews even after several attempts. However, very generic information are passed over the telephone conversation with responsible officials of these holiday operators. Keeping in mind about such limitation, data collection is designed in meaningful and achievable ways that involved the customers of these holiday operators where the research only covered consumption/adoption side of AR. Selected stores of Virgin Holidays and Kuoni Travels both in and around London are targeted as the location for data collection. On the other side also, selected stores of Thomson in and around London are targeted for Thomson Cruises customers. This is because both in-land and cruise ship holidays of Thomson are found booked from these stores. Having verbal consent of the store management of these selected stores, only loyal customers of these holiday operators are selected having prior knowledge in AR. These respondents are approached for data collection on their way back from these stores. Thus, no interruption in day-to-day business activities in these stores are made. Respondents are clearly asked the reasons and positive factors of AR adoption with negative factors of not adopting AR. This is supported by open-ended discussions. Maximum length of these interviews are 10 min that is considered as sufficient to reach data saturation covering necessary data and information. The interviews are taken in person and audio-recorded. In addition, to collect secondary data, both online and offline resources including tourism industry reports are used. These 3 holiday operators are evidenced to allow their customers to adopt AR for marketing purposes.

3.4 Data Analysis and Interpretation

Collected data are self-transcribed. This offers the researcher to properly bring out the contents of these interviews. The researcher listened to each of these interviews

Table 2 Respondent profile table

#	Gender	Age	Customer of	#	Gender	Age	Customer of
R01	M	20–30	Virgin Holidays	R11	M	50–60	Kuoni Travel
R02	F	30–40	Kuoni Travel	R12	F	40–50	Kuoni Travel
R03	M	20–30	Virgin Holidays	R13	M	50–60	Virgin Holidays
R04	F	30–40	Kuoni Travel	R14	F	30–40	Kuoni Travel
R05	M	50-60	Virgin Holidays	R15	F	50–60	Virgin Holidays
R06	M	30–40	Virgin Holidays	R16	F	30–40	Thomson Holidays
R07	F	20–30	Virgin Holidays	R17	F	20–30	Thomson Holidays
R08	F	30–40	Thomson Holidays	R18	M	40–50	Kuoni Travel
R09	M	50–60	Kuoni Travel	R19	M	40–50	Kuoni Travel
R10	F	30–40	Thomson Holidays	R20	M	30–40	Kuoni Travel

for several times and then transcribed manually. Data analysis follows qualitative approach with an aim to make non-technical readers understand research findings easily and comprehensively. Thus, data analysis also avoids excessive use of technical terms and made clear explanation of any technical term used. Data analysis in this research has not involved any rigorous statistical analysis. However, findings of this research actually lead to further research with complex statistical analysis through using updated data analysis software (Table 2).

4 Findings and Analysis

Findings are presented in a more explanatory and analytical manner for general readership. Findings outline tourism product or service consumers are becoming more technology savvy relying more on updated technologies that are innovative. AR is an example of such innovative technology. On the other side of AR adoption, all respondents mentioned Virgin Holidays, Kuoni Travel and Thomson Cruises are the leading AR user in the United Kingdom for serving tourism consumers.

4.1 Reasons of AR Adoption by Tourists

Innovativeness appear as key reason as stated by respondent 11, ‘innovativeness and service features are the main reasons to adopt AR’. Also, respondent 16 states that, ‘innovativeness and uniqueness are the two basic reasons and positive factors to adopt this technology’. Respondent 1 identify a couple of specific reasons of AR adoption as, ‘AR accommodates hidden reality that is exciting and AR is thrilling at the same manner’. In the almost related statement, respondent 2 says, ‘AR is interesting and learning as well’. In another statement respondent 7 opines that, 'I think acceptance possibility and reduced complexities are the two basic reasons and positive factors'. Respondent 8 has almost similar opinion as, 'AR is reliable and AR is a valid technology'.

Usability comes as the next reason as, respondent 10 mentions that, 'AR is mainly used because, this is user-friendly and mobile phone usable and the user does not have to open my laptop every time to use AR'. Also, respondent 18 says that, 'AR is designed as capable to produce a good picture of the desired destination that a respondent wishes to visit'. On the other side, respondent 19 informs that, 'AR is easy to use and offers huge information'. In a similar manner respondent 20 shows that, 'easing off difficulties that a consumer normally faces to purchase a product or service is the reason to adopt AR'. Another respondent 15 stresses on that, 'AR is useful and effective in making a consumer to purchase a specific tourism product or service'. Respondent 13 particularly mentions its usability and eagerness to try a new technology. On the almost same position, respondent 17 mentions that, 'interest creation capacities and attractiveness of this technology are reasons and positive factors for using it'. Other respondent 6 asserts that, 'assessing the impacts of a newly introduced technology is the other reason to adopt AR by tourists'. This respondent believes that, as a new technology, AR can really benefit and uplift customers perceived expectations to a higher level to adopt this technology. Thus, respondent 12 thinks that, 'consumer expectations and aspirations to use a new technology are the vital reasons and positive factors'. Respondent 14 also believes that, 'AR as playful enjoyable and competitive to use to serve a purpose'.

Better content is the other reason to adopt AR by tourism product and service consumers as mentioned by respondent 5, 'contents of AR find an accepted position among the tourists'. This respondent also states that reasons and positive factors of AR adoption are contents and interactiveness. In addition, this respondent believes that, the contents of AR can be diverse accommodating many aspects while the interactiveness feature is also great, to some extent.

There are also some other diverse features of AR appear as reasons categories of R adoption by tourists in respondent statements. Respondent 3 coins that, reasons to adopt AR are: first, it offers a pleasant purchase journey and second, it offers personal experiences. In addition, lack of available technology to replace AR appear as the response as respondent 4 answer that, the dominant reason to use AR is the lack of effective technologies to help a tourism product or service purchase. Also, respondent 9 answers that, lack of effective and applicable technology are the reasons for AR adoption by tourists.

4.2 Positive Factors of AR Adoption by Tourists

Innovativeness feature of AR appears as the specific positive factor for its by tourism product and service consumers. Supporting this positive factor, respondent 11 says that, 'I would mention two features as: innovativeness and service features'. Also, respondent 16 mentions that, 'the very generic advantages of AR are:

innovativeness, uniqueness; and faster popularity'. In the same manner respondent 7 accepts that, 'this technology can be well accepted and can be readily available'. In addition, respondent 8 suggests that, 'I should say the two very important advantages of AR are reliability and validity of this technology'. Following innovativeness feature of AR, respondent 15 mentions that, 'AR is helpful but many consumers need to know that, AR needs to be granted as useful and general consumers should be aware about that'. Based on innovative features of AR, respondent 18 says that, 'AR can create a perceived image and can help to create a positive impression about a destination'.

Usability feature is the other positive factor found to adopt AR by tourism products and service consumers. This is stated by respondent 19 as, 'AR is easy to use and can accommodate a wide range of information'. Also, this respondent believes that, this technology is effective and usable. Also, respondent 13 coins that, 'from experience, I would that, better usability and effectiveness are the positive factors to adopt AR'. Stressing on trouble-free usability feature of AR, respondent 20 mentions that, 'the best advantage of AR is its capacity to ease off most of the troubles and difficulties related to time, costs and efforts'. Similarly, respondent 20 says that, 'the two advantages of AR as found are user-friendliness and easy to use'. According to respondent 4, 'I have found AR as promising and able to fill the existing gap of an effective technology. This technology helps a lot to allow consumers have a good product or service purchase'.

Several other factors are also mentioned by the respondents. Respondent 5 indicates that, 'wider range of contents and interactivity are the two basic advantages of AR'. Respondent 12 points that, 'this technology is capable to meet demands of tourism consumers where the expected performances are matched to their desired benefits'. On the other side respondent 14 mentions that, 'three basic features: playfulness, enjoyable and competitive are the key positive factors to adopt AR by tourism product and service consumers'. Experience generation is the other positive factor as explored by respondent 3 and this respondent states that, 'AR is capable to offer pleasant purchase experience'. This respondent also says that, 'this technology can generate memorable personal experiences'.

Feature of AR is found as interesting in the statement of respondent 1 as, 'with hidden reality, this technology is exciting and thrilling'. This respondent believes that, this is a technology that would benefit tourism consumers in a great way. According to respondent 2, 'AR is a technology that makes a product or service purchase interesting. This technology is a learning experience at the same time'. On the other side respondent 6 mentions that, 'AR is a new technology having diverse features where customer views and ideas about this technology are also positive as far as understood'. Respondent 17 argues that, 'some consumers have more interests in using AR'. Reasons and positive factors of AR adoption by tourists generated empirically are symmetrical to literature based reasons and positive factors mainly indebted to Augment (2016), Hopkins (2009), Sykes (2013), Jackson (2014), Johnson (2015), Larkin (2011), Lord (2012), Pauley (2016), Smith (2010), Spillers (2009), Total Immersion (2016).

4.3 Negative Factors of AR Adoption by Tourists

Availability issue appears as the negative factor of not adopting AR by tourism products and service consumers. In the statement, respondent 19 says that, 'in many cases, consumers are not fully aware that, AR is so easy to use and contains so much information and consumers need to know about it'. Likely, respondent 12 mentions that, 'in many cases, people expects too much from a new and innovative technology'. This respondent doubts that, AR can hardly be able to meet such expectations as in some cases, this technology may have limitations. Also, respondent 13 argues that, 'some features of this technology require adequate knowledge in computing and in some cases, these can turn as disadvantages'. Respondent 8 insists that, 'AR still needs to be familiarised as a reliable and valid technology where many people need to know about it'. Respondent 9 stresses that, 'the basic disadvantages of AR are its less publicity and less attractiveness and people know very little about it'. Similarly, respondent 17 says that, 'the two basic disadvantages of AR that, I can mention are: it is promising but still unable to attract massive number of consumers to adopt it and this is a disadvantage. Thus, AR can manage to attract only selective consumers having access of the Internet'. In a related manner respondent 6 highlights that, 'the very key disadvantage of this technology as believed is its unavailability and this technology is not yet fully available where some of the features are quite difficult to understand making this as widely complex for non-technical users'. Respondent 15 finds that, 'the great disadvantages as found from using AR are: common consumers do not often know that, this technology really helps'. On the other side respondent 16 finds that, 'the basic disadvantages of AR are: its less advertisement and consumers yet to know about this technology benefitting them in great ways'. Also, according to respondent 11, 'this technology needs to be readily available and till now it is less available to common tourism consumers'.

The other negative factor of not adopting AR by tourism product and service consumers is the technological issue as mentioned by respondent 5, 'as in some cases, AR can be a bit complex and misunderstood by tourists and this technology requires expertise in some cases that tourists may do not have'. Supporting this statement, respondent 1 mentions that, 'bringing reality in digital format is a complex and difficult matter to consider and in this regard, some tourism consumers may not find AR as heavily interesting'. Also, according to respondent 10, 'some people cannot download this technology in an easy manner due to technological difficulties and that can be the crucial disadvantage of AR'. On the almost similar opinion respondent 3 argues that, 'while making personal experiences, consumers' personal aspects become issues and personal artefacts can be disclosed in some cases and this is the key disadvantage of this technology'. This respondent also believes that, 'this technology is yet to be fully operational meaning that it needs further updates to make it fully accessible and operational'. In addition, respondent 20 remarks that, 'any specific disadvantage is not easy to find but this technology can be highly sophisticated and difficult in a sense'.

Usability issue is the other disadvantage as mentioned by respondent 2 as, 'the great disadvantages of AR are: some customers may find it less interesting and this technology may be less appealing to them as this in some cases requires advanced technological knowledge'.

There are some other disadvantages of AR as mentioned by the rest other respondents. In opinion, respondent 4 highlights that, 'the generic disadvantage of AR that, this can make customers lazy enough to visit a high-street travel agent and this can in turn reduce their business and even threaten their existence'. Also in accordance to respondent 7, 'some customers may not widely accept this technology because they may be fussy and thus, this is difficult to say that, this technology can be readily accepted by all'. In addition, respondent 14 argues that, 'this technology requires specialised knowledge mainly to enjoy those playful and enjoyable features. Also. Virtual Reality (VR) in some cases threatens it growth and popularity'. This statement is supported by respondent 18 as, 'AR in few cases can be difficult to use and understand where the usability can become issue in given contexts'. Apparently, empirical findings as negative factors of not adopting AR match with literature findings as outlined mainly by Larkin (2011), Andy (2014), Pauly (2016), Hopkins (2009) and Dribble (2014).

A summary based on empirical evidences supported by the literature generated data of key reasons and positive factors of AR adoption by tourism product and service consumers with negative factors of not adopting AR by tourism product and service consumers can be the below (Fig. 1).

Findings of this research supports that, AR is an innovative technology that enhances experiences getting supported from *mobile, handheld and wearable devices* (Jung et al. 2015). Results also align with findings from dominant theories as: the Diffusion of Innovations theory (Rogers 1962) and the Technology Acceptance Model (Davis 1986, 1989; Davis et al. 1989) with derivatives that AR is a technological innovation and also with AR specific theories in tourism (Chung et al. 2015; Jung et al. 2015; Leue et al. 2014; tom Dieck and Jung 2015; Rauschnabel and Ro 2016). The Internet has facilitated a relatively newer wave of advancements in mobile and personal computing resulting to increase the adoption of an innovative technology as AR for tourism product and service consumers. Supported by this wave of technological advancements, product and service consumers have witnessed more modified wearable devices as Smartphones, Smart

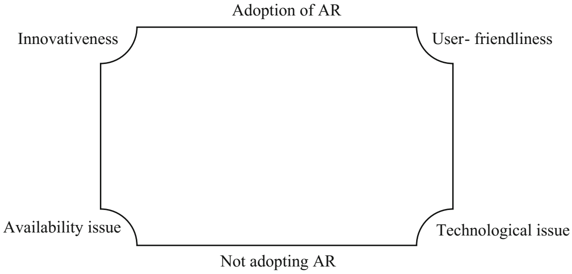


Fig. 1 Key reasons and positive factors of AR adoption by tourism product and service consumers and negative factors of not adopting AR by tourism product and service consumers

glasses, Smartwatches or even fitness bands. Also, the use of 3D head-mounted displays is mentionable in this regard that allows users to view data by looking straight ahead. These modifications are interesting for exploring a relatively new technology that offers incentives to users coupled with a bit more different experiences. Such experience can come in a computer generated, real-world environment as branded as 'Augmented Reality'. Thus, this research is conducted on a trendy and innovative technology as AR where innovativeness and user-friendliness appear as key reasons and positive factors of AR adoption by tourism product and service consumers where availability issue technological issue appear as negative factors of not adopting AR by tourism product and service consumers.

5 Conclusion

This research is based on an identified knowledge gap of AR literature in tourism. Thus theoretically, this research initiates factor determination research of AR adoption in tourism while contributing positively to this identified knowledge gap. On the other side of managerial perspective, holiday operators/managers can learn the reasons, positive factors ad negative factors while making an innovative technology available for the customers. Also, as managerial implications, findings can support tourism enterprises understanding customer demands and act in accordance to fulfil their expectations. Basic limitation of this research is the data and access restriction by the all 3 case holiday operators. Better data support could possibly enrich contents of this research. Results of this research can help them preparing more consumer-friendly approaches. The aim of this research is to delineate the features of AR while determining the reasons and positive factors for its adoption by tourism product and service consumers as well as negative factors of not adopting AR by tourism product and service consumers. This research clearly determines innovativeness and user-friendliness appear as key reasons and positive factors of AR adoption by tourism product and service consumers where availability issue technological issue appear as negative factors of not adopting AR by tourism product and service consumers as result of this research. In tourism, technological innovations are adopted by tourism product and service consumers. This research also explores a closer proximity between AR as an innovation and tourism consumers, in terms of their innovativeness, usability and availability of an innovative technology. Among many others, attractiveness, information generation, experience capacities, playfulness are some other influential reasons and factors of adopting AR by tourism product and service consumers. The, recent development of mobile phone and handheld computing devices is found as the most dominant factor of AR adoption. Virgin Holidays, Kuoni Travels and Thomson Cruises are found as competitive in making AR available for their customers. These holiday operators make AR as an innovative technology having potentials to be adopted by tourism product and service consumers. Further research can contribute to eliminate basic limitations of this research by including larger sample groups and including voices of the target holiday operator management. Also, future research studies should incorporate both tourism service providers and tourism product and service consumer opinions on line of criticality.

References

Anandan, C. (2009). *Product management*. Delhi: Tata McGraw-Hill.

Andy, W. (2014). *5 reasons why augmented reality fails for brands.* Retrieved January 2016, from http://www.enginecreative.co.uk/blog/5-reasons-augmented-reality-fails-brands.

Augment. (2016). *5 reasons to use augmented reality in education*. Retrieved February 2016, from http://www.augment.com/blog/5-reasons-use-augmented-reality-education/

Butler, R. W. (2013). Richard Branson: 'Screw it, let's do it'. In R. W. Butler & R. Russell (Eds.), *Giants of tourism* (pp. 136–150). Wallingford: CABI.

Bywater, M. (2001). Travel distribution: Who owns whom in the European travel distribution industry. In D. Buhalis & E. Laws (Eds.), *Tourism distribution channels* (pp. 151–171). London: Continuum.

Canwell, D., & Sutherland, J. (2003). *Leisure and tourism*. London: Nelson Thornes.

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.

Cruise Market Watch. (2017). *Market share-2015 worldwide market share*. Retrieved on Janurary 2017, from http://www.cruisemarketwatch.com/market-share/.

Dadwal, S., & Hassan, A. (2015). 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. 78–96). Hershey, PA: IGI Global.

Davis, F. D. (1986). *A technology acceptance model for empirically testing new end-user information systems: Theory and results*. Massachusetts: Sloan School of Management, Massachusetts Institute of Technology.

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

Davis, F. D., Bagozzi, R. P., & Warshaw, P. R. (1989). User acceptance of computer-technology —A comparison of 2 theoretical-models. *Management Science, 35*(8), 982–1003.

Debbage, K. G., & Ioannides, D. (2005). *The economic geography of the tourist industry: A supply-side analysis*. London: Routledge.

Dribble, A. (2014). *The 3 biggest problems facing augmented reality today-and how to fix them.* Retrieved January 2017, from http://brainberryglobal.com/3-biggest-problems-facing-augmented-reality-today-fix/.

Goodhue, D. L., & Thompson, R. L. (1995). Task-technology fit and individual performance. *MIS Quarterly, 19*(2), 213–236.

Hassan, A., & Jung, T. (2016). Augmented reality as an emerging application in tourism education. In D. H. Choi, A. Dailey-Hebert, & J. S. Estes (Eds.), *Emerging tools and applications of virtual reality in education* (pp. 168–185). Hershey, PA: IGI Global.

Hassan, A., & Rahimi, R. (2016). Consuming "Innovation": Augmented reality as an innovation tool in digital tourism marketing. In P. Nikolaos & I. Bregoli (Eds.), *Global dynamics in travel, tourism, and hospitality* (pp. 130–147). Hershey, PA: IGI Global.

Hassan, A., & Ramkissoon, H. (2017). Augmented reality for visitor experiences. In J. N. Albrecht (Ed.), *Visitor management*. Oxfordshire: CABI (in press).

Hassan, A., & Shabani, N. (2017). Usability analysis of augmented reality for tourism destination promotion. In S. K. Dixit (Ed.), *Routledge handbook of consumer behaviour in hospitality and tourism*. Oxon: Routledge (in press).

Hassan, A., Shabani, N., Ekiz, A., Dadwal, S. S., & Lancaster, G. (2017). *Augmented reality in tourism and factors for its adoption: An empirical study*. Paper accepted for presentation at the 22nd Annual Graduate Education and Graduate Student Research Conference in Hospitality and Tourism. Texas, TA: The University of Houston Conrad N. Hilton College of Hotel and Restaurant Management and the School of Hotel and Tourism Management at The Hong Kong Polytechnic University.

Henderson, S. J., & Feiner, S. K. (2007). *Augmented Reality for Maintenance and Repair (ARMAR).* Retrieved March 2016, from http://graphics.cs.columbia.edu/projects/armar/pubs/henderson_feiner_AFRL_RH-WP-TR-2007-0112.pdf.

Hopkins, D. (2009). *Advantages and drawbacks of using augmented reality*. Retrieved January 2016, from http://www.dontwasteyourtime.co.uk/technology/advantages-and-drawbacks-of-using-augmented-reality-augmentedreality/.

Jackson, C. (2014). *Augmented reality and the future of printing and publishing opportunities and perspectives*. Retrieved March 2015, from http://www.inglobetechnologies.com/docs/whitepapers/AR_printing_whitepaper_en.pdf.

Johnson, K. (2015). *6 reasons why Augmented Reality will be as common as eye glasses.* Retrieved February 2016, from: http://usdailyreview.com/6-reasons-why-augmented-reality-will-be-as-common-as-eye-glasses/.

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,* 75–86.

Kuoni Travel (2016). *Kuoni Travel.* Retrieved January 2016, from https://www.google.co.uk/search?q=kuoni+travel+logo&biw=1280&bih=927&source=lnms&tbm=isch&sa=X&ved=0ahUKEwi0u9mJgsTLAhUsCZoKHZUcCT4Q_AUIBigB#imgrc=FaIf3cFe05wZvM%3A.

Larkin, F. (2011). *Advantages and disadvantages of augmented reality.* Retrieved January 2016, from http://www.behindthespin.com/features/advantages-disadvantages-of-augmented-reality.

Layar. (2016). *Layar for Google glass.* Retrieved March 2017, from https://www.layar.com/glass/.

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

Lin, C. H., Shih, H. Y., Sher, P. J., & Wang, Y. L. (2005). Consumer adoption of e-service: Integrating technology readiness with the technology acceptance model. In *Technology management: A unifying discipline for melting the boundaries.* Portland: 483–488.

Lord, T. (2012). 5 reasons to get excited about augmented reality in 2013. Retrieved January 2016, from http://venturebeat.com/2012/12/23/augmented-reality/.

Mann, M., & Ibrahim, Z. (2005). *The good alternative travel guide: Exciting holidays for responsible travellers*. London: Earthscan.

Needle, D. (2004). *Business in context: An introduction to business and its environment*. London: Cengage Learning EMEA.

Parasuraman, A. (2000). Technology Readiness Index (TRI) a multiple-item scale to measure readiness to embrace new technologies. *Journal of Service Research, 2*(4), 307–320.

Pauley, P. (2016). *4 reasons why experiential marketing with virtual and augmented reality boosts sales*. Retrieved January 2016, from http://www.pauley.co.uk/blog/4-reasons-why-experiential-marketing-with-virtual-augmented-reality-boosts-sales/.

Rauschnabel, P. A., & Ro, Y. K. (2016). *Augmented reality smart glasses: An investigation of technology acceptance drivers.* Retrieved January 2016, from http://www.philipprauschnabel.com/wp-content/uploads/2016/01/RAUSCHNABEL-RO-2016-AR-Smart-Glasses-IJTMKT-forthcoming.pdf.

Rogers, E. M. (1962). *Diffusion of innovations*. New York: Free Press of Glencoe.

Smith, A. (2010). *Benefits of augmented reality marketing.* Retrieved January 2016, from http://www.socialmediatoday.com/content/5-benefits-augmented-reality-marketing.

Spillers, F. (2009). *What's next in mobile user experience? Augmented reality.* Retrieved January 2016, from http://www.demystifyingusability.com/2009/09/augmented-reality-user-experience.html.

Sykes, J. (2013). *5 reasons you should pay attention to augmented reality interactive storytelling.* Retrieved January 2016, from http://blog.coerll.utexas.edu/augmented-reality-interactive-storytelling-system/.

Thompson, J. L., & Martin, F. (2005). *Strategic management: Awareness and change*. London: Cengage Learning EMEA.

Thomson (2017). *Thomson Cruises gets techy with new winter 2014/15 programme and announces new port 'O' call.* Retrieved January 2017, from http://press.thomson.co.uk/thomson-cruises-gets-techy-with-new-winter-201415-programme-and-announces-new-port-o-call/.

tom Dieck, M. C., & Jung, T. (2015). A theoretical model of mobile augmented reality acceptance in urban heritage tourism. *Current Issues in Tourism,* 1–21.

Total Immersion. (2016). Augmented reality as a virtual support to industries. Retrieved January 2016, from http://blog.coerll.utexas.edu/augmented-reality-interactive-storytelling-system/.

Venkatesh, V., & Bala, H. (2008). Technology acceptance model 3 and a research agenda on interventions. *Decision Sciences, 39*(2), 273–314.

Venkatesh, V., & Davis, F. D. (2000). A theoretical extension of the technology acceptance model: Four longitudinal field studies. *Management Science, 46*(2), 186–204.

Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: Toward a unified view. *MIS Quarterly, 27*(3), 425–478.

Vijayasarathy, L. R. (2004). Predicting consumer intentions to use on-line shopping: The case for an augmented technology acceptance model. *Information & Management, 41*(6), 747–762.

Virgin. (2016). *Home.* Retrieved February 2016, from https://www.virgin.com/travel/through-the-looking-glass-could-augmented-reality-reshape-our-cities.

Walczuch, R., Lemmink, J., & Streukens, S. (2007). The effect of service employees' technology readiness on technology acceptance. *Information & Management, 44*(2), 206–215.

Augmented Reality: Providing a Different Dimension for Museum Visitors

Larissa Neuburger and Roman Egger

Abstract This paper addresses how Augmented Reality (AR) can be used as a tool to provide different dimensions to the conventional museum experience. The principle of AR works by furbishing the actual environment with extra information, which enables users to have a different perception of reality. When integrating both the concepts of AR and Experience, the author discovered that this could be a powerful tool for museums, which have to grapple with the question of how to engage their visitors. Therefore an AR-application-prototype was developed for the Dommuseum Salzburg. The objective was to gauge the value of AR and whether or not it made a significant difference towards the museum experience. The visitor experience was assessed using the experience model (Pine/Gilmore), as well as the Museum Experience Scale (MES). On the whole, this paper aims to show how technology can be used in the curation process, by facilitating and enhancing the presentation of exhibits in a museum.

1 Introduction

The author of this paper advocates a need to critically assess the state of affairs in museums, as visitor numbers in the Federal Museums in Austria have been on the decline over the past few years (Standard 2012). Instead of relying on tried and tested approaches, there is a need for museums to reinvent themselves and to use the vast array of possibilities offered by new media, in order to draw in more visitors. The typical museum visitor is discontent, restless and on a quest for stimuli. To put it succinctly, people are not satisfied with ordinary, homogenous tourism products anymore but are looking for customized, emotional experiences

L. Neuburger (✉) · R. Egger
Innovation & Management in Tourism Department,
University of Applied Sciences Salzburg, Salzburg, Austria
e-mail: roman.egger@fh-salzburg.ac.at

R. Egger
e-mail: lneuburger.bwib-m2013@fh-salzburg.ac.at

T. Jung and M.C. tom Dieck (eds.), *Augmented Reality and Virtual Reality*,
Progress in IS, DOI 10.1007/978-3-319-64027-3_5

(Brunner-Sperdin 2008). No longer willing to be passive consumers, the contemporary tourist has certain aspirations, namely to be at one and to immerse themselves in the tourist experience. They now demand information, entertainment, active participation and multisensory stimulation in combination with innovative design elements (Pine II and Gilmore 1999). Bearing in mind these findings by previous researchers, the author of this paper is particularly interested in the concept of experience and how to integrate this with AR, in order to ascertain how the experience of museum visitors can be improved and enhanced. The author hopes that this paper will be able to provide concrete suggestions and valuable insights for museums to re-strategize and embrace the potentialities of AR. This paper seeks to clarify what AR is about, and to present its relevance, benefits and challenges. The central question is formulated below and the subsequent questions listed afterwards, are also relevant to this paper:

Can Augmented Reality enhance the experience of visitors in museums?

RQ1: Which factors influence the experience of a museum's visitor?
RQ2: In which ways can Augmented Reality enhance the experience of visitors in museums?
RQ3: How can Augmented Reality be implemented in museums from a technical point of view?

2 Literature Review

2.1 The Experience Economy

The concept of the Experience Economy evolves from the process of tertiarization of the economy and can be seen as the enrichment of products or services with components of experiences. Declining profits of conventional transactions, new production possibilities due to modern technologies, rising expectations of customers as well as the struggle to escape the everlasting price battles, can be seen as the cause for this development (Weiermair 2001). Also, the growth of prosperity levels and the affluent society are important factors for the development of the Experience Economy (Pine II and Gilmore 1999). Therefore there exists a big opportunity to create value by staging experience, as this is a saturated world with mostly undifferentiated goods and services (Pine II and Gilmore 2011). Based on this background, Pine and Gilmore (1999) developed a model about staging experiences. With this model they describe the perfect experience that can be found in the balance of Absorption and Immersion on the one hand and Active and Passive Participation on the other hand. Furthermore this perfect experience consists of elements of the four different realms Entertainment, Education, Esthetics and Escapism. As this model was also used as a basis for the research of this paper it is further explained here. In the model the engagement of the customer is shown over two different axes. The horizontal axis defines the involvement of the customer that shows the passive involvement of the customer on the one side, where the customer is not actively and directly influencing the event and the active involvement on the other side, where an active participation and a direct influence is taking place. The vertical axis describes the connection and the relationship between the customer and the event. On the one side of the axis, absorption can be seen as the total preoccupation of the visitor's attention during an event. In contrast to that, immersion can be found on the other side of the axis and represents the physical or cognitive aspect of the visitor's participation so that he even becomes part of the event itself. Whereas watching TV is an example of absorption, the physical participation in a virtual PC game can be named as an example of immersion. The combination of these two dimensions shown on the two axes leads to four different realms describing the perfect experience: Entertainment, Education, Escapism and Esthetics. Entertainment is a combination of absorption and passive involvement and can refer to attending a performance, listening to music or reading books only for pleasure. In contrast to Entertainment, Education requires the active participation of the visitors. In order to enhance one's knowledge and abilities, it is necessary to involve people not only cognitively but also physically. The third realm of Escapism describes the total immersion of the visitor into the experience but also his active participation at the same time. The consumer is not only passively watching or listening but also shapes his experience actively. Therefore the consumer cannot only forget his everyday life problems but also immerses into a totally different world and slips into a different life. In the realm of Esthetics the consumer as well is immersed in a different world but does not influence it and leaves the external event untouched. In this realm especially, the experience of all five senses plays an important role.

The richest experiences are those that offer all aspects and elements of all dimensions. This spot in the middle can be named as the "sweet spot" and represents the perfect overall experience (Pine II and Gilmore 1999).

2.2 Museum Experience

Since Falk and Dierking published their first book about the museum experience in 1992, the number of museum institutions has been increasing. Although the museum industry has achieved a high level of professionalization since then, the focus of museums professionals on the experience of museum visitors is now more important than ever and museums are on their way to becoming service providers of the society as the approach from object-focused exhibitions has changed, where the focus is now on providing information on the exhibitions (Falk and Dierking 2013; Barricelli and Golgath 2014). Therefore museum visitors are now rather seen as customers or even guests of the museum (John 2008a). Museums have tried over the last years not only to be places of collection, conservation, research and communication but have additionally become places of trust for the visitors (Barricelli and Golgath 2014). The challenge of museums in the 21st century is their existence in the dual reality of tangible objects, digital technologies and social media (Falk and Dierking 2013). But museums are also under pressure to justify their existence towards public, funders or governments and have to find a balance between being an institution for collection and preservation and a visitor-orientation place of experiences. Therefore the museum as an institution has to allow itself to scrutinise and reinvent its motifs (Priddat and Van den Berg 2008). So rather than focusing on the collection and marketing campaigns to increase visitor numbers and to broaden the target audience, the museum has to concentrate on the visitor and the visitor experience (Falk and Dierking 2013). The overall aim for the museum is to create a positive experience to the visitor so that he wants to return to the museum after his visit (Lila Wallace-Reader's Digest Fund 2000). In the best case scenario, the visitor leaves the museum thinking that the museum is a pleasant place of leisure and learning, by learning something new and by discovering emotional experiences (Barricelli and Golgath 2014).

The museum experience can be compared with a journey the visitor is travelling through. This visitor journey can also be compared to the customer journey, which is a basic tool for the analysis of visitor experiences in the tourism sector. Falk and Dierking (2002) see the museum experience as a timeline—from the visitor's first thoughts about the museum, through the actual visit until the memories that linger on in the mind of the visitor after the museum visit (Falk and Dierking 2002). The museum experience has to be seen within the background context and the situation of the visitor. Therefore the visitor is involved in a personal, social and physical context of which the certain experience depends on. The personal context refers to the personal background of the visitor, his experiences and the knowledge he brings to the museum as well as his interests, motivations and concerns. All these values are individual and therefore every visitor arrives with his own background, expectations and experiences. The social context describes the social interaction the visitor has with other visitors or the staff of the museum. The museum experience depends on the company of the visitor and the group in which the visitor is part of, the degree of crowd density and the knowledge as well as the friendliness of the museum staff. The physical context appears to the visitor when he enters the museum. It can be named as the "feel", the architecture or the ambience of the museum. Not only the behaviour of the visitor depends on that but also the length of his stay and his return can be influenced by the physical context. When he enjoys the smell, the sound, the surrounding and the fulfilment of his needs, the visitor is much more likely to stay long, revisit and recommend the museum to others. So it is important for museum professionals to not only focus on one or two of the concepts but to see the museum experience as a holistic construct influenced by the personal, social and physical context (Falk and Dierking 2002).

2.3 Augmented Reality

AR "[…] describes the concept of augmenting a view of the real world with 2D images or 3D objects […]" (Woods et al. 2004). As AR is a fairly new concept in tourism and still in its rudimentary phase of development, a clear and ultimate definition cannot be given yet (Han et al. 2013). Smartphones and tablets are now used on an unprecedented scale and this has led to changes not only in communication and human behaviour, which in turn stimulated the development of AR. An important aspect of AR is its ability to "[…] enhance a user's perception of and interaction with the real world" (Azuma 1997). AR works in several ways; the augmented objects can be seen through a visor, which can be head-mounted, where the camera is installed on the head of the user mostly with a see-through-display on smart glasses or hand-held mobile devices like smartphones or tablets. The visor consists of a display screen and a small camera, which captures the real world around the user and sends those pictures to the computer, which tracks the position, the elements and the rotation of the camera. Then the artificial components of the AR application are sent back to the display screen. In this way, the user has the illusion of looking through the augmented content into the real world. The big advantage of virtual objects not being limited to costs or physical limitations makes AR a practical and powerful tool. Virtual objects can be 2D images, 3D objects, videos (animated 2D images), animated 3D objects and sound (Woods et al. 2004; Mehler-Bicher et al. 2011). With advancements and developments over the recent years, AR can be seen as a flexible and practicable tool with high visual quality to overcome the problems associated with limited space and objects being too valuable such that they can be liabilities, while providing a strong source of support that enhances museum content. Within the museum industry, AR is still in its infantile stage but it is becoming increasingly embraced as a credible, versatile and powerful technological tool among the scientific community and the public (Woods et al. 2004; Noh et al. 2009). Another advantage of AR is that it does not exclude museums with limited financial resources, as they too, can make use of an AR system. The AR system is one that does not require the acquisition of expensive hardware systems have to be acquired and many AR software providers offer systems which can be implemented and applied by museum professionals without any IT expertise (Wojciechowski et al. 2004). The average visitor would not find AR too alienating, foreign or radical, as he would already be accustomed to holding mobile devices for the purpose of photography. Therefore, scanning an AR object with the device is a very natural gesture and can lead to an organic museum experience (Sherman 2011).

3 Methodology

Based on the results of the literature, an empirical research study with an experimental design was conducted in order to strengthen the findings of the literature. Furthermore an AR prototype was developed to be able to test the experience enhancement of the museum visitors. The application was designed to provide background information on the selected artworks of the museum exhibition. An impression of the prototype can be seen in Fig. 1.

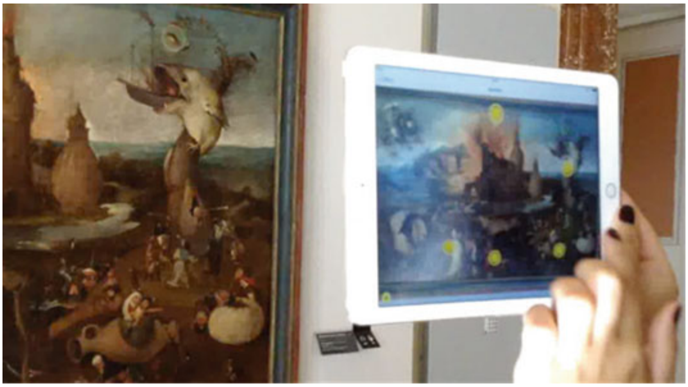


Fig. 1 Example picture AR application prototype

From both sample groups in the experiment, a quantitative questionnaire had to be completed by the participants in the aftermath of the conducted experiment. The two groups filled out the same questionnaire, in order to gauge the differences between their respective experiences.

In order to assess the experience of the museum visitors, the concept of measuring the experience is important. Therefore, the author chose to utilize the experience model conceptualized by Pine and Gilmore (2011). The four realms of the model (‘entertainment’, ‘education’, ‘aesthetics’ and ‘escapism’) were operationalized in order to deduce suitable questions for the quantitative questionnaire that had to be completed by the participants in the aftermath of the conducted experiment. In order to adequately measure how special the museum experience was for the participants, the concept of the Museum Experience Scale (MES) by Othman et al. (2013) was also added to the survey. The MES also consists of four dimensions, which are defined by ‘engagement’ with the museums and its exhibitions, ‘knowledge’ and ‘learning’ obtained from the museum exhibition and its artefacts, ‘meaningful experiences’ by interacting with the artefacts of the museum exhibitions and ‘emotional connection’ with the exhibits and the exhibition. For the process of the operationalization of the concept, different papers were used that had already applied the concepts in empirical studies, with proven validity of the constructs.

In order to create a more enjoyable and meaningful visit for the visitors, the AR application prototype was designed to provide background information on the selected artworks. The development of the AR application prototype was made possible through the support of the Dommuseum in Salzburg, the software company Wikitude and the cooperation with a software engineer in order to enhance the quality of the prototype. The objects that were chosen for use in the AR prototype were the most important objects of the exhibition and contained some additional information that could be shown to the visitors the AR application. The experiment was conducted over nine full-day sessions in the Dommuseum Salzburg. After the random selection of participants in the museum, participants were also randomly assigned to two different groups, the control group and the experimental group. Participants of the control group were asked to visit the four rooms of the museum individually and independently in order to fill out a questionnaire afterwards. The experimental group was asked to try out a museum app with additional information about several museum objects.

4 Findings

In order to answer the research questions of this paper the collected data from the written questionnaires was recoded and analysed with SPSS 21. Due to illegible writing and partially filled out questionnaires, some cases had to be excluded from the sample. Therefore, the number of questionnaires had to be reduced from $n = 185$ to $n = 176$ as important answers about the experience were missing.

4.1 Reliability Analysis

The purpose of the reliability scale was to verify if the measurement instrument (in this case the questionnaire) could represent the several constructs completely and consistently and if the same results would emerge with a repeated experiment. In order to ensure the inner consistency of the constructs, the Cronbach's Alpha test was applied in this research. The values of the Cronbach's Alpha reliability test are acceptable in almost all constructs as they meet the required $\alpha = 0.7$ and therefore demonstrate a strong internal reliability of the items representing the different constructs. Only the construct of 'entertainment' shows a value of $\alpha = 0.56$. Although the required value for most tests is $\alpha = 0.7$, a value of $\alpha \geq 0.5$ can be accepted in order to compare two groups, which was also conducted in this research (Mücke 2010).

4.2 Comparison of Groups

In order to evaluate the different results between the groups, the independent t-test was used. In order to avoid an analysis of every single item, the items of the different constructs were summed up to a common value for each construct of the model. In order to test the hypothesis, the author also wants to analyse the results separately. Therefore, the different items of the questionnaire were deliberately tested with a 7-level Likert-Scale. As the middle point was located at $M = 3.5$ it can be said that values in between $3.5 \leq M \geq 7$ can be evaluated as high. In addition to the results of the t-test, the effect size was also indicated in order to prove the extent of the observed effect (Field and Hole 2003).

Table 1 T-Test experience scale

	Analysis Experience Scale * $p < 0.01$ ** $p < 0.05$			
Variable	Mean experimental group	Mean control group	t	Effect size d
Entertainment	5.47	4.58	5.71*	0.86
Education	6.06	5.41	3.86*	0.58
Escapism	4.79	4.17	2.98*	0.45
Esthetics	5.79	5.51	1.65	0.25
Overall Experience	5.53	4.92	4.36*	0.66

H1: AR enhances the overall experience of the museum visitors.

H1 could be accepted because of the significant difference between the values of the experimental group and the value of the control group showing an additional intermediate effect. The exact numbers can be seen in Table 1. Therefore, it is evident that the experience of visitors who used the AR application to explore the museum exhibition exceeded in quality, the experience of visitors who visited the exhibition only with an audio guide or without any additional information. In order to deepen the analysis of the overall experience, the different concepts and constructs were also explored. The values of the overall experience can be generally evaluated as relatively high values for the overall experience in the museum.

H1a: AR enhances the 'entertainment' realm of the museum visitors.

The construct of 'entertainment' also shows a significant difference between the experimental group and the control group. Entertainment is one of the biggest aspects when it comes to enhancing the experience of a museum. Museum visitors are often confronted with too much information or obtuse exhibition content, which can be too intimidating for most people. Providing visitors with information and access to the museum exhibitions in an entertaining and playful way also enhances the overall experience. This concept of 'edutainment', which had already been mentioned in this paper, combines education and entertainment in a way where the visitors can have fun while learning and yet are able to retain more content and information long after they depart from the museum. The AR application offers boundless possibilities to enhance the entertainment factor in a museum, as it is interactive and summarizes information in the form of multimedia content. Therefore, the visitors can experience the real exhibition and at the same time, obtain stimulation from videos or pictures, which refer to the real artefacts of the museum.

H1b: AR enhances the 'education' realm of the museum visitors.

The difference between the experimental group and the control group is also significant with an intermediate effect. One of the greatest priorities of museums is the educational aspect and having to deal with the transmission of information to the visitors. As already mentioned, the biggest opportunity here is to combine education with entertainment, to transfer knowledge to the visitors interactively through multimedia features. Museums always face the challenge of finding the right balance of designing the exhibition in an aesthetically appealing way but at the same time, they have to take care not to pay too much attention to form at the expense of substance, as the visitor fundamentally needs to be provided with solid information so as to be able to interpret the exhibition and engage with the artefacts. The usage of AR can provide visitors with additional information to the artefacts that often cannot be envisaged otherwise, as different visual perspectives of artefact (such as the inside of the book in the Dommuseum) show and moreover provide this information interactively and in an entertaining, playful way. Therefore, it can be said that AR can enhance the museum-going experience and educate visitors in a memorable way.

H1c: AR enhances the 'escapism' realm of the museum visitors.

This hypothesis can also be accepted due to the value's significant difference between the experimental group and the control group with an acceptable effect size. 'Escapism' describes the situation of the visitor who is so thoroughly immersed in the experience so that he temporarily forgets about his everyday life, all his problems and concerns. A museum experience itself is able to lead the visitor into this alternative psychological condition. AR can additionally enhance this aspect by showing the visitor a whole new virtual world without letting him lose the connection to the real museum exhibition. Therefore, the application of AR can immerse the visitor totally into the museum situation, let him forget about time and his everyday life beyond the museum, leaving him with a heightened, impressionable and enhanced experience.

H1d: AR enhances the 'aesthetics' realm of the museum visitors.

The difference of the two groups in the realm of 'aesthetics' is not significant enough to lead to a rejection of the hypothesis. This insignificant difference can probably be explained through the external influencing factors concerning the location of the museum. Due to its location in a side wing of the Cathedral, the visitors can see and experience the church through the windows of the Dommuseum. In that way, visitors can be influenced by stimuli from the church like the Holy Mass every Sunday or organ concerts which are organised a few times per week. As visitors from the experimental group as well as from the control group are influenced by the described stimuli, there can be no significant difference found between the two groups.

Table 2 T-Test museum experience scale

	Analysis museum experience scale * $p < 0.01$> ** $p < .05$			
Variable	Experimental group	Control group	t	Effect size d
Engagement	5.96	5.29	4.01*	0.60
Knowledge & learning	6.07	5.42	4.20*	0.63
Meaningful experience	5.31	4.72	3.55*	0.54
Emotional connection	4.00	3.52	2.19**	0.33
Overall museum experience	5.33	4.74	4.24*	0.64

H2: AR enhances the overall museum experience of the museum visitors.
The result shows the difference between the experimental group and the control group regarding the overall museum experience is significant as can be seen in Table 2. Therefore it can be said that the museum experience of those visitors who use the AR application is higher than the museum experience of visitors who visit the museum in a traditional way.

H2a: AR enhances the engagement of the museum visitors.
Within the dimension of 'engagement', a significant difference was found between the visitors being part of the experimental group and visitors of the control group. As a conclusion it can be said, that the engagement of the visitors with the museum and the museum artefacts can be enhanced with the application of AR. Especially because of the additional, visualized information, the visitors feel more engaged with the museum and its exhibition and this information helps them to understand the content and interpret it in the right context.

H2b: AR enhances the knowledge of museum visitors.
When comparing the results of the two scales, it is interesting to see that the values of the items 'education' as part of the experience scale, and 'knowledge' and 'learning' as part of the MES are almost identical. Therefore the hypothesis can be accepted, as there is also a significant difference between the experimental group and the control group. The effect size shows a similar intermediate characteristic as the construct of 'engagement'. As already mentioned, the transfer of knowledge and information can be enhanced with the application of AR to visualize additional information

H2c: AR enhances the 'meaningful experience' of the museum visitors.
The realm of 'meaningful experience' as part of the MES also shows a significant difference. Therefore, the hypothesis can be accepted with the significant difference between the experimental group and the control group. So it can be concluded that the experience not only can be enhanced by the application of AR but this can also lead to a meaningful experience. This 'meaningful experience' can be influenced by the balance of the content visualized in AR application and the context AR is used in.

H2d: AR enhances the 'emotional connection' of the museum visitors.
The 'emotional connection' refers to the rapport and affinity that museum visitors build up with the artefacts of an exhibition and shows a significant difference in the dimension of the emotional connection between the two groups but only on a significant level of $p < 0.05$. Nevertheless the hypothesis can be accepted with the significant difference between the two groups. The effect size $d = 0.33$ shows the lowest value in all constructs and represents only a small effect. The values in general are relatively low and are not much higher than the middle point of the frequently-used Likert Scale of 3.5. Most likely this can be explained by the religious content of the exhibition. Religious content in a museum is very complex for the visitors as well for the museum itself. Therefore, visitors cannot build up an emotional connection with the exhibition especially visitors from other countries that are not familiar with the culture and religion of Austria, and therefore face actual limitations Therefore, AR can be used to familiarize the visitors with these religious artefacts in a way that facilitates their understanding and appreciation for them.

5 Discussion and Conclusion

While AR has already been around for more than 20 years, the development of this technology has yet to reach its limits and no one can really predict where these limitations lie. AR is increasingly finding its way through contemporary life, a phenomenon that is compounded by new technological developments. In contrast to VR that appears to be at the peak of its popularity right now, there is plenty that hints at AR being the new supreme technology of the future, which is why it is even more important to investigate its effects, uses and influences in different areas. Furthermore, the importance of museums is something that will and has to persist, as they are formidable institutions that showcase the numerous cultural treasures of this world and the accumulation of centuries worth of historical knowledge.

The 21st century poses some challenges to the relevance of museums. They have to strive hard to avoid coming across as inaccessible ivory-towers. Potential museum visitors have less leisure time but at the same time, more possibilities to spend their leisure time, with a wide array of activities at their disposal. People also have higher expectations of what they can derive from their leisure activities and do not only want to spend their time and money without discernment, but to engage in unforgettable experiences as well as escaping from their everyday life routine or problems. The museum experience is a highly complex construct that has to be considered in this context. Today, the materialisation of museum artefacts and the digital world can be bridged, by including high-tech components and invisible technologies in order to meet the expectations of the visitors and enhance their experiences on the one hand, without affecting, disturbing or influencing the specially-designed exhibitions.

Given the results of the conducted experiment in the Dommuseum Salzburg, it can be said that AR definitely has the potential to enhance the experience of museum visitors. The results can answer the overall research question and show that both the overall experience defined by Pine and Gilmore (1999) and the Museum Experience by Othman et al. (2013) has been unequivocally enhanced by AR. When broken down into the different realms and dimensions of the two tested models, it can be said that the realms of ‘entertainment’, ‘education’ and ‘escapism’ as well as ‘engagement’, ‘knowledge/learning’ and ‘meaningful experience’, all demonstrate higher numerical values, alluding to the success of AR. The results also show an intermediate to large effect size. Only the realms of ‘aesthetics’ being part of the experience model and ‘emotional connection’ as part of the Museum Experience Scale do not show significant values or suggest only a very low effect size due to the special location of the museum next to the Cathedral of Salzburg and its special religious artefacts with their complex meaning. Once again, the author would like to reiterate that AR enabled the museum visitors to feel more entertained and engaged, to gain more educational knowledge, while being able to experience escapism and simultaneously have an exceptionally meaningful experience.

The question of how AR can enhance the experience of the visitors can be addressed with the different types of content that were used in the application prototype. The content that can be used to augment the various museum exhibits depends on the available additional information of the different artefacts. According to the visitors from the experiment, they strongly had a preference for pictures that either showed different aspects of the artefact or reference images with background information of the artefacts. According to observations during the experiment, it can be deduced that videos can be used but with an improved technology like overlay videos. Obviously limited text should be used, in order to avoid information overload. The appearance of the actual object has to be visible and fully-preserved, as many museum visitors are still on a quest to view the 'real' thing as opposed to something replicated.

From a technical point of view, the usage of iPads showed that tablets are suitable devices for AR due to their appropriate size but it is still a challenge to develop a stable application for all possible devices on the market. The most important technical aspect is the implementation of the AR application for usage on the visitor's own devices. The visitors should have the possibility to download the app for their own devices (iOS as well as Android) for free or to include it in the ticket price with a special code. In this context, the availability as well as the free usage of a WIFI connection is important. Afterwards, the visitors can explore the exhibition individually at their own pace without disturbing other visitors. The AR experience then also depends on the visitor's device, its computing power and its display resolution. Very small devices have other requirements that differ from tablets with relatively big display screens. In addition, the museum could provide some devices for the visitors but one has to foresee that this creates additional responsibilities for the staff, such as having to deal with deposits and ensuring proper returns. New technological developments in the area of smart glasses and wearables will also add a whole new dimension to this topic.

In summary, it can be said that it is relatively easy to implement AR in a museum and one of the undeniable advantages have to do with the fact that AR is a budget-friendly technology. The effect of AR on the experience of the visitors and its yet unforeseen consequences, can be seen as much bigger and priceless for the image of the museum, boosting its attractiveness of the museum and possibly cultivating a deeper sense of the loyalty the visitors, when used in an optimal way.

References

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

Barricelli, M., & Golgath, T. (2014). *Historische Museen heute*. Wochenschau Verlag, Germany.

Brunner-Sperdin, A. (2008). *Erlebnisprodukte in Hotellerie und Tourismus. Erfolgreiche Inszenierung und Qualitätsmessung*. Berlin: Schmidt.

Falk, J., & Dierking, L. (2002). *The museum experience*. Washington: Howells House.

Falk, J., & Dierking, L. (2013). *Museum experience revisited.* Walnut Creek: Left Coast Press.

Field, A., & Hole G. (2003). *How to design and report experiments.* London: Sage.

Han, D., 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.

John, H. (2008a). Hülle mit Fülle. Museumskultur für alle—2.0. In H. John & A. Dauschek (Eds.), *Museen neu denken. Perspektiven der Kulturvermittlung und Zielgruppenarbei* (pp. 15–66). Bielefeld: Transcript.

Lila Wallace-Reader's Digest Fund. (2000). *Service to people: challenges and rewards. how museums can become more visitor-centered.* Retrieved July, 2015, from http://www.wallacefunds.org/publications/pdf/ACF384E.pdf.

Mehler-Bicher, A., Reiss, M., & Steiger, L. (2011). *Augmented Reality: Theorie und Praxis*. Munich: Oldenbourg.

Mücke, S. (2010). *Skalenbildung—Arbeitsschritte der Testanalyse*. Potsdam: University Potsdam.

Noh, Z., Sunar, M., & Pan, Z. (2009). A review on augmented reality for virtual heritage system. In M. Chang et al. In *Proceedings of the 4th International Conference on E-Learning and Games: Learning by Playing. Gamebased Education System Design and Development.* (5670) Banff, 50–61.

Othman, M. K., Petrie, H., & Power, C. (2013). Measuring the usability of a smartphone delivered museum guide. *Procedia—Social and Behavioral Sciences, 97,* 629–637.

Pine, B. J., II, & Gilmore, J. H. (1999). *The experience economy*. Boston: Harvard Business Press.

Pine, B. J., II, & Gilmore, J. H. (2011). *The experience economy*. Boston: Harvard Business Press.

Priddat, B. & Van den Berg, K. (2008). Branding Museums. Marketing als Kulturproduktion—Kulturproduktion als Marketing. In H. John & B. Günter (Eds.), *Das Museum als Marke. Branding als strategisches Managementinstrument für Museen,* (pp. 29–48). Bielefeld: Transcript.

Sherman, A. (2011). *How tech is changing the museum experience. Mashable.* Retrieved July, 2015, from http://mashable.com/2011/09/14/high-tech-museums/.

Standard, (2012). Bundesmuseen verzeichneten 2011 einen Rückgang. Retrieved November, 2015, from http://derstandard.at/1326502878492/Zwei-Prozent-Minus-Bundesmuseen-verzeichneten-2011-einen-Rueckgang.

Weiermair, K. (2001). Von der Dienstleistungsökonomie zur Erlebnisökonomie. In H. H. Hinterhuber, H. Pechlaner, & K. Matzler (Eds.), *IndustrieErlebnisWelten. Vom Standort zur Destination*, (pp. 35–48). Berlin: Schmidt.

Wojciechowski R., White M., and Cellary W. (2004). Building virtual and augmented reality museum exhibitions. In *Proceedings of the Ninth International Conference on 3D Web Technology* (pp. 135–187).

Woods E., Billinghurst M., Looser J., Aldride G., Brown D., Garrie B., & Nelles C. (2004). Augmenting the science centre and museum experience. In *Proceedings of the 2nd international conference on Computer graphics and interactive techniques in Australasia and South East Asia* (pp. 230–236).

Eye of the Veholder: AR Extending and Blending of Museum Objects and Virtual Collections

Ronald Haynes

Abstract Enhanced and innovative museum exhibitions are enabled by collaborative use of Augmented Reality, interconnecting collections and complementing physical with relevant virtual objects for all participants. Carefully assembling related objects from multiple collections benefits museum visitors and researchers, cohering experiences in a blended collection environment. We propose collaboration between suitable institutions to develop a Veholder (Virtual Environment for Holdings and Online Digital Educational Repositories) community project. This should help share key museum holdings, rich sources of material for general learning and focussed research, which otherwise remain hidden in storage or in distant repositories. While preserving natural and cultural heritage, this collaborative AR approach can extend the wider impact of collections, aiding our overall understanding, deeper appreciation, and shared knowledge. Discussions about research-based specialist collections held at the Universities of Cambridge and Copenhagen have indicated keen interest in further development, with additional partnering institutions and funding options being actively sought.

Keywords Augmented reality · Museums · Virtual collections · Blended collections · 360 viewing · 3D scanning · Calibration and real-world scaling

1 Introduction

We visit and engage with a museum for what is found there, but we also learn by discovering what is not there. A museum can be both exhilarating and challenging, at times overwhelming with wonder, stirring the imagination and prompting a desire to share knowledge and experiences. There are times which may also spark our curiosity about what is not available—because of insufficient space, external exhibition loans, or perhaps the lure of what similar materials might be found

R. Haynes (✉)
Information Services, University of Cambridge, Cambridge, UK
e-mail: rsh27@cam.ac.uk

T. Jung and M.C. tom Dieck (eds.), *Augmented Reality and Virtual Reality*,
Progress in IS, DOI 10.1007/978-3-319-64027-3_6

elsewhere. Every dinosaur must have cousins in other museums, but is every specimen (e.g. T. Rex) the same size and the same shape, or are there variations readily found if you could get more of them together in one space?

Every Egyptian mummy in one collection will have curated contemporaries or related cultural artefacts awaiting our discovery elsewhere, in someone else's collections—yet if placed together would they not tell us much more about all these representatives of the same period? So it is for many such collections, from Art History to Zoology, which despite having well-established and shared classification systems will not always have sufficient extent or context in a single collection to satisfy those with a keener interest, or to answer the continuing quest for greater knowledge. Neither is it possible for local museum visitors to always travel to see distant collections, nor can local museums always create the perfect special exhibition bringing together all suitable representative objects.

Awareness of Augmented Reality (AR) is now well-established, at least through particular types of mobile apps such as Pokémon GO and the Ikea Catalogue, however it is still relatively new in the museum. Partly due to the popular enthusiasm with the other mobile apps, AR is a growing area for museums planning to provide additional behind-the-scenes information, alternative image views, and potentially interactive capabilities with existing collections in an institution. However, if used in carefully coordinated ways, AR can also be extremely useful in providing the means for two or more suitable collection-holders to extend their individual collections, providing each with a greater context for the better understanding of the connections between the objects in each, while supporting conservation requirements and overcoming many practical constraints of location and cost.

Following an agreed framework for scanning each collection in a precisely reproducible manner, in order to produce an accurate virtual copy of items from each local collection, provides instant benefits by way of options for the enhanced display of the local items. It also enables the blending of local physical objects with remote virtual items, into an extended collection or special exhibition. This combination of physical and virtual objects, which can be curated as a combined collection, can be developed either for engagement with the general public, or enhanced to enable additional sharing with fellow researchers (e.g. via higher resolution or multiple types of scans for greater object detail). Such connected collections may together contain items representing the same period of time (e.g. Bronze Age), or originating in the same place (e.g. Equatorial Africa), or perhaps arising from connected cultures (e.g. parts of the Persian Empire), or perhaps those created of similar form or material (e.g. onyx items, or bone remains or artefacts—whether tools, artwork, or religious items), or any other shared characteristics.

We wish to propose a collaboration between suitably matched museums and collections, to develop what might be called a 'Virtual Beholder' or VEHOLDER, a Virtual Environment for Holdings and Online Digital Educational Repositories. This Veholder project addresses anyone seeking generalist or specialist knowledge in museums, archives, special collections, etc., enabling them to visit and experience correlated specimens and knowledge, not all of which are physically available in one location. It is conceived as providing ‘Augmented Knowledge’ (AK), by the combination of physical, tangible objects and suitably-matched virtual, high-quality 3D-scanned items, thus expanding the physical limits of knowledge and opening new avenues for both researchers and the public.

Given the potential for virtual visits to other collections, and the ability for high-quality images and 3D scans to be visualised on their own, or preferably to be visualised alongside related collection specimens, this mixing of physical and virtual collections is helpful in conserving, researching, communicating and ideally exhibiting human heritage in a blended manner—tangible and intangible together—and so this combination fits well within the wider mission of the museum. This is absolutely well-suited for a museum’s mission, in line with the definition given by the International Council of Museums (ICOM): “A museum is a non-profit, permanent institution in the service of society and its development, open to the public, which acquires, conserves, researches, communicates and exhibits the tangible and intangible heritage of humanity and its environment for the purposes of education, study and enjoyment” (http://icom.museum/the-vision/museum-definition [November 28, 2016]).

With the advances and emerging possibilities found with AR, we are enabled with the possibility of such a combination of collections. By mixing physical objects in one locale with complementary virtual objects in a collaborating remote collection—or optionally providing the combination of two or more virtual object collections, making them available to those museums remote from any of the collaborative collections—we create the means of expanding the content, context and mission of each participating museum. High resolution 3D scanning, reliably and reproducibly scaled, coupled with suitable Augmented Reality displays and systems, enable both the specialist researcher, the enquiring student, and the interested general public to get the most out of otherwise hidden and (understandably) carefully-shielded collections.

As one example, the specialist Duckworth Collections (www.human-evol.cam.ac.uk/duckworth.html [November 28, 2016]), which is part of the Leverhulme Centre for Human Evolutionary Studies at the University of Cambridge, has specimens which are regularly used for comparative studies, to consider structural changes (morphology) and functional developments over time and species, and this study would be mutually enhanced both by offering high resolution scans of its specimens to other such collections as well as having access to high resolution scans of their collection. This has been part of the promising discussion and ongoing planning with specialists at the Natural History Museum of Denmark (http://snm.ku.dk/english [November 28, 2016]), part of the University of Copenhagen, and working together with the Universities’ museums and collections, along with other partnering institutions, we hope to improve the Veholder project more generally.

2 Literature Review

While AR use in museums is still relatively new, current planning seems largely aimed toward the use of smartphones and tablets, as evidenced by recent searches of the literature, websites, and the main app stores, particularly for available museum-related downloads in the latter. Thus far, no mention has been found of a coordinated and collaborative project to blend physical and virtual catalogues, nor to make use of museum-ready smart glasses to provide a combined and coherent view of an extended and themed exhibition. Wojciechowski et al. (2003) in "Augmented Reality Interface for Museum Artefact Visualization" helpfully summarised and presented projects which piloted many key AR aspects, including the use of portable computing and head-mounted displays (HMD) to mix AR historical reconstructions within cultural settings. These projects now seem dormant, having completed their studies (and websites unavailable).

With significant updates to available hardware and possibilities, only one pair of smart glasses has been found to be museum-ready, the Epson Moverio BT-350, due to be available by April of 2017 and engineered for multiple public users as a more durable version of the third-generation BT-300 already in use. Along with reduced size, cost, and use of the well-supported Android platform, these smart glasses are better suited than earlier HMD, including in museum settings similar to pilot projects noted above—see Epson case studies, such as: Brescia Museums—A Walk in the past with Moverio smart glasses (Epson 2016).

The option for live (as well as pre-recorded) virtual guided tours using 360 and 3D cameras and smart glasses has also not been found in searches, however it is a natural prequel to the plan to develop blended 3D-scanned and combined collections and exhibitions. It is also a natural complement to the very successful great performances which are now in many cinemas, with live theatre, opera, music and dance regularly available streamed live, along with pre-recorded art gallery visits and exhibitions (BBC 2017). Additionally, 360 3D tours would also be a live complement to the Street View approach which Google is providing in association with a number of museums (e.g. British Museum—With Google) (British Museum 2016).

There are a number of specific technologies and techniques for high-quality 3D scanning, for instance Niven et al. (2009) present in their "Virtual skeletons: using a structured light scanner to create a 3D faunal comparative collection". This approach is generally used by those involved with the Veholder project, but of course only one of many types available. African Fossils (2016) is a good example of current online curation of 3D image collections, while Ynnerman et al (2016) in "Interactive Visualization of 3D Scanned Mummies at Public Venues" show advanced possibilities with multiple combined scanning and visualisations techniques.

For future consideration, Kiourt et al. (2016) in "DynaMus: A fully dynamic 3D virtual museum framework" present interesting options and possibilities for a virtual museum, including interactive input as part of the selection of content, which could be provided by multiple online resources, using advanced web and game technologies. Additionally, Carrozzino et al. (2010) in their "Beyond virtual museums: Experiencing immersive virtual reality in real museums" convey their rich case studies, results, and issues from their focus on VR (virtual reality) in immersive installations in museums. The experience with VR will help refine the use of AR in museums, while somewhat serving as a contrast in terms of the issues which are either more attached to the use of VR (e.g. some experiences of isolation) or not identical in AR (e.g. improving virtual cultural representation).

3 Findings

As a work-in-progress, ongoing discussions with subject, museum, and 3D technology specialists in several institutions have included a comparison of experiences of 3D digitisation of objects from museum collections. In particular, we have initially explored opportunities for collection collaboration between Cambridge and Copenhagen. The identified opportunities include work in progress with the staff of the Leverhulme Centre for Human Evolutionary Studies (LCHES) on a proposal for a coordinated 3D scanning of selected samples from the Duckworth Collections (www.human-evol.cam.ac.uk/duckworth.html), including an option to make use of existing CT (high-resolution, X-ray-based 3D computer tomography) scans of 50 ancient human skeletons, potentially to be paired with selected scans in a complementary collection. These have been part of the discussions with the Director and collection specialists in the Natural History Museum of Denmark (http://snm.ku.dk/english), at the University of Copenhagen. Although both institutions have been building up their 3D scanned collections for some time, it was acknowledged that generally each 3D scan has often been a 'stand-alone' operation—consistent and useful on its own, and likely to be useful alongside other 3D scanned objects, but not necessarily able to guarantee precision in all aspects when being captured in the scanning process, nor when being displayed subsequently and in the context of other collection objects.

Given the variations which can come with different 3D scans, the key areas of establishing a common framework for calibration and accurate scale representation were identified, especially for research purposes, but also for general comparative and realistic display of objects. The differences between 3D scanning technologies and outcomes have been part of the considerations, and while CT scans provide high-quality detail—including of the internal structure of objects—they are not ideal for scanning all objects, and are not the best option when wanting to scan and carefully represent the colour and perhaps textures of an object. Given general experience and the state of the art, there has been an inclination to making use of structured light 3D scanners, in common with the experience of Niven et al. in their work on "Virtual skeletons: using a structured light scanner to create a 3D faunal comparative collection". Such scanners, which have become well-known in research collections, can provide reasonable speed, detail, and high-quality images.

Given a set of 3D images, in order to be able to see any virtual objects displayed next to a physical object, to be able to achieve AR (or MR–Mixed Reality), some kind of displaying device is required. While it is possible to use a laptop or smart phone or tablet, for use with a blended museum collection the best devices currently available are smart glasses. These leave your hands free to work with any display interfaces provided, and the better ones provide a clear image in front of you, while enabling you to see the physical objects in front of and around you—so perfect for the blending of collections. While many were introduced to smart glasses by the publicity surrounding Google Glass, the withdrawal of that early technology was soon followed by the announcement of Microsoft Hololens, which uses two display areas—one for each eye—so providing for the option of stereoscopic display of 3D images, which can either float in the air (e.g. a small weather report window) or be associated and anchored to a physical object (e.g. a 3D model appearing to sit in a fixed position on top of a table). While these products receive great publicity, there are other developments in the smart glasses area which seem be more suitable for museum purposes. On the high end there is the Meta 2, while there are very capable and well-priced options available with Epson Moverio smart glasses and headsets (Epson Moverio 2016). The apps and development options for Moverio seem very promising, and the Android-based devices provide the promise of a large and well-known platform base for rapid testing. As noted above Epson have a useful case study, about their smart glasses used to augment with original structures the viewing of the ruins in an outdoor museum—"Brescia Museums—A Walk in the past with Moverio smart glasses" (Epson 2016).

To return to the concern about scale, we need to be able to ensure that the calibration of all the equipment and data involved (e.g. scanning equipment, smart glasses, file format for storage of the 3D scans) will provide real-world scaling when it comes to final display and related operations. We should be able to verify that 3D models are precisely taller, shorter, stouter, the same, etc. when compared to physical specimens. The London Charter for the Computer-Based Visualisation of Cultural Heritage (www.londoncharter.org) might be a helpful guide, for instance with its call for intellectual and technical rigour in digital heritage visualisation, along with access and sustainability strategies in the research, management and communication of cultural heritage. We need to be able to provide an AR environment where, if we placed an original physical item (e.g. a skull) next to a 3D image of the same skull (e.g. using smart glasses), then they would be the exact same dimensions—you could superimpose the 3D image on top of the original and they would exactly line up. This is especially important for researchers, but also important for non-specialist viewers of any of the collection, so that they can know the comparative size and shape of a 3D image when displayed next to the complementary physical object in the collection they are viewing. It appears that the application developed using Epson Moverio smart glasses for Brescia Museums have had to solve this.

Given the many pieces of equipment and techniques, both for 3D scanning and image storage and display (not to mention for printing), it is clear that the assurance of accurate calibration and scale indicated above will need to be part of establishing a reproducible regime for the full 3D collection processing workflow. This will provide the promise of working with virtual objects alone or in a blended mode alongside physical objects, and be sure that the scan of say an ancient skull would be able to be measured or placed next to the original and show no distortion or anything but the true original size and shape. So far, we have not been able to discover an established scale or set of operations which could provide such assurance. If we should find such a workable solution, we would be glad to adopt it or collaborate to further develop it, if helpful, as part of a much-needed community effort for standardisation, which will ensure wider assurance and adoption.

If not ready or available, and therefore still needed as it seems however, we believe that establishing such a scalable solution is possible, but that it can only be accomplished in a community context. It thereafter should be included as a necessary part of any further project and funding planning, to ensure a more authoritative and sharable set of scanned collection objects for the future. While common scaling is crucial for research purposes, we believe it would be generally helpful for any such virtual collections to be shared with the general public, as well. When blending physical objects with related virtual objects, it aids general understanding to ensure the context of dimension makes for reliable comparisons (e.g. do we expect all T. Rex skeletons to look and be sized alike). One of the differences which may be worth considering when blending collections is that of image resolution, with research-grade collection items presented at the highest resolution, while public-grade collections might be presented at a lower grade—including for improved speed and lower costs, when compared with those associated with displaying the larger files involved with research-related items.

4 Discussion

At the Augmented Reality conference IFITTtalk@Manchester, held 25th November 2015 in Manchester, there was some discussion about standards for content from different projects to be reusable or able to be combined with other projects. While this was mainly about Virtual Reality (VR) material, it seems similarly true for AR (and MR), at least in the sense of ensuring that calibration and scale and reproducibility can be assured when scanning takes place at different times and locations, using different equipment, file storage options, and display technologies.

Given the time and collaboration required to establish any such standard (http://digitalsenses.ieee.org/standards) with a coalition of the willing, it may be prudent to consider experimenting with a simpler collaboration, perhaps also on a smaller scale, including by testing the sharing of partial collections between two museums, using smart glasses. This could even be via initial pilots, by virtually joining a regularly-scheduled guided tour in another museum, perhaps adding the option of a separately-scheduled and customisable tour (e.g. exploring combined Celtic collections), considering the overall experience and the question of suitable tour fees, as and where appropriate. This would give valuable experience with the use of smart glasses within and between museums, and ideally by the general public, and help enhance the working partnerships required as well as prepare the way for when the blended 3D collections are available.

One of the best-established ways in which 3D visits to museums has been handled for over a 150 years is via the stereograph (see Fig. 1). With stereo-viewing smart glasses we have the option to incorporate these older images into existing collections—either as a kind of time-travel reference or as an extension of existing displays.

The image (Fig. 1) shows a mid-1800s stereograph of The Megatherium, British Museum, scanned from an Albumen silver print taken from a glass negative. (www.metmuseum.org/art/collection/search/271658).

Furthering this old idea of a 3D museum tour, from still stereographs to a live streaming video feed, we now have the ability to link museums via high-quality 3D and 360-degree cameras broadcasting directly to stereo-viewing smart glasses (see Fig. 2). This would enable guides in two (or more) museums to show and explain items and displays at each site, perhaps using a hat-mounted camera, or alternatively a moving camera platform (e.g. possibly even a guided robotic platform). Visitors wearing smart glasses would be able to follow the view and focus of the

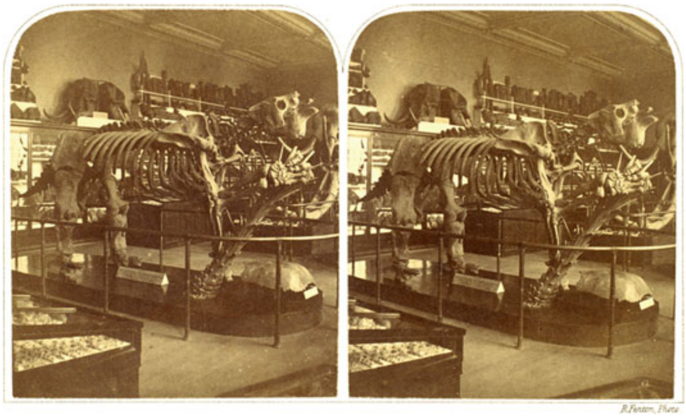


Fig. 1 Image courtesy of The Metropolitan Museum of Art/Roger Fenton (1850s)

Fig. 2 Images courtesy of Live Planet, Inc./Seiko Epson Corporation

guide, whether local or remote, but also look around and get a better idea of surroundings and display context, much as is the case with those in the same physical gallery.

The possibility for pairing (Fig. 2), for example, a Live Planet 360º 4K Stereoscopic (3D) live-streaming camera with an Epson Moverio BT-350 smart glasses, could provide coordinated and blended inter-museum tours and visits. Other currently-available 360 cameras which may be useful include Orah 4i, ALLie 360 VR, Giroptic HD 360 and Ricoh Theta S 360 cameras. (Currently, no other public museum-ready smart glasses are known to be readily available.)

This model, of linking from one museum to guides in another museum, was an earlier stage of what has developed into the plan for 3D blended collections, and should prove to have merit on its own. As a hint of how smart glasses are being used in some guided, practical applications, it is worth considering Hewlett-Packard Enterprise's Visual Remote Guidance (2016). While such 2D live interactions may be a simpler form of AR, they should also help establish what seems another key element to future blended models, which is the linking of museums and the ability to assist and support public (or researcher) participation from one museum collection to another. Given the levels of combined expertise, and the unique ability of museum professionals and volunteers to provide the content, context and support for the cultural material to be shared, the museum-to-museum model is worth testing and, ultimately, worth maintaining to ensure success. It also helps ensure that museums can continue to fulfill their mission, which provides something of benefit for everyone.

In "Why a Virtual Museum?" (2016) Georges Ricard, Curator of The Virtual Egyptian Museum, maintains that "there is a definite benefit to the virtual experience that cannot be duplicated in a real museum. Some of the notable virtual advantages we can envision include: Lighting … Scale … Peripheral Vision … Non-Linear Visit … Presentation of Historical Context … Access and Conservation". These advantages are evident in this and other members of the Virtual Museum Transnational Network (2016). By contrast, in *The Museum and the Web: Three Case Studies—Comparing the Virtual and the Physical Visits* (2017) Marcy McDonald provides supporting citations suggesting that "Three-dimensionality and scale are unarguably two of the most distinguishing, and irreproducible, elements of the physical exhibit." While there is much to commend in a purely physical (traditional) museum, and much to appreciate in a purely virtual museum, as will be clear from above the virtual museum experience we propose is intended as a blended one and as such is intended to connect one museum to another museum, combining the best of physical and virtual collections, for mutual and general benefits (see Fig. 3).

The use of smart glasses with a museum display (Fig. 3), is indicated here with a physical dinosaur skeleton which has a computer visualised overlay of muscle and skin, along with extra text and visual detail about the display. The images are from an Epson concept video (https://youtu.be/hhYPqF3aHUs), which illustrates existing or technically possible scenarios (dependent on software use or development), and also shows the smart glasses wearer interacting with the augmented display using

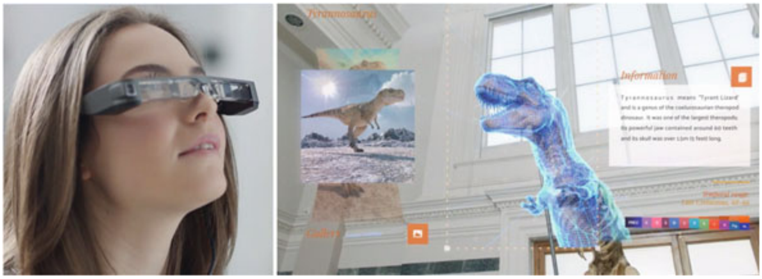


Fig. 3 Images courtesy of Seiko Epson Corporation

hand gestures to frame and capture a photograph of a self-selected scene of the enhanced visual information.

While the example in Fig. 3 shows an AR-enhanced display (e.g. of a single dinosaur specimen with additional virtual details), the AR enhancements could as easily include high-resolution 3D images (e.g. one or more additional dinosaur specimens), with remote collection images shown as well, using the smart glasses to enable viewing of both local physical object and remote or scanned images, for blended inter-museum experiences. As indicated, precise 3D scanning is intended as a major growth area for the development of collections, enabling enhanced options for the display of local collections, as well as the sharing of the virtual and physical. Also noted was the need to establish and adhere to a framework, to ensure scale and details needed to provide the means for reliable comparisons amongst specimens in blended collections.

Given the timing and testing required for the various options indicated, these can be treated as either separate (but closely related) projects, or ideally as phases for the larger overall Veholder project. For instance, Phase I could be the live-streaming guided option, using smart glasses and live guides to introduce the new technology and to help blend collection images and concepts. Phase II could be the introduction of 3D scanned images, potentially using existing material (whatever the scanning techniques, scaling and image detail available), and involving live guides to introduce the technologies and collections, as well as help explain and clarify any oddities in the blending of the particular virtual and physical combinations. Phase III could be the introduction of a specifically curated and blended special exhibition, with 3D images suitably scanned and precisely scaled for compatibility across the collections, and which would ideally be live-guided (but which could be prepared for self-paced interaction, as well). Phase IV could be the development of a much larger catalogue, perhaps after several special exhibitions (e.g. Phase III), presenting an expanding volume of suitably matched 3D images, available for more extensive self-paced interaction or guided presentations, across more of the participating museums' collections.

For the future, an additional phase may be to consider making selected image collections available to a wider community outside of the museum, including those without any museum nearby (and potentially to the virtual visitor at home with the potential to test suitability of use in a sedentary mode with low-cost VR goggles). Given the various technologies and cultural communication issues involved, most likely the live-guided phases would be best-suited to consider initially in all phases, given successful trials, with the curated phases (III, IV) being possible candidates to test self-paced interaction from a distance. Any extra costs, incurred by the additional demands of a potentially global extra-museum group of virtual visitors, might be shared with partnering institutions who might be able to provide a more localised support, for example smaller museums not otherwise participating in the blended collection efforts, or perhaps local libraries, or educational facilities, or possibly other local spaces made possible perhaps by sympathetic corporate sponsorship.

For reference, the Natural History Museum of Denmark (SNM), as with similar European museums, is a member of CETAF (Consortium of European Taxonomic Facilities: consolidating 59 European institutions' taxonomic research capability) and SYNTHESYS (an EC-funded project to create an integrated infrastructure for natural history collections). Increasingly, the emphasis is on high resolution scanning projects to facilitate research, in addition to the existing access, education, and outreach efforts. Large scale digitisation programmes enabling 'big data' approaches to for instance biodiversity are underway in a number of European natural history museums, including notably Leiden and London. We plan to liaise further with Copenhagen and the museum networks to help establish the common framework described, to further aid open access to data, in keeping with the museums' mission.

5 Conclusion

Discussions with specialists from research-based collections held at the Universities of Cambridge and Copenhagen and elsewhere have indicated keen interest and commitment for further development of the shared, blended 3D collections project, with additional partners and funding options being actively sought.

It was noted that institutions understandably tend to be more protective of their collections of rare skeletal and fossil remains, when for instance compared to other specimens, however the aim is to continue to provide open access in all digitisation projects. The model would be one of mutual sharing for general benefit.

Blending physical and virtual collections can be achieved in phases, with more immediate options helping to build up the necessary partnerships and providing key shared experiences in the collaborative efforts involved. These phases could include:

- Phase I—live-streaming guided option, using smart glasses and live guides to introduce the new technology and help blend collection images and concepts
- Phase II—introduction of 3D scanned images, potentially using existing material and involving live guides to introduce the technologies and collections, and clarifying any oddities in the blending of the particular virtual and physical combinations

- Phase III— introduction of a curated, blended special exhibition, with 3D images suitably scanned and precisely scaled for compatibility across collections, ideally live-guided (but could be prepared for self-paced interaction)
- Phase IV—development of larger catalogue, presenting an expanding volume of suitably matched 3D images, available for more extensive self-paced interaction or guided presentations, across more of the participating museums' collections
- An additional phase may be to consider making selected collections available to a wider community outside of the museum (with the potential to test suitability of use in a sedentary mode with low-cost VR goggles). Most likely the live-guided phases would be best-suited initially in all phases, given successful trials, with the curated phases (III, IV) being possible candidates to test self-paced interaction from a distance.
- Any extra costs, incurred by additional demands of a global group of virtual visitors, might be shared with partnering institutions able to provide more localised support, for example smaller museums, local libraries, educational facilities, or possibly other spaces made possible perhaps by supportive sponsorship.

It is promising that there is agreement for cooperation on initial collaborative projects, which for Cambridge and Copenhagen at least may be related to primates and human evolution, and that sharing of experience in these areas should continue. There was also interest in benchmarking progress and proposals against other leading institutions in the sector. This was part of making initial contact with other institutions, and the follow up with them will include an attempt at a wider community of sharing, and of resolution of the calibration, scale, and related file format challenges. More details of the Veholder project will be found on its website (veholder.org).

Acknowledgements This exploration grew in part from the presentations and discussions at the Augmented Reality conference IFITTtalk@Manchester, in November 2016, and the author wishes to thank Timothy Jung and all the Creative AR and VR Hub group. Special thanks for the ongoing support and collaboration go to the Leverhulme Centre for Human Evolutionary Studies at the University of Cambridge, in particular Robert Foley, Marta Mirazon Lahr, Fabio Lahr, Federica Crivellaro, Frances Rivera, and Alex Wilshaw. Special mention goes to Emily Fricke, visiting Summer Intern from Bucknell University. Additional thanks go to the collaborating partners from Statens Naturhistoriske Museum (SNM), University of Copenhagen, in particular Peter Kjærgaard, Anders Drud Jordan, and Nikolaj Scharff. Special mention goes to project collaborator Richard Mee.

References

African Fossils. (2016, November 28). (africanfossils.org).

Augmented Reality conference IFITTtalk@Manchester. (2017, July 22). www.mmu.ac.uk/creativear/conferences/2015-augmented-realityifitttalkmanchester.

BBC. (2017) *Is watching opera in the cinema just as good?* Retrieved March, 2017, from http://www.bbc.com/culture/story/20150114-opera-in-the-cinema-blasphemy.

British Museum. (2016). *British museum—with google*. Retrieved November 2016, from www.britishmuseum.org/with_google.aspx.

Carrozzino, M., & Bergamasco, M. (2010). Beyond virtual museums: Experiencing immersive virtual reality in real museums. *Journal of Cultural Heritage., 11,* 452–458.

Duckworth Collections. (2016). *Duckworth collections*. Retrieved November, 2016, from www.human-evol.cam.ac.uk/duckworth.html.

Epson. (2016). *Epson case study: Brescia museums—A walk in the past with Moverio smart glasses*. Retrieved November, 2016, from www.epson.co.uk/insights/casestudy/6217.

Epson Moverio. (2016). *Epson Moverio BT-300: A new way of seeing the world*. Retrieved November, 2016, from https://youtu.be/hhYPqF3aHUs.

HPE. (2016). *HPE Visual Remote Guidance for the Enterprise*. Retrieved November, 2016, from https://www.hpe.com/h20195/v2/GetPDF.aspx/4AA5–8053ENW.pdf.

ICOM. (2016). Museum Definition- ICOM. Retrieved November, 2016, from http://icom.museum/the-vision/museum-definition.

Kiourt, C., Koutsoudis, A., & Pavlidis, G. (2016). DynaMus: A fully dynamic 3D virtual museum framework. *Journal of Cultural Heritage, 22,* 984–991.

London Charter. (2016). *London charter for the computer-based visualisation of cultural heritage*. Retrieved January, 2016, from www.londoncharter.org.

Natural History Museum of Denmark. (2016). *Natural history museum of Denmark*. Retrieved November, 2016, from http://snm.ku.dk/english.

Niven, L., Steele, T. E., Finke, H., Gernat, T., & Hublin, J.-J. (2009). Virtual skeletons: Using a structured light scanner to create a 3D faunal comparative collection. *Journal of Archaeological Science, 36,* 2018–2023.

Standards Activities—IEEE Digital Senses. (2017, March 4). (http://digitalsenses.ieee.org/standards).

The Megatherium, British Museum, Roger Fenton (1850s) (2017, February 11). (http://www.metmuseum.org/art/collection/search/271658).

The museum and the web: Three case studies—Comparing the virtual and the physical visits. (2017, March 4). (http://xroads.virginia.edu/~MA05/macdonald/museums/virtual.html).

Virtual Museum Transnational Network. (2016, November 28). (www.v-must.net/virtual-museums).

Why a Virtual Museum? (2016, November 28). (www.virtual-egyptian-museum.org/About/Story/About.WhyVirtual-FR.html).

Wojciechowski, R., Walczak, K., & White, M. (2003). Augmented reality interface for museum artefact visualization. In *Proceedings of the 3rd IASTED International Conference on Visualization, Imaging and Image Processing*.

Ynnerman, A., Rydell, T., Antoine, D., Hughes, D., Persson, A., & Ljung, P. (2016, December 12). Interactive Visualization of 3D Scanned Mummies at Public Venues. *Communications of the ACM, 5*, 72–81 (http://cacm.acm.org/magazines/2016/12/210363).

Virtual Reality as a Travel Promotional Tool: Insights from a Consumer Travel Fair

Alex Gibson and Mary O'Rawe

Abstract Although the potential of virtual reality (VR) as a technology in tourism has been recognised for more than twenty years, (Horan, Hosp Inf Technol Assoc—Electron J 1:1–7, 1996; Williams and Hobson, Tourism Manage 16:423–427, 1995), we have witnessed a renewed interest in both academic and business circles recently (Jung et al., Information and communication technologies in tourism 621–635, 2016). From a marketing perspective, VR offers the potential to build a sensory experience of a tourism destination or attraction, and can be used in sales contexts to complement, or indeed, supplant traditional promotional tools such as brochures. The immersive nature of the experience offers a deeper and more emotional assessment of the tourist offering from the consumer's perspective, and an opportunity to build imagery and influence the consumer decision-making process from the marketing communicator's viewpoint. Research was conducted into consumers' attitudes and experiences of 360-degree VR videos, which have been developed by Fáilte Ireland (Ireland's domestic marketing and product development agency) to showcase a number of activities along the *Wild Atlantic Way*. Using a quantitative research approach constructed along the dimensions of the Technology Acceptance Model (TAM) (Davis, MIS quarterly 319–335, 1989), 129 surveys were carried out at two consumer travel shows. Respondents' VR experience was rated positively across all demographic cohorts and against the selected dimensions of the TAM model. Using VR to promote the *Wild Atlantic Way* was found to greatly increase the likelihood of visiting the destination itself in the future. This offers very encouraging prospects for destination marketers. This research contributes to a deeper understanding of how VR can aid in destination marketing and promotion, and potential limitations to its wider deployment.

A. Gibson (✉) · M. O'Rawe
School of Hospitality Management and Tourism,
Dublin Institute of Technology, Dublin, Ireland
e-mail: alex.gibson@dit.ie

M. O'Rawe
e-mail: mary.orawe@dit.ie

T. Jung and M.C. tom Dieck (eds.), *Augmented Reality and Virtual Reality*,
Progress in IS, DOI 10.1007/978-3-319-64027-3_7

Keywords Virtual reality · Travel and tourism promotion · Destination marketing · *Wild Atlantic Way*

1 Introduction

Information and communication technology (ICT) has been the subject of significant academic research in tourism, as the impacts of the shift to eTourism (Buhalis and Law 2008) have been felt since the Millennium (Kim et al. 2008; Liang et al. 2016). Coupled with the mobile internet influence, it is clear that much has changed in industry and user technology in the international tourism landscape, and that the ways tourism services are consumed and accessed have altered (Ukpabi and Karjaluoto 2016).

One emerging field of considerable interest is virtual reality (VR). In the general commercial arena, recent intense activity by major IT companies has seen massive investments in both hardware and software development, and acquisitions in the augmented reality (AR) and virtual reality (VR) space, with a projected market value of some €80bn. by 2025 (Goldman Sachs 2016).

Specific to tourism, a number of opportunities for virtual reality are now evident (Guttentag 2010), among which is the area of marketing and promotion. This is the primary lens through which the authors explored the use of VR in a tourism context. A structured self-completion survey, using convenience sampling, was administered to 129 respondents (attendees at Ireland's largest consumer travel show, Holiday World) subsequent to their trial of a VR experience. The VR experience showcased a range of 360-degree videos of Ireland's *Wild Atlantic Way*, developed by the agency charged with domestic marketing and product development, Fáilte Ireland.

Further, this study uses a conceptual framework developed by Davis (1989) known as the Technology Acceptance Model whereby determinants of user acceptance of technology were examined. Having previously been extensively validated in travel and tourism, TAM was deemed to offer suitable influential constructs. In particular, the dimensions of perceived usefulness and perceived ease of use, as well as behavioural intention were adopted by the authors to inform the study of the efficacy of VR in the context of the marketing and promotion of Ireland's *Wild Atlantic Way*. The behavioural intention dimension examined respondents' willingness to use VR again, and to recommend it to others. A key dimension of the research was to investigate the extent to which the VR experience enhanced likelihood to visit the featured region. Selected external variables were also examined, including demographics.

2 Overview of the Concept of Virtual Reality

Virtual reality is not a new phenomenon. Williams and Hobson (1995, p. 423) attribute the coining of the phrase to Myron Kruger in the mid-1970s. Its potential throughout many strands of society has been debated since, and particularly over the last 25 years, with Williams and Hobson (1995, p. 425) commenting that, even then, it had “the potential to revolutionalise the promotion and selling of tourism”. But what is this technology, and how has it developed in tourism since then?

2.1 Definitions and Perspectives of VR

A myriad of definitions now exists of VR, based on a range of different technologies, concepts and theories. Guttentag (2010, p. 638) in exploring definitional challenges in his article, points to “navigation”, “immersion” and “interaction” as key features of VR which are commonly included by various authors. Williams and Hobson (1995, p. 424) draw on the typology presented by Cruz-Neira et al. (1994) of the components of a VR experience, in purporting that visualisation components, immersion and interactivity are central. Expanding the criteria of immersion, Gutiérrez et al. (2008) define VR according to its characteristics of providing both physical immersion and psychological presence. In these contexts, the user is isolated from the real world to some degree, ranging from semi-immersion to full immersion, where there is no interaction with the outside world. Sanchez-Vives and Slater (2005, p. 333) tease out that presence entails having a sense of being inside the virtual environment, rather than where the user’s body is actually physically located. To achieve this presence, various technologies are used, including head-mounted displays (HMDs) such as Samsung Gear, Oculus Rift and HTC Vive, or handheld controllers such as Oculus Touch.

Guttentag (2010, p. 638) proposes a definition of VR as “the use of a computer-generated 3D environment…that one can navigate and possibly interact with, resulting in real-time simulation of one or more of the user’s five senses”. He sees user-control as a key feature of VR. So, although definitions differ, there is a broad agreement that the ability to “navigate” and “interact with” the virtual environment is often deemed a crucial characteristic (Wiltshier and Clarke 2015, p. 5). Sherman and Craig (2003, p. 6) draw together these elements in describing the four key features that a VR experience consists of, namely, “a virtual world, immersion, sensory feedback (responding to user input), and interactivity”.

Does this exclude those technologies where the user has no control over the VR experience? This is a growing point of debate, as technologies such as 360-degree video, the featured technology in this study, emerge in the hospitality and tourism arena. Guttentag (2010) asserts that this technology does not fulfil the necessary characteristics mentioned above to be considered true VR. Thus, it offers a more passive experience to the user than the classic definitions of VR.

However, 360-degree video does blur the line between interactive and passive VR, and furthermore, is an important early stage technology in the VR family, as it offers a gateway to more fully interactive VR (Stuart 2016; Jacobious 2016). These applications are now considered VR-type applications, demonstrating that there is a widening interest in the industry to use VR-based instruments to promote products and services.

Wiltshier and Clarke (2015) propose a more flexible interpretation of VR so that a wider array of technologies could be explored in their own study. For the research undertaken here, the authors adopted the same understanding.

3 Virtual Reality in Travel and Tourism Marketing

Guttentag's (2010, p. 640) exploration of the use of VR in tourism identifies six areas as presenting valuable potential: planning and management, entertainment, education, accessibility, heritage preservation and marketing. Although all these areas present worthy opportunities for research and a growing evidence base, the latter area is the lens through which the authors chose to explore the use of VR in a tourism context.

3.1 Past and Current VR Developments in Hospitality and Tourism

It has been established that tourism researchers and tourism professionals now have a keen interest in the phenomenon of VR as applied to the tourism sector (Cheong 1995; Sussmann and Vanhegan 2000; Williams and Hobson 1995). Guttentag (2010, p. 646) sees the opportunities that VR offers the tourism sector as quite significant. But this is a renewed interest, rather than a brand new interest, as we can point to Second Life as a communication and promotional tool which has been used in travel and tourism since its launch in 2003 (Mascho and Singh 2013). Indeed, VR simulators date back to 1962 with the Sensorama Simulator, a machine that presented the user with 3D images, smells, sounds, wind and vibrations (Spence and Gallace 2011). Currently, in line with the surge in general commercial interest, VR is becoming a popular choice for hotels, restaurants, travel agents and attractions, with many adding a virtual tour as a component of their promotional mix (Guerra et al. 2015). VR has recently been successfully used by Marriott as a part of their suite of developments in this arena. Beginning their journey to redevelop their brand promise, *Travel Brilliantly*, in 2014 with their *Teleporter* programme, they 'transported' their guests to different corners of the globe via a fully immersive, 4-D sensory experience (emarketer.com 2015). This was followed by their *VR Postcards* innovation, and the *VRoom Service* programme. That VR has worked for

Marriott as smart brand-building, and a very realistic opportunity to play and win, is evident in coverage by brand analysts (Adamson 2015).

The focus of this research was on a series of 360-degree videos, a format growing rapidly in popularity in tourism promotion. Similarly to Fáilte Ireland, Visit Scotland has embraced VR through an app that allows prospective tourists to 'visit' 26 attractions without leaving home. ScotlandVR recreates the country using a mix of 360-degree video, and animated maps, menus and photos. The Chief Executive of Visit Scotland comments that "far from being a fad or gimmick, VR is revolutionising the way people choose the destinations they might visit, by allowing them to 'try before they buy' and learn more about the country in a unique and interactive way" (Roughhead 2017).

The Tourism Authority of Thailand, has also released four 360-degree videos, including imagery of an elephant sanctuary, as have Tourism Australia, whose videos depict aquatic and coastal travel experiences, including snorkelling in the Great Barrier Reef (Levere 2017).

3.2 VR's Potential Role in the Consumer Decision-Making Process

A number of authors have previously examined VR's potential as a promotion and marketing aid in tourism. Cheong (1995) explored the early days of VR use in the travel industry from both the developer's planning aspect and the sceptic's angle. But it is the role of VR in the decision-making process, and specifically the activities around information-searching that have received the most attention.

Gretzel and Fesenmaier (2003) promoted the benefits of using immersive virtual reality technologies to build a sensory experience into marketing communication strategies, with a particular aim of supporting the information-searching and decision-making process for the consumer. In anticipation of their visit to a destination, tourists develop an image of a destination that is made up of previous experiences, word of mouth, press articles, different advertising measures and common beliefs (Baloglu and Brinberg 1997, as cited in Buhalis 2000). It is the "experiential" source (Kotler et al. 2017, p. 156) which offers the most scope in terms of examining and using the product (destination) in advance. For services such as a destination or holiday choice, this presents a compelling case. The long-standing acceptance of fundamental service characteristics of tourism include the understanding that production and consumption are simultaneous (Kotler et al. 2017), so that any ability to try out the product (destination) in advance is nulled. In essence, VR allows the user or tourist to experience a sample of the destination (Sussmann and Vanhegan 2000; Giordimaina 2008). Guttentag (2010) also points to the key role of information in decision-making, the positive role played by VR in the information-setting process, and its advantages in terms of creating destination imagery and information which is both realistic and experiential.

Wiltshier and Clarke (2015, p. 4) pinpoint a number of distinct stages in consuming a tourism product—pre-experience activities, engagement in the experience through value sources, and post-experience outcomes. Providing sensory information at the pre-experience stage could be deemed especially valuable in promotion activities, in contrast to the limits presented by descriptive information (Gratzer et al. 2004). This need to consider both the cognitive and affective aspects of image-building (Hyun and O'Keeffe 2012, p. 30) was deemed central to this study.

3.3 VR's Advantages in Building Image and Experience

Creating a compelling and distinctive image in the competitive tourism marketplace has always been a challenge. Berger et al. (2007) cited the benefits of using VR in terms of the realism of the experience, and the three-dimensional representations of the destination. The experience model proposed by Pine and Gilmore (1999) pinpointed the central roles of the customer (user) in experience creation, and considering their work is a reminder of the importance of the customer in experiences. Wiltshier and Clarke (2015, p. 2) also state that an experience occurs "whenever companies intentionally construct it to engage customers".

The concept of destination image is extensively examined by Hyun and O'Keeffe (2012) in their exploration of a telepresence model. A variety of aspects of image are considered, and in asserting the link between users feeling present in a virtual destination, and a positive influence on conation ("directed effort by the user to directly engage with the destination") (p. 30), they highlight the potential for VR in image-building. Further, they point to evidence that virtual conation can translate into actual purchase (p. 34) presenting clear opportunities for VR.

In the era of a growing need for information to be experiential (Stamboulis and Skayannis 2003), by implementing VR into their promotional strategies, destination management organisations (DMOs) have the possibility to influence customers immensely in their travel destination choice.

Despite this attention and activity, research around VR in tourism remains a long way from maturity. Cabello et al. (2011, p. 1) comment that "using virtual world technologies as a new means of information for potential tourists is a big challenge where the methods, goals and needs still need to be exactly identified". Some years on, this remains the case. Significant potential exists, but practices using VR are varied and many commercial forays into the area are still early-stage.

As examples of VR in tourism and hospitality grow, it becomes more important to differentiate practices between industry sectors. What works for DMOs will not necessarily be effective for hotels. Wan et al. (2007) advise that it is critical to consider the characteristics of the targets (theme parks/destinations/hotels) when using VR as an advertising or promotion tool, as results differ. Thus, a 'one-size-fits-all' approach should be avoided.

4 Technology Acceptance Model

Users adopt emerging technologies in a variety of ways. Many studies have set out to explain these patterns of behaviour, and construct models and frameworks to convey such adoption patterns

The Technology Acceptance Model (TAM) was used by the authors to inform the study. TAM was originally developed by Davis (1989) as a means of studying and, indeed, predicting, user acceptance of information technology. Two main constructs were hypothesised—"perceived usefulness" and "perceived ease of use" (Davis 1989, p. 319), which are theorised to be fundamental determinants of user adoption of information technology. Kim et al. (2008) also describe perceived usefulness and perceived ease of use as "influential determinants" (p. 393). Davis describes a system high in "perceived usefulness" as one for which a user "believes in the existence of a positive use-performance relationship", and "perceived ease of use" as "the degree to which a person believes that using a particular system would be free of effort" (p. 320).

Other theories have also attempted to examine and predict the various determinants of user technology acceptance. The Diffusion of Innovation theory (Rogers 1995) takes a multi-disciplinary approach in examining five key characteristics that may affect adoption of technologies—relative advantage, complexity, compatibility, trialability and observability (Kim et al. p. 396). Through these constructs, innovation adoption is viewed as a process of uncertainty reduction and information gathering (Wang and Qualls 2007). The Theory of Reasoned Action (TRA) (Ajzen and Fishbein 1980) further attempts to explain the relationship between user beliefs, attitudes and system use (technology adoption), and is itself the foundation of the TAM.

The TAM model has since been built upon extensively from multiple disciplinary vantage points and has received widespread empirical support (Kim et al. 2008), through studies such as adoption of mobile technology, (Kim et al. 2008), online games (Hsu and Lu 2004) and virtual worlds (Huang et al. 2013).

4.1 Technology Acceptance Model in Travel and Tourism

In the context of travel and tourism, the notion that TAM is a useful and practical framework for understanding consumers' acceptance of ICT has been validated on many occasions. Ukpabi and Karjaluoto (2016) in their synthesis of the theories, frameworks, models and antecedents of applications of ICT in tourism, found that TAM was the most commonly used model, either as a sole research framework, or in combination with other models (p. 6). They also remind us that adoption is a critical success factor for the deployment of ICTs in tourism, and due to the dynamism of the industry, the literature requires constant updating (p. 2). Understanding tourists' use of virtual worlds has been validated by Huang et al.

(2013, p. 498) using TAM in their study of Second Life. Exploring user acceptance of 3D virtual worlds in travel and tourism marketing, they found positive and significant impacts between perceived ease of use and perceived usefulness on the experience of enjoyment. Wang and Qualls (2007) used the TAM at an organisational level to consider hospitality organisations' adoption of technology, enhancing the theoretical foundation provided by TAM by adding organisational constructs.

Although the determinants proposed by TAM are not the only variables which might be of interest, "they do appear likely to play a central role" (Davis 1989, p. 323). Coupled with the convergence among a wide range of studies (Ku and Chen 2015; Sahli and Legoherel 2015; Lin 2010; Ku 2011), the authors deemed these suitable and valuable paradigms for this study.

Despite an extensive literature search on TAM in the specific context of VR, this area remains almost wholly unexamined.

5 Methodology

Travel trade and consumer shows are long established as part of the tourism promotion mix. In 1990, Pizam pointed to their role in encouraging attendees to buy tourism products and visit tourist destinations. Both trade and consumer exhibitions are major sales promotions opportunities for travel and tourism firms, from state tourism agencies to small independent operators.

Despite the acknowledged economic contribution and popularity of trade and consumer exhibitions as a key component of the MICE sector, research on such shows and exhibitions has been sporadic at best. It seems that as consumer purchasing has moved more towards digital channels, many aspects of exhibitions have become notably under-researched (Mair 2010). Trialing VR at a consumer show therefore offered the authors both a very convenient platform to investigate VR as a destination promotional tool, and an opportunity to gather insights from the consumer show.

Holiday World Show is Ireland's leading consumer travel show. Founded in 1989, the show runs in two locations annually and attracts over 1,000 travel professionals and over 50,000 visitors. It could be described as a "vertical show"…"organised to promote a single or related industry category to a particular audience" (Motwani et al. 1992, p. 39).

5.1 Research Approach

This research was carried out at both the Belfast and Dublin Holiday World shows from 20–22 January 2017 (Belfast) and 27–29 January 2017 (Dublin). Using convenience sampling, respondents were administered a self-completion survey after they had tried the VR experience. A total sample of 129 responses was obtained over the six days of sampling.

The *Wild Atlantic Way* is a touring route encompassing over 2,500 km of spectacular scenery, much of it inaccessible or environmentally sensitive. Fáilte Ireland, who have responsibility for domestic marketing and product development in the Republic of Ireland, recently commissioned a series of four 360-degree films showcasing four separate tourist activities and destinations on the *Wild Atlantic Way*.

This VR technology was piloted by Fáilte Ireland in 2016 as a potential sales tool at ITB Berlin (Fáilte Ireland 2016). The cutting-edge views of the *Wild Atlantic Way* were then made available across all *Wild Atlantic Way* digital platforms as well as across social media channels. Anglim (2016) points out that by using this innovative technology to bring almost life-like experiences to visitors as they research and book their holidays, it is hoped that Ireland can stand out in a crowded marketplace. The four videos depict activities in four seaboard counties in Ireland, including horse-riding, cycling through the Burren, surfing through the Cliffs of Moher and sea stack climbing. Participants were free to choose which video they would watch, and could select more than one.

This research was supported by Fáilte Ireland who supplied the technologies and support staff required in both locations. A promotional stand was erected in a dedicated area, and Samsung Gear VR headsets and headphones were provided. An audio element was deemed important so that users could experience a greater sense of immersion. This is supported by Guttentag (2010, p. 639) who comments that audio is "important for the creation of realistic VEs". Reinhard's (2010) thinking on "sense-making in virtual worlds" informed the creation of the questionnaire from the perspectives of "being entertained" and "desiring to engage". The self-completion questionnaire administered to respondents addressed several themes deriving from the TAM model, using a Likert Scale to assess their attitude to three key components—usefulness, ease of use, and overall behavioural intent.

Other themes were explored in the research, but not reported here, such as VR's potential to substitute for visiting the destination, and the extent to which the VR experience contributed to attendees' enjoyment of the travel show.

Unsurprisingly, there was no difficulty in encouraging attendees to try out the VR experience. Indeed, it was observed that VR added greatly to the "attraction efficacy" (Gopalakrisna and Lilien 1995, cited in Milner 2009, p. 6) of the Fáilte Ireland stand.

6 Findings and Discussion

The sample obtained represented a broad cross-section of the attendance at the Holiday World Show, and is reflective of the older age-bias of attendees of the event. Good practice in research and DIT's own research ethics practices precluded any respondents under the age of 18 from participating in the survey Table 1.

A recent Priceline study (2016) states that "almost half of Millennials would use a VR headset to preview a destination they are planning to travel to". The authors wished to see if there was any indication of a relationship between respondent age and their evaluations of VR along key predictive user acceptance measures. A Chi-Square analysis was conducted to establish any significant associations between a number of the study's key variables and age of respondent.

Interestingly, the relationship between age category and prior use of VR was found not to be significant (p = 0.25). This shows that in addition to the appeal of this technology to 'digital natives' (Margaryan et al. 2011), VR technology adoption was evenly spread across age cohorts.

Some 26.8% of all respondents had tried a virtual reality experience before; of these exactly 50% had tried a travel-related virtual related experience. As Table 2 shows, no significant differences ($p < 0.05$), were observed within the age cohorts surveyed. Reinhard's (2010) contention that exposure to media technologies is affected by respondent age would appear to be challenged in the case of VR, according to these findings.

Table 3 outlines findings from the Likert-scale measurement of users' acceptance of the VR technology along the dimensions of Usefulness and Perceived Ease of Use as described by Davis (1989). As the TAM model was developed in the context of worker performance as the dependent variable, the authors sought to develop a more appropriate construct for travel. The extent to which the technology would encourage likelihood to visit the promoted region was of particular interest to the Fáilte Ireland organisation, and so was included in the set of measurement constructs.

Across all dimensions there was a high degree of agreement that the VR technology had positive impact. The highest rating for the technology was for its entertainment value. This is an important validation as it reflects current commentary on the critical importance of developing compelling content in VR experiences. Among a small minority of respondents, there was a sense that the disadvantages of the technology outweighed the advantages. This finding may partly explain the lower mean score for the extent to which some respondents felt that the technology needed expert help to be used. In relation to the impact of VR

Table 1 Demographic profile of respondents (n = 129)

Age of respondents	%
18–25	11.2
26–45	33.6
46–64	41.6
65+	13.6

Table 2 Chi square analysis —age relationship with key variables

	p
Prior use of virtual reality	0.25
Ease of use of technology	0.56
Usefulness of technology	0.09

Table 3 TAM criteria (n = 129)

Criteria	Mean	s.t.d.
Usefulness	Max 5	
A useful technology	4.41	0.929
Creates a realistic sense of destination	4.45	0.941
Advantages outweigh disadvantages	4.27	0.982
An entertaining technology	4.52	0.894
Ease of Use		
Possible to use without expert help	4.07	1.11
Is clear and understandable	4.30	0.925
Overall is easy to use	4.41	0.936
Intentions		
Like the idea of using VR	4.38	0.965
Probably will use VR again	4.38	1.036
Would recommend VR to other people	4.47	0.955
More likely to visit *Wild Atlantic Way*	4.24	0.731

on respondents' future intentions of use, and likelihood to recommend, the findings offer much encouragement for travel marketers. The extent to which trial of the VR experience would enhance likelihood to visit the *Wild Atlantic Way* was particularly noteworthy. A chi-square analysis was performed to see if there was any relationship between levels of prior awareness of *Wild Atlantic Way* and the extent to which VR led respondents to feel more likely to visit the area. This was not proven ($p = 0.66$), and points to a picture of a technology that can work in terms of both brand awareness and brand affinity. This dimension of the technology is one that warrants further investigative work. From the perspective of a destination marketing organization such as Fáilte Ireland, the return-on-investment from VR is something that continues to be a concern. This study indicated that VR can become a strong element in the broader range of integrated marketing communication (IMC) tools.

7 Conclusions

Liang et al. (2016, p. 1) point to the "technological superstorm" in ICT in tourism. This has been observed in the literature review for this research, and in the ever-emerging examples of technology-enhanced tourism developments. In 1995, Williams and Hobson (p. 425) commented that the "VR revolution has yet to happen". In 2017, the revolution has still not taken force, but momentum is growing very quickly.

The authors have examined and uncovered a number of theoretical impacts of VR, through the lens of destination marketing and promotion, via their primary research on VR as a promotional tool for Ireland's *Wild Atlantic Way*. This work, whilst investigative, adds useful consumer-related findings, highlighted by

Liang et al. (2016, p. 13) as lacking in tourism research. They also point, in their specific study on m-tourism, to the absence of empirical data in many existing studies, and the subjectivity of "a very large proportion". These concerns are transferable to additional aspects of tourism technology research.

Moderating factors may have an influence on the relationship between a user's perception of VR and their adoption behaviour, and it is difficult to reflect this dynamism in the research. Various push and pull factors and motivations could be investigated further. For example, Guttentag (2010 p. 645) points out that tourists seeking risk and novelty may look for different sensations in a VR environment to those looking for business travel opportunities.

This study did not include any tactile sensations. Research in this area is growing, with a move towards 'haptic devices' in the form of gloves or more substantial suits which cover an entire body (Gutiérrez et al., 2008). In time, such additional technologies will be most worthy of investigation.

Practical and ethical implications of developments around VR are more difficult to predict, and have not been dealt with by this study.

Using the Technology Adoption Model yielded a range of useful findings, reinforcing the potential of VR in destination image-building, and providing information at the pre-experience stage of the consumer decision making process. Overall, the research showed that VR is a useful tool in the marketing communications mix, offering DMOs the possibility to influence customers in their travel destination choice. Irrespective of the demographic cohort, VR is a technology which was deemed easy to use, useful and enjoyable. Respondents were strongly of the view that VR increased their likelihood to visit the *Wild Atlantic Way*. This offers exciting prospects for destination marketers in a turbulent and competitive tourism landscape.

The lens adopted by the authors focused exclusively on the marketing dimension of Guttentag's (2010) six areas of potential for VR examination. However, VR certainly has a much broader application in tourism. In future research, the authors intend to pursue study of VR's role in destination substitution, which was only nominally addressed in this study. Providing evidence that virtual conation can be translated into actual purchase will be an important aspect of proving the efficacy of VR to travel and tourism marketing, and to the speed of its future acceptance.

Acknowledgements The authors acknowledge the support of Fáilte Ireland in this research, and the assistance of Holiday World organisers in facilitating the research at their 2017 shows

References

Adamson, A. (2015). *Virtual reality: Not right for all marketers, but brilliant for marriott, forbes*. Retrieved March, 2017, from https://www.forbes.com/sites/allenadamson/2015/11/17/virtual-reality-not-right-for-all-marketers-but-brilliant-for-marriott/#588fece7683a.

Anglim, D. (2016). *Virtual reality brings wild Atlantic way to life*. Retrieved March, 2017, from http://www.Fáilteireland.ie/Utility/News-Library/Virtual-Reality-Brings-Wild-Atlantic-Way-to-Life.aspx.

Ajzen, I., & Fishbein, M. (1980). *Understanding attitudes and predicting social behavior*. NJ: Prentice Hall.

Berger, H., Dittenbach, M., Merkl, D., Bogdanovych, A., Simoff, S., & Sierra, C. (2007). Opening new dimensions for e-tourism. *Journal of the Virtual Reality Society, 11*(2–3), 75–87.

Buhalis, D. (2000). Marketing the competitive destination of the future. *Tourism Management, 21* (1), 97–116.

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.

Cabello, J., Collado, A., Cruz-Lara, S., Armisen, A., Franco, J., Janer, J., Oyarzun, D. & Geraerts, R. (2011). Standards in virtual worlds. Virtual travel use case metaverse1 project. *Journal of Virtual Worlds Research*, *4*(3), 1–5.

Cheong, R. (1995). The virtual threat to travel and tourism. *Tourism Management, 16*(6), 417–422.

Cruz-Neira, C., Sandin, D., Defanti, T., Kenyon, R., & Hart, J. (1994). The cave: Audio visual experience automatic virtual environment. *Communications of the ACM, 35*(6), 65–72.

Davis, F. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly,* 319–339.

eMarketer.com (2015). Marriott's virtual reality transports guests 'Around the World'. Retrieved March, 2017, *from* https://www.emarketer.com/Article/Marriotts-Virtual-Reality-Transports-Guests-Around-World/1013409.

Fáilte Ireland (2016). Virtual reality brings wild atlantic way to life. Retrieved, March, 2017, from http://www.Fáilteireland.ie/Utility/News-Library/Virtual-Reality-Brings-Wild-Atlantic-Way-to-Life.aspx.

Giordimaina, J. G. (2008). Multi sensory marketing and its application in tourism. *Journal of the Institute of Tourism Studies, 1*(2), 42–45.

Goldman Sachs (2016). *Equity Research*. Retrieved March 2017, from http://www.goldmansachs.com/our-thinking/pages/technology-driving-innovation-folder/virtual-and-augmented-reality/report.pdf.

Gratzer, M., Werthner, H., & Winiwarter, W. (2004). Electronic business in tourism. *International Journal of Electronic Business, 2*(5), 450–459.

Gretzel, U. & Fesenmaier, D. R. (2003). Experience-based internet marketing: An exploratory study of sensory experiences associated with pleasure travel to the Midwest United States, *Proceedings of International Federation for Information Technology and Travel and Tourism*.

Guerra, J., Pinto, M., & Beato, C. (2015). Virtual reality shows. A new vision for tourism and heritage. Retrieved March, 2017, from http://arstechnica.com/gaming/2016/10/best-vr-deadset-2016-psvr-rift-vive.

Gutiérrez, M., Vexo, F., & Thalmann, D. (2008). *Stepping into virtual reality*. London: Springer.

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

Horan, P. (1996). Virtual reality applications in the hospitality/tourism industry, *Hospitality Information Technology Association—Electronic Journal*, *1*:1–7.

Huang, Y., Backman, S., Backman, K., & Moore, D. (2013). Exploring user acceptance of 3D virtual worlds in travel and tourism marketing. *Tourism Management, 36,* 490–501.

Hsu, C. L., & Lu, H. P. (2004). Why do people play on-line games? An extended TAM with social influences and flow experience. *Information & Management, 41*(7), 853–868.

Hyun, M. Y., & O'Keeffe, R. M. (2012). Virtual destination image: Testing a telepresence model. *Journal of Business Research, 65,* 29–35.

Jacobious, P. (2016). *Virtual reality in tourism.* Retrieved March, 2017, from http://www.virtual-reality-in-tourism.com/.

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

Kotler, P., Armstrong, G., Harris, L., & Piercy, N. (2017). *Principles of marketing*. London: Pearson.

Kim, D.-Y., Park, J., & Morrison, A. (2008). A model of traveller acceptance mobile technology. *International Journal of Tourism Research, 10,* 393–407.

Ku, E. C. (2011). Recommendations from a virtual community as a catalytic agent of travel decisions. *Internet Research, 21*(3), 282–303.

Ku, E. C. S., & Chen, C. (2015). Cultivating travellers' revisit intention to e-tourism service: The moderating effect of website interactivity. *Behaviour and Information Technology, 34*(5), 465–478.

Liang, S., Schuckert, M., Law, R., & Masiero, L. (2016). The relevance of mobile tourism and information technology: An analysis of recent trends and future research directions, *Journal of Travel & Tourism Marketing*, 1–17.

Lin, C. (2010). Examining e-travel sites: An empirical study in Taiwan. *Online Information Review, 34*(2), 205–228.

Levere, J. (2017). *Before you take the trip: How about a virtual 'test drive'?* The New York Times. Retrieved March, 2017, from https://www.nytimes.com/2017/02/12/business/media/travel-virtual-reality.html?_r=0.

Mair, J. (2010). *A review of business events literature 2000–2009*. Leeds: Paper presented at the global events congress.

Margaryan, A., Littlejohn, A., & Vojt, G. (2011). University students' use of digital technologies. *Computers & Education, 56,* 429–440.

Mascho, E., & Singh, N. (2013). Virtual tourism: Use of "Second Life" for destination marketing. *Anatolia, 25*(1), 140–143.

Milner, L. (2009). Consumer behaviour at an industrial travel show. *Tourism Review, 64*(4), 4–11.

Motwani, J., Rice, G., & Mahmoud, E. (1992). Promoting exports through international trade shows, a dual perspective. *Review of Business, 13*(4), 38–42.

Pine, B., & Gilmore, J. (1999). *The experience economy: Work is theatre and every business a stage*. Boston: Harvard Business School Press.

Pizam, A. (1990). Evaluating the effectiveness of travel trade shows and other tourism sales promotion techniques. *Journal of Travel Research, 29*(1), 3–8.

Priceline (2016). *Intersection of technology and consumer experiences.* Retrieved March, 2017, from http://www.prnewswire.com/news-releases/new-survey-from-the-priceline-group-reveals-insights-into-how-travelers-expect-technology-to-transform-experiences-300282329.html.

Reinhard, C. (2010). Interviews within experimental frameworks: How to make sense of sense-making in virtual worlds. *Journal of Virtual Worlds Research, 3*(1), 3–25.

Rogers, E. (1995). *Diffusion of innovations* (4th ed.). New York: The Free Press.

Roughead M. (2017). *Scotland transposed to VR in effort to lure tech-savvy visitor.* Retrieved March, 2017, from http://www.thedrum.com/news/2017/03/07/scotland-transposed-vr-effort-lure-tech-savvy-visitors.

Sanchez-Vives, M., & Slater, M. (2005). From presence to consciousness through virtual reality. *Nature Reviews Neuroscience, 6*(4), 332–339.

Sahli, A. B., & Legoherel, P. (2015). The tourism web acceptance model: A study of intention to book tourism products online. *Journal of Vacation Marketing, 22*(2), 179–194.

Sherman, W., & Craig, A. (2003). *Understanding virtual reality. Interface, application and design*. San Francisco: Morgan Kauffman.

Spence, C., & Gallace, A. (2011). Multisensory design: Reaching out to touch the consumer. *Psychology & Marketing, 28,* 267–308.

Stamboulis, Y., & Skayannis, P. (2003). Innovation strategies and technology or experience-based tourism. *Tourism Management, 24*(1), 35–43.

Stuart, H. (2016). *The Debate about whether 360 video is VR- and Why it Doesn't Matter*. Retrieved March, 2017, from https://www.virtualreality-news.net/news/2016/sep/14/debate-about-whether-360-video-vr-and-why-it-doesnt-matter/.

Sussmann, S., & Vanhegan, H. (2000). *Virtual reality and the tourism product. Substitution or complement?* Retrieved March, 2017, from http://aisel.aisnet.org/ecis2000/117.

Ukpabi, D. & Karjaluoto, H. (2016). Consumers' acceptance of information and communications technology in tourism: A review. *Telematics and Informatics,* (article in press, forthcoming).

Wan, C., Tsaur, S., Chiu, Y., & Chiou, W. (2007). Is the advertising effect of virtual experience better or contingent on different travel destinations? *Information Technology and Tourism, 9*(1), 45–54.

Wang, Y., & Qualls, W. (2007). Towards a theoretical model of technology adoption in hospitality organizations. *Hospitality Management, 26,* 560–573.

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

Wiltshier, P., & Clarke, A. (2015). *Virtual cultural tourism: Six pillars of VCT using co-creation, value exchange and exchange value.* Paper presented at the Tourism and Hospitality Research, TPPP conference, Eastbourne, UK

The Impact of Augmented Reality (AR) Technology on Tourist Satisfaction

Ruhet Genç

Abstract Augmented Reality (AR) is currently one of the most popular technologies among global technological applications. Aside from completely immersing the user in a synthetic environment in which the user cannot experience the real world around herself, as Virtual Reality (VR) technology does, AR superimposes the computer-generated data while allowing the user to enhance her perception of reality and of the surrounding. Furthermore, AR has many application areas, varied from medical treatment to educational purposes. Particularly, AR technology is employed in tourism sector, increasing the involvement of touristic activity while diversifying the bundle of tourism experiences. The literature, however, is insufficient, in terms of capturing the main impact of AR technology on the satisfaction levels of tourists. This paper aims to fill the gap by investigating the past literature on AR technology and then presenting a naïve model where the significant effect of AR technology can be seen on the basis of tourist satisfaction.

Keywords Augmented reality · Virtual reality · Tourism · Satisfaction

1 Introduction

By definition, augmented reality (AR) is a variation of virtual reality (VR) as commonly known or in other terms virtual environments (Azuma 1997). Until recently, VR technologies were accepted as the most outstanding technologies based on the idea of total immersion of the user in a virtual world generated by computer technology (Fritz et al. 2005). While VR Technologies completely immerse a user in a synthetic environment where the user cannot see the real environment around, AR technologies allows the user to see the real world around by the means of virtual objects superimposed upon or composited into real world

R. Genç (✉)
Faculty of Administration and Economics, Turkish German University,
Istanbul, Turkey
e-mail: drgench@gmail.com

T. Jung and M.C. tom Dieck (eds.), *Augmented Reality and Virtual Reality*,
Progress in IS, DOI 10.1007/978-3-319-64027-3_8

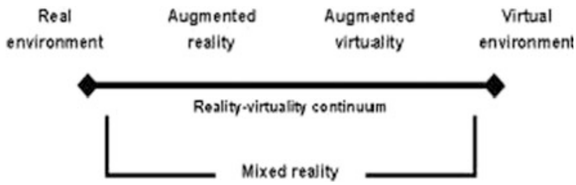


Fig. 1 Real—virtual continuum (Van Krevelen and Poelman 2010)

(Azuma 1997). In general, AR is a visualization technique which superimposes the computer-generated data such as text, video, graphics, GPS data and other multimedia formats on top of the real world view, like captured by the camera of a mobile phone, computer or other technologic devices (Kounavis et al. 2012), augmenting one's view and transforming it so that user's perception of reality and of the surrounding environment would be enhanced (Osterlund and Lawrence 2012). Hence, AR technologies have become increasingly popular, both in scientific world and for the general use of public (Fritz et al. 2005).

Figure 1 reflects the continuum between the real and virtual environment. As seen in the figure, AR stands within the mixed reality. AR provides local virtuality as opposed to virtual reality or virtual environment and augmented virtuality, where real objects are added to virtual objects (Van Krevelen and Poelman 2010).

The application of AR technology can be found in numerous areas, including medical, manufacturing and repair, annotation and visualization, robot path planning, entertainment, military aircraft, education and stimulated training (Azuma 1997; Yu, Jin et al. 2010). AR technology is also used in tourism sector, targeting to improve the tourist experiences (Kounavis et al. 2012).

Previous research clearly depicts the potential of AR technology to create an interactive and enjoyable tourism experience (Yovcheva et al. 2014; Tom Dieck and Jung 2015). However, there has been no such research modelling the impact of AR on tourist satisfaction in a quantitative sense. The aim of this paper is to investigate the role of AR technology in tourism sector, specifically focusing on the effect of AR technology on tourist satisfaction. The paper will start with a basic literature review of what has happened in tourism sector after the development of AR technology. Then, the paper will present a naïve model, considering the impact of AR technology on tourist satisfaction. Lastly, concluding remarks will be presented and possible contributions of AR technology to tourism sector will be discussed.

2 Literature Review

2.1 Augmented Reality in Tourism

Based on the available frameworks and toolkits, many applications of AR technology have been developed for several decades. Although some of these applications have started as pilot applications or research projects, a number of them are still available in commercial areas. Nevertheless the examples are extremely varied (Kounavis et al. 2012). Mobile AR applications, for instance, are significantly different from each other, while they are all designed for specific tourist purposes. AR technologies can be used to create informative and interactive tours regardless of it is real estate or an art museum (http://www.businessnewsdaily.com/9245-augmented-reality-for-business.html#sthash.ZqS1PuKq.dpuf [Dec. 9, 2016]).

To begin with the historical progress of AR technology in tourism industry, Tuscany+ appears as the first AR application in 2010, specifically developed for Tuscany region in Italy, by Fondazione Sistema Toscana and operates as a digital tourist guide. Tuscany+ delivers tourist information, including accommodation, dining, the city's nightlife and sightseeing, in Italian and English by drawing the information from internet sources, such as Wikipedia and Google Places (http://www.turismo.intoscana.it).

Next, Basel is another city with its own AR tourist guide, the project "Augmented Reality for Basel", which is accessible through the Layar AR browser and available in English, German, French and Spanish as of 2011. In general, the content is drawn from the city of Basel's dedicated database where the users can retrieve valuable information for the city of Basel and its outskirts, and in particular with respect to Basel's sites, museums, restaurants and hotels, as well as the information for events and shopping centres are accessible (http://www.perey.com/AugmentedRealityForBasel/ [Dec. 9, 2016]).

Last example of AR technology application in touristic activities can be given as the StreetMuseum application, which has been developed by Thumbspark Limited particularly for the needs of the Museum of London in 2010. This application offers users the opportunity to visualize the city of London from numerous points of history. By pointing the camera of their mobile phones at present day street views, the users have historical pictures of these places. The pictures are drawn from the Museum of London's vast collection and they are superimposed on top of the real view. Moreover, additional information can be accessed through the information buttons of the system. In general, StreetMuseum provides tourists a chance to design their route at their own selection and discover the history of London, its altered landscapes and important landmarks (http://www.museumoflondon.org.uk).

Furthermore, there are numerous AR applications that are suitable for road trips and currently used by travellers all around the world. WikiTude, Yelp Monocle, Google Search App and Metro AR Pro can be counted as the examples of this kind of applications, highly suggested by well-known blogs designed for travellers' use (http://www.cntraveler.com).

2.2 *The Impact of Augmented Reality on Tourist Satisfaction*

Having discussed the examples of AR technology in tourism, the benefits of AR technology in tourism sector can be discussed as the next step. According to Garcia-Crespo et al. (2009) tourism sector is currently in need of technology-based integrated value added services which offer interactivity and entertainment throughout their highly dynamic structure. Augmented Reality appears as a technology which is capable of providing tourists much more personalized content and services shaped by their own preferences. In particular, AR tourist guides can display content upon request while tourists are travelling around a city, discovering the city landscape, sites and landmarks. Parallel to the development of mobile AR applications, tourists are able to discover the world by adding new layers to their perception of reality and of surroundings. These developments, in turn, provide tourists a new interactive and highly dynamic experience (Kounavis et al. 2012). Furthermore, accessing these applications over mobile devices with GPS functionalities, tourists have become capable of navigating themselves interactively with the help of direct annotations of the preferred destinations (Takada et al. 2009).

Considering the functionality, the contribution of AR technology on tourist satisfaction will be better understood. There are numerous functions of AR technology which cannot be achieved by any other touristic applications, specifically comparing it with VR technology. First, search and browsing (i.e. categorical search) mechanism provides tourists to access relevant information (Rasinger et al. 2009). Routing and navigation are the fundamental elements of AR technology, which also provides tourists an opportunity to plan their own tours for a better leisure experience (Umlauft et al. 2003). An important part of the generating the tours is naturally communication, which has been enhanced by the AR technology through realizing direct contact with accommodation providers, exhibition owners, or any other service providers (Rasinger et al. 2009). Moreover, AR technology helps tourists to obtain an overview of larger territory via map services (Suh et al. 2010), interactive view (Wither et al. 2009) or filtering out unnecessary content (Tokusho and Feiner 2009). The technology is also context-aware, allowing tourists to catch important or interesting information, particularly in urban areas which are rich in information (Rasinger et al. 2009) and exploration of visible surroundings without pre-defined criteria (Ajanki et al. 2010).

Although some scholars claim that AR applications at touristic destinations and attractions have no direct positive impact on tourist experiences (Yovcheva et al. 2013), introduction of AR technologies are found to be valuable by numerous scholars for various reasons. For instance, Martínez-Graña et al. (2013) claim that AR applications are specifically valuable for the tourism industry since they improve tourists' social awareness of the immediate surroundings and unknown territory. Furthermore, AR applications help tourists gain a deeper understanding of the origins of geoheritage such as volcanic sites (Martínez-Graña, et al. 2013). On the other hand, AR technology has been acknowledged as a popular tool for the education of museum visitors (Casella and Coelho 2013), and they are capable of presenting historical events and introducing tourism destinations (Benyon et al. 2014). Finally, it has been also concluded that AR technology may be used by the mass market, and naturally, tourism industry will likely to engage with these new and developing applications (Jung et al. 2015).

In this section, the historical progress of AR technology has been discussed by giving worldwide examples as well as current applications popularly used by travellers on internet. Then, the benefits and functionality of AR has been presented in order to depict the possible impacts of AR on the satisfaction levels of tourists. In the next section, a naïve model will be developed to reveal these possible impacts of AR on a quantitatively measurable structure for tourist satisfaction.

3 Method

The impact of Augmented Reality can be measured on the basis of overall satisfaction of tourists as well the alterations in technology. Tourist satisfaction, as stated in the beginning of this paper, is the ultimate goal for explaining the impact of Augmented Reality. Moreover, impact of Augmented Reality is fundamentally dependent on technological progress. Adding these two variables, the model will be as following:

$$\mathrm{AR} = \beta_1 \mathrm{TS} + \beta_2 \mathrm{TP}^{\mathrm{t}} + \varepsilon \tag{1}$$

where,

AR implies *impact of Augmented Reality*,
TS implies *tourist satisfaction*
TP implies *technological progress*
t implies *time* (or periods/seasons in which touristic markets work)
β_1 and β_2 imply coefficients
ε implies residual
The hypothesis of the study will be as following:
H_1: $\beta_1 > 0$, tourist satisfaction is a significant determinant for the impact of Augmented Reality
And,
H_2: $\beta_2 > 0$, technological progress is a significant determinant for the impact of Augmented Reality

4 Findings

According to the model used in the study, the impact of Augmented Reality is measured through two main variables, these are: tourist satisfaction and technological progress. First of all, tourist satisfaction is a crucial factor since the applications of AR technology in tourism sector mainly target to increase the satisfaction of tourists that they receive from their touristic experiences. Quantitative measurement of tourist satisfaction may be achieved through measuring the changes in Quality of Life (Genç 2012). There are two main indicators for measuring the term quality of life; these are objective and subjective measures. In accordance with the scientific purposes, we need to focus on objective indicators, such as economic indices (Gross Domestic Product, poverty rate, etc.), social indicators (unemployment rate, school attendance rate), life expectancy and literacy rate (Genç 2012). Secondly, technological progress forms the basis of further development of AR technology. Without taking technological progress into consideration, changes in AR technology cannot be captured; hence the impact of changing AR technology cannot be understood properly. Moreover, technology has the characteristics of developing exponentially. In other terms, it has acceleration for doubling itself, which phenomenon is known as Moore's Law named after the work of Gordon Moore (1965) on integrated circuits. These two variables, tourist satisfaction and technological progress are assumed to increase linearly with the coefficients $ß_1$ and $ß_2$, respectively.

Furthermore, there may be other variables which have a significant impact on measuring the effect of innovations; hence they are represented with ε. Although the model has not been tested on real variables, it will be useful to focus on a quantitative analysis, in order to measure the impact of innovations on a scientific basis.

5 Conclusions

In summary, the AR technology allows people to view images which blend into and sit on top of the existing physical landscape as opposed to VR technology, which delivers an entirely immersive, virtual experience without providing any interaction with the surrounding environment (http://realbusiness.co.uk/tech-and-innovation/2016/11/22/will-2017-be-watershed-businesses-using-augmented-reality/ [Dec. 9, 2016]). By providing people a different opportunity for the perception of reality and of their surroundings, AR technology creates a significant impact in tourism sector, specifically on the satisfaction levels of tourists. Tourists may enjoy with this new kind of reality in all over the world, hence their level of satisfaction increases parallel to the advancements in AR technology. Although the analysis in this paper does not include real world data, it is still intuitive for further research, based on the dynamics of the model developed in this paper. Quantitative measurement is the most reliable way to reveal the impact of any particular phenomenon; hence the impact of AR should be examined according to a model, constructed by taking possible effects into consideration. The model above is restricted in two components, tourist satisfaction and technological progress; however this model is open to renew itself with new findings. In conclusion, the benefits and functionality of AR technology are the reasons why AR technology has become increasingly popular over last decades, especially in tourism sector. Since technological progress is merely unstoppable, there will be much more contributions of AR technology to tourist satisfaction in near future. All in all, a satisfied touristic experience is one of the valuable parts of overall human life and AR technology contributes to overall increase in life quality, by allowing diversified tourism activity, along with other functions in education, business and so on.

References

Ajanki, A., Billinghurst, M., Gamper, H., Jarvenpaa, T., Kandemir, M., Kaski, S., et al. (2010). An augmented reality interface to contextual information. *Virtual Reality, 15*(2–3), 455–470.

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

Basel Augmented Reality Tourist Guide (2011). Accessed December, 2016, from http://www.perey.com/AugmentedRealityForBasel/.

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

Casella, G., & Coelho, M. (2013). Augmented heritage: Situating augmented reality mobile apps in cultural heritage communication. *Proceedings of the 2013 International Conference on Information Systems and Design of Communicatio* (138–140)

Chase, J. (2014). *These augmented reality apps take travel to a whole new level*. Accessed December, 2016, from http://www.cntraveler.com/stories/2014-03-31/best-augmented-reality-travel-apps.

Fritz, F., Susperregui, A., & Linaza, M. T. (2005). Enhancing cultural tourism experiences with augmented reality technologies. *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,* 306–15.

Genç, R. (2012). Tourist consumption behavior and quality-of-life. In *Handbook of tourism and quality-of-life research* (pp. 135–148). Netherlands: Springer.

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.

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,* 1–6.

Martínez-Graña, A. M., Goy, J. L., & Cimarra, C. A. (2013). A virtual tour of geological heritage: Valourising geodiversity using Google Earth and QR code. *Computers & Geosciences, 61,* 83–93.

Moore, G. (1965) Cramming more components onto integrated circuits.*Electronics, 38*(8), 114–117.

Museum of London: Streetmuseum (2010). Retrieved December, 2016, from http://www.museumoflondon.org.uk/Resources/app/you-are-here-app/index.html.

Osterlund, J., & Lawrence, B. (2012). Virtual reality: Avatars in human spaceflight training. *Acta Astronautica, 71,* 139–150.

Rasinger, J., Fuchs, M., Beer, T., & Hopken, W. (2009). Building a mobile tourist guide based on tourists' on-site information needs. *Tourism Analysis, 14,* 483–502.

Real Business (2016). *Will 2017 be the watershed for business using augmented reality?* Retrieved December, 2016, from http://realbusiness.co.uk/tech-and-innovation/2016/11/22/will-2017-be-watershed-businesses-using-augmented-reality/.

Suh, Y., Shin, C., Woo, W., Dow, S. & MacIntyre, B. (2010). Enhancing and evaluating users' social experience with a mobile phone guide applied to cultural heritage. *Personal and Ubiquitous Computing, 14*(8), 1–6.

Takada, D., Ogawa, T., Kiyokawa, K., Takemura, H. (2009). A context-aware AR navigation system using wearable sensors. *Proceedings from the 13th International Conference Human-Computer Interaction,* 1–10.

Tokusho, Y., & Feiner, S. (2009). *Prototyping an outdoor mobile Augmented Reality street view application.* Paper presented at ISMAR 2009, 8th International Symposium on Mixed and Augmented Reality: Let's go out: Workshop on outdoor mixed and augmented reality, Orlando, FL, USA.

Tom Dieck, M.C., & Jung, T. (2015). A theoretical model of mobile augmented reality acceptance in urban heritage tourism. *Current Issues in Tourism, 18*, 1–21.

Tuscany+. (2010). Retrieved December, 2016, from http://www.turismo.intoscana.it/allthingstuscany/aroundtuscany/tuscany-the-first-augmented-realitytourism-application/.

Umlauft, M., Pospischil, G., Niklfeld, G., & Michlayr, E. (2003). Lol@, a mobile tourist guide for UMTS. *Information Technology and Tourism, 5*(3), 151–164.

Uzialko, A. C. (2016). *Augmented reality check: Innovative ways businesses are embracing AR.* Retrieved December, 2016, from http://www.businessnewsdaily.com/9245-augmented-reality-for-business.html#sthash.ZqS1PuKq.dpuf.

Van Krevelen, D. W. F., & Poelman, R. (2010). A survey of augmented reality technologies, applications and limitations. *International Journal of Virtual Reality, 9*(2), 1.

Wither, J., DiVerdi, S., & Höllerer, T. (2009). Annotation in outdoor augmented reality. *Computers & Graphics, 33*(6), 679–689.

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: Springer.

Yovcheva, Z., Buhalis, D., & Gatzidis, C. (2014). Empirical evaluation of smartphone augmented reality browsers in an urban tourism destination context. *International Journal of Mobile Human Computer Interaction, 6*(2), 10–31.

Yu, D., Jin, JS., Luo, S., Lai, W., & Huang Q. (2010). A useful visualization technique: A literature review for augmented reality and its application, limitation and future direction. In M. L. Huang, Q. V. Nguyen, & K. Zhang (Eds.), *Visual information communication,* (311–317). USA: Springer.

Part II
Augmented and Virtual Reality in Retail and Fashion

Augmented Reality and Virtual Reality in Physical and Online Retailing: A Review, Synthesis and Research Agenda

Francesca Bonetti, Gary Warnaby and Lee Quinn

Abstract Augmented reality (AR) and virtual reality (VR) have emerged as rapidly developing technologies used in both physical and online retailing to enhance the selling environment and shopping experience. However, academic research on, and practical applications of, AR and VR in retail are still fragmented, and this state of affairs is arguably attributable to the interdisciplinary origins of the topic. Undertaking a comparative chronological analysis of AR and VR research and applications in a retail context, this paper synthesises current debates to provide an up-to-date perspective—incorporating issues relating to motives, applications and implementation of AR and VR by retailers, as well as consumer acceptance—and to frame the basis for a future research agenda.

Keywords Augmented reality · Virtual reality · Retail · Literature review · Future research

1 Introduction

The early 2000s saw the increasing adoption of advanced technologies by retailers in both their physical and online stores, to enhance both the store environment (i.e. the place where the product is bought or consumed), and the shopping experience (Pantano 2015). This is especially true for what can be termed 'consumer-facing' technology; namely technologies and devices that the consumer experiences directly whilst in the physical or online store, such as interactive screens, online

F. Bonetti (✉) · L. Quinn
School of Materials, The University of Manchester, Manchester, UK
e-mail: francesca.bonetti@postgrad.manchester.ac.uk

L. Quinn
e-mail: lee.quinn@manchester.ac.uk

G. Warnaby
Faculty of Business and Law, Manchester Metropolitan University, Manchester, UK
e-mail: g.warnaby@mmu.ac.uk

T. Jung and M.C. tom Dieck (eds.), *Augmented Reality and Virtual Reality*,
Progress in IS, DOI 10.1007/978-3-319-64027-3_9

product visualisation and customisation, digital signage, etc. Amongst these technologies, augmented reality (AR) and virtual reality (VR) applications are rapidly evolving and increasingly used in retail environments (Javornik 2016; McCormick et al 2014).

Olsson et al (2013, p. 288) define AR as a technique 'to combine real and computer-generated digital information into the user's view of the physical world in such a way they appear as one environment'. AR blends the virtual and real worlds (Huang and Liao 2015), through a virtual layer that can add images, textual information, videos or other virtual elements to the user's viewing of physical environment in real time (Carmigniani et al. 2011). AR typically captures real-world data, usually with a digital camera in a webcam or mobile phone. Using devices such as smartphones or tablets, wearables (headsets), projectors or fixed interactive screens, AR can provide a creative and innovative way to capture consumers' attention by enabling them to interact with virtual products (McCormick et al. 2014; Reitmayr and Drummond 2006). Experiential value is created through product simulation, media richness, sound, GPS data and videos (McCormick et al 2014). The AR shopping experience enables consumers to interact smoothly with virtual items, thereby improving their visualisation of products and hopefully their subsequent image of the brand, which in turn, enhances buying intentions of consumers (Jiyeon and Forsythe 2008).

In contrast, VR utilises a wearable device (typically a headset), which blocks out 'real world' sensory experiences to provide an arguably more engaging and innovative shopping environment by immersing users in virtual, entertaining 3-D worlds. Here, they can interact in real time and move physically within the virtual world, typically through movements of the head, but possibly also through motion tracking of limbs (Pantano 2015; Dad et al. 2016; Sherman and Craig 2002; Fuchs et al. 2011; Whyte 2002). For VR to succeed, the headwear needs to be comfortable and confer credible immersive virtual effects. VR can therefore be defined in terms of a medium composed of interactive computer simulations that replace or augment the feedback to the user's actions through one or more senses, conferring the feeling of being psychologically immersed in the simulation—in other words, a virtual world (Sherman and Craig 2002; Fuchs et al. 2011).

AR and VR's rapid development has attracted growing academic research interest, as well as further developments and applications. Originating as a research topic with some early exploratory work (Brody and Gottsman 1999; Gold 1993), only more recently has there been a more substantial consideration of these technologies in both the academic literature and in practice (Poushneh and Vasquez-Parraga 2017; Javornik 2016; Mann et al. 2015). However, a fragmented body of existing academic research and limited evidence of practical uses of AR and VR in a retailing context means that a coherent basis for further research is lacking. While this is arguably attributable to the interdisciplinary nature of the subject, there remains a pressing need for a critical examination and synthesis of the chronological developments and key current debates in AR and VR research and applications in retail, in order to locate future directions for a research agenda. Consequently, this review provides a twofold contribution: (1) it critically synthesises and examines current debates on AR and VR from different fields, and (2) it draws upon this synthesis to outline a future research agenda.

2 Literature Review

2.1 Developments of Research and Applications of AR and VR in Retail

From its origins in cinematography in the 1950s, AR has evolved enormously. Since the 1990s, mobile AR and wearable computers started to be developed and put to use, gaining increasing attention in computer science fields, together with the areas of VR, 3-D technology and mobile technology (Javornik 2016). Since then, the technology has also been applied in retail, gaming, medicine, navigation and education contexts. In the case of VR, early examples of the use of this medium date back to the 1970s in the aviation industry. Only recently has the use of VR been more widely extended with the development of virtual technologies (Sherman and Craig 2002). Another influencing factor has been a significant increase in the intrinsic power of computers and especially the possibility of creating computer-generated images and enabling real-time interaction between the user and the real world through VR systems (Fuchs et al. 2011; Craig et al. 2009). Consequently, both these technologies have generated much interest, arising from their potential impact as disruptive technologies in various contexts. Figure 1 provides a comparative timeline of developments in AR and VR research in a specific retail context, indicating the disciplinary origins of the research.

Use of AR technology in retailing occurs at various touchpoints of the consumer journey—physical, mobile and online (Javornik 2016; Carmigniani et al. 2011). Research and applications of AR in retail indicate that it has been regarded as facilitating experiential marketing (Bulearca and Tamarjan 2010). Indeed, early studies on AR explored its uses in augmented commerce through shopping agents, to bridge the gap between electronic and traditional commerce (Brody and Gottsman 1999). In the case of VR, early research considered a visual simulation system called Visionary Shopper, which provided a shopping environment and experience as close as possible to reality, where users could interact with products. This system was tested on shoppers and was regarded as being an enjoyable and fun experience, thereby promising more interactive technologies in the future (Gold 1993). The importance of interactivity in VR using web capability to simulate reality also emerged in the 1990s (Leinfuss 1996), emphasizing the importance of familiarisation with VR technologies and concepts. These early studies on virtual environments assessed the degree of immersion of the technology, including the inclusiveness of displays used, surroundings, etc. arguing that human beings were becoming 'more and more intertwined with computers' (Slater and Wilbur 1997, p. 614). Applications of VR devices for real-world modification began with

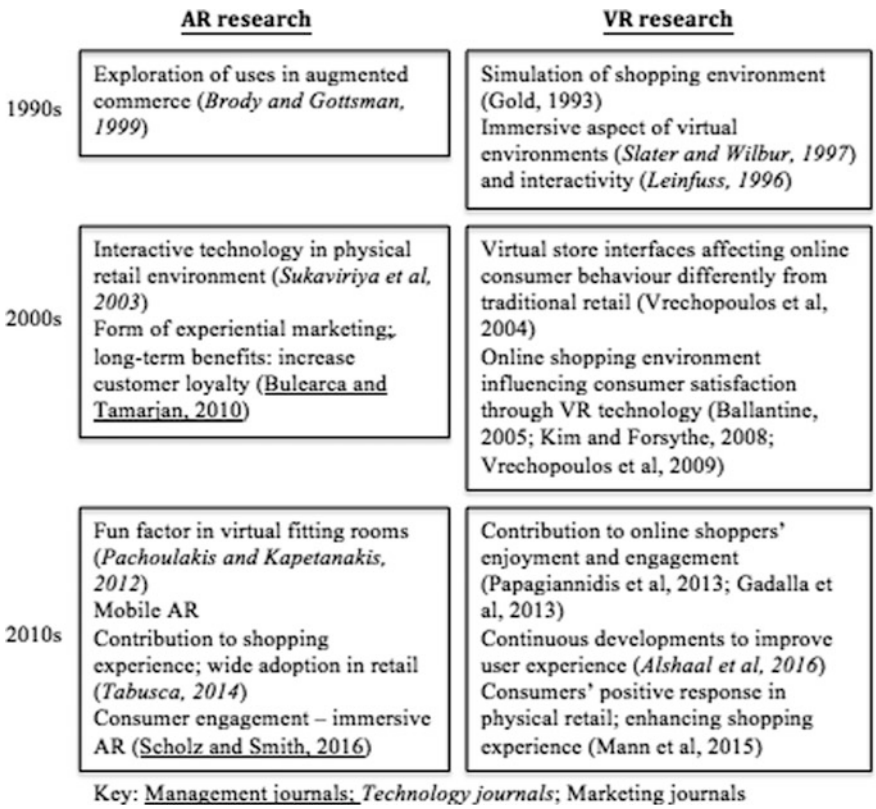


Fig. 1 Comparative timeline of AR and VR research

Electrolux announcing the opening of VR showrooms allowing consumers to build virtual kitchens using in-store computers (Williamson 1996) and Sainsbury's pioneering use of VR technology to decrease development costs and improve the results of supermarket redesigns through an interactive VR headset (Sainsbury's, 1995). Entertainment giant Blockbuster was an early adopter of VR to create a virtual warehouse through simulation (Batiz 2001), and in 1999 Burger King used 3-D technology to simulate a new retail store concept and fully understand the design, thus enabling interaction (Summerour 2001).

Research during the 2000s on AR used in a physical retail environment (through interactive displays, which predicted users interacting with steerable technology and triggering information on the product, promotions and locations—see Sukaviriya et al. 2003), highlighted both its functional and hedonic aspects. Early applications of AR in retailing include virtual try-on using personalised or non-personalised virtual models to simulate the appearance of apparel product combinations on a body form, rotating the model through front and back views that can be enlarged (Lee et al. 2006). There were also contrasting views on the long-term benefits of

AR, ranging from it being perceived as being exclusively a promotional tool (Woods 2009), to fostering positive consumer-brand relationships (Owyang 2010) and consumer satisfaction by generating an experiential value effect (Chou 2009). Bulearca and Tamarjan's (2010) study also indicated that use of AR was beneficial for companies and brands in that it could lead to increased customer loyalty, with research on in-store and online adoption of AR evidencing consumers' positive responses to the technology, making them engage with retailers and more willing to go shop at stores offering this technology (Pantano 2015; McCormick et al. 2014).

In the case of VR, and in particular virtual store layout, while some state that it has a critical influence on traffic and sales (Lohse and Spiller 1998), others claim that the characteristics of the virtual layout determine shoppers' willingness to buy online (Burke 2002). Vrechopoulos et al. (2004) suggest that a virtual grocery store layout significantly affects online consumer behaviour. However, predictions generated from conventional retail store layout theory do not generally correspond in a virtual setting, due to consumers' ability to reach any place in the virtual store directly. Thus, more consumer-friendly virtual shopping interfaces would further influence consumers' buying behaviour online. This is consistent with Ballantine's (2005) findings indicating that the level of interactivity and amount of information provided by the online shopping environment through the virtual interface strongly influences consumer satisfaction, thus impacting on consumer behaviour online. Subsequent studies on consumer behaviour in VR retailing in an online context showed that VR's applications enabling shoppers to interact with the product (e.g. apparel) enhance the hedonic value of the shopping experience (Kim and Forsythe 2008), and information agents (e.g. avatars) have a positive effect on consumer behaviour when static information on the website is limited (Sivaramakrishnan et al. 2007). Vrechopoulos et al. (2009) indicate that VR layout does not influence behaviour, and that consumers visit virtual worlds mainly for entertainment and socialising reasons.

More recently, whilst Kang's (2014) study on AR use for apparel e-shopping identified that consumers' utilitarian performance expectancy (e.g. convenience, emotional, monetary and social values) is positively related to usage intentions and hedonic performance, expectancy was not. Other studies show the impact of AR on users' experience, satisfaction, enhancement of the perception of reality and overall a fun, pleasant and personalised experience to be relevant for users (Poushneh and Vasquez-Parraga 2017). This was further supported by Pachoulakis and Kapetanakis' (2012) findings, where it emerged that AR used for virtual fitting rooms, through the user's computer or phone camera (allowing users to virtually see how a dress would fit on them through a virtual changing room from their homes—see Kumari and Bakan 2015; Kang 2014), was regarded as contributing to the 'fun factor' of shopping (Pachoulakis and Kapetanakis 2012).

An explosive growth of mobile AR subsequently occurred, taking advantage of widely distributed personal mobile technology such as smartphones and tablets (Craig 2013; Javornik 2016). This consists of a form of consumer-led interactions, personalisation, customisation and AR (Magrath and McCormick 2013), such as IKEA's AR app 'being able to measure the width and height of the real-life room seen through the camera's objective and then render a very accurate piece of furniture, in relation to the rest of the actual surrounding environment' (Tăbuşcă 2014, p. 5). Studies of mobile apps for shopping using AR indicate that take-up is set to go mainstream due to relatively high user satisfaction linked to experiential benefits along with advantages to retailers (Dacko 2016). Moreover, in-store large AR mirrors also constitute a form of AR application (Craig 2013). For example, US virtual technology company ModiFace has created an augmented reality mirror simulating the effects of makeup, skincare and teeth whitening products to offer consumer a more realistic try-before-you-buy shopping experience Podeszwa and Baron (2016). Similarly, fashion retailer Rebecca Minkoff's AR mirrors fit garments to the consumer's body shape by holding them up against the individual's body (McCormick et al. 2014).

Overall, Scholz and Smith (2016) stress the importance for retailers of adopting immersive AR, crafting experiences that generate value for consumers, and thus the importance of focusing on consumer engagement. Regarding VR, more recent research states that VR systems are failing to keep up with users' high standards and expectations in terms of user experience and usability (Alshaal et al. 2016). However, Papagiannidis et al.'s (2013) findings show that the use of VR transcends environmental boundaries, where enjoyment and engagement positively influence user satisfaction when choosing apparel products in a virtual store, thus influencing purchase intention. In particular, features of VR technologies help enhance the social experience, virtual trial of products and co-production opportunities (Gadalla et al. 2013). Amongst the latest applications, Tommy Hilfiger offers shoppers in their main flagship stores a 3-D virtual trip with a front-row view of the brand's fashion show to entertain and inspire consumers, highlighting items of the collection that they would see in the video of the runaway show (Tabuchi 2015). Users virtually sit not far from models, and the headset reacts to their movements: they can look in all directions; by turning around, they can see rows of guests almost touchable and moreover they can virtually go to the backstage area of the show (Howland2016). Beauty retailer Sephora created a virtual try-on feature app in selected stores which can simulate cosmetics on a person's face in real-time and 3D (Nesbit 2014). Results from Mann et al. (2015) showed that consumers respond to the use of VR technology in physical stores positively, in which VR delivers more appealing shopping experiences than traditional store environments.

2.2 The Interdisciplinary Nature of AR and VR Research

Drawing on the comparative timelines of AR and VR research in Fig. 1, it is important to analyse its various disciplinary origins. The interdisciplinary nature of the subject and different academic areas of research—ranging from technology to management and marketing—are evident. The fragmented nature of research into

AR and VR arguably emanates as a consequence of these different perspectives. Further exploration of this fragmented research context is needed to develop a future research agenda.

3 Current Debates in AR and VR Research and Applications

The above review of the chronological development of AR and VR research and applications in retail has served as a basis for synthesising and framing some key current debates in the field. These are structured in terms of *Adoption*, *Applications* and *Acceptance*. These areas are now examined in more detail to help shed light on the fragmented research to date, and hopefully assist managers in making informed decisions when designing their retailing and marketing strategies.

3.1 Retailers' Adoption *of AR and VR*

From this overview of the literature on AR and VR, contrasting perspectives emerged from retailers' adoption of these technologies. In some cases, challenges related to taking the risk and investing in these new forms of technology, without knowing exactly the expected generated profits, and against only the promise of implementation within the shopping experience, prevent several retailers from adopting them (Piotrowicz and Cuthbertson 2014). This is the case for VR, where some critics claimed that, although this technology helps enhance the in-store experience, it is more a tool to gain consumers' attention than a viable in-store solution. This is because it is costly and time-consuming (it takes a lot of floor space and resources and is only used by few shoppers a day), and most of the time helps only build the brand whilst generating minimal return on investment (Milnes 2016). Moreover, when a new technology is adopted and implemented by retailers, they should promote the new tool to make potential users aware of it and provide all necessary relevant information (Zagel 2016). Low level of technology expertise and commitment of employees and sales associates can also represent a challenge for retailers, especially where training is necessary to make sales associates comfortable with the new tools in order to communicate and promote them properly to potential users (Piotrowicz and Cuthbertson 2014).

Benefits also emerged from retailers' adoption of AR and VR, including overcoming operational barriers, saving time and cutting costs; for example, Sainsbury's use of VR technology to decrease development costs and improve the results of supermarket redesigns through an interactive VR headset (Sainsbury 1995). In other instances, the use of these advanced technologies by retailers helped enhance the shopping experience, across all retail channels. Indeed, Pantano (2015) suggests these technologies could contribute to creating new marketing experiences. This is particularly the case with product categories such as apparel. Here in particular, pure-play online retailers may have to compensate for some of the perceived disadvantages of selling online; thus not having a physical store consisting of design and tactile factors, such as merchandise that consumers can touch and try on to make comparisons of product quality, size and style. Finally, early adopters of new emerging AR and VR technologies benefit from being perceived as highly innovative and market leaders regarding the use of technologies by consumers and competitors (as in the case of both Burberry's and Rebecca Minkoff's use of AR mirrors), as opposed to merely keeping up with competition (Teo and Pian 2003; Pantano 2014).

3.2 AR and VR **Applications** *in Retail*

Current applications and implementation of AR include online use of personalised or non-personalised virtual models to virtually try on clothes and simulate product combinations (Lee et al. 2006). Virtual fitting rooms allow individuals to use their camera to virtually see how a dress would fit on them (Kumari and Bakan 2015; Kang 2014). Such functionality is offered by Zugara through the e-commerce solution 'Webcam Social Shopper', providing the ability to let consumers 'hold' different items of clothing up against themselves and see how they would look (Zugara 2015). Mobile apps constitute a form of consumer-led interactions and AR (Magrath and McCormick 2013). In-store use of AR is possible through digitally-enhanced mirrors, used for fitting purposes and to offer recommendations, personalised offers and product location in the store (Zagel 2016). UK fashion retailer Topshop, for instance, launched AR fitting rooms in selected stores for consumers' virtual trial of products; Bloomingdale's allows shoppers walking past its store to virtually try on glasses from the street by aligning glasses on the user's nose (Grinspan 2012). Amongst other VR devices currently being used by retailers, Sephora offers in-store virtual try on of cosmetics to enhance the shopping experience; VR headsets have been adopted by some fashion retailers including Tommy Hilfiger and Dior (Howland 2016)—the latter has installed Dior Eyes in selected stores to transport shoppers to 3D catwalk shows and virtually highlight the craftsmanship behind the creation of the products. VR creates experiences also in a home context, allowing consumers to shop from home by seeing the item and interacting with it. VR in online retailing is increasingly developing to substitute input devices (e.g. mouse, keyboard) with more natural user interactions (e.g. gestures such as tapping and swiping) to improve the user experience (Alshaal et al. 2016).

3.3 Consumers' Acceptance *of AR and VR*

Important reactions of consumers driving the acceptance and use of AR and VR systems emerged from this review. Consequently, relevant managerial implications can be derived, especially as technological progress and retailers' adoption of innovative technologies do not necessarily and always correspond to consumers' acceptance and usage of new forms of technology. Davis (1989) technology acceptance model (TAM), and its more recent extensions, has traditionally been considered a key tool to measure the discrepancy between the technological innovations which both consumers and organisations are expected to use, and those that they will accept and use. Amongst the key factors are the perceived usefulness of technology (PU) in enhancing the user's activity, and the perceived ease-of-use (PEOU) of using a particular system. Moreover, user's individual differences and characteristics and attitudes about the technology also act as external variables influencing a user's PU and PEOU (Gelbrich and Sattler 2014).

Consumers react positively to AR's entertaining and experiential value, interactivity, PU and contribution to speeding-up the processes of purchase decision-making, incorporating both its functional and hedonic roles (Huang and Liao 2015). In particular, consumers' levels of cognitive innovativeness play an important role in influencing their behaviours towards accepting and using AR. Here, consumers with high cognitive innovativeness put more emphasis on usefulness, aesthetics and service excellence presented by AR. Positive reactions emerged from the use of AR by online shoppers. AR helps decrease the perceived cognitive risk arising from the uncertainty of not seeing products, and their combinations. Moreover virtual interaction before buying online can deliver product information that closely resembles the information acquired from examining the product directly, thus stimulating mental imagery (Poncin and Mimoun 2014). Considering VR, results from Mann et al. (2015) highlight consumers' positive reaction towards VR technology in physical stores, enhancing the shopping experience, and thus making it more appealing than with traditional merchandising techniques. However, economic and social factors may inhibit consumers' acceptance, for instance relating to high costs and social acceptability associated with VR headsets. Overall, consumers' understanding of how to use new technology (and its working properly) is fundamental to obtain users' positive reactions that lead to the acceptance of technologies, as the opposite can reduce PU, PEOU, intuitiveness and lead to frustration and dissatisfaction (Lee et al. 2012).

4 Conclusion

The fragmented nature of academic and applied research on AR and VR has arisen as a consequence of the interdisciplinary nature of the subject and the different academic domains of research, ranging from technology, to marketing and management contexts. Based on a critical review and synthesis of the chronological development of key debates on AR and VR research and retail applications, it becomes possible to frame a future research agenda. Possible directions to better realise the potential of AR and VR in the retail context are outlined below.

Research indicates a need to develop more efficient and enhanced consumer-friendly shopping interfaces for the successful adoption and implementation of AR and VR in online retailing. Here, a shared understanding, and cooperation, between different disciplines (including Marketing, Retailing, Human-Computer Interaction, etc.) is key to designing effective virtual shopping environments (Vrechopoulos et al. 2004; Ballantine 2005). Collaboration between AR and VR technology providers and retailers also emerges as an important factor. Joining forces and skills to develop marketing and retailing strategies that effectively enrich and enhance consumers' shopping experience by comparing views, sharing insights and knowledge of consumers' characteristics towards acceptance of technology, dealing with barriers and requirements for implementation, needed innovations, market trends, etc. will be important (Dacko 2016; Poushneh and Vasquez-Parraga 2017). Conversely, some critics have claimed that although VR is helping enhance the in-store experience, there is a risk that it becomes more a tool for gaining consumers' attention than a viable in-store solution. Thus, it will only be adopted by a limited number of retailers (Javornik 2016), particularly as the technology is costly and time-consuming to implement while its return on investment may be minimal (Milnes 2016). Consequently, this is more likely to be a special technology for a small number of experience-driven retailers. Further research on how these phenomena are evolving and including different disciplines is needed to gain a fuller understanding.

Regarding consumers' acceptance of these advanced technologies, in 2016 Facebook founder Mark Zuckerberg predicted that future VR headsets would look like a normal pair of glasses (Lopez 2016). This could potentially increase uptake by a broader range of shoppers by making them more socially acceptable (e.g. discrete and subtle), useful, easy and natural to interact with, and even fashionably acceptable (Carmigniani et al. 2011; Poushneh and Vasquez-Parraga 2017). As for the near future, mobile technology offers a strong potential to be an important driver for consumer adoption of VR. Although consumers may currently be reluctant to purchase a VR headset, having the facility to view VR experiences and interact with products through their mobile devices will lower the barriers to adoption because they are already familiar and comfortable with the technology involved (Howland 2016). However, AR and VR advocates have acknowledged different challenges. From a security and privacy perspective, AR systems, although very advanced, at the same time do not protect the user's privacy, thus allowing others to access or see information (Carmigniani et al. 2011). This can be an advantage, as users do not need to wear or carry any extra viewing device, thus making the technology more acceptable; however, it represents a problem concerning privacy and security of information. AR and VR technologies are constantly evolving to enhance online retailing; however, further research is needed to assess consumers' evolving acceptance and usage of these technologies, examining whether perceived barriers concerning privacy, acceptability and price accessibility are likely to be overcome and the important managerial implications deriving from such insights.

Overall, this review offers a number of contributions. It provides a detailed and critical review and synthesis of the chronological developments in AR and VR research and their application in a retail context. It also synthesises and examines important and current debates on the subject across different domains. Consequently, it signposts a clearer framework for locating future research inquiry and it highlights a research agenda that could provide the catalyst for this process.

References

Alshaal, S. E., Michael, S., & Pamporis, A. (2016). *Enhancing virtual reality systems with smart wearable devices, mobile data management (MDM).* Paper presented at the 17th IEEE International Conference.

Ballantine, P. W. (2005). Effects of interactivity and product information on consumer satisfaction in an online retail setting. *International Journal of Retail & Distribution Management, 33*(6), 461–471.

Batiz, G. (2001). Virtual reality. *Warehousing Management, 8*(5), 31–32.

Brody, A. B., & Gottsman, E. J. (1999). *Pocket bargainfinder: A handheld device for augmented commerce.* Paper presented at the International Symposium on Handheld and Ubiquitous Computing.

Bulearca, M., & Tamarjan, D. (2010). Augmented reality: A sustainable marketing tool. *Global Business and Management Research: An International Journal, 2,* 237–252.

Burke, R. R. (2002). Technology and the customer interface: What consumers want in the physical and virtual store. *Journal of the Academy of Marketing Science, 30*(4), 411–432.

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.

Chou, H. J. (2009). The effect of experiential and relationship marketing on customer value: A case study of international American casual dining chains in Taiwan. *Social Behaviour and Personality, 37*(7), 993–1007.

Craig, A. B. (2013). *Understanding augmented reality: Concepts and applications*. Waltham: Morgan Kaufmann.https://books.google.co.uk/books?hl=en&lr=&id=7_O5LaIC0SwC&oi=fnd&pg=PP1&dq=Craig,+A.+B.+(2013).+Understanding+augmented+reality:+concepts+and+applications.+Newnes.&ots=LGEvsWzNka&sig=UhsvtKBUkM_Lak3SFoZ9i79a2EU#v=onepage&q&f=false.

Craig, A. B., Sherman, W. R., & Will, J. D. (2009). *Developing virtual reality applications: Foundations of effective design*. London: Morgan Kaufmann.

Dacko, S. G. (2016). Enabling smart retail settings via mobile augmented reality shopping apps, *Technological Forecasting and Social Change*. doi:org/10.1016/j.techfore.2016.09.032.

Dad, A. M., Barry, D., & Rehman, A. A. (2016). 3D servicescape model: Atmospheric qualities of virtual reality retailing. *International Journal of Advanced Computer Science and Applications, 7*(2), 25–38.

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

Fuchs, P., Moreau, G. & Guitton, P. (2011). *Virtual reality: Concepts and technologies*. CRC Press.

Gadalla, E., Keeling, K., & Abosag, I. (2013). Metaverse-retail service quality: A future framework for retail service quality in the 3D internet. *Journal of Marketing Management, 29* (13–14), 1493–1517.

Gelbrich, K., & Sattler, B. (2014). Anxiety, crowding, and time pressure in public self-service technology acceptance. *Journal of Services Marketing, 28*(1), 82–94.

Gold, L. N. (1993). Virtual Reality Now a Research Reality. *Marketing Research., 5*(4), 50–51.

Grinspan, I. (2012). *Try on sunglasses from the street in bloomingdale's new display.* Retrieved May, 2016, from http://ny.racked.com/2012/4/19/7728253/try-on-sunglasses-from-the-street-in-bloomingdales-interactive-display#4571298.

Howland, D. (2016). *The new realities of VR and retail.* Retrieved May, 2016, from http://www.retaildive.com/news/the-new-realities-of-vr-and-retail/414482/.

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.

Jiyeon, K., & Forsythe, S. (2008). Adoption of virtual try-on technology for online apparel shopping. *Journal of Interactive Marketing, 22*(2), 45–59.

Kang, M. J.-Y. (2014). Augmented reality and motion capture apparel e-shopping values and usage intention. *International Journal of Clothing Science and Technology, 26*(6), 486–499.

Kim, J., & Forsythe, S. (2008). Adoption of virtual try-on technology for online apparel shopping. *Journal of Interactive Marketing, 22*(2), 45–59.

Kumari, N., & Bakan, S. (2015). A real time virtual fitting room application. *International Engineering Research Journal (IERJ), 1*(4), 122–125.

Lee, H.-H., Fiore, A. M., & Kim, J. (2006). The role of the technology acceptance model in explaining effects of image interactivity technology on consumer responses. *International Journal of Retail & Distribution Management, 34*(8), 621–644.

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.

Leinfuss, E. (1996). Virtual worlds, real applications. *InfoWorld, 18*(48), 57–59.

Lohse, L. G., & Spiller, P. (1998). Electronic shopping: How do customer interfaces produce sales on the internet. *Communications of the ACM, 41*(7), 81–87.

Lopez, N. (2016). *Facebook says VR headsets will look like Ray-Bans in 10 years.* Retrieved May, 2015, from http://thenextweb.com/facebook/2016/04/12/facebook-says-will-vr-headsets-size-normal-glasses-next-10-years/#gref.

Magrath, V., & McCormick, H. (2013). Marketing design elements of mobile fashion retail apps. *Journal of Fashion Marketing and Management: An International Journal, 17*(1), 115–134.

Mann, M. K., Liu-Thompkins, Y., Watson, G. S., & Papelis, Y. E. (2015). *a multidisciplinary examination of 3d virtual shopping environments: Effects on consumer perceptual and physiological responses, ideas in marketing: Finding the new and polishing the old.* (752–755). Springer International Publishing,

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.

Milnes, H. (2016). *VR isn't scalable': Bursting the in-store digital tech bubble. Retrieved on* May, 2015, from http://digiday.com/brands/retailtech2016-vr-isnt-scalable-bursting-the-in-store-digital-tech-bubble/.

Nesbit, T. (2014). *Sephora's augmented reality mirror adds virtual makeup to customers' faces.* Retrieved May, 2016, from http://www.psfk.com/2014/06/sephora-augmented-reality-mirror-try-on-makeup.html?utm.

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.

Owyang, J. (2010). Disruptive technology—the new reality will be augmented. *Customer Relationship Management Magazine, 32*(2), 32–33.

Pachoulakis, I., & Kapetanakis, K. (2012). Augmented reality platforms for virtual fitting rooms. *The International Journal of Multimedia & Its Applications, 4*(4), 35.

Pantano, E. (2014). Innovation drivers in retail industry. *International Journal of Information Management, 34*(3), 344–350.

Pantano, E. (2015). *Successful technological integration for competitive advantage in retail settings*. IGI Global: US.

Papagiannidis, S., Pantano, E., See-To, E., & Bourlakis, M. (2013). Modelling the determinants of a simulated experience in a virtual retail store and users' product purchasing intentions. *Journal Of Marketing Management, 29*(13–14), 1462–1492.

Piotrowicz, W., & Cuthbertson, R. (2014). Introduction to the special issue information technology in retail: Toward omnichannel retailing. *International Journal of Electronic Commerce, 18*(4), 5–16.

Podeszwa, M. & Baron, K. (2016). *CES: ModiFace updates ar beauty makeover tool.* Retrieved January, 2016 from http://blog.decodedfashion.com/stories/ces-modiface-updates-ar-beauty-makeover-tool.

Poncin, I., & Mimoun, M. S. B. (2014). The impact of "e-atmospherics" on physical stores. *Journal of Retailing and Consumer Services, 21*(5), 851–859.

Poushneh, A., & Vasquez-Parraga, A. Z. (2017). Discernible impact of augmented reality on retail customer's experience, satisfaction and willingness to buy. *Journal of Retailing and Consumer Services, 3,* 229–234.

Reitmayr, G. & Drummond, T. (2006). Going out: robust model-based tracking for outdoor augmented reality, *Proceedings of the 5th IEEE and ACM International Symposium on Mixed and Augmented Reality*.

Sainsbury (1995). Sainsbury's wins race to develop world's first virtual reality supermarket. *Assembly Automation*, 15(4):5–10.

Scholz, J., & Smith, A. N. (2016). Augmented reality: Designing immersive experiences that maximize consumer engagement. *Business Horizons, 59*(2), 149–161.

Sherman, W. R., & Craig, A. B. (2002). *Understanding virtual reality: Interface, application, and design*. San Francisco: Elsevier.

Sivaramakrishnan, S., Wan, F., & Tang, Z. (2007). Giving an 'e-human touch' to e-tailing: The moderating roles of static information quantity and consumption motive in the effectiveness of an anthropomorphic information agent. *Journal of Interactive Marketing, 21*(1), 60–75.

Slater, M., & Wilbur, S. (1997). A framework for immersive virtual environments (FIVE): Speculations on the role of presence in virtual environments. *Presence: Teleoperators and virtual environments, 6*(6), 603–616.

Sukaviriya, N., Podlaseck, M., Kjeldsen, R., Levas, A., Pingali, G. & Pinhanez, C. (2003). Augmenting a retail environment using steerable interactive displays, *Extended Abstracts on Human Factors in Computing Systems*, 978–979.

Summerour, J. (2001). Virtual reality. *Progressive Grocer, 80*(8), 25–28.

Tabuchi, H. (2015). *Tommy Hilfiger introduces virtual reality headsets for shoppers.* Retrieved February, 2015, from http://www.nytimes.com/2015/10/21/business/tommy-hilfiger-introduces-virtual-reality-headsets-for-shoppers.html.

Tăbușcă, A. (2014). Augmented reality–need, opportunity or fashion'. *Journal of Information Systems & Operations Management, 8*(2), 5–10.

Teo, T. S. H., & Pian, Y. (2003). A contingency perspective on Internet adoption and competitive advantage. *European Journal of Information Systems, 12*(2), 78–92.

Vrechopoulos, A. P., Keefe, R. M. O., Doukidis, G. I., & Siomkos, G. J. (2004). Virtual store layout: an experimental comparison in the context of grocery retail. *Journal of Retailing, 80*(1), 13–22.

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

Whyte, J. (2002). *Virtual reality and the built environment*. San Francisco: Routledge.
Williamson, M. (1996). Virtual shopping takes stage at retail show. *Computing Canada, 22,* 20–22.
Woods, A. (2009). Augmented reality: Reality check. *Revolution Magazine, 1,* 36–39.
Zagel, C. (2016). *Service fascination*. Germany: Springer Fachmedien Wiesbaden.
Zugara (2015). *The webcam social shopper (WSS).* Retrieved April, 2015, from http://zugara.com/virtual-dressing-room-technology/webcam-social-shopper#prettyPhoto[]/3/.

Technological Innovations Transforming the Consumer Retail Experience: A Review of Literature

Natasha Moorhouse, M. Claudia tom Dieck and Timothy Jung

Abstract Technological advancements are largely responsible for the intensified competitiveness within the industry and the shift in consumers shopping and buying behavior. Global trends such as mobile devices and social media have led to a revolutionary change that has driven the decline in traditional 'brick and mortar' footfall, leading to the unfortunate failure of long-standing retailers that once dominated our high streets. Despite survival to date, current retail firms remain with high pressure to change strategy to connect with the digital natives of today. The integration of online and physical worlds must focus on promoting the experiential benefits that the in-store environment provides by integrating emergent technologies into the entire retail process. The following paper provides an insight into current technological innovations that are transforming the consumer experience in a myriad of ways. Then, recommendations for practitioners regarding strategic implementation of future Augmented Reality (AR) and Virtual Reality (VR) technologies are presented, followed by an overview of future implications of said technologies.

Keywords Retail · Technology · Augmented reality · Virtual reality · Consumer experience · Innovation

N. Moorhouse (✉) · M.C. tom Dieck · T. Jung
Manchester Metropolitan University, Faculty of Business and Law, Manchester, UK
e-mail: natasha.moorhouse@stu.mmu.ac.uk

M.C. tom Dieck
e-mail: c.tom-dieck@mmu.ac.uk

T. Jung
e-mail: t.jung@mmu.ac.uk

T. Jung and M.C. tom Dieck (eds.), *Augmented Reality and Virtual Reality*,
Progress in IS, DOI 10.1007/978-3-319-64027-3_10

1 Introduction

Technological innovations have the potential to dramatically modify the retail landscape (Hopping 2000). The mobile revolution transformed the ways consumers search for, and purchase goods and services, and the retail sector is now characterised by exploration of innovative methods to amplify the consumer experience and consumer satisfaction through emergent technology integration into the entire retail process (Pantano et al. 2017). However, certain technological platforms present challenges for retailers when the technology becomes the central *foci* of the experience, thus, implying that paradoxical experiences with technologies could potentially have adverse effects on retailers marketing efforts.

Therefore, the following study investigates the key opportunities and challenges of current technological innovations in terms of consumer response, including mobile, in-store, and emergent technologies. Followed by an exploration of how the challenges can be overcome, and such knowledge extended to strategically implement future Augmented Reality (AR) and Virtual Reality (VR) technologies to further enhance the consumer retail experience. The study contributes to the extensive research in the respective fields, and provides an overview for practitioners regarding consumer response of existing technological innovations and marketing efforts; further highlighting how future AR and VR technologies can be strategically implemented to create human-led, socially engaging and entertaining experiences, as demanded by the digitalised population. Finally, a number of forecasts and implications are presented regarding AR and VR developments, followed by recommendations for academia regarding future consumer research.

2 Literature Review

2.1 Current Technological Innovations Transforming the Consumer Retail Experience

Mobile Technologies

The mobile revolution has driven the change from multi-channel to omni-channel retailing. This created a notable shift from the division of physical and online retailing to the free movement amongst online, mobile and the physical store within a single transaction process (Piotrowicz and Cuthbertson 2016). Few benefits of mobile devices include portability and ubiquity (Pantano et al. 2017). Consumers are no longer restricted by store opening hours due to the widespread adoption of mobile devices, shifting traditional space and time boundaries (Bourkalis et al. 2009), by empowering consumers with increased flexibility and control over when, where and how they select and purchase goods and services (Niemeier et al. 2013; Piotrowicz and Cuthbertson 2016).

Nowadays, 80% of internet users worldwide use their mobile device to browse online (Chaffey 2016), whilst global spending on mobile applications has risen from $4 billion to $35 billion from 2009–2015 (Statista 2016a). Evidently, consumers want to use their own, personal devices to search for price comparison, search for offers and product information, execute payments seamlessly, and learn from previous customer reviews (Yarrow 2014). Regarding the latter, social media and online retail websites that are easily accessible on mobile devices provide the ideal platform for social interaction, thus, providing a hub where consumer product and service reviews are shared and easily amplified to a wider audience (Niemeier et al. 2013).

Popular social media sites such as Facebook and Twitter allow consumers to share and express thoughts and opinions on products and services at any point throughout the retail process (Niemeier et al. 2013). The ability to share satisfaction or dissatisfaction with the brand in real-time in-store presents challenges for retailers that often lack control over the consumers social network influence (Piotrowicz and Cuthbertson 2016); and negative reviews in an online community affects brand credibility, brand perception, customer loyalty, sales and share price (Niemeier et al. 2013). Considering Facebooks somewhat 1.5 billion monthly active users (Statista 2016b), it is crucial for firms to build online relationships with consumers to encourage positive promotion and product rating (Piotrowicz and Cuthbertson 2016). This is because the customer "serves as a medium between herself or himself and the wider social media network, which is maintained even in in-store environments via mobile devices" (Piotrowicz and Cuthbertson 2016, p. 9).

The moment of effective consumption is now separated from the moment of purchase because of services such as click-and-collect (Pantano et al. 2017). Consumers can complete transactions on their mobile device, via mobile application or web browser, later collecting in-store or at a collection point, thus, limiting the opportunity for human interaction and communication (Pantano et al. 2017). A ubiquitous network that consumers can access from anywhere at any time enables a high level of connectivity and ease of purchase, which is beneficial for both consumer and retailer (Pantano et al. 2017). However, Piotrowicz and Cuthbertson (2016) state that online and mobile solutions should be utilised to drive consumers to physical stores and encourage human interaction. In doing so, the retailer retains a sense of control over the experience, and can resolve any issues that may arise, prior to posting negative reviews which can be seen by the masses.

In-store Technologies

Retailers have notably integrated technologies in-store as a method to attract new and existing markets and create an efficient service process. For instance, the integration of self-service technologies (SST's) into the retail process i.e. self-scanning and self-checkout (SCO) that allow consumers to scan products and make payments themselves (Nathalie et al. 2016), have emerged as a method to support the retail process (Lai and Chuah 2010), by reducing queuing time, and avoiding consumers becoming increasingly irritated and agitated (Yarrow 2014).

Retailers are continuously encouraging consumers to adopt emergent technologies (Pantano et al. 2017), to improve the consumer experience and elevate the consumers image of the store (Yarrow 2014). In addition, more modern payment solutions i.e. Samsung Pay and Apple Pay, and digital wallets providing seamless linkage between mobile devices and payment cards, are forecast for mainstream adoption (Taylor 2016); with the number of global mobile payment users forecast to amount to 663.8 million by 2021 (Statista 2016c).

However, whilst consumers enjoy the benefits that technologies such as SST's provide, they often experience a sense of annoyance and irritation when it fails to perform or problems are encountered (Johnson et al. 2008). This implies that paradoxical experiences with technologies could potentially have adverse effects on consumer satisfaction, impairing the effectiveness of firms marketing strategies and consumer loyalty (Johnson et al. 2008). Subsequently, raising concern and questioning the effectiveness of technologies on the consumer retail experience; thus, certain US-retailers have removed SCO's to promote human interaction and allow for a more enhanced, personalised customer experience (Nathalie et al. 2016).

Despite such efforts to attract and retain consumers, footfall in physical retail stores has declined, which has led retailers including BHS and American Apparel head into administration as they struggle for survival in the hugely competitive marketplace (Retail Research 2016). Retailers rapidly need new methods to entice consumers back in-store, by engaging consumers in the co-creation of interactive and innovative, personalised experiences that integrates and synthesises physical retail settings with mobile opportunities (Pantano et al. 2017). Considering the digitalised population, it is inevitable that retailers are looking towards emergent technologies to attract consumers in-store. The most recent technologies gaining recognition by retailers are AR and VR. AR is an interactive technology that intertwines the physical environment and digital environment by overlaying virtual annotations such as information, images and audio in real time (Javornik 2016a); whilst VR fully immerses users into a digital world (McKone et al. 2016).

Emergent Technologies

Labelled as a 'disruptive' technology, similar to the disruption created by the smartphone and the internet, VR allows for a new form of worldwide communication through HMD (Head Mounted Displays) such as Oculus Rift, HTC Vive, and Samsung GearVR (Rosedale 2017). Whilst the consumer market demands increased quality such as high-resolution displays, lightweight, compact, as well as reduced cost (Rosedale 2017), VR has many barriers as consumers are not yet familiarised with wearing HMD's (McKone et al. 2016). Having said that, VR has been found useful in a wide range of industries including gaming, retail, business and education (Rosedale 2017), and in tourism, VR has been found to engage tourists and encourage them to visit destinations (Jung et al. 2017). Finally, the revenue of VR products is projected to reach \$5.2 billion by 2018 (Statista 2016d).

In the retail context, the aim of AR is to create immersive brand experiences, interactive marketing campaigns, and innovative product experiences for consumers

(Scholz et al. 2016). A popular method for AR is mobile devices, which makes it the ideal platform for retailers aiming to connect with consumers and the growing popularity of mobile devices. Currently, consumers utilise mobile devices in-store to perform price and product comparison to find a cheaper alternative whilst shopping in-store via bar code scanning or internet search (Piotrowicz and Cuthbertson 2016). However, by implementing mobile AR in-store, the shopping experience is enhanced as consumers can easily access enriched product information compared with both online and physical stores without AR (Poushneh and Vasquez-Parraga 2017). In addition, purchase certainty increases due to the ability to see virtual product demonstrations in-store, which is a unique value of AR as perceived by consumers (Dacko 2016). For example, Lego stores are using AR to project an animated version of the completed Lego set inside the box prior to purchasing to increase brand engagement and purchase certainty (Kipper and Rampolla 2013). Overall, consumers are motivated to use AR applications to enhance real world shopping experiences and to access promotions and in turn, retailers benefit from increased profits and competitiveness in such a dynamic industry (Poushneh and Vasquez-Parraga 2017).

Beyond retail, AR is available to consumers in a multitude of ways such as mobile navigation applications, tour guides (Javornik et al. 2016), and language translation (Kipper and Rampolla 2013), as well as an innovative learning tool in cultural heritage tourism (Moorhouse et al. 2017). Furthermore, the AR market is forecast to generate $90 billion in revenue by 2020 (Statista 2016e).

Industry Applications of AR and VR

Furniture stores such as IKEA and Wayfair have adopted AR applications because of its ability to measure the physical environment and apply the graphic overlay accordingly (Young 2016). By enhancing consumers' visualisation of furniture coordination the product experience and decision-making process is significantly enhanced (Oh et al. 2008). In addition, AR-enriched user experiences increases consumer satisfaction and willingness to purchase (Poushneh and Vasquez-Parraga 2017). Likewise, virtual try-ons such as the 'Magic Mirror' focus on a new form of AR that uses motion capture techniques to superimpose virtual annotations, such as make-up or accessories, over the users' real image, seeking to create a truly realistic visionary as opposed to a superimposed digital image (Javornik et al. 2016).

Moreover, car manufacturers such as BMW, Mini and Nissan, are leading the way in creative car advertisements by implementing AR into the company magazine, users can access a 3D projection of the car being advertised (Kipper and Rampolla 2013). Such studies portray how technology is rapidly progressing and highlights the power of most recent developments in explaining, configuring and recommending products (Rese et al. 2016). Beyond consumer engagement, certain companies are using AR technology to evaluate the impact of marketing ads and campaigns by tracking user behaviour, location, and interaction patterns in real time (Liao 2015). By analysing consumer browser and shopping behavior practitioners gain valuable information for new product development and marketing strategies (Oh et al. 2008).

With regards to VR, leading fashion retailers have recently adopted VR applications with an aim to provide memorable and innovative experiences for consumers for both at-home and in-store use. For instance, Balenciaga broadcast its Autumn-Winter 2016 show in VR, whilst Dior has created its own VR headset (Young 2016). Moreover, VR has opened up new horizons for online furniture retailers, which was one industry found to be lagging behind following the rapid growth of e-commerce, as VR allows consumers to experience products in a realistic environment, as well as collect efficient information prior to visiting a physical store (Oh et al. 2008).

The present use of VR is enabling 360-degree view mainly for entertainment, however, it also provides the opportunity to create virtual worlds that allows users to interact with one another in an incredibly lifelike manner due to the ability to capture eye-movement and facial expressions (Rosedale 2017). Such developments could see virtual business meetings with international colleagues made accessible through HMD's; a disruptive change that could impact global change by minimising business travel which currently accounts for 30% global energy use (Rosedale 2017). Despite the unfamiliarity of consumers wearing VR headsets (McKone et al. 2016), the social aspect of VR could be the trigger for mainstream adoption.

3 Challenges and Opportunities for Integrating Technological Innovations

The rapid progression of technological innovations, in particular the explosive growth of mobile devices, has transformed the retail industry in numerous ways. The shift in consumer shopping and buyer behavior has presented new challenges and invaluable opportunities for retailers to connect with the digitalised population. From reviewing the success and consumer response of existing technological platforms, a number of prerequisites of successfully employing future AR and VR technologies into the retail experience have arisen.

3.1 Social Engagement and Connectivity

First, the proliferation of mobile devices and social media platforms have retracted firms power and control of marketing and advertising, and consumers are more likely to listen to previous customer reviews over the firm. As Yarrow (2014) previously identified, online browser and social media behaviour is a key determinant in understanding individuals' feelings and beliefs. Therefore, firms must build on their social media presence and interact with consumers through mobile and social platforms, and a number of retailers have recognised the opportunity of AR in doing so. Thus, it is critical that new AR developments offer mobility and sociability, as well as provide direct linkage to social media applications, in order to establish a positive relationship with the digitalised population. In doing so, retailers will strategically utilise consumers as a form of marketing and advertising, whilst maintaining a strong social media presence and connectivity to the broader population, thus attracting new markets.

Furthermore, Dacko (2016) found that retail valuations increase substantially the more mobile AR applications are used in-store due to the creation of experiential shopping benefits. For example, mobile AR in-store encourages consumers to instantly share personalised experiences to the online community, is perceived as 'playful' and 'credible', and has the potential to be a driver for future behaviour (Javornik 2016b). The sharing of enchanting experiences online promotes positive brand image to the online community and will attract new markets in-store to try the innovative technology. Finally, the additional information and virtual product demonstration will contribute to increased sales and purchase certainty (Dacko 2016).

3.2 Human Interaction and Communication

Secondly, the need for human interaction and communication is needed when integrating emergent technologies, as unfamiliarity with said technologies often leaves consumers apprehensive about trying them due to fear of incapability and usage complexity. Drawing on consumer response to previous technologies employed to support the retail process, marketers, technology developers and retailers can learn a vast amount in terms of future AR and VR developments. Neuhofer et al. (2015) argue that it remains critical for businesses to exploit and integrate emergent technologies into its entire strategy, although substituting human encounters with technologies should be avoided. For example, friendly salespersons should remain available to assist less-experienced consumers with the use of SST's to extend the consumer experience rather than act as a barrier (Nathalie et al. 2016; Piotrowicz and Cuthbertson 2016). Similarly, future AR and VR technologies should refrain from being "an isolated screen in a dark corner", rather, such technologies should fully interact consumers and employees (Piotrowicz and Cuthbertson 2016, p. 5).

Additionally, clear instructions, video demonstrations and payment compatibility are crucial determinants of consumers' perceptions of their ability and willingness to use SST's (Nathalie et al. 2016), which could further be applied to AR and VR, as relatively new forms of technology, consumers are not yet familiarised with using the devices, which may refrain consumers from adoption as previously mentioned. Likewise, Javornik (2016) found that the success of new AR technologies depends on consumers comfortability with trying the device, and that employees must understand how to entice consumers to the application and encourage them to use it (Javornik 2016). The solution is to strategically implement technologies by equipping employees with AR and VR technologies that enhance human-led service and experience creation processes (Neuhofer et al. 2015).

4 Discussion and Conclusion

Many retail firms waste time and monetary value on their marketing division due to lack of consumer understanding. This research creates insights into the prerequisites of new technology development by distinguishing the need for social engagement and human interaction and communication via mobile and in-store technologies, further highlighting the importance of ubiquitous connectivity when developing and integrating future technologies. The elements have been determined by reviewing current technologies that continue to transform the retail industry, and have provided a number of recommendations for practitioners aiming to integrate AR and VR. Finally, a review of scholarly predictions of AR and VR usage have been proposed, followed by recommendations for academia in terms of future consumer research.

Both AR and VR have the potential to create a more differentiated and personalised consumer retail experience (McKone et al. 2016). The majority of internet users worldwide are expected to be utilisng VR headsets on a daily basis within the next 7–10 years (Rosedale 2017). The ability to interact with one another in virtual worlds has the potential to open up a plethora of opportunities for retailers to connect with consumers from the comfort of their own home (Rosedale 2017). The future could see retail departments such as customer service providing an outstanding level of customer care and assistance through personalised VR experiences, whereby arising concerns can be immediately resolved in novel ways, limiting the risk of negative exploitation to the masses via web or social media. In turn, firms gain back an element of control over the consumer experience, which was initially superseded by the proliferation of mobile devices and the empowerment of consumers increased flexibility and control (Niemeier et al. 2013; Piotrowicz and Cuthbertson 2016).

To date, it seems that AR is favored for in-store use given the adoption of AR by leading brands IKEA, Lego, BMW, Nissan and Micra (Young 2016; Kipper and Rampolla 2013). Pantano et al. (2017) suggest that retailers favor AR due to its ability to synthesise personal mobile devices with existing retail settings. Hence, the marketing investment in AR is expected to grow exponentially as marketers configure innovative ways to deploy the technology (Liao 2015). In order to further the power of AR, new developments should interact the consumer and the employee and serve to deliver unique and personalised experiences (McKone et al. 2016), which will ensure avoidance of paradoxical experiences occurring.

Furthermore, AR and VR are forecast for mainstream adoption within the next five years (Dacko 2016; Rosedale 2017), and are expected to replace desktop and mobile displays for the majority of tasks completed on them today (Rosedale 2017). The future could see physical retail stores transform to acting as a 'hub' integrating all technologies and sales channels (Piotrowicz and Cuthbertson 2016). The development and implementation of a mixed realities (AR and VR) model has the power to significantly change consumers' view of retailers in the future (McKone et al. 2016).

The present review makes a number of contributions. First, it provides a critical insight into the most powerful technological innovations that are transforming the retail industry and consumers shopping and purchase behaviour. This highlights the importance of understanding consumer response to emergent technologies, and offers practitioners the opportunity to further extend and apply such knowledge in the development of future technologies. In addition to this, the review provides a projection of future AR and VR developments, which indicates the importance of firms in rapidly configuring a mixed realities model. Secondly, the identification of two crucial elements that future technologies must entail if they are to be accepted by the digitalised population are discussed, and recommendations have been established for practitioners' implementation.

Furthermore, it is crucial to continuously conduct consumer research and monitor response to new technologies to limit firms wasted marketing efforts. This is particularly important considering that there is only limited evidence with regards to successful business models and return on investments. Finally, field experiments regarding AR and VR are needed to test new concepts and identify new prerequisites as consumer demands continue to change. Research should therefore investigate the topic from the technology acceptance perspective by exploring consumers' willingness to purchase.

References

Bourkalis, M., Papagiannidis, S., & Li, F. (2009). Retail spatial evolution: Paving the way from the traditional to metaverse retailing. *Electronic Commerce Research., 9*(1), 135–148.

Chaffey, D. (2016). *The state of mobile marketing 2016*. Smart Insights: Actionable Marketing Advice.

Dacko, S. G. (2016). Enabling smart retail settings via mobile augmented reality shopping apps. *Technological Forecasting and Social Change, 1,* 1–14.

Hopping, D. (2000). Technology in Retail. *Technology in Society, 22*(1), 63–74.

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

Javornik, A. (2016b). "It's an illusion, but it looks real!" consumer affective, cognitive and behavioral responses to augmented reality applications. *Journal of Marketing Management,* 987–1011.

Javornik, A., Rogers, Y., Moutinho, A. M., & Freeman, R. (2016). Revealing the shopper experience of using a 'Magic Mirror' augmented reality make-up application.

Johnson, D. S., Bardhi, F., & Dunn, D. T. (2008). Understanding how technology paradoxes affect customer satisfaction with self-service technology: The role of performance ambiguity and trust in technology. *Psychology & Marketing, 25*(5), 416–443.

Jung, T., tom Dieck, M. C., Moorhouse, N., & tom Dieck, D. (2017, January). *Tourists' experience of virtual reality applications*. Paper presented at the IEEE International Conference on Consumer Electronics. Las Vegas.

Kipper, G., & Rampolla, J. (2013). *Augmented reality, an emerging technologies guide to AR*. US: Elsevier.

Lai, P. M., & Chuah, K. B. (2010). Developing an analytical framework for mobile payments adoption in retailing: a supply-side perspective. *Proceedings of International Conference on Management of e-Commerce and e-Government*, 356–361.

Liao, T. (2015). Augmented or admented reality? The influence of marketing on augmented reality technologies. *Information, Communication & Society, 18*(3), 310–326.

McKone, D. Haslehurst, R. & Steingoltz, M. (2016). Virtual and augmented reality will reshape retail. *Harvard Business Review,* 2–1.

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. 8*:1–5.

Nathalie, T. M. D., & Djelassi, S. (2016). An integrated model of self-service technology (SST) usage in a retail context. *International Journal of Retail and Distribution Management, 44*(5), 540–559.

Neuhofer, B., Buhalis, D., & Ladkin, A. (2015). Smart technologies for personalized experiences: a case study in the hospitality domain. *Electron Markets, 1,* 243–254.

Niemeier, S., Zocchi, A., & Catena, M. (2013). *Reshaping retail: Why technology is transforming the industry and how to win in the new consumer driven world.* Wiley and Sons Ltd.

Oh, H., Yoon, S., & Shyu, C. (2008). How can virtual reality reshape furniture retailing? *Clothing and Textiles Research Journal, 26*(2), 143–163.

Pantano, E., Priporas, C. V., Sorace, S., & Iazzolino, G. (2017). Does innovation-orientation lead to retail industry growth? empirical evident from patent analysis. *Journal of Retailing and Consumer Services, 1,* 88–94.

Piotrowicz, W., & Cuthbertson, R. (2016). Introduction to the Special issue information technology in retail: Toward omnichannel retailing. *International Journal of Electronic Commerce, 18*(4):5–15.

Poushneh, A., & Vazquez-Parraga, A. Z. (2017). Discernible impact of augmented reality on retail customer's experience, satisfaction and willingness to buy. *Journal of Retailing and Consumer Services, 34,* 229–234.

Rese, A., Baier, D., Geyer-Schulz, A., & Schreiber, S. (2016). How augmented reality apps are accepted by consumers: A comparative analysis using scales and opinions. *Technological Forecasting & Social Change,* 1–14.

Retail Research. (2016). *Who's gone bust in retailing 2010–2016? centre for retail research.* Retrieved, December, 2016, from http://www.retailresearch.org/whosegonebust.php.

Rosedale, P. (2017). Virtual reality: The next disruptor: A new kind of worldwide communication. *IEEE Consumer Electronics Magazine, 6*(1), 1–5.

Scholz, J., & Smith, A. N. (2016). Augmented reality: Designing immersive experiences that maximize consumer engagement. *Business Horizons, 59,* 149–161.

Statista, (2016a). *Global spending on mobile apps from 2009–2015 (in billion U.S. dollars).* Retrieved January, 2017, from https://www.statista.com/statistics/236519/global-spending-on-mobile-apps-since-2009/.

Statista, (2016b). *Global social network penetration rate as of January 2016, by region*. Retrieved January, 2017, from https://www.statista.com/statistics/269615/social-network-penetration-by-region/.

Statista, (2016c). *Mobile Payments.* Retrieved January, 2017, from https://www.statista.com/outlook/331/100/mobile-payments/worldwide#market-users.

Statista, (2016d). *Forecast revenue for virtual reality products* worldwide from 2014 to 2018 (in million U.S. dollars).* Retrieved January, 2017, from https://www.statista.com/statistics/426276/virtual-realiy-revenue-forecast-worldwide/.

Statista, (2016e). *Forecast augmented and virtual reality market revenues worldwide from 2016–2020.* Retrieved January, 2017, from https://www.statista.com/statistics/612845/global-augmented-virtual-reality-revenue/.

Taylor, E. (2016). Mobile payment technologies in retail: a review of potential benefits and risks. *International Journal of Retail and Distribution Management, 44*(2), 159–177.

Yarrow, K. (2014). *Decoding the new consumer mind. How and why we shop and buy……..* : Jossey-Bass.

Young, S. (2016). *Virtual diamonds and Dior Eyes: Could augmented reality be about to revolutionise fashion retail?* Retrieved January, 2017, from http://www.independent.co.uk/life-style/fashion/augmented-reality-virtual-reality-fashion-retail-a7425076.html.

Measuring Consumer Engagement in the Brain to Online Interactive Shopping Environments

Meera Dulabh, Delia Vazquez, Daniella Ryding and Alex Casson

Abstract Online shopping environments are becoming more interactive as technology advances. As a result, it is necessary to explore marketing theories and neuro scientific explanations to why this is the case. A reviewed approach of consumer engagement to online interactive shopping environments is considered in this chapter. The online interactive elements of traditional fashion websites that are considered includes; social media, browsing and videos. Measurements of consumer engagement are reviewed via marketing consumer engagement theories (CE) and a cognitive neuroscience technique using an Electroencephalogram (EEG) (A non-invasive procedure measuring the brain's electrical activity). ASOS.com, the U.K. top fashion online pure player, is used as a preliminary research study, the results demonstrate that engagement is significantly different in social media, video and browsing tasks and browsing for jackets online elicits more engagement. Originality of this research stems from the novel way to look at engagement and the ability to combine traditional and non-traditional marketing methods thus addressing emerging fields of the future such as virtual shopping.

Keywords Online Interactivity · Consumer Engagement · EEG

M. Dulabh (✉) · D. Vazquez · D. Ryding · A. Casson
Department of Design, Fashion & Business, University of Manchester, Manchester, UK
e-mail: meera.dulabh@manchester.ac.uk

D. Vazquez
e-mail: delia.vazquez@manchester.ac.uk

D. Ryding
e-mail: daniella.ryding@manchester.ac.uk

A. Casson
e-mail: alex.casson@manchester.ac.uk

T. Jung and M.C. tom Dieck (eds.), *Augmented Reality and Virtual Reality*,
Progress in IS, DOI 10.1007/978-3-319-64027-3_11

1 Introduction

Retail consumers are increasingly browsing and purchasing fashion items online. Store based retailers have prioritised internet retailing as a growth channel to which 90% of store based retailers in the UK have transactional websites (Euromonitor 2011). In the consumer market of 2015, total online sales of fashion products were £42.5 billion (Inc VAT) (Mintel 2016a). These consumers tend to shop on a computer (89%) or smartphone (41%) (Mintel 2016a). A majority of retailers are becoming internet only specialists with no physical store presence also known as pure-play internet retailers (Euro Monitor International 2011). A leading UK fashion pureplay retailer is that of ASOS.com who have brought in a revenue of £7 M in 2016 (Statista 2017) and is considered the most interactive fashion website consisting of 8 million consumers in over 200 countries (Mintel 2014). In fact Snap Chat (a user generated social media channel) is being constantly used by ASOS as they post from it several times per week for young consumers aged 16–24 (Mintel 2016b). Those that use these channels are millennials who are the keenest shoppers in this generation as most use six or more retailers per year to shop in online and in store (52%) (Mintel 2016b). This goes to show that “Kids are getting older younger” with the current technological age in 2017 being generation Z born in the years 1991–2002 (Euromonitor International 2014). With that 70% of these shoppers are females (Skorupa 2012).

User Generated trends in social media: Twitter, Whatsapp, Facebook, Snapchat, Instagram and blogs evidences the current succession in web 3.0 (social, semantic, sentient and mobile web), progression to web 4.0 (integration of intelligent systems) and an end goal to create a Virtual Reality (VR) metaverse (everything 2D in web 1.0, 2.0, 3.0 and 4.0 will be streamlined in 3D via VR) (KPMG 2017). That being said, Virtual Reality and Augmented Reality (AR) projects which are forecasted to be used in the future with £650M worth of hardware sales in 2016, currently have a high commercial focus on video games (Mintel 2016a; Deloitte Global 2017). A recent study showed that 58% of digital consumers think that shopping with technology would be more fun with 30% of the sample forecasting fitting rooms with interactive mirrors for the future and only 10% forecasting VR shopping for the future (Mintel 2016b). An example of this would be the augmented reality app Pokemon Go which included Pokestops in retailer New Look likewise North Face used virtual reality for outdoor activities to promote their outdoor gear (Mintel 2016b). Due to the demand in consumer expenditure online in particular, consumer testing via biometric methods in both the online retail and VR domains is necessary as most research currently assessing consumer behaviour comes from surveys (Klienschmit et al. 2012).

For retailers to keep up with changing demands of the consumer and technology, it is necessary to investigate what constitutes as an interactive in order to sustain a competitive advantage. With this in mind the chapter is structured with a mentioning of online interactive environments with a focus on videos, social media and browsing content of websites. Once this is reviewed, measuring consumer behaviour to these interactive environments is considered. Engagement is the behaviour that has been chosen to be measured due to the strong support in marketing and neuroscience journals evidenced in Sects. 3 and 4. Finally in Sect. 5 all of this is put together in a preliminary study using these three interactive environments (from ASOS.com) and measuring electrical brain responses to this stimuli. Its further suggested that this technique can be used in the newly emerging platform of virtual reality shopping.

2 Online Interactivity

2.1 Introduction

As interactive environments have evolved with time, an extended breadth of choice for the consumer has emerged in the form of desktops, laptops, mobile apps, apple watches or a combination of all of these which leads to the question, do consumers want online interactive environments? Only if the interactivity pays off (Steckel et al. 2005). The fact that we are unable to touch and see physical features of products online gives us many choices of product to choose from. Having all this of choice is desirable, but, consumers have limited cognitive resources and may be unable to process this abundance of information (Habul and Trifts 2000). Therefore, interactive decision aids can help combat this problem to which consumers can make better decisions with less effort (Habul and Trifts 2000). Benefits to online interactivity includes having more access to information, customisation of product and content, and availability of tools to help the information acquisition process (Steckel et al. 2005; Haubul and Trifts 2000) and includes four features; reciprocity, responsiveness, nonverbal information and speed of response (Yoo et al. 2015). Online interactivity is influenced by web atmospherics constituting to the conscious designing of web environments to create positive reactions in consumers (Daily 2004; Manganari et al. 2009) and influences users engagement with the website by expanding their perceptual bandwidth such as psychological arousal on cognitive functioning (Kahnerman 1973; Xu and Sundar 2014), (Manganari et al. 2009) devise an “Online Store Environment Presentation Framework” in which they split their research into four components; virtual layout and design, virtual atmospherics, virtual theatrics and virtual social presence.

2.2 Virtual Social Presence

Virtual social presence is a way that consumers can communicate with friends, family or the general public when online. Common themes of this include electronic word of mouth and virtual communities (Manganari et al. 2009), Morandin

(2013) makes sense of virtual communities by expressing it as “A way in which consumers find meaning in their lives through joint experience with a brand with friends in a brand community”. Virtual communities enable members to post articles, reviews and product recommendations with feedback from other members (Gearhart and Zhang 2014). Product recommendations through virtual communities allows the provision of consumer trust (Hsaio et al. 2010). Websites of “Facebook.com” and “Twitter.com” provide a free public forum in which users can connect with friends and share information such as blogs, videos, photos, links and audio files. Electronic Word of Mouth (e-WOM) includes any positive or negative statement made by consumers about a product or company which is made available to a mass community via the internet (Henning-Thurau et al. 2004), taking the form of discussion forums, text-based comments, video reviews, product reviews and social networking sites (SNS) (King et al 2014; Yoo et al. 2015). Compared to word of mouth (WOM), e-WOM takes place in computer mediated environments, whereas WOM occurs in face-face communication and does not contain this electronic element (Kin et al. 2014). eWOM systems are very influential, in fact, it is reported that 61% of consumers check online forums, consumer blogs and other sources for online customer reviews before they purchase products, simply because consumers trust consumer produced information (Yoo et al. 2015). However the lack of face-face in e-WOM interaction raises concern in that anonymity encourages unethical behaviour (Steckel et al 2005; Kiesler and Sproull 1992). Negative comments online otherwise known as negative word of mouth (NWOM) has a stronger impact on a consumers judgement, consumers trust and purchase intention compared to a website with positive comments, in females this effect is higher than males (Zhang et al. 2014; Yoo et al. 2015).

2.3 Virtual Theatrics

Virtual theatrics is a way in which retailers make their brand look like a ‘theatre’ through the use of images, video’s, graphics and animation (Managari et al. 2008). Fiore and Kelly (2007) demonstrate how a demo video is striking and engaging compared to a static image. Visual merchandising incorporates images, music, products, colour and animation which in turn influences whether or not a customer will enter a store or a website (Ha et al. 2007).

Pure-play retailers such as ASOS.com have catwalk videos to present their product as they do not have a physical store presence. However, Kawaf & Tagg (2017) report that the novelty of catwalk videos is warring off as consumers are wanting content that is ‘closer to real life’. That being said, mall haul videos (vlogs); short videos where influential individuals promote fashion products and express opinion is video content ‘close to real life’. eWOM has become very influential in shaping consumer’s attitudes and decisions especially from vlogs as it satisfies social and self monitoring needs (Harnish and Bridges 2016). This demonstrates how videos are becoming a form of social media.

2.4 Virtual Atmospherics

The term atmospherics is used in academic fields to represent "the design of shopping environments to provoke emotional effects in the buyer that enhance his purchase intention" (Kotler 1973, p. 50). Navigation systems are links on a website that enables the user to find information through links to other pages, search facilities, directories or sitemaps (Nielsen 1999). Webster and Ahuja (2006) demonstrate how some websites have failed in aiding navigational support as they get disorientated. Kluge et al. (2013) distinguished differences between a conventional online shopping homepage design with luxury shopping homepages. According to them, homepages are important as they are the first point of contact for users to which their initial impression is formed influencing their decision making process of whether or not to continue using the website. Luxury homepages differ to that of conventional homepages as they incorporate financial, functional, individual and social dimensions all entwined to represent the multi-sensory experience online. Websites that use an unstructured design, monotonous colours, or messy presentation of products can lead consumers to feel confused and angry (Koo and Ju 2010; Okonkwo 2010).

2.5 Multi-sensory Shopping Experiences

Fiore and Kelly (2007) implement the use of sound as an atmospheric cue operating online. They found that larger organisations tend to integrate sound into their websites as it ignites memory of the interface rather than the visual representation of a physical store. Gorn et al. (2004) found for each dimension of colour, cool colours tended to relax consumers more, when an expensive item was presented in front of a cool background, this increased the likelihood of purchasing the product. Touch in the context of shopping can be defined as any physical contact between a shopper and a product. Touching the product enables the consumer to assess the products properties and the more frequent the touch, the more engaged the consumer is with that product (Peck and Childers 2003; Zhang et al. 2014). Shopper density refers to the physical density in a given space (Zhang et al. 2014). Theories on over crowding report that confined spaces with a high frequency of shoppers tend to provoke a negative emotional response. The widely accepted idea is that perceived crowding negatively affects shopping satisfaction as it leads to invasion of personal space (Metha 2013; Zhang et al. 2014). Wade et al. (2012) suggested that shoppers need room when shopping to prevent 'butt brushing' and to allow them to navigate their way around the shop freely.

2.6 Virtual Shopping Environments

Augmented, virtual and mixed reality are becoming in demand as the technology progresses and augmented reality has been researched academically with regards to consumer engagement (Huang and Liao 2017). In Virtual Reality (VR) and traditional online shopping, males are more focused on practical characteristics with rational thinking whereas females are more focused on the entertainment and emotional catharsis (Zhao et al. 2017). Virtual avatars which are computer created beings also known as second life can also be described using virtual liminoid theory which suggests with the use of augmented reality technology (ARIT), consumers transition from a physical context through to virtual context via clothes fitting in AR. This state from real to virtual self triggers a psychological state which promotes the decoration of an avatar and this state is a form of engagement described as immersion or flow (Huang and Liao 2017; Jung and Pavlowski 2014). Haptic imagery being a 3D visiotactile stimuli has been used with AR to stimulate a real sense of touch (Huang and Liao 2017). Neuro-imaging studies using fMRI scans reveals in real life humans who create versions of themselves in AR or use virtually created clothes on themselves feel as though that is their real body in AR otherwise known as a sense of body ownership (Kelley et al. 2002; Kircher et al. 2000; Turk et al. 1991). Thus, the concept of embodied cognition to which a sense of 'real to virtual self' is created of AR online shopping is through the body's online experience and self (Zhao et al. 2017). In fact, self related interactive information is a trigger for the brain area responsible for the perception of self (Bargh 1982; Huang and Liao 2017). When comparing interfaces, it was found that a 2D interface enabled consumers to spend longer searching and engaging with it compared to a 3D interface, as a 2D interface is highly interactive (Mazursky and Vinitzky 2005). However, one would think that a 3D interface is more interactive due to novelty. To test this, some websites are introducing 3D interfaces as a virtual atmospheric cue for consumers. Wu et al. (2013) Creates a 3D mock shop in virtual reality and found that those who shopped in a store based on trends of fashion spent more money than those that shopped in the colour/visual stores. Those who shopped in the colour stores experienced more pleasure/purchase intention than those who shopped in the trend- lead stores. Immersive 3D store environments are seen to simulate products more closely than a 2D virtual store environment due to a richer presentation of the product and a greater level of interactivity (Jiang and Benbasat 2007). However, the threat is that consumers who are more functional when shopping will perceive vivid presentation to be less useful as content will be deemed as ambiguous (Hoch and Deighton 1989). Consumers who shop for fun rather than function are less likely to discriminate against ambiguous information (Gilovich et al. 2015). Wu et al (2015) suggest that in a 3D virtual environment retailers shouldn't focus on designing a merely functional environment in 3D but a clear environment focusing on lifestyle rather than merchandise. Virtual shopping tasks have also been performed to help those with disabilities. Negut et al. (2016) found that stroke patients did not complete their task efficiently in a virtual shopping task and lacked a cognitive strategy in planning compared to controls.

3 Engagement

Engagement has been commonly used in psychology, marketing, sociology, political science, organisational behaviour and education (Goodman 2012; Csikszentmihalyi 1997; Achterberg et al. 2003; Resnick 2001; Saks 2006). The definition of engagement seems to vary to different academics, some focus on the psychological aspects of engagement whilst others stress a behavioural focus. Brodie et al. (2011, p. 260) define this as a "psychological state which occurs by virtue of interactive, co-creative experiences with a focal agent (brand)…ultimately leading to loyalty" (Dessart et al. 2016; Brodie et al. 2011). Brodie et al (2011) in their working definition suggests that consumer engagement is a multi-dimensional concept consisting of cognitive, behavioural and emotional dimensions. In the nueroscience, Berka et al (2007) suggests that engagement reflects information gathering, visual attention and attention allocation. Other scholars characterise user engagement as a subset of 'flow' (mentioned in more detail below) but in a more passive state, as user control, attention, curiosity and intrinsic interest is absent in this construct (Chapman et al. 1999). In contrast to these common factors contributing to what engagement is, some definitions neglect the importance of motivation. Burns and Fairclough (2015) define engagement as a psychological state in which intrinsic motivation causes selective attention at a psychological level, engagement has been operationalised through indicators of attentional and emotional processes, often overlooking motivational factors (Arapakis et al. 2014). In marketing, there are varying definitions to consumer engagement, however, these definitions are focused mainly on brand relationship rather than focus on the consumer (Mollen and Wilson 2010; Hollebeek 2011; Brodie et al. 2013). Also, little attention is given to consumer engagement as a psychological, cognitive and interactive component to consumer behaviour (Bowden et al. 2009; Brodie et al. 2013; Patterson et al. 2013). This section describes marketing theories of consumer engagement, categorising them into cognitive, emotional and behavioural components.

3.1 Measuring Engagement via CE Theory

The origins of CE stems was discovered three decades ago in Norway (Gronroos 2010; Gummesson 1994). Since then, recent developments of CE were rooted in "service-dominant (S-D) logic" which views CE in the light of relationship marketing (RM) to create, sustain and enhance close relationships with their consumers (Mende et al. 2013; Vargo and Lusch 2004, 2008). The actual term of "consumer/customer engagement" only transpired in the academic marketing in the last 5 years (Brodie et al. 2011). This section focuses on CE as a multi-dimensional concept. Where the majority of research scholars lends focus to CE as uni-dimensional either focusing on emotion (Catteeuw et al. (2007), Roberts and Davenport (2002), cognition (Blumenfield and Meece 1988; Guthrie and Cox 2001) and behavioural (Balsano 2005; Saczynski et al. 2006) as constructs existing on their own only a handful of studies view emotional, cognitive and behavioural aspects of engagement occurring together, being multi-dimensional (Brodie et al. 2011; Macey and Sneider 2008).

Figure 1 is adapted from Hollebeek et al. (2014) which visually depicts from their framework the multi-faceted nature of consumer engagement. Here we have just drawn out the cognitive, emotional and behavioural aspects of this.

CE is suggested to extend beyond 'involvement' in that is not just the 'mere existence of cognition' is more interactive, experiential and adds value to the consumer (Brodie et al. 2011). Flow can be described as intrinsic enjoyment, loss of self-consciousness and complete absorption to which an individual becomes extremely engrossed towards shopping online (Csikszentmihalyi 1988; Higgins 2006). Novak and Hoffman (2003) found that increased flow creates greater expectations with future computer technology. Telepresence which is a milder version of flow to which the real and virtual world become blended is reported to be shaped by the media advertisements or videos (Javornik 2016). The concept of flow, overlaps with fluency theory in that although both involve low effort and high involvement, fluency contains ease of processing information or remembering something, which in turn puts the 'mind at ease' (Higgins 2006; Winkielman and Cacioppo 2001). Immersion as an engagement concept is now applied to the virtual

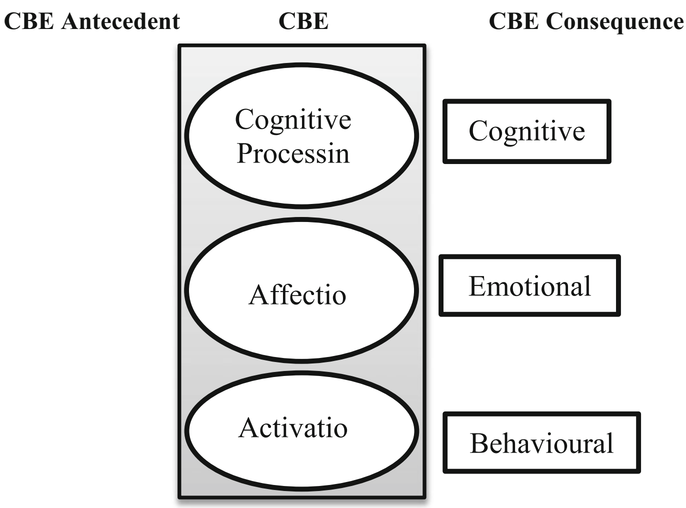


Fig. 1 Adaptation of CBE framework, Hollebeek et al. (2014)

Table 1 Types of consumer engagement and what they mean

Construct	Originators	Conceptual definition	Dimension
Flow	Csikzentmihalyi (1988)	Individual's intrinsic enjoyment, loss of self-consciousness and complete absorption towards shopping online	Cognition
Focused attention	Burke and Leykin (2014)	Attention acts as a filtering mechanism but only one activity utilised concentration	Cognition
User engagement	Obrien and Toms (2010)	This scale identifies interactivity with flow, play, focused attention, perceived usability, telepresence, satisfaction and purchase intention	Behavioural
Involvement	Zaichowsky (1985)	An individuals level of interest	Behavioural
Absorption	Agarwal and Karahanna (2000)	An intrinsic state that leads to episodes of total attention	Behavioural
Arousal	Mehrabian and Russell (1973)	Unitary emotional response ranging from sleep to frantic excitement	Emotion

world related to sensory experiences such as increasing screen size, sound quality, graphical fidelity or 3D screen capabilities. O' Brien and Toms (2010) developed a scale to measure user engagement. In this scale there were ten attributes of engagement with some of the key attributes being aesthetics, focused attention, challenge, control, feedback, motivation, novelty and perceived time. Out of all of these outcome measures, focused attention was the highest attribute involved in engagement accounting for 29.73% of the sample.

The table 1 above summarises the main types of consumer engagement. Involvement (Zaichowsky 1985) and flow (Csikzentmihalyi 1988) are the most reported subsets of engagement in marketing literature to date.

4 EEG Engagement

This section flows differently to the above in that engagement theories are reviewed from neuroscientific and electrical engineering literature rather than just marketing literature. This paves way for a comparison of engagement from two different fields. This section is divided up in looking at the parts of the brain associated with engagement rather than just defining engagement. It must be noted that limited neuroscientific literature report findings with engagement and online interactivity, this is where our novelty of the preliminary study in Sect. 5 comes in.

4.1 Anatomical Explanations of Engagement in the Brain

Engagement occurs mainly in the front of the brain otherwise known as the prefrontal cortex. The prefrontal cortex is believed to play a role in affective behaviour and judgement, lesions to this area result in impairment of executive functions such as decision making, organisation and planning (Afifi and Bergman 2005). Neuro-imaging studies have shown higher engagement level processes to be associated in the frontal part of the brain involved in emotion and cognition and the temporal part of the brain involved in accessing memories with the general consensus being, the more engaged a consumer is, the more likely they are to draw from memories (Fugate 2007). Davidson's model of motivation proposes that the brain is divided into both the approach (left side of brain) and withdrawal (right side of brain) (Davidson 1998). The levels of FAA (Frontal Alpha Asymmetry) is considered as a consistent index of approach activation (Engel and Fries 2010; Schmeichel et al. 2010). FAA is merely the difference of cortical activation of the alpha band (8–10 Hz) frequency band emitted from the brain in the frontal cortex between the left and right hemispheres of the brain (Briesemeister et al. 2013). Traditionally emotion is the common way of measuring consumer behaviour using the emotional valence system, however the FAA proves that information processing also a motivational component of engagement can be measured instead (Arapakis et al. 2017). As well as approach behaviours there are also withdrawal/avoidance behaviours (Davidson 1998). With emotion recognition in the brain, a negative scenario would expect a negative emotion/negative result. However, in the context of information interaction, people who consume both positive or negative information could be equally as engaged but engaged in a negative way (Arapakis et al. 2017). This therefore leads researchers to conclude that future research on user engagement should apply to an approach/avoidance model of motivation rather than the more commonly used bi-factoral model of emotions (Arapakis et al. 2017). The brain default network lends support for activation when participants are not focused in tasks demanding attention which can constitute to disengagement or mind wandering/boredom (Greicius et al. 2003). A study looking at neural engagement during social approach motivation provides evidence in the brain via fMRI scanning to approach-avoidance paradigms connected towards a motivational component for engagement (Wu et al. 2015). The nucleus accubens (NAcc) is a key node in the brain related to reward processing and this triggers approach behaviour (Knutson and Cooper 2005). The behavioural activation system (BAS) in the brain is an area that generates positive affect resulting in approach behaviour (Kennis et al. 2013; Wu et al. 2015).

Figure 2 summarises from the relevant literature cited above which parts of the brain is associated with engagement. From the diagram it is clear that mainly the front and back part of the brain is activated when looking at interactive media.

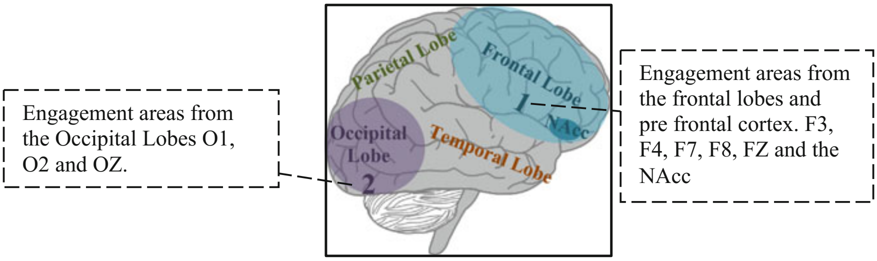


Fig. 2 Consumer engagement EEG sites

4.2 Measuring Engagement with EEG

An EEG is a technique for recording and analysing electrical activity of the brain. In order to record signals adequately, electrodes are placed in pairs on the scalp to which each pair transmits a signal to of of several recording channels of the EEG. The signal has a difference in voltage between the pair. The rhythmic fluctuation of this potential difference is depicted as oscillations on a line graph (Fine 2008). These oscillations measure frequencies of electrical currents to which are represented by waves and heir length each given the name of a Greek letter (Casson et al. 2010, Cohen 2014).

Measuring computer-mediated media (such as watching videos on YouTube), is more passive and therefore suggested to be measured via electrophysiological techniques (Arapakis et al 2017). Previous studies measuring engagement via EEG with passive media (TV adverts, social media channels etc.) have limited operationalisation of user engagement. For example, audiovisual media providing sensory information through images and sounds can also have physical attributes such as homepage visuals, attractive characters etc. that elicits automatic and emotional responses that is rarely measured (II lan et al. 2004). A study measuring mental workload in online shopping comparing Augmented Reality (AR) and Virtual Reality (VR) found that males have a higher mental workload for expensive products in VR than females (Zhao et al. 2017). Studies of left-brain activity demonstrates how complete absorbtion when shopping online even with limitations of online interfaces, consumers are so intrinsically involved with this experience that they do not seem to care about external factors around them (Demangeot and Broderick 2007). The term engagement can also represent the eagerness to fulfil a goal (Parsons et al. 2015). However, little research has been conducted using an EEG for consumer engagement and brain behaviour relationships (Fugate 2007). Neuro-imaging studies have shown higher engagement level processes to be associated in the frontal part of the brain involved in emotion and cognition and the temporal part of the brain involved in accessing memories with the general consensus being, the more engaged a consumer is, the more likely they are to draw from memories (Fugate 2007). Few studies, although not wholly grounded in marketing theory, have investigated the positive relationships with consumer engagement concepts such as flow, novelty and enjoyment using an EEG (Wang and Hsu 2014; Leger et al. 2014; Yilmaz et al., 2014). An EEG study exemplifying the importance of a two-way interaction between biology and our social environment, with mind as a concept for understanding the bidirectional influence between brain and behaviour (Howard-Jones et al. 2015). There is a body of research that examines EEG responses to like/dislike analysis without considering a holistic perspective of consumer behaviour. One study looks at high emotional value and low emotional value of luxury products when alone and then when in a group. Using emotion and attention (Pozharliev et al. 2015). Explained above in Sect. 2 was the importance of a multidimensional view to engagement, incorporating emotion, cognition and behavioural aspects (Brodie et al. 2011). Romano's pyramid of activation of the brain complements this by providing a physiological explanation for this when making a decision. Attention is used first to choose important information, eliminating unnecessary stimuli. Emotion then produces physiological changes in the body such as changes in heart rate, respiration, muscle tone and temperature. Then action regulator occurs before an action takes place and attends to automatic mechanisms deciding what to store into memory and transform into actions, this all happens the frontal lobe (Romano 2013). Too much or too little information of causes boredom and disengagement and in turn avoidance (Parsons et al. 2015). Table 2 is summarising all the studies associated with EEG engagement and shopping, media and online interactive environments.

Table 2 Derivatives of EEG engagement

Author	Type of engagement	Algorithm	EEG Device	Frequency band	Explanation
Rabbi et al. (2012)	Task engagement	Beta/ (Alpha + Theta)	B-Alert wireless sensor headset	Increased beta activity when wearing the space suit (increased Alertness). As time spent increased, theta activity increased	EEG changes were quantified and compared with direct responses of participants partaking different tasks. B-Alert/AMP (Attention, memory, Profiler) software was used as part of the EEG wireless acquisition system. 256 samples per second
Szafir and Mutlu (2012)	Attention in designing adaptive agents	Beta/ (Alpha + Theta)	Neurosky	–	Engagement levels measured in 30 s timeframes using two-way repeated measures ANOVA
Mc mahan et al(2015)	Engagement in gaming	Frontal Theta Frontal Theta/Parietal Alpha Beta/ (Alpha + Theta)	Emotiv	Measured in AF3, AF4, F3, F4, F7, F8, F5 & FC6	Engagement levels increased during death events compared to general game play events using this index

(continued)

Table 2 (continued)

Author	Type of engagement	Algorithm	EEG Device	Frequency band	Explanation
Freeman et al (1999)	Adaptive automation with a visual tracking task	Beta/ (Alpha + Theta)	BIOPAC EEF100A	Measured in CZ, PZ, P3 and P4	200 samples per second.1/theta out of the three engagement indexes yielded the highest level of engagement
Pope et al. (1995)	–	Beta/ (Alpha + Theta)	–	EEG was recorded at sites CZ, T5, P3, PZ, P4, O1 and O2	Closed loop method enables an index of engagement to be identified which is maximally sensitive to changes in task demand
Arapakis et al. (2017)	Engagement in online news reading	Frontal Alpha Asymmetry (FAA). Frontal alpha in left hemisphere and Prefrontal alpha in right hemisphere	Emotiv	Left (FC3, F3 & F7), Right (FC4, F4, F8)	EEG as well as Entrophy analysis reveals that there is a motivational component of emotion associated with engagement. In a negative scenario, a negative emotion would evoke behavioural avoidance

5 Preliminary Study

Putting all of the information from Sects. 1, 3 and 4 constitutes to a design and a few results of a preliminary study. The main aim is to explore the impact of consumer engagement on interactive features in online fashion shopping environments (Social media, browsing and video's) measuring brain responses. The study has been designed to collect responses with female millennial consumers only 10 initial participants were analysed. Purposive sampling was used involving participants that are available to the researcher (Bryman 2011). Female fashion consumers who shop online were be investigated (Mintel 2014). ASOS.com was the website under investigation. The study involved the participant visiting ASOS Instagram, looking at images only, interacting in likes, follows and sharing. Then the participant searches for a 'Jacket' via ASOS website. Finally the participant watches the catwalk video of their preferred jacket. The idea is to see out of the three levels of interactivity, which engages a consumer, the most or at which level of engagement (see Figs. 1 and 3).

ASOS Instagram

ASOS Browsing: Web page

ASOS Video: Catwalk Social Media

Fig. 3 ASOS Instagram, browsing and catwalk stimuli

Fig. 4 Experiment setup

Figure 4 demonstrates how this experiment was set up on participants. The experiment will measure 12 sites of engagement on the scalp. A high quality EEG traditionally used for medical conditions is used due to its high quality data signals. The device is called the actiCHamp housing up to 160 channels and has the highest sampling frequency of 100 kHz. Oscillatory patterns of activity in the EEG range from and widths (alpha, beta, theta, delta and gamma) (Ohme and Matukin 2012). Using an EEG engagement will be measured in the areas marked in Fig. 1. by using algorithms **Beta/Alpha + Theta** on all locations, **Theta/Alpha** on frontal midline and parietal and **Theta** on frontal locations.

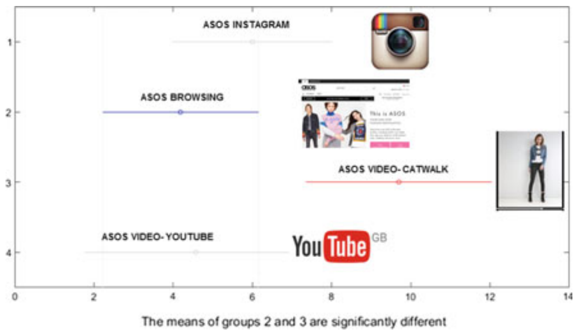


Fig. 5 Initial findings of 10 participants

5.1 Findings

Pilots consisted of 10 EEG results. EEG analysis was conducted in MatLab and two-way ANOVA was generated as a parametric test to see a difference between the 3 stimuli (social media, browsing and videos: Instagram and Youtube) (Fig. 5).

ANOVA provides a statistical test of whether or not the means of several groups are equal, and therefore generalizes the t-test to more than two groups. ANOVAs are useful for comparing (testing) three or more means (groups or variables) for statistical significance. A significant result was found between catwalk and browsing. The ANOVA reveals higher engagement for browsing than watching the video catwalk at real time. (Lower level of theta activity proves to be a higher level of engagement). However, there are many factors to consider as only first 10 participants were used so it is not a significant sample size. Also focusing on one retailer (ASOS.com) doesn't mean each level of interactivity is engaging or not engaging.

6 Conclusion

From the literature presented above, three levels of interactivity virtual social presence, virtual theatrics and virtual atmospherics prove to be relevant in today's generation and therefore useful in measuring consumer responses. Engagement has been looked at by two perspectives, marketing and neuroscience which hasn't been viewed in this way before. It can be seen that engagement is difficult to measure for both disciplines. The review provides evidence that there are techniques that enable engagement to be measured in marketing via surveys using likert and semantic differential scales. In neuroscience engagement can be measured by looking at the front and back of the brain and algorithms using electrical bandwidths alpha, beta and theta can be used. The preliminary study proved that the concept using EEG for measuring engagement to online interactive aspects of ASOS worked and a significant difference between browsing and catwalks was found. Fashion retailers are actively searching for the latest technology innovations that can improve the shopping experience. John Lewis for example is using a company called JLAB to use Instagram as a social checkout by allowing consumers to buy products through its Instagram feed (Mintel 2016b). This shows how pivitol social media, browsing and videos are when it comes to future technological developments for retail. In the case of AR and VR shopping environments for the future, It is likely that more pure-play retailers will utilise real world retail spaces to support their virtual stores (Euromonitor International 2011).

References

Achterberg, W., Pot, A. M., Kerkstra, A., Ooms, M., Muller, M., & Ribbe, M. (2003). The effect of depression on social engagement in newly admitted Dutch nursing home residents. *The Gerontologist, 43*(2), 213–218.

Afifi, A, K. & Bergman, R, A. (2005). *Functional neuroanatomy*. McGraw-Hill, pp. 3–416.

Agarwal, R., & Karahanna, E. (2000). Time flies when you're having fun: Cognitive absorption and beliefs about information technology usage. *MIS quarterly*, 665–694.

Arapakis, I., Barreda-Angeles, M., & Pereda-Banos, A. (2017). Interest as a proxy of engagement in news reading: Spectral and entropy analyses of EEG activity patterns. *IEEE Transactions on Affective Computing*.

Balsano, A. B. (2005). Youth civic engagement in the United States: Understanding and addressing the impact of social impediments on positive youth and community development. *Applied Developmental Science, 9*(4), 188–201.

Bargh, J. A., & Pietromonaco, P. (1982). Automatic information processing and social perception: The influence of trait information presented outside of conscious awareness on impression formation. *Journal of Personality and Social Psychology, 43*(3), 437.

Barnes, S, J., Mattsson, J. & Hartley, N. (2015). Assessing the value of real-life brands in Virtual Worlds, *Technological Forecasting & Social Change*, 92, 12–24.

Barnes, S, J.& Mattsson, J. (2008). Brand value in virtual worlds: an axiological approach. *Journal of Electronic commerce Research*, 6(1): 195–206.

Berka, C., Levendowski, D. J., Lumicao, M. N., Yau, A., Davis, G., Zivkovic. & Craven, P. L. (2007). EEG correlates of task engagement and mental workload in vigilance, learning, and memory tasks. *Aviation, space, and environmental medicine*, 78(5): B231–B244.

Briesemeister, B. B., Tamm, S., Heine, A., & Jacobs, A. M. (2013). Approach the good, withdraw from the bad—a review on frontal alpha asymmetry measures in applied psychological research. *Psychology, 4*(03), 261.

Brodie, R. J., Hollebeek, L. D., Juric, B., & Ilic, A. (2011). Customer engagement: conceptual domain, fundamental propositions, and implications for research. *Journal of Service Research*, 1–20.

Brodie, R. J., Ilic, A., Juric, B., & Hollebeek, L. (2013). Customer Engagement in A Virtual Brand Community: An exploratory Analysis. *Journal of Business Research, 66*(1), 105–144.

Bryman, A. (2011). Research methods in the study of leadership. The SAGE handbook of leadership, 15–28.

Burke, R. R., & Leykin, A. (2014). Identifying the Drivers of Shopper Attention, Engagement, and Purchase. In Shopper Marketing and the Role of In-Store Marketing,147–187.

Burns, C. G., & Fairclough, S. H. (2015). Use of auditory event-related potentials to measure immersion during a computer game. *International Journal of Human-Computer Studies, 73,* 107–114.

Casson, A., Yates, D., Smith, S., Duncan, J., & Rodriguez-Villegas, E. (2010). Wearable electroencephalography. *IEEE Engineering in Medicine and Biology Magazine,29*(3), 44–56.
Catteeuw, F., Flynn, E., & Vonderhorst, J. (2007). Employee engagement: Boosting productivity in turbulent times. *Organization Development Journal, 25*(2), 151.
Cohen, M. X. (2014). Analysing Neutral Time Series Data: Theory and Practice, MIT Press: Cambridge, Massachusetts, London.
Csikszentmihalyi, M. (1997). Finding flow: The psychology of engagement with everyday life. Basic Books.
Dailey, L. (2004). Navigational web atmospherics: Explaining the influence of restrictive navigation cues. *Journal of Business Research, 57*(7), 795–803.
Davidson, R. J. (1998). Anterior electrophysiological asymmetries, emotion, and depression: Conceptual and methodological conundrums. *Psychophysiology, 35*(5), 607–614.
Deloitte Global (2017). Global Predictions 2017 Available at s://www2.deloitte.com/global/en/pages/technology-media-and-telecommunications/articles/tmt-predictions.html. Accessed March 2017.
Demangeot, C., & Broderick, A. J. (2007). Conceptualising consumer behavior in online shopping environments. *International Journal of Retail & Distribution Management, 35*(11), 878–894.
Dessart, L., Veloutsou, C., & Morgan-Thomas, A. (2016). Capturing consumer engagement: duality, dimensionality and measurement. *Journal of Marketing Management, 32*(5–6), 399–426.
Engel, A. K., & Fries, P. (2010). Beta-band oscillations—signalling the status quo? *Current Opinion in Neurobiology, 20*(2), 156–165.
Euromonitor International (2011). Virtual Retailers Entering the Real World: New Store-Based Concepts From Pure-Play Internet Retailers Available at. http://blog.euromonitor.com/2011/11/virtual-retailers-entering-the-real-world-new-store-based-concepts-from-pure-play-internet-retailers.html. Accessed 24th April 2017.
Euromonitor International (2014). What's New with the Emerging Market Consumer? Available at. https://www.portal.euromonitor.com/portal/analysis/blogindex. Accessed 15. Oct. 2015.
Fine, C. (2008). The Britanica Guide To The Brain. Running Press Book Publishers, 3–338.
Fiore, S, G. & Kelly, S. (2007). Surveying the use of sound in online stores: Practices, possibilities and pitfalls for user experience, *International Journal of Retail & Distribution Management,* 35(7): 600–611.
Fredricks, J. A., Blumenfeld, P. C., & Paris, A. H. (2004). School engagement: Potential of the concept, state of the evidence. *Review of educational research, 74*(1), 59–109.
Freeman, F. G., Mikulka, P. J., Prinzel, L. J., & Scerbo, M. W. (1999). Evaluation of an adaptive automation system using three EEG indices with a visual tracking task. *Biological Psychology, 50*(1), 61–76.
Fugate, D. L. (2007). Neuromarketing: a layman's look at neuroscience and its potential application to marketing practice. *Journal of Consumer Marketing, 24*(7), 385–394.
Gearhart, S., & Zhang, W. (2014). Gay bullying and online opinion expression: Testing spiral of silence in the social media environment. *Social science computer review, 32*(1), 18–36.
Gilovich, T., & Kumar, A. (2015). Chapter Four-We'll Always Have Paris: The Hedonic Payoff from Experiential and Material Investments. *Advances in Experimental Social Psychology, 51,* 147–187.
Gorn, G. J., Chattopadhyay, A., Sengupta, J., & Tripathi, S. (2004). Waiting for the web: how screen color affects time perception. *Journal of Marketing Research, 41*(2), 215–225.
Greicius, M. D., Krasnow, B., Reiss, A. L., & Menon, V. (2003). Functional connectivity in the resting brain: a network analysis of the default mode hypothesis. *Proceedings of the National Academy of Sciences, 100*(1), 253–258.
Gummesson, E. (1994). Making relationship marketing operational. *International Journal of Service Industry Management, 5*(5), 5–20.

Guthrie, J. T., & Cox, K. E. (2001). Classroom conditions for motivation and engagement in reading. *Educational psychology review, 13*(3), 283–302.

Ha, Y., Kwon, W. S., & Lennon, S. J. (2007). Online visual merchandising (VMD) of apparel web sites. *Journal of Fashion Marketing and Management, 11*(4), 477–493.

Harnish, R. J., & Bridges, K. R. (2016). Mall Haul Videos: Self-Presentational Motives and the Role of Self-Monitoring. *Psychology & Marketing*, *33*(2), 113–124.

Häubl, G., & Trifts, V. (2000). Consumer decision making in online shopping environments: The effects of interactive decision aids. *Marketing science, 19*(1), 4–21.

Hennig-Thurau, T., Gwinner, K. P., Walsh, G., & Gremler, D. D. (2004). Electronic word-of-mouth via consumer-opinion platforms: What motivates consumers to articulate themselves on the Internet? *Journal of interactive marketing, 18*(1), 38–52.

Higgins, E. T. (2006). Value from hedonic experience and engagement. *Psychological Review, 113*(3), 439.

Hoch, S. J., & Deighton, J. (1989). Managing what consumers learn from experience. *The Journal of Marketing,* 1–20.

Hollebeek, L. (2011). Exploring customer brand engagement: definition and themes. *Journal of Strategic Marketing, 19*(7), 555–573.

Hollebeek, L. D., Glynn, M. S., & Brodie, R. J. (2014). Consumer brand engagement in social media: Conceptualization, scale development and validation. *Journal of interactive marketing, 28*(2), 149–165.

Howard-Jones, P., Ott, M., van Leeuwen, T., & De Smedt, B. (2015). The potential relevance of cognitive neuroscience for the development and use of technology-enhanced learning. *Learning, media and technology, 40*(2), 131–151.

Hsiao, K. L., Chuan-Chuan Lin, J., Wang, X. Y., Lu, H. P., & Yu, H. (2010). Antecedents and consequences of trust in online product recommendations: An empirical study in social shopping. *Online Information Review, 34*(6), 935–953.

Huang, T. L., & Liao, S. L., (2017). Creating e-shopping multisensory flow experience through augmented-reality interactive technology. *Internet Research, 27*(2), 449–475.

Ilan, A. B., Smith, M. E., & Gevins, A. (2004). Effects of marijuana on neurophysiological signals of working and episodic memory. *Psychopharmacology (Berl), 176*(2), 214–222.

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.

Jiang, Z., & Benbasat, I. (2007). The effects of presentation formats and task complexity on online consumers' product understanding. MIS Quarterly, 475–500.

Jung, Y., & Pawlowski, S. D. (2014). Understanding consumption in social virtual worlds: A sensemaking perspective on the consumption of virtual goods. *Journal of Business Research, 67*(10), 2231–2238.

Kawaf, F., & Tagg, S. (2017). The construction of online shopping experience: A repertory grid approach. *Computers in Human Behavior*, *72*, 222–232.

Kahneman, D. (1973). *Attention and effort* (p. 246). Englewood Cliffs, NJ: Prentice-Hall.

Kennis, M., Rademaker, A. R., & Geuze, E. (2013). Neural correlates of personality: an integrative review. *Neuroscience and Biobehavioral Reviews, 37*(1), 73–95.

Kiesler, S., & Sproull, L. (1992). Group decision making and communication technology. *Organizational Behavior and Human Decision Processes, 52*(1), 96–123.

King, D. L., Delfabbro, P. H., Kaptsis, D., & Zwaans, T. (2014). Adolescent simulated gambling via digital and social media: An emerging problem. *Computers in Human Behavior, 31,* 305–313.

Kircher, T. T., Senior, C., Phillips, M. L., Benson, P. J., Bullmore, E. T., Brammer, M., et al. (2000). Towards a functional neuroanatomy of self processing: effects of faces and words. *Cognitive Brain Research, 10*(1), 133–144.

Kleinschmit, M., Reid, A., & Rizzo, R. (2012). Virtual Future: real Life or Fantasy. *Esomar*, 1– 16.

Kluge, P. N., Königsfeld, J. A., Fassnacht, M., & Mitschke, F. (2013). Luxury web atmospherics: an examination of homepage design. *International Journal of Retail & Distribution Management, 41*(11/12), 901–916.

Knutson, B., & Cooper, J. C. (2005). Functional magnetic resonance imaging of reward prediction. *Current Opinion in Neurology, 18*(4), 411–417.

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

Koo, D. M., & Ju, S. H. (2010). The interactional effects of atmospherics and perceptual curiosity on emotions and online shopping intention. *Computers in Human Behavior*,

KPMG (2017). The future of virtual and augmented reality: Digital disruption or disaster in the making? Available at. http://www.kpmgtechgrowth.co.uk/the-future-of-virtual-and-augmented-reality-digital-disruption-or-disaster-in-the-making/. Accessed March 2017.

Léger, P. M., Davis, F. D., Cronan, T. P., & Perret, J. (2014). Neurophysiological correlates of cognitive absorption in an inactive training context. *Computers in Human Behavior, 34,* 273–283.

Macey, W. H., & Schneider, B. (2008). Engaged in engagement: We are delighted we did it. *Industrial and Organizational Psychology, 1*(1), 76–83.

Manganari, E, E., Siokomos, G, J. &Vrechopoulos, A, P. (2009). Store atmosphere in web retailing, *European Journal of Marketing*. 43 (9/10):1140–1153

Martinez-Peñaranda, C., Bailer, W., Barreda-Ángeles, M., Weiss, W., & Pereda-Baños, A. (2013). A psychophysiological approach to the usability evaluation of a multi-view video browsing tool. In *International Conference on Multimedia Modeling*, 456–466

Mazursky, D., & Vinitzky, G. (2005). Modifying consumer search processes in enhanced on-line interfaces. *Journal of Business Research, 58*(10), 1299–1309.

Mcmahan, T., Parberry, I., & Parsons, T. D. (2015). Evaluating Electroencephalography Engagement Indices During Video Game Play.

Meece, J. L., Blumenfeld, P. C., & Hoyle, R. H. (1988). Students' goal orientations and cognitive engagement in classroom activities. *Journal of Educational Psychology, 80*(4), 514.

Mehrabian, A., Russell, J, A. (1973). A Measure of Arousal Seeking Tendency, *Environment and Behavior*, 5(3): 315.

Mehta, R., Sharma, N. K., & Swami, S. (2013). The impact of perceived crowding on consumers' store patronage intentions: Role of optimal stimulation level and shopping motivation. *Journal of Marketing Management, 29*(7–8), 812–835.

Mende, S., & Roseman, D. (2013). The aligning forces for quality experience: Lessons on getting consumers involved in health care improvements. *Health Affairs, 32*(6), 1092–1100.

Mintel (2016a). Fashion Online Available at file:///home$/Desktop/PhD%20Reading/Market%20Research/Fashion%20%20Online%20-%20UK%20-%20August%202014%20-%20%20Executive%20Summary.pdf. Accessed 7th November 2016.

Mintel (2016b). Fashion Online Available at file:///G:/Paper%202017%20ARVR/Fashion-%20Technology%20and%20Innovation%20-%20UK%20-%20September%202016%20-%20Executive%20Summary.pdf. Accessed 20th April 2017.

Mollen, A., & Wilson, H. (2010). Engagement, telepresence and interactivity in online consumer experience: Reconciling scholastic and managerial perspectives. *Journal of Business Research, 63*(9), 919–925.

Morandin, G., Bagozzi, R. P., & Bergami, M. (2013). Brand community membership and the construction of meaning. *Scandinavian Journal of Management, 29*(2), 173–183.

Neguț, A., Matu, S. A., Sava, F. A., & David, D. (2016). Virtual reality measures in neuropsychological assessment: a meta-analytic review. *The Clinical Neuropsychologist,* 1–20.

Nielsen, J. (1999). Designing web usability: The practice of simplicity. New Riders Publishing.

Novak, T. P., Hoffman, D. L., & Yung, Y. F. (2000). Measuring the customer experience in online environments: A structural modelling approach. *Marketing science, 19*(1), 22–42.

O'Brien, H. L., & Toms, E. G. (2010). The development and evaluation of a survey to measure user engagement. *Journal of the American Society for Information Science and Technology, 61*(1), 50–69.

Ohme, R. & Matukin, M. (2012). A Small Frog that Makes a Big Difference, IEEE Pusle, 28–33

Okonkwo, U. (2010). Luxury online: Styles, systems, strategies. Palgrave Macmillan.
Peck, J., & Childers, T. L. (2003). To have and to hold: The influence of haptic information on product judgments. *Journal of Marketing, 67*(2), 35–48.
Pope, A. T., Bogart, E. H., & Bartolome, D. S. (1995). Biocybernetic system evaluates indices of operator engagement in automated task. *Biological psychology*, 40(1): 187–195
Pozharliev, R., Verbeke, W. J., Van Strien, J. W., & Bagozzi, R. P. (2015). Merely Being with You Increases My Attention to Luxury Products: Using EEG to Understand Consumers' Emotional Experience with Luxury Branded Products. *Journal of Marketing Research, 52*(4), 546–558.
Rabbi, A. F., & Fazel-Rezai, R. (2012). A fuzzy logic system for seizure onset detection in intracranial EEG. *Computational intelligence and neuroscience*, 1–12.
Resnick, P. (2001). The social cost of cheap pseudonyms. *Journal of Economics & Management Strategy, 10*(2), 173–199.
Roberts, D. R., & Davenport, T. O. (2002). Job engagement: Why it's important and how to improve it. *Employment Relations Today, 29*(3), 21–29.
Romano, J. (2013). *The Neuropyramid*. Bubok.
Saczynski, J. S., Pfeifer, L. A., Masaki, K., Korf, E. S., Laurin, D., White, L., et al. (2006). The effect of social engagement on incident dementia the Honolulu-Asia aging study. *American Journal of Epidemiology, 163*(5), 433–440.
Saks, A. M. (2006). Antecedents and consequences of employee engagement. *Journal of managerial psychology, 21*(7), 600–619.
Schmeichel, B. J., Harmon-Jones, C., & Harmon-Jones, E. (2010). Exercising self-control increases approach motivation. *Journal of Personality and Social Psychology, 99*(1), 162.
Skorupa, J. (2012). Shopper experience study, *RIS news magazine*.
Statista (2017). Retail sales of ASOS worldwide in financial year 2014 to 2016, by region (in 1,000 GBP) Available at https://www.statista.com/statistics/500739/asos-retail-sales-by-region-worldwide/. Accessed March 2017.
Steckel, J. H., Winer, R. S., Bucklin, R. E., Dellaert, B. G., Drèze, X., Häubl, G., et al. (2005). Choice in interactive environments. *Marketing Letters, 16*(3), 309–320.
Szafir, D., & Mutlu, B. (2012). Pay attention!: designing adaptive agents that monitor and improve user engagement. In Proceedings of the SIGCHI conference on human factors in computing systems, 11–20
Tacchino, G., Gandolla, M., Coelli, S., Barbieri, R., Pedrocchi, A., & Bianchi, A. M. (2016). EEG Analysis during active and assisted repetitive movements: Evidence for differences in neural engagement. *IEEE Transactions on Neural Systems and Rehabilitation Engineering*.
Turk, M., & Pentland, A. (1991). Eigenfaces for recognition. *Journal of Cognitive Neuroscience, 3* (1), 71–86.
Vargo, S. L., & Lusch, R. F. (2004). Evolving to a new dominant logic for marketing. *Journal of marketing, 68*(1), 1–17.
Vargo, S. L., & Lusch, R. F. (2008). Service-dominant logic: continuing the evolution. *Journal of the Academy of Marketing Science, 36*(1), 1–10.
Wade Clarke, D., Perry, P., & Denson, H. (2012). The sensory retail environment of small fashion boutiques. *Journal of Fashion Marketing and Management, 16*(4), 492–510.
Wang, Y. & Hsu, C., (2011). Network traces of virtual worlds: Measurements and applications, in proceedings of the secondannual ACM conference on Multimedia Systems, 105–110
Wang, C. C., & Hsu, M. C. (2014). An exploratory study using inexpensive electroencephalography (EEG) to understand flow experience in computer-based instruction. *Information & Management, 51*(7), 912–923.
Webster, J., & Ahuja, J. S. (2006). Enhancing the design of web navigation systems: The influence of user disorientation on engagement and performance. *MIS Quarterly*, 661–678.
Winkielman, P., & Cacioppo, J. T. (2001). Mind at ease puts a smile on the face: psychophysiological evidence that processing facilitation elicits positive affect. *Journal of Personality and Social Psychology, 81*(6), 989.

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.

Wu, Z., Li, Y., & Radke, R. J. (2015). Viewpoint invariant human re-identification in camera networks using pose priors and subject-discriminative features. *IEEE Transactions on Pattern Analysis and Machine Intelligence, 37*(5), 1095–1108.

Xu, Q., & Sundar, S. S. (2014). Lights, camera, music, interaction! *Interactive persuasion in e-commerce. Communication Research, 41*(2), 282–308.

Yılmaz, B., Korkmaz, S., Arslan, D. B., Güngör, E., & Asyalı, M. H. (2014). Like/dislike analysis using EEG: determination of most discriminative channels and frequencies. *Computer Methods and Programs in Biomedicine, 113*(2), 705–713.

Yoo, C. W., Kim, Y. J., & Sanders, G. L. (2015). The impact of interactivity of electronic word of mouth systems and E-Quality on decision support in the context of the e- marketplace. *Information & Management, 52*(4), 496–505.

Zaichkowsky, J. L. (1985). Measuring the involvement construct. *Journal of consumer research, 12*(3), 341–352.

Zhang, Y., Feick, L., & Mittal, V. (2014a). How males and females differ in their likelihood of transmitting negative word of mouth. *Journal of Consumer Research, 40*(6), 1097–1108.

Zhang, X., Li, S., Burke, R. R., & Leykin, A. (2014b). An examination of social influence on shopper behavior using video tracking data. *Journal of Marketing, 78*(5), 24–41.

Zhao, X., Shi, C., You, X., & Zong, C. (2017). Analysis of mental workload in online shopping: Are augmented and virtual reality consistent?.*Frontiers in Psychology*, 8.

Part III
Augmented and Virtual Reality in Business, Marketing and Storytelling

Augmented Reality Smart Glasses: Definition, Concepts and Impact on Firm Value Creation

Young K. Ro, Alexander Brem and Philipp A. Rauschnabel

Abstract In recent decades, the developments of new media have revolutionized individuals' behaviors tremendously. Mobile devices, in particular, have developed an 'always and everywhere online' mentality. But what comes next? Recent developments emphasize the rise of a new technology that is termed 'Wearable Augmented Reality Devices', where Augmented Reality Smart Glasses (such as Microsoft HoloLens or Google Glass) represent prominent examples. These technologies offer huge innovation potential for companies and societies, which are discussed in this article. By doing so, this paper provides managers and researchers an applied description of the technology and a discussion of how it differs from existing mobile and augmented reality technologies. Finally, insights are given into how these technologies may increase firm value and further change the behaviors of consumers and adopters.

Keywords Augmented reality smart glasses · ARSGs · Mixed reality · Head mounted display · Definitions · Firm value · Future research

1 Introduction

Augmented Reality Smart Glasses (ARSGs), such as Google Glass or Microsoft HoloLens, have recently gained increased attention . Broadly speaking, ARSGs are a new wearable augmented reality (AR) device that capture and process a user's physical environment and augments it with virtual elements. Recent forecasts

Y.K. Ro · P.A. Rauschnabel (✉)
College of Business, University of Michigan-Dearborn, Dearborn, Michigan, USA
e-mail: prausch@umich.edu

Y.K. Ro
e-mail: yro@umich.edu

A. Brem
School of Business and Economics, Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Germany

T. Jung and M.C. tom Dieck (eds.), *Augmented Reality and Virtual Reality*,
Progress in IS, DOI 10.1007/978-3-319-64027-3_12

predict that ARSGs will substantially influence societal media behaviors, and market research institutes predict tremendous growth rates for this new type of technology (e. g., Technavio 2015; Stockinger 2016). Consumers and media have discussed the advantages and potential concerns of this technology for individuals and society as a whole, such as data security concerns (Fodor and Brem 2015). Although there is a huge potential for ARSGs to create value for consumers, companies and societies as a whole, little research has been published in this area to date (Stockinger 2016). However, academics and managers call for early market knowledge to better understand the mechanisms that drive this promising technology (Rauschnabel et al. 2015; Eisenmann et al. 2014; Tomiuc 2014).

Knowledge about new technologies and their (potential) customers is important in the early stages of innovation diffusion (Brem and Viardot 2015). In these critical phases, knowledge about the opportunities and challenges might increase the probability of successful implementation, decrease the probability of product failures, and thus increase diffusion speed (Attewell 1992). Likewise, early knowledge can provide an advantage for companies that might increase efficiency when using ARSGs (Hein and Rauschnabel 2016). This knowledge can also help policy makers focus on laws that cover the specific appropriate and inappropriate use characteristics of ARSGs—e.g., that ARSGs could distract people from driving a car or that wearing ARSGs in public might violate privacy and copyright laws.

In this article,[1] we address the research gap of deficient early knowledge on the strengths and weaknesses of ARSGs as follows: First, we provide a new classification of online technologies. By doing so, we integrate ARSGs in the evolution of media technologies and discuss its distinctiveness compared to other technologies, such as virtual reality glasses. Second, we generate an outline explaining how ARSGs can increase firm value. Besides enhancing or improving the performance of existing tasks, the potential for new business models for innovative applications arise.

2 Virtual and Augmented Reality Devices

2.1 Overview

Driven by new technologies, virtual and augmented worlds are converging. Recently, ARSGs have attracted a lot of attention as a new breakthrough innovation (Technavio 2015; Rauschnabel et al. 2015; Rauschnabel and Ro 2016; Eisenmann et al. 2014; Tomiuc 2014; Jung et al. 2015). Figure 1 proposes a novel media evolution framework of five media generations. The x-axis in this figure reflects the passage of time and the y-axis the influence of each generation's technologies on users' lives.

[1]This chapter is a revised version of a working paper published by the authors on researchgate.net, see Rauschnabel, Brem and Ro (2015).

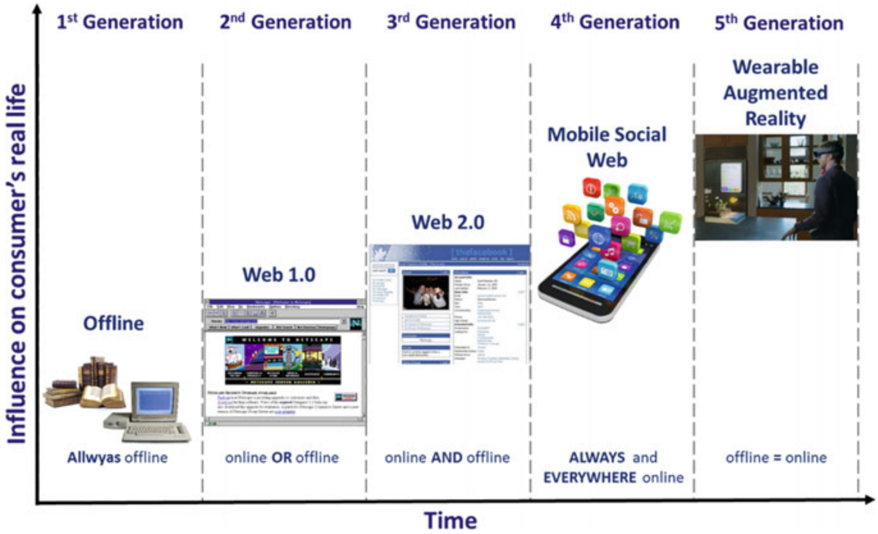


Fig. 1 Evolution of media devices

The first generation of media is termed offline media and includes uni-directional offline media such as newspapers, television and Teletex. These technologies were mostly stationary and digital technologies from that time received their information either from internal storages, cartridges (e.g., game consoles), CD ROMs, or via analog radio frequencies (e.g., TV or Radio). Consumers' role was passive, i.e. they consumed media.

The second generation (1990s), dubbed as Web 1.0, describes early online technologies where static websites structured like digital brochures are prominent examples. Consumers' roles in this generation of media were primarily passive, i.e., consuming content that was mostly produced and published by professional organizations—e.g. companies. Although two-way communications were possible, most of the Web 1.0 technologies were still uni-directional. Broadly speaking, these early websites were 'digital brochures' and most content was produced by professional organizations. Only a few very innovative users created personal websites, primarily by manually programming HTML code, and hosted these websites and offered free web hosting services such as geocities.com.

The third generation, starting in the early 2000s, has been dubbed Web 2.0, or social media (Kaplan and Haenlein 2010). Social media is characterized by complex and multi-directional communications. Users serve both as consumers and producers of content, giving rise to the term 'prosumers'. Faster internet connections, higher user-friendliness among devices, and higher levels of trust and acceptance of the Internet represent examples of why people were more likely to experiment with and use Web 2.0 technologies. Examples of early Web 2.0 technologies are Facebook (at that time 'TheFacebook'), SecondLife, and Myspace.

Staring around 2010, the fourth generation of media extended social media from static devices to mobile device such as laptop computers, tablets, and smartphones.

However, other forms of wearable devices such as smart watches, smart clothes, or smart wristbands, are also covered by this generation of media. These mobile technologies enable users to have access to their 'social media environment' anytime and anywhere. Not surprisingly, social media applications—such as Facebook or Instagram—are the most popular smartphone apps.

The fifth generation of media is the so called wearable augmented reality devices ('WARD') era, i.e., wearable technologies that merge virtual and physical realities. In other words, these technologies meld the real world with virtual elements. One example of this fifth generation of media are augmented reality ARSGs, which are the focus of this article. Wearable augmented reality devices are only made possible due to developments in communication networks. It is now technically feasible to transport data at high rates and ensure shorter latencies (10–100 ms). There are advances in data security, and the communication network is now able to process several devices or several connectivities within the same efficiency range. Networks are also now able to address mobility requirements of new technologies from near field, over short range, local in- and out-door to a global efficiency range.

In this fifth generation, communication reaches a new level concerning human senses involved in media; it is the communication generation that could encompass all human sensory impressions.

The idea of augmented reality is not new; these technologies have been developed and researched during the last few years (Javornik 2016a; Stockinger 2016; Pantano et al. (2017). An example of an established AR technology are the "virtual mirrors" that are often used by fashion retailers (Javornik et al. 2016). Virtual mirrors are displays with integrated cameras that film a consumer, who then can choose the different clothing he/she is wearing on the screen. Mobile AR applications can be used on most mobile devices such as tablets or smartphones. For example, users can capture a famous building in a city with their camera, then use a mobile AR-app, such as Cyclopedia, that recognizes the building and provides the corresponding information about this building from Wikipedia. However, extant AR examples are either just applications for mobile, stationary devices or devices that were specifically developed for professional contexts (e.g., virtual mirrors). ARSGs, in contrast, are conceptualized as a new generation of media since they are (a) specifically developed AR technologies, and (b) also made for the masses.

2.2 *Definition of Augmented Reality Smart Glasses*

Based on our theorizing and prior research, we develop the following definition of Augmented Reality Smart Glasses

(synonym: data glasses, digital eye glasses, or personal imaging system):

> Augmented Reality Smart Glasses (ARSGs) are defined as wearable Augmented Reality (AR) devices that are worn like regular glasses and merge virtual information with physical information in a user's view field.

Most ARSGs are worn like glasses, and few examples (e.g. Google Glass) could also be mounted on regular spectacle frames. Several technologies (e.g., camera, GPS, microphones etc.) capture physical information and augment them with virtual information that can be gathered from the internet and/or stored on the ARSGs memory, primarily accomplished through location-, object-, facial-, and image-based recognition technologies. This virtual information is then presented in real-time on a display, which, in brief, is a transparent screen in front of a user's eye (s). A user can see both the virtual and 'real' world through these displays. Prominent examples of ARSGs are Microsoft HoloLens, Everysight Raptor or Google Glass.

3 Value Creation with Smart Glasses

The core proposition of this article is that ARSGs can be a means to create corporate value for businesses and also for society as a whole. Therefore, it is necessary to distinguish between internal and external value creation factors (see Fig. 2). Internal value creation factors cover aspects where smart glasses can be used by a firm's employees to work more effectively. External value creation means that companies can increase revenues by offering applications for ARSGs that can be used by consumers or for interactions with customers. Important to note is that, due to the novelty of the technology, not all of the potentials have been addressed in

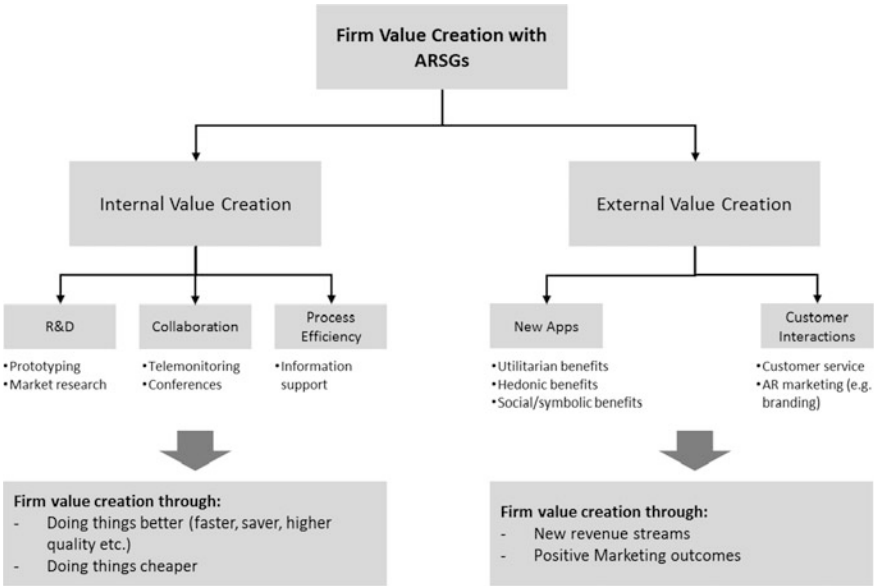


Fig. 2 Firm value creation with augmented reality smart glasses

prior research or practice. Thus, this overview also provides suggestions for future research.

3.1 Internal Value Creation

Research and Development: Traditional research and development activities include a lot of investments into discovery and trial-and-error-processes. This is usually linked with a high investment into hardware such as printers, and into product concepts, usually done with different approaches to prototyping. Even though nowadays 3D printers are becoming more and more prevalent in use, this is still a high investment in terms of financial and time resources. With the use of ARSGs, these processes can be virtualized by using 3D applications—and it even goes further through the usage of social media for the evaluation of new product ideas. Hence, such devices can foster and facilitate the full innovation process within a company and its research and development activities.

Beyond that, ARSGs offer new methods of market research for firms. Consider, for example, survey applications that cover physical information—such as a product or a store—and integrated surveys. Extended versions of ARSGs could combine the advantages of mobile surveys and eye-tracking (as well as other forms of observational data) and provide marketers with new methods and enhanced results/outcomes of market research. Prior research has also focused on new technologies for product testing. For example, the use of virtual 3D-screens have been investigated as a means to test packaging and display its benefits compared to 2D-tests with the limitation of artificial laboratory situations (Berneburg 2007). ARSGs could also be used to present products more realistically. For example, new forms of a bottle could be virtually displayed on a respondent's dining table at home and evaluated in a realistic situation, thus increasing the external validity of product tests.

Collaboration: Early attempts have been made to use ARSGs as a means to promote collaborative work. For instance, Muensterer and colleagues tested the acceptance of Google Glass in a pediatric hospital and used it for telemonitoring with colleagues all over the world (Muensterer et al. 2014). Similarly, manufacturers of ARSGs, such as Microsoft (2015), highlight the benefits of collaborations with varied examples—in a personal setting (a father, who from distance, helps his daughter fix a drain at home) or in a professional setting (researchers in a lab analysing rocks on Mars). Likewise, collaborations in customer-firm interactions are possible, for example, for functions such as customer service and product support. Finally, virtual meetings through services like Skype can be much more efficient if additional information can be shared in real-time and with full visibility through ARSGs. The movie Kingsman provides several fictitious examples how ARSGs can enhance conferences by augmenting conversation partners into a conference room.

Process Effectiveness: Using ARSGs at work could increase an employee's efficiency, as information is always accessible. This is possible, as in times of big data, digitalization, and the 'Internet of Things', products and systems can communicate autonomously with each other and provide employees with relevant information (Lee and Lee 2015). The advantages of ARSGs compared to other forms of devices are threefold: First, only relevant information is displayed. For example, a cook can exclusively take a look at the information about the next ingredients that are necessary for a recipe, rather than being confronted with the whole recipe at once. ARSGs have the ability to recognize in which step of the cooking process the cook is at the moment and what will come next. Besides, ARSGs can help improve the logistical function in supply chains by aiding workers in a retailer's warehouse. Searching for the right products that are requested by a consumer and navigating the worker through the warehouse in the most effective route are just a couple of the popular features associated with ARSGs. Second, information is automatically available when needed and can be enriched with additional online information if desired. For example, designers and engineers can work on collaborative product development projects from virtually any dispersed location around the globe and make changes or alterations to parts of a product or component design in real time, with the changes being made visible to all members of the product development team. If a service technician has problems installing or repairing a machine, additional information can be received by the ARSGs in real-time, or colleagues can join in virtually. Similarly, face recognition could help police officers identify wanted criminals and fugitives and provide themselves with additional information such as criminal records. Third, in contrast to other mobile augmented reality devices, ARSGs can be used hands-free, offering workers greater flexibility. This can be helpful for things such as documentation in medical settings (e.g., forensic medicine), as studied by Albrecht et al. (2014).

3.2 External Value Creation

Companies can also increase value for customers with the help of service functions. Currently, many companies use virtual reality applications. For example, the Swedish furniture chain IKEA offers a 3D kitchen planner on its website in which consumers can plan their purchases virtually. An AR app can extend this experience on tablet computers or smartphones. In a future with ARSGs, this could even go a step further with consumers wearing ARSGs while walking through an empty room and planning their new fittings by placing virtual furniture in a real room. In contrast to mobile AR, ARSGs can provide a much more realistic and hands-free experience. Likewise, consumers with service requests could contact a company via ARSGs. Consider a customer's service request from an automotive company where the customer has problems programming a car's computer. A service representative could then see what the consumer sees and give particular advice on what to do.

3.3 New Apps as Growth Potentials

Whereas the aforementioned benefits focused solely on the use of ARSGs in firms, ARSGs also offer the potential for new applications. Consumers tend to be more likely to adopt certain technologies and media when they address particular needs. For example, consumers use social media to obtain gratifications such as entertainment, socialization, self-presentation, information, and others. With regards to ARSGs, there are three clusters of needs that can be addressed by ARSGs applications.

3.3.1 Effectivity Factors

Effectiveness, in this case, describes how 'useful' ARSGs are for consumers by making their life more efficient, and thus address more utilitarian needs and wants. Prior research, such as the widely cited technology acceptance model (Davis 1989), has shown that the perceived usefulness of a new technology is a core determinant of the adoption intention of new technologies (Davies et al. 1989; King and He 2006). In the matter of ARSGs, people who perceive them as a technology that makes their lives more efficient are more likely to adopt them (Rauschnabel et al. 2015a). Other scholars have shown that AR technologies, including ARSGs, can serve as an effective tool to navigate tourists or visitors in museums (Jung et al. 2015; Leue et al. 2015; tom Dieck and Jung 2015). Hein and Rauschnabel (2016) also propose a concept to combine ARSGs with Enterprise Social Networks. Also, consumers who perceive that using ARSGs does not require large mental effort due to their more intuitive and self-explanatory use perceive higher levels of effectivity benefits.

In line with this, commonly discussed applications include navigation systems and organizers. In fact, from a technological perspective, navigation apps could be more effective than common navigation systems since they are able to capture real-world information such as construction-induced speed reductions and detours or provide accurate navigation directions in complex situations.

3.3.2 Hedonic Factors

In simple layman's terms, hedonic factors can be described as 'fun' characteristics. Not surprisingly, people often use a particular form of media for hedonic purposes. These include entertainment, the passing of time, playing games, or escaping from reality. ARSGs offer many opportunities for consumers to receive hedonic benefits. Consider, for example, virtual games that can be played in a real environment. Current computer games are applied in famous environmental contexts depicted in movies such as Tomb Raider or James Bond. Games played on or with ARSGs offer the opportunity to play these games in familiar, real environments. For instance, a re-launch of the famous Tamagotchi game in the 1990s is possible, where users care about a realistic looking and behaving virtual ‘pet’. Likewise, the popular workout smartphone apps could be applied on ARSGs and enhanced to offer additional benefits such as showing joggers the exact directions in the view-field. An important distinction between ARSGs and other technologies (e.g., smartphones or laptop computers) is that they can be used while the user is engaged in some other activity. For example, playing a game on a smartphone or a laptop computer usually requires high levels of a user’s physical and mental concentration and thus hinders the development of applications that require a user’s physical play. To illustrate, one could consider the idea of an ego-shooter game that can be played in a user’s yard or house, in which a user chases enemies in his or her house or garden. Finally, ARSGs can also be used to document one’s life and share this content with peers/friends.

3.3.3 Social and Symbolic Factors

Consumer researchers have long known that products or brands that are used in public are linked to social and symbolic aspects (Bearden and Etzel 1982). It is also a well-known finding from fashion marketing that people dress themselves in a manner that allows them to present themselves in a particular way. Augmented reality smart glasses are, as any wearable device, a new form of fashion accessory for users. Thus, psychological similarities between what is known from fashion adoption and ARSGs are very likely, although research in this domain has remained scarce. However, recent evidence suggests that people who believe that their friends and colleagues will adopt the use of ARSGs will also be likely to adopt them (Rauschnabel et al. 2015a).

Also, past experience has shown that users of (new) technologies often form communities, and in these communities, ties between the members are an important determinant of technology adoption (Muñiz and O’Guinn 2001; Felix 2012). In fact, several communities for ARSGs users have already emerged. For example, *EduGlasses.com* is a resource center and online community for educators that use ARSGs in classrooms and other educational settings. GoogleGlassForum.net is another example of an online community that focuses on Google’s ARSGs program. These examples enable registered users to engage in discussions about topics related to ARSGs. Research about these online communities has revealed the importance of social factors that drive user participation (e.g., Hennig-Thurau et al. 2004).

Assuming that corresponding apps will be developed in the future, for example, dating apps, ARSGs can be a means to satisfying unmet social needs. These apps offer various benefits as compared to regular online dating websites or mobile apps since users can, for example, see and identify potential partners in real life with ARSGs. Likewise, ARSGs can also help members maintain existing social relationships in a similar manner as social networks. For example, Google promotes the benefits of Google Glass by showing examples where users can identify friends nearby and motivate them to meet in person and by displaying relevant information about their friends (e.g. a person’s birthday).

3.4 Customer Interaction

ARSGs also provide numerous opportunities for customer interactions (Javornik 2016b). For example, customers can be supported in after sales service, can review products, and so forth. Consider, for example, a customer entering a showroom at an automobile dealership. This customer can integrate a customer representative in his or her view field (as, for example, discussed in the collaboration section). As in prior stages of the media evolution (see Fig. 1), we propose that apps for ARSGs will arise that allow users to interact with brands—for example, similarly to Facebook brand pages and other forms of social media marketing (Felix et al. 2017). This might probably result in a new discipline 'AR marketing' (Javornik 2016b; Javornik 2016c), and existing offline communication activities (e.g. exhibitions and other marketing events) can be complemented with an AR component.

3.5 Value for Society

When it comes to new technologies, many consumers are sceptical and discuss potential negative consequences of the use of a new technology for society (Fodor and Brem 2015). In the early days of the Internet, it was concluded that using the Internet influenced people negatively, particularly with regards to their social lives and depression (Kraut et al. 1998). Follow-up studies revealed that the initial findings were not as dramatic as proposed (Tyler 2002). Besides potential negative consequences that will be discussed in the next paragraph, various positive effects for society as a whole can emerge.

ARSGs can make rescue teams more efficient, and support medical doctors at work, as discussed above. The use in various settings (e.g. in maintenance and construction work) can decrease user's risks, and thus, contribute positively to public healthcare systems. Although potential privacy concerns exist, ARSGs can be used to record one's environment, and thus help law enforcement personnel with solving crimes. Research has also revealed that ARSGs can facilitate the everyday life of patients with Parkinson's disease (McNaney et al. 2014). Recent discussions about the use of ARSGs in classrooms and education indicate further positive effects on society as a whole.

4 Barriers

Like any technology, the growth of ARSGs might be limited due to some factors. From a technological perspective, the short duration of the batteries, a limited number of applications, missing standards and lack of ubiquitous high-speed internet connection are examples of crucial factors that current are not always available. However, it is likely that further developments in technology will address these barriers. From a more psychological perspective, users often criticize the design of the extant models, which could be one reason why Google stopped distributing its ‘Explorer Program’. Likewise, fear of electro smog, or negative influences on the eyes, are other criticisms that are often discussed among consumers, although current research does not support these fears.

Important to note is also the fact that several legal, ethical and political challenges arise that might hinder the development of ARSGs. For example, wearing ARSGs in public could violate privacy and copyright laws. Both the National Association of Theatre Owners (NATO) and the Motion Picture Association of America (MPAA) have allied themselves in prohibiting the use of ARSGs in cinemas due to concerns regarding movie piracy by illegal recording (Barrie 2014). To reduce potential conflicts with regards to individual privacy concerns, some manufacturers such as Google have announced that they will not develop facial recognition apps, but it might be a matter of time until other developers program such applications.

Manufacturers of ARSGs also advertise the benefits of using ARSGs as navigation systems. Whether this distracts drivers and provides a risk for other traffic participants, however, is yet unknown. Analogous to older technologies, people might criticize that the use of ARSGs could make society less social. For example, the popular Walkman-Effect describes the criticism surrounding Sony’s portable cassette player in the 1980s, where people were afraid that Walkman users would become distracted in everyday life. Regarding health issues, potential concerns are addictive ARSGs usage behaviors.

Not surprising is the fact that, due to public criticism (e.g., privacy concerns), not all people perceive ARSGs in a positive manner (Fodor and Brem 2015). In particular, the user image of ARSGs is often expressed in a negative way. In online discussion boards, many users call smart glass wearers ‘glassholes’.

5 Conclusion

In this chapter, we addressed an innovative topic that has the potential to be very influential in research, companies, and in general for the creation of new business models: Augmented Reality Smart Glasses (ARSGs). Therefore, we started with a definition and integration of ARSGs into the current media and technology landscape. According to this, ARSGs are the logical next step of media development as they combine wearable devices with AR technologies. In line with this assumption, various forecasts predict high growth rates within the next few years, and thus indicate that ARSGs could be the next ‘big thing’. Whereas most research on technology and new media investigates research questions of existing devices or applications, the aim of this research was to discuss a new and promising technology in the very early stage of development. Therefore, we provide relevant definitions, and discussed potential success factors of ARSGs adoption. We hope that these discussions stimulate managers in considering ARSGs for their business and for scholars to place emphasis on this new and promising technology—both as a research tool and as a research topic. As a research tool, ARSGs can offer new ways for data collection or presentation (e.g. stimuli in experiments). As a study object, ARSGs can make use of theories from numerous disciplines, including marketing, MIS, operations and supply chain management, innovation management, media/communication research, psychology, and so forth. Finally, we conclude with a call for policy makers to be aware of the characteristics of ARSGs and the need for corresponding laws and regulations—ideally, before ARSGs become more ubiquitous in the general population. Policy makers have underestimated the power of former technologies and media, such as mp3 s, cellphones, drones and so forth. Starting to develop regulations for ARSGS in a pre-mass market stage might reduce uncertainty among consumers and legal consequences.

References

Albrecht, U. V., von Jan, U., Kuebler, J., Zoeller, C., Lacher, M., Muensterer, O. J., & Hagemeier, L. (2014). Google Glass for Documentation of Medical Findings: Evaluation in Forensic Medicine. *Journal of Medical Internet Research*, *16*(2).

Attewell, P. (1992). Technology diffusion and organizational learning: The case of business computing. *Organization Science, 3*(1), 1–19.

Barrie, J. (2014). Google Glass Is Now Banned From All US Movie Theaters. Business Insider Retrieved from http:// businessinsider.com/movie-industry-bans-google-glass (6/09/2015).

Bearden, W. O., & Etzel, M. J. (1982). Reference Group Influence on Product and Brand Purchase Decisions. *Journal of Consumer Research*, 183–194.

Berneburg, A. (2007). Interactive 3D Simulations in Measuring Consumer Preferences: Friend or Foe to Test Results? *Journal of Interactive Advertising, 8*(1), 1–13.

Brem, A., & Viardot, É. (2015). Adoption of Innovation: Balancing Internal and External Stakeholders in the Marketing of Innovation (pp. 1–10). Springer International Publishing.

Davis, F. D. (1989). Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. *MIS Quarterly, 13*(3), 319–340.

Eisenmann, T., Barley, L. & Kind, L. (2014). Google Glass, Harvard Business School Case 814–102.

Felix, R. (2012). Brand communities for mainstream brands: the example of the Yamaha R1 brand community. *Journal of Consumer Marketing, 29*(3), 225–232.

Felix, R., Rauschnabel, P. A., & Hinsch, C. (2017). Elements of strategic social media marketing: A holistic framework. *Journal of Business Research, 70,* 118–126.

Fodor, M., & Brem, A. (2015). Do Privacy Concerns Matter for Millennials? Results from an Empirical Analysis of Location-Based Services Adoption in Germany. *Computers in Human Behavior, 53*(12), 344–353.

Hennig-Thurau, T., Gwinner, K. P., Walsh, G., & Gremler, D. D. (2004). Electronic Word-of-Mouth via Consumer-Opinion Platforms: What Motivates Consumers to Articulate Themselves on the Internet? *Journal of Interactive Marketing, 18*(1), 38–52.

Hein, D. W., & Rauschnabel, P. A. (2016). Augmented reality smart glasses and knowledge management: A conceptual framework for enterprise social networks. In *Enterprise social networks* (pp. 83–109). Springer Fachmedien Wiesbaden.

Javornik, A. (2016a). 'It's an illusion, but it looks real!' Consumer affective, cognitive and behavioural responses to augmented reality applications. *Journal of Marketing Management, 32*(9–10), 987–1011.

Javornik, A. (2016c). What Marketers Need to Know about Augmented Reality, *Harvard Business Review*, https://hbr.org/2016/04/what-marketers-need-to-understand-about-augmented-reality.

Javornik, A., Rogers, Y., Moutinho, A. M., & Freeman, R. (2016). Revealing the Shopper Experience of Using a" Magic Mirror" Augmented Reality Make-Up Application. In Conference on Designing Interactive Systems (Vol. 2016, pp. 871–882). Association for Computing Machinery (ACM).

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.

Kaplan, A. M., & Haenlein, M. (2010). Users of the World, Unite! The Challenges and Opportunities of Social Media. *Business Horizons, 53*(1), 59–68.

King, W. R., & He, J. (2006). A Meta-Analysis of the Technology Acceptance Model. *Information & Management, 43*(6), 740–755.

Kraut, R., Patterson, M., Lundmark, V., Kiesler, S., Mukophadhyay, T., & Scherlis, W. (1998). Internet paradox: A Social Technology that Reduces Social Involvement and Psychological Well-Being? *American Psychologist, 53*(9), 1017.

Lee, I., & Lee, K. (2015). The Internet of Things (IoT): Applications, Investments, and Challenges for Enterprises. *Business Horizons, 58*(4), 431–440.

Leue, M. C., Jung, T., & tom Dieck, D. (2015). Google glass augmented reality: Generic learning outcomes for art galleries. In Information and Communication Technologies in Tourism 2015 (pp. 463–476). Springer International Publishing.

McNaney, R., Vines, J., Roggen, D., Balaam, M., Zhang, P., Poliakov, I., & Olivier, P. (2014). Exploring the Acceptability of Google Glass as an Everyday Assistive Device for People with Parkinson's. In *Proceedings of the 32nd Annual ACM Conference on Human Factors in Computing Systems* (pp. 2551–2554). ACM.

Muniz, A. M., & O'guinn, T. C. (2001). Brand community. *Journal of consumer research, 27*(4), 412–432.

Muensterer, O. J., Lacher, M., Zoeller, C., Bronstein, M., & Kübler, J. (2014). Google Glass in Pediatric Surgery: An Exploratory Study. *International Journal of Surgery, 12*(4), 281–289.

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.

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.

Rauschnabel, P. A., Brem, A., & Ivens, B. S. (2015a). 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,* 635–647.

Rauschnabel, P. A., Brem, A., & Ro, Y. (2015b). *Augmented reality smart glasses: definition, conceptual insights, and managerial importance*. Working paper, The University of Michigan-Dearborn, ResearchGate.

Stockinger, H. (2016). The future of augmented reality-an Open Delphi study on technology acceptance. *International Journal of Technology Marketing, 11*(1), 55–96.

Technavio (2015). *Global Smart Glasses Market for Augmented Reality 2015–2019*, Elmhurst, IL.

Tomiuc, A. (2014). Navigating culture. Enhancing visitor museum experience through mobile technologies. From smartphone to google glass. *Journal of Media Research*, *7*(3), 33–47.

tom Dieck, M. C., & Jung, T. (2015). A theoretical model of mobile augmented reality acceptance in urban heritage tourism. *Current Issues in Tourism*, 1–21.

Tyler, T. R. (2002). Is the Internet Changing Social Life? It seems the more Things Change, the more they Stay the Same. *Journal of Social Issues, 58*(1), 195–205.

The Sensorama Revisited: Evaluating the Application of Multi-sensory Input on the Sense of Presence in 360-Degree Immersive Film in Virtual Reality

Sarah Jones and Steve Dawkins

Abstract It has been suggested that 360-degree immersive film viewed in virtual environments, does not allow for a sense of presence owing to the lack of interactivity, agency and realism. This paper outlines the findings of a research project to evaluate how such a sense of presence can be enabled through the introduction of multi-sensory input to the viewing experience. Using an original 360-degree film that was shot in Hong Kong's Chungking Mansions as a basis for research, this paper interrogates Ryan's assertion that Virtual Reality (VR) that combines interactivity, immersion and narrativity is an example of the "total art" that VR producers need to aspire to. By adding changes in heat and scent to the viewing experience, the extent to which those sensory stimuli, which would not normally be part of a viewing experience, lead to an increased feeling of presence is evaluated. In doing so, we suggest that the viewing experience may not need all three elements of total art to be equivalent in order for a meaningful viewing experience to occur.

Keywords Presence · 360-degree film · Multi-sensory · Virtual reality

1 Introduction

With the emergence of affordable and accessible VR viewing technology and spherical cameras, there has been a growing move towards the production of 360-degree film that can be argued to provide a more immersive, embodied experience of moving images than 2D film (Jones 2016; de la Pena et al. 2010). This has led some to define VR as being the "ultimate empathy generator" (De La Pena et al. 2010), with the creator of one innovative example of a 360-degree documentary, *Clouds Over Sidra* (2015), describing the film as an "empathy machine" (Milk 2015). For storytellers, focusing on stories that build a stronger

S. Jones (✉) · S. Dawkins
School of Media and Performing Arts, Coventry University, Coventry, UK
e-mail: sarah.jones@coventry.ac.uk

T. Jung and M.C. tom Dieck (eds.), *Augmented Reality and Virtual Reality*,
Progress in IS, DOI 10.1007/978-3-319-64027-3_13

connection between the audience and the subject could, potentially at least, lead to a significantly different relationship between the audience and the text.

One of the main concerns for VR filmmakers is in maximizing the experience in order to sustain this connection and so this research starts with a deceptively simple question: does adding multi-sensory input to the viewing experience enhance the sense of presence in 360-degree film and, if so, to what extent?

It is clear that, on first experiencing 360-degree film, there is a 'wow' moment and a sense of wonder because this experience is profoundly different to viewing in a traditional flat manner. However, even on a second experience, this wears off and some of the inadequacies of the technology begin to be apparent. One reason for this might be that current technologies of production, or the way they have been used, mean that interaction and agency is limited in 360-degree film (Smith 2015). There are also wider concerns over audience compassion fatigue within media (Höijer 2004, Nikunen 2016) that consequently suggest the limitations of VR and 360-degree film to sustain the emotional impact within immersive storytelling.

The challenge of creating and maintaining presence in the virtual world in order to enable maximum engagement is widely acknowledged as being the goal for VR creators. As Pimental and Texeira noted during the first wave of VR in the 1990s:

the question isn't whether the created world is as real as the physical world, but whether the created world is real enough for you to suspend your disbelief for a period of time (Pimentel and Texeira 1993).

Lombard and Ditton (1997) describe presence as "the illusion that a mediated experience is not mediated". Creating a 360-degree filmed experience for immersion that with is indistinguishable from reality is challenging when the user is not actively involved in the story. Ryan's concept of "total art" (2015) suggests that such a simple suspension of disbelief is not enough as that is what many existing forms of media already enable. VR has to aspire to total art in order to differentiate itself. Although 360-degree gaming appears to offer Ryan's three pre-requisites for total art, 360-degree film currently does not allow for the interactivity and infinite worlds that VR needs to create this total sense of presence.

This paper analyses that central predicament. Using an original film, *'Rapid Passage through Various Ambiences*' (2016), as a basis for new research, to create the experience of being within the Chungking Mansions in Hong Kong. It adds in a range of sensory stimuli to evaluate the correlation between presence and cross-modal work. Through interviews with participants, the layers of immersion are analysed to understand the impact of sensory experiences to create presence for the user within 360-degree film.

2 Literature Review

Despite being established as an emerging technology as far back as the 1950s with Heilig's Sensorama and the "Experience Theatre", the re-emergence and accessibility of VR since 2014 means that is has established itself as a growing medium for storytelling. Much has been written about CGI within the virtual world and its applications across industries including health (Hsu et al. 2013) and education (Huang et al. 2010) but the inclusion of the more accessible spherical narrative film in these studies is limited. There are early academic studies into spherical panorama still images which demonstrated that they could offer a "proper point of view", as Barker's 1787 patent suggests. Uricchio (2011) argued that Barker's work on the panorama was one of the earliest ideas that suggested the immersive opportunities of virtual reality within the still image and that it produces a "second order reality" (Otto 2007) highlighting that film imagery could offer presence but there have been limited studies since. From this, we can deduce that the opportunities for 360-degree film can enable us to place someone in a virtual environment and making the user "feel as if really on the very spot" (Uricchio 2011).

The aim of VR to transport you to another time and place has been well documented but the scope to extend this to film-making and immersive storytelling fails due to the lack of definition and agency that often exists within this medium. The concept of VR as a "total art" can give our best understanding of where the potential for 360-degree film lies. Ryan (2015) defines total art as being characterised by three main elements: narrativity, immersion and interactivity. For her, total art could be likened to art forms, such as the opera, where a state of immersion capture the different sensory experiences that are able to transport the audience to another time and place. Her argument is that VR should go a few steps further than the previous total art form of opera, by combining sound, graphics, text (spoken or written), movement (both by the interactor and the objects within the virtual environment), olfactory effects, and haptic sensations" (1997: np). It is at this point that this happens that we can begin to define VR as total art.

Examples of VR as total art are clear where the combination of narrativity, immersion and interactivity gives the sense of presence in the virtual environment. By presence, we follow Pimentel and Texeira's (1993) definition of creating an environment that enables the experiencer to suspend *all* belief. Lombard and Ditton (1997) recognised that in a virtual environment, the user would be aware of using a head-mounted display but still, "to some degree, her perceptions overlook that knowledge and objects, events, entities, and environments are perceived as if the technology was not involved in the experience". Presence is the single defining characteristic of virtual reality and defines the moment that the mind tricks the body into feeling that it is somewhere else. Ideas of presence have long been studied within neuroscience (Reiner 2011).

Content analysis of interactive virtual reality content carried out by Dolan and Parets (2015) identified four narrative relationships within virtual experiences. In their study, they isolated four types of possibility based on the user's experience and the influence that they can exert on the narrative. A user can exist either as an observer or a participant depending upon how active they are in the experience (See Fig. 1). They develop this to categorise the influence, identifying when the viewer is actively making decisions and in control of the experience. When we apply this to 360-degree narrative film, actions are limited within the virtual environment. A narrative is often prescribed by the director and although a user can experience

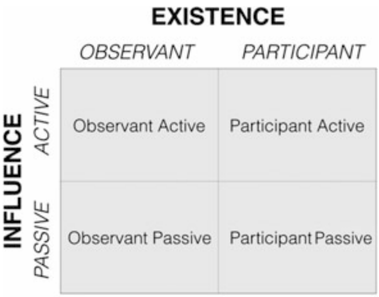


Fig. 1 Narrative relationships within virtual experiences

the environment as they choose, they are not free to make the decision to go to another space and consequently the experience is that of a participant. Dolan and Parets' research described this as being "relatable to traditional media where you do not exist in the world or influence the story" (2016). The storyteller retains complete control of the action and what is presented to the viewer.

VR has long focused on the idea of the body. Fuchs et al. (2006) identified the idea of VR as one that allowed the subject "to remove himself from physical reality in order to virtually change the time, place and or type of interaction" (2006, p. 7). Through the combination of immersion and interactivity with multimodal experiences, we can see how the body can be transformed to a virtual being. Concepts of the virtual body and technological embodiment have long been established within film, theatre and art research (Featherstone and Burrows 1996; Bouko 2011). Studies in theatre allow research into self-representation to cross over into mixed media formats, which can then be applied to immersive film. To achieve a sense of virtual embodiment, Bouko suggests that the weighting of the self needs to be lessened to create a new virtual body. By applying this idea to immersive film, we can develop the sensory experiences in a way that that they can simulate a new state of presence. The importance of the bodily experience is clear within the literature of one that is intertwined with the representation of the virtual (Bouko 2011).

The idea of the virtual embodiment is magnified when we add the application of non-visual interfaces. The research findings develop a new idea concerning subjective body ownership illusion (Bergstrom et al. 2016) that show that immersive virtual reality with multi-sensory experiences, can replicate the subjective, physiological and cognitive effects of the body in a virtual world. It explores the extent to film which film and moving image material can be, and needs to be, supplemented by other sensory experiences—smell, heat, touch—to be fully immersive and explores the extent to which actual knowledge of the space in the film enabled a more fully-embodied experience. Friedman et al. studied the notion of time travel in the virtual world concluding that if a sense of presence can be achieved, then a user can change their own perceptions of events and have a sense of body ownership and agency over the virtual body (Friedman et al. 2014).

The nature of immersive storytelling means that you want to be able to reach out and touch what is around you and feel that you are in the heart of the action.

Personal space in virtual reality has long been discussed (Hall 1963; Bailenson et al. 2001; Wilcox et al. 2006) with research showing intrusion can cause significant negative reactions. This can be exploited to enhance the emotional connection and "evoke real audience discomfort when faced with a virtual 'closetalker' (Wilcox et al. 2006). It is also said to cause more discomfort when the close proximity is to people, rather than objects (Bailenson et al. 2001).

Studies in cross-modal work usually focus on haptics and are limited to touch. The importance of olfactory stimuli have been identified as adding presence within healthcare with Krueger (1996) suggesting that the development of virtual surgical training systems would be limited until odors were present in the environment. Heat lamps were used within the University of Virginia VR group to replicate the environment of a fire-breathing dragon so that you would feel the heat sensitivities on your skin. Evaluations of these multimodalities are limited in literature, however, the value to adding presence has been recognised in a number of studies. Munyan et al. (2006) found that the more senses that were added, the greater the level of presence would be. This reflected on the use of presence connected to memory of the virtual environment and focused on olfactory stimuli. In an earlier 1999 study that surveyed 322 participants on the effects of a tactile, olfactory, audio and visual cues in relation to memory and objects in the virtual world, it was clear that increasing modalities enhanced both presence and memory (Dinh et al. 1999). The depth of the visual didn't have an impact on presence but the findings pointed to "the more sensory cues that were added, the greater the sense of presence".

These studies have all been carried out in CGI virtual environments. By using these ideas to create a multi-sensory experience, the application of non-visual interfaces can be added to test the layers of immersion and use techniques to disrupt the experience of being in the virtual environment within a 360-degree film.

3 Methodology

There is currently a gap in literature concerning 360-degree films and their contribution to immersive technologies and virtual reality. With the current limitations that do not allow 360-degree to achieve total art status, this research fills that gap by exploring the extent to which the experience of 360-degree film can be enhanced by the addition of multi-sensory input into the experience. In doing so, it explores how the sense of presence and immersion can be enhanced and attempts to discover whether, if interactivity is currently not possible in 360-degree narrative film, such an enhanced sense of presence moves it closer towards Ryan's notion of total art.

An experimental 360-degree film, entitled *Rapid Passage through Various Ambiences*, was produced around the Chungking Mansions in Hong Kong in June

2016. Famous as the setting for Wong Kar-Wai's Chungking Express (1994), the Mansions is a seventeen storey commercial and residential complex, described as "a world hub of low-end globalisation" (Mathews 2011). On the ground floor, the building is a complex maze of touts, and tourists that is home to an estimated 4000 people and is visited by approximately 10,000 people each day. Hostels, providing some of the cheapest accommodation in Hong Kong, are situated on the upper floors of the Mansions.

The title of the film is lifted directly from Guy Debord's definition of the *dérive*: a mode of walking that emphasises curiosity, drifting, exploration and wonder (Debord 1996). The film was shot over a two-day filming period embracing the concept of 'drifting' and with no pre-production deliberately to capture the chaos of the activity and the diverse communities that make up the Mansions. The film was intended to be experiential; it was directed to capture the essence of the experience of being there. The intention of the editing was to break newly-established filming conventions for 360-degree film—stitch lines from the cameras are visible, camera operators are in shot, and characters break the personal space filming line—in order to create the sense of uneasiness that a first-time visitor to the Mansions may feel (Fig. 2)

On the first viewing of the film in a head-mounted display (HMD), it was clear that although there was a level of immersion that enabled the viewer to have the

Fig. 2 A screenshot from *rapid passage through various ambiences* (2016) with the invasion of personal space to create the experience of uneasiness

Fig. 3 The viewing tent

'wow moment' and to start to understand what it was like to be situated in the film world, there was no sense of the chaos and confusion and bodily sensations that replicated the physical experience of being in the real environment. The film felt 'empty'.

The aim of this research project is to examine whether a 360-degree film, such as *Rapid Passage Through Various Ambiences*, needs multiple layers of non-visual interfaces to create a more "total art" immersive experience and consequently, presence. The evaluation provides an understanding of the extent in which the experience of immersion might influence experiences within a virtual world. In short, what needs to be 'added' to the film itself to create a more totally-immersive experience and if such an experience is, indeed, possible.

Fig. 4 Testing rapid passage through various ambiences (2016)

In this exploratory study, twenty participants of mixed genders, ages and ethnicities watched the film on a HMD through a mobile device. The participants were selected randomly through a call out to staff and students located within the University, ensuring a diverse pool of respondents. The testing occurred while in the controlled space of a tent in a room with no other external stimuli. The participants put on the HMD outside the tent and were then led into it.

1. The first viewing was a simple view with a HMD (see Fig. 4).
2. The second viewing, approximately one week after the first, added in 'layers of immersion' at the start of the experience. A temperature-controlled environment was created so that users would feel the heat intensities of being in the environment and the blast of a fan as they moved through the market and smells appropriate to the market environment were introduced (see Fig. 3).

Immediately after viewing, participants were asked to fill in a form rating a series of statements to get them to reflect upon the experience and to focus in on the areas being examined in the research. This was followed by a semi-structured interview with each participant which was designed to establish their understanding of the experience of the space and how immersed they felt within the virtual environment. The framework for interviews with audiences was developed from previous studies around VR examining the levels of immersion and understanding of stories, primarily questions regarding presence, focus on place, illusion, plausibility and co-presence (Banakou et al. 2013).

The statements that participants rated were as follows:

1. I had the sensation of being in Chungking
2. There were times when Chungking was more real for me than where I was watching the film
3. I felt like I could respond to the people as if they were real people.
4. Even though the virtual body wasn't me, I had the sensation that I was there.
5. I felt that the virtual body was someone else.
6. I felt like I was moving around Chungking.
7. I felt immersed in the environment.
8. My body responded to the environment.
9. I was lost in the environment.
10. I felt like I could interact with the environment and the people.
11. My body was interacting with the environment.
12. I could choose my experience in ChungKing.

Once focussed, the participants were immediately interviewed. Table 1 displays the questions for each interview related to the areas on the rating form.

Table 1 Interview questions

Interview 1	Interview 2
1. Have you ever seen a VR film before? How did you feel on first watching one? **2.** When watching this film, did you forget that you were in a tent? How long did it take you to forget? If you didn't forget, what was it that made you not forget? **3.** Describe the sensation of being in the place? Did it feel like it was your body there? Why? If not, why not? 4. Describe how you felt about the people in the film. Who did you identify with most and why? Were there moments when you felt uncomfortable? Why? 5. Did it feel like you were moving around chungking? Did you feel active or passive in that movement? Why? Did you feel like you could interact with the environment? Why/why not? 6. Did you feel 'immersed' in the environment? Did you feel any bodily sensations (fear etc.)? What was it, specifically, that made you feel that? 7. Do you have any other observations about the experience of watching the film?	1. Sum up, if you can, how you felt the first time that you saw the film 2. Describe how the second viewing felt different (positive or negative)? How *significantly* different did it feel and why? 3. Describe the sensation of being in Chungking with the external stimuli (smell/heat)? Did it feel *more* like it was your body there than the first viewing? Why? If not, why not? 4. Did: • the smells make a difference to the viewing experience? Describe what that difference was and how significant it was. • the heat make a difference to the viewing experience? Describe what that difference was and how significant it was 5. Did the external stimuli have an effect on how you felt about your interaction with the environment? Did it affect how active or passive you felt? Why? 6. Did the external stimuli make you feel more 'immersed' in the environment than the first viewing? Why/why not? 7. Did the external stimuli have an effect on any bodily sensations you felt (fear etc.)? 8. What elements do you think could to be added to VR film to take it up to the next level of immersivity or embodiment? Real-time body parts (such as own hands) 9. Do you have any other observations about the experience of watching the film with the external stimuli?

4 Findings

The interviews took place directly after the experience. They followed the same structure focusing on initial reactions, the different sensory experiences, interaction in the environment, presence and embodiment.

The initial response to being inside an environment that added in thermoceptive (heat) and olfactory (smell) stimuli was that it created a more immersive experience. Previous studies (Ischer et al. 2014) indicated the importance in setting the right environment to carry out experiments in presence where standard laboratories rarely replicated the *"complexity of real world experiences"*. By replicating the correct environment, participants said they felt *"significantly more immersed"* when there was sensory stimuli;

> I got into the tent and straight away I could smell the different smells and the heat that was coming into the tent as well, it made it feel a lot more realistic that I was there.

There was a varied response to the addition of olfactory stimuli. Previous literature has recognised its impact on presence and memory and, although it enhanced presence, the smells were not distinct enough to elicit full immersion. For this study, it was not possible to add a range of different smells at different times in the experience. More sophisticated technology is needed to do this, which will be the focus of a further study. Some participants said the smells seemed to stabilise in the experience because there wasn't a range of smells that were linked to the scenes. For example, two scenes in the film showed laundry and rubbish/sewers. Most participants said they wanted to be able to smell these. However the variety of smells in the market scenes, which dominate the film, could be said to have a small impact on presence.

> When you are walking through the streets, there's all the different parts of the market. You can imagine you are there and someone sat in a café next you and you can smell what they're eating.

The impact of heat sensitivities had a much stronger impact on presence. Nearly all participants responded positively to the element of heat being added to the environment. They all spoke about the "expectation" of the environment being hot. A crowded market place in a country like Hong Kong is expected to be hot and crowded so there is the feeling that it is necessary to experience the heat if there is to be a sense of presence. A cold room would not create the right conditions for presence in the environment to be achieved. Participants spoke of the "*expectation that it is hot*" and the "*passive heat all around you*". They said, "*it just makes you feel like you're there and your body responds to it really well as if you're there*". With the heat increasing throughout the experience, it felt more real to participants:

> The heat once got almost a bit too hot but that's what would happen in that situation. It added to it massively.

With Lombard and Ditton defining presence as being when the mind forgets the elements of technology, it can be argued that when actions in the virtual word are mirrored in the real world, that sense of presence is achieved. Through adding in heat, participants responded in the manner in which they would if they were in the Chungking Mansions. One said, "*I felt like I wanted to take my jacket off because I thought I was in a different country so why would I have my jacket on?*". This was further drawn out and discovered during questions focusing on interactivity. Through adding in heat and smells, one participant described it as "*the film really responds to you*".

One participant noted that they didn't feel like they could interact in the environment but that wasn't down to a lack of immersion. Instead they stated that they wouldn't choose to interact with people in this environment in the real world. Instead they would walk through and observe but not try and connect. This again suggests that moment of presence where their behaviour was the same in both environments.

Half of participants spoke about virtual embodiment and how the added senses can create this extended level of immersion adding to the impact of presence. This was pointed to as being a result of the senses.

> There was definitely more of a sense of embodiment.…because your senses are reactive to what is around you and visually as well you can see the same thing as last week but because you can smell and feel different things you feel like you are much more of a part of it.

The heat also enhanced this from other participants. The environment was set-up with a heater in one area of the tent which blasted the air in in one position. Although it was noted that it would be better to have the air circulating in different areas, for the majority of participants it was either seen as anything worth noting, or the air created the feeling of movement helping the case for virtual embodiment.

> It felt like you were moving round and passing you and you did feel more embodied in the space in that way.

This study focused on enhancing presence through multi-modalities work, but it also seemed to play a role in the interactivity of the environment.

> With my senses being alert I looked into a lot more detail about what was going on. Whether that's with the second time watching it or because my body was responding in a different way. I was looking at more finer details. I was looking at where the smell could be coming from.

Some ambiguities were identified during the interviews. In the first viewing, one participant reported moments of motion sickness, which is accentuated in this film due to the high level tracking shots meaning a disconnect between the body and mind. Although a common concern within virtual reality (Ohyama et al. 2007), technologies and established filming conventions for 360-degree film are helping to remove this problem. However, in this film specifically, it was designed to create that sense of uneasiness to replicate the experience of being in the environment and so tracking shots and flash frame sequences were used to add distortion. Only one participant reported motion sickness. In the second week, the participant didn't suffer, as reported:

> I didn't seem to experience it at all. I don't know if that is that it's not just your eyes telling you are in a different place and moving but the hot air the smell and the whole ambiance of it all.

Further studies on this are needed. This data suggests that by adding in different senses, it can enhance the trickery of your mind that you are in this environment and mean that it is a more authentic experience so you would expect the motion.

A common statement in the interviews focused on the issue of the sensory stimuli being added to a film that they had already watched. This was necessary to be able to measure the impact on presence but it did point to a concern. Around half of the participants spoke about the experience as being less immersive, which was suggested that an element of the narrative is lost when you have experienced it before. One participant said that they weren't as "*curious*" as they were when they watched it the first time. Another said, "*this time I knew what I was expecting so I* *didn't go straight there*", signifying a drop in the level of presence. To understand better then, a number of participants watched the film for the first time with the added sensory stimuli. The responses clearly signify a more intense experience of feeling presence in the environment. A participant, who had experienced VR previously, stated;

> The sensory side of it was unbelievable so that was amazing to have the sensory side of the smell and heat which helped immerse you in it. But the movement, I actually felt like I was moving around in the environment in a more natural way than I did before so I felt like I could almost control where I was rather than just being led by the environment.

It indicates a quicker response to feeling presence and more authenticity to being in the environment. Although there is no interactivity in the 360-degree film, where you can choose different pathways, narratives or move around in different directions. The respondent here felt like there was movement and agency in the environment given the added senses.

The senses added impact to the uneasiness that was created in the film. One scene focuses on a man who passes through the market and then spots the camera. He is curious as to what it is and comes close to the camera to investigate (Fig. 1). Many respondents spoke about the uneasiness in this scene and how it made them jump or feel that their personal space has been invaded. The participant who only watched the film with the added senses described it with a lot more intensity in the language that was used.

> Once I got scared in there when a big guy came up to me and looked and for a minute I felt threatened by him and thought he was going to hit me. I actually felt…this is how immersive it is… as I really felt he was in my space and I felt out of control totally as I thought I really don't know what he was going to do. I was really tense. I had in the back of my head that I could, if I wanted, to come out of it and take the thing of. I didn't like him and I was on the edge.

The same scene was also discussed by other participants with the heat leading to more "*agitation*". One participant said that "*heat puts you on edge more*" so this scene made you feel more uneasy. Another participant had a comparable experience,

> Generally the heat itself makes you feel more uncomfortable in there so it adds to the element of people coming closer to you. Your mind tricks you into thinking it's the heat coming off him, rather than the general heat in the area adding to the uncomfortability (sic.).

However, there were moments when the suspension of disbelief and sense of presence were reduced. Paradoxically, it was in the above example. One respondent was so scared that they tried to push the person away but, clearly could not. As they put it: "*It goes against the laws of physics*" not being able to touch the person and, at that point, the overwhelming sense of presence disappeared.

From this we can deduce that specific ideas that are being explored in the film, in this case the sense of uneasiness in the virtual environment, can be heightened and accentuated through adding in multisensory modes at specific intervals in the 360-degree film.

5 Conclusion

The added sensory stimuli to 360-degree film enhances the level of presence in a virtual environment, bringing us closer to the sense of total immersion that has been significant within CGI virtual environments. Heat and olfactory additions create a more immersive experience within 360-degree film and create the sense of interaction and embodiment that has been lacking within simple spherical film. To create virtual worlds that allow the user to suspend disbelief, 360-degree films need to work that bit harder and utilise the opportunities that multimodalities bring to enhance presence in the virtual environment.

However, our research also suggests that any answer needs to be a little more nuanced around three main areas and that further research needs to be carried out in all of these areas to fully determine the extent to which it does:

1. The experience of viewing 360-degree film is profoundly different to traditional forms of screen-based media: it is experiencing rather than viewing. As a result, it is argued that traditional terms for the users of such films—such as audience or viewer—is replaced with a new term: 'experiencer'. From this research, it is clear that the experience of 360-degree film is enhanced by the addition of multi-sensory input and, from this very small study, would argue that there is a hierarchy of affect: visual, auditory, thermoceptive and olfactory, in that order. Further studies might explore this and the extent that other forms of sensory input, such as the "movement and haptic sensations" that Ryan advocates, might have on the experience.
2. The spaces that multi-modality need to be experienced in have to be relatively sophisticated to enhance the sense of presence fully. There are numerous current examples of '4D' film where, in a stable and controlled environment, such as a theme park, multi-sensory input is added to the experience. This research suggests that the addition of stimuli needs to be carefully controlled for it to achieve maximum effect. Although respondents mentioned that heat could be a constant in relation to our film, they all mentioned that olfactory stimuli needed to be appropriate to the narrative and to be variable in intensity. Currently, such sophistication and expense precludes true multi-modality from happening in a domestic setting which has profound implications for who is able to access it, when and how and, more importantly, who is excluded from it.
3. That new means of experiencing might involve technologies that both enhance the sense of presence while, paradoxically limiting it: for example, the use of helmets. The VR experience relies on a complex set of circumstances being just right. If one, such as the fit of the HMD, is not, the experience is diminished to the extent where disbelief cannot be suspended. This also applies to the addition of other sensory input.

References

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

Banakou, D., Groten, R., & Slater, M. (2013). Illusory ownership of a virtual child body causes overestimation of object sizes and implicit attitude changes. *Proceedings of the National Academy of Sciences of the United States of America, 110,* 12846–12851. doi:10.1073/pnas.1306779110.

Bergstrom, I., Kilteni, K., & Slater, M. (2016). First-Person Perspective Virtual Body Posture Influences Stress: A Virtual Reality Body Ownership Study. *PLoS ONE, 11*(2).

Bouko, C., & Slater, M. (2011). Identity, otherness and the virtual double. *Technoetic Arts, 9*(1), 17–30.

Debord, G. (1996). *Theory of the derive.* In Andreotti, L. & Costa, X. *Theory of the dérive and other Situationist writings on the city*. Museu d'art contemporani de Barcelona.

De la Peña, N., Weil, P., Llobera, J., Giannopoulos, E., Pomés, A., Spanlang, B., et al. (2010). Immersive journalism: immersive virtual reality for the first-person experience of news. *Presence: Teleoperators and Virtual*. *Environment, 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. *Proceedings Virtual Reality, 1999, IEEE,* 222–228.

Dolan and Parets, (2015). *Redefining the Axiom of Story: The VR and 360 Video Complex.* https://medium.com/@devon.michael/redefining-the-axiom-of-story-the-vr-and-360-video-complex-bee3c20d69df

Dolan, D. & Perets, M. (2016). *Redefining the Axiom of Story: The VR and 360 Video Complex.* Retrieved December, 2016, from https://medium.com/@devon.michael/redefining-the-axiom-of-story-the-vr-and-360-video-complex-bee3c20d69df#.94ngjcddg.

Featherstone, M., & Burrows, R. (1996). *Cyberspace/cyberbodies/cyberpunk: Cultures of technological embodiment*. London: Sage.

Friedman, D., Pizarro, R., Or-Berkers, K., Neyret, S., Pan, X., & Slater, M. (2014). A method for generating an illusion of backwards time travel using immersive virtual reality-an exploratory study. *Frontiers in Psychology, 5,* 943.

Fuchs, P. & Moreau, G. (2006). *Introduction à la réalité virtuelle/Introduction to Virtual Reality.* In Fuchs et al. (Eds.), *Le Traité de la réalité virtuelle. Volume 2: L'interfaçage, l'immersion et l'interaction en environnement virtuel/The Treatise of Virtual Reality. Volume 2: Interfacing, immersion and interaction in virtual environment* (3–30), Paris: ENSMP Presses.

Hall, E. T. (1963). A system for the notation of proxemic behavior. *American Anthropologis, 65* (5), 1003–1026.

Heilig, M. (1998). *Beginnings: Sensorama and the Telesphere Mask*. In Dodsworth, C. (Ed.) *Digital Illusion* (343–351). New York:ACM Press.

Höijer, B. (2004). The Discourse of Global Compassion: The Audience and Media Reporting of Human Suffering. *Media, Culture and Society, 26,* 513–531.

Hsu, E., Li, Y., Bayram, J., Levinson, D., Yang, S., & Monahan, C. (2013). State of virtual reality based disaster preparedness and response training. *PLoS Currents, 5,* 1.

Huang, H., Ulrich, R., & Liaw, S. (2010). Investigating learners' attitudes toward virtual reality learning environments: Based on a constructivist approach. *Computers & Education, 55*(3), 1171–1182.

Ischer, M., Baron, N., Mermoud, C., Cayeux, I., Porcherot, C., Sander, D., et al. (2014). How incorporation of scents could enhance immersive virtual experiences. *Frontiers in Psychology, 5,* 736.

Jones, S. (2016) Disrupting the Narrative: Immersive Journalism in Virtual Reality, *Journal of Media Practice (forthcoming)*

Krueger, M. W. (1996). *Addition of Olfactory Stimuli to Virtual Reality Simulations for Medical Training Applications.* http://www.dtic.mil/dtic/tr/fulltext/u2/b220530.pdf

Lombard, M., & Ditton, T. (1997). At the Heart of It All: The Concept of Presence. *Journal of Computer-Mediated Communication*. doi:10.1111/j.1083-6101.1997.tb00072.x.

Mathews, G. (2011). *Ghetto at the Center of the World: Chungking Mansions*. Hong Kong University of Chicago Press.

Milk, C. (2015). "How virtual reality can create the ultimate empathy machine". Paper Presented at Ted2015.

Munyan, B.G., Neer, S.M., Beidel, D.C., Jentsch F. (2006) *Olfactory Stimuli Increase Presence in Virtual Environments.*.In Scavone, C. (Ed). *PLoS ONE*. doi:10.1371/journal.pone.0157568

Nikunen, K. (2016). Media, passion and humanitarian reality television. *European Journal of Cultural Studies, 19*(3), 265–282.

Otto, P. (2007). Between the Virtual and the Actual: Robert Barker's Panorama of London and the Multiplication of the Real in late eighteenth-century London. *Romanticism on the Net, 46,* 1.

Ohyama, N., Watanabe, M., Akizuki, T., & Harada, T. (2007). Autonomic responses during motion sickness induced by virtual reality. *Auris, Nasus, Larynx, 34*(3), 303–306.

Pimentel, K., & Texeira, K. (1993). *Virtual Reality: Through the New Looking-Glass*. London: McGraw Hill.

Reiner, M. (2011). Presence: Brain, virtual reality and robots. *Brain Research Bulletin, 85*(5), 243–244.

Ryan, M. L. (1999). Immersion vs. interactivity: Virtual reality and literary theory. *SubStance, 28* (2): 110–137.

Ryan, M. L. (2015). *Narrative as Virtual Reality 2: Revisiting Immersion and Interactivity in Literature and Electronic Media*. JHU Press.

Smith, W. (2015). *Stop calling Google's Cardboard 360-degree videos VR.* Retrieved December, 2016, from https://www.wired.com/2015/11/360-video-isnt-virtual-reality/.

Uricchio, W. (2011). A 'proper point of view': The panorama and some of its early media iterations. *Early Popular Visual Culture, 9*(3), 225–238.

Wilcox, L., Allison, R., Elfassy, S., & Grelik, C. (2006). Personal space in virtual reality. *ACM Transactions on Applied Perception (TAP), 3*(4), 412–428.

Directions for Studying User Experience with Augmented Reality in Public

Ana Javornik

Abstract This paper discusses the different components of experience with AR applications in public—mainly in commercial contexts, but also relevant for the cultural and touristic contexts. It draws on recent studies and developments of AR marketing and investigates user-, technology- and context-related factors. In particular, it discusses the core experiential momentum—"augmentation"—and its value for the user, as well as the role of social interaction. Most importantly, the framework underlines the lack of studies that investigate the impact of AR on behaviour and behaviour change and calls for further research in that area. Finally, implications for designing AR experience in public are proposed.

Keywords User experience · Augmentation · Public interaction · Marketing

1 Introduction

Mass adoption of applications such as Pokémon Go and SnapChat filters has proven there is a considerable interest in the use of AR. Despite the fact that AR technology has been present in different formats for a long time (Azuma et al. 2001; Rogers et al. 2002), it is still considered a novelty. There is, to date, a significant lack of understanding to what extent AR is actually being used outside of the academic lab and how the real world environment influences such use.

AR by definition functions differently than other interactive technologies in terms of its "reliance" on the physical world. It is based on the fusion of the physical environment with the virtual to a much larger extent than is the case for more traditional interactive technologies, such as the established mobile applications, social media platforms or emails. Given that the physical surroundings are much more important for AR experience, the contexts where AR is used—for

A. Javornik (✉)
Newcastle University Business School, Newcastle upon Tyne, UK
e-mail: ana.javornik@ncl.ac.uk

T. Jung and M.C. tom Dieck (eds.), *Augmented Reality and Virtual Reality*,
Progress in IS, DOI 10.1007/978-3-319-64027-3_14

example the positioning of markers or placement of AR screens—greatly impact the nature and quality of experience.

This study aims to provide a more holistic overview of the components that need to be taken into account when designing a user journey with AR that takes place in public. For that purpose, this paper indicates which factors precede the experience which are central to the experience and what the potential outcomes are. It draws on findings from media studies, human-computer interaction, marketing and computer science, underlying the necessity of an interdisciplinary approach to the study of AR. Furthermore, we shortly discuss two recent placements of AR in public context and illustrate the framework's applications through those examples, along with the research questions that could serve as guidance for further empirical studies of AR in public.

2 Background

Studies of consumer and user experience with other interactive technologies (internet, social media, mobile phones, virtual reality, wearables) focused predominantly on factors such as: technology affordances related to the user interface, user demographics and psychographics, different types of engagement such as social, affective or cognitive and, evidently, behavioural in terms of purchases, performance and reuse.

This rich body of research related to these technologies has for instance proven that affordances like interactivity or modality play a major role in online consumer experience (Sundar et al. 2015) and that they have further impact on variables such as website attitude, e-retailer trust and purchase intentions (Dennis et al. 2009; van Noort et al. 2012). Moreover, perceptions of characteristics such as ease-of-use, usefulness, visibility and privacy further impact consumer willingness to use websites, mobiles and wearables (Rohm et al. 2012; Lunney et al. 2016; Chuah et al. 2016; Pagani and Malacarne 2017), along with consumer characteristics like demographics, tech savviness or personal traits (Dennis et al. 2009). The nature of engagement needs to be observed both on an individual and social level (Pagani and Mirabello 2011), in relation to different values such as enjoyment, utility and community participation (Calder et al. 2009).

Many of these aspects remain relevant for studying AR. Rauschnabel et al. (2015) for example showed that consumer characteristic such as introvertism vs. extrovertism significantly impact willingness to adopt wearable AR. Scholz and Smith (2016) emphasize the relevance of engagement between users and brands and the support of meaningful content when creating immersive AR experience.

However, additional insights are required. Some digital technologies—mobile, social media, wearables—became ubiquitous in terms of their use in the sense that individuals would be accustomed to constantly interacting with them, for instance just before going to bed, when walking down the street, when they are spending time with their friends and so forth (Cecchinato et al. 2014). On the other hand, numerous AR apps or set-ups of AR experiences have until now not been perceived as a technology that one would feel like using all the time or anywhere, but more like for specific tasks and in specific environments (Rehrl et al. 2014). That has partially to do with some technical limitations—for example, holding a smartphone in the air to keep seeing the overlaid information is not an intuitive use of technology that one would engage in for an infinite amount of time, but in some contexts it can appear both useful and hedonic. Wearable AR is facing other issues, too. Wearing HoloLens for a longer period can prove to be challenging because of its weight and also because of the users' concerns how it might affect their appearance (Rauschnabel and Ro 2016). Furthermore, it can potentially still lead to some motion sickness, even thought the issues are not as severe as, for instance, with VR headsets (Hern 2017).

An interesting exception to this was of course Pokémon Go where people were willing to play an AR game when walking down the street or when in an office. However, safety and social issues arose around it, along with its decreased popularity. Google Glass was designed with the intention that people would continuously wear it, but there was little evidence that users were comfortable with constant virtual overlay, as it could quickly appear intrusive, besides the issues related to the social acceptance of technology.

While cases of AR apps that are not related to specific context might (continue to) rise, it is currently equally or more relevant to discuss how to contextualize AR experience, set up in public spaces.

3 Dimensions of User Experience with AR

User experience with AR thus requires revisiting some of the established factors and rethinking them in the context of AR, but it also calls for understanding some of the factors that have not been focused on to such an extent beforehand.

As indicated above, more than around its ubiquitous deployment, a deeper appreciation is required around the specific contexts in which AR can enhance the experience in a meaningful way (Scholz and Smith 2016), also referred to as *situatedness* (Javornik et al. 2017). Due to the nature of how it functions (i.e. its ability to enhance physical contexts), AR works very much in conjunction with the physical environment. In public places such situatedness proves even more complex because the external influences can be unpredictable and thus may interfere with the experience. For example, if in an art gallery the overlaid information appears based on markers of the painting, the constant flow of people passing by might interrupt the augmentation. Or if a virtual mirror is situated opposite a strong light, this can interfere with a user's reflection in the mirror and consequently with the try-on. As observed with Pokémon Go and with other AR apps destined for outdoor use, physical context can also lead to safety issues—if a user gets so immersed in the screen that he forgets about his surrounding, that can jeopardize his safety. On the other hand, the physical context can very well play into the experience. If appropriately integrated, the situatedness would enhance the experience.

Some previous studies have looked at the *user* side. Rauschnabel et al. (2015) for instance showed the impact of psychological characteristics such as introversion and extroversion on a user's propensity to adopt AR wearables. Technological savviness can also be expected to have multileveled influence on the quality of the experience. On one hand technologically savvy users will be more willing to experiment and will also be capable of having a fuller exploration of the technology, but that affinity will be probably coupled with higher expectations. However, technologically less savvy users might express more admiration and find themselves more in awe of different formats of augmentation, resulting in a higher level of surprise. With public AR mirrors, moreover, the person would see herself virtually enhanced in a mirror and if the people passing by could see that reflection, the social embarrassment can represent an obstacle in such situations (Wouters et al. 2016), which could have different effects based depending on the level of shyness.

Moreover, more needs to be understood around the interface *features* and the related affordances that are suitable for AR. Interactivity was defined as one of the key characteristics of the internet (Song and Zinkhan 2008). Virtuality or vividness is seen as central for creating immersion into virtual worlds (Jennett et al. 2008). Because AR appears in a camera-view, other features—interactivity, virtuality etc.—need to adapt to that in order to not take over the screen and obstruct the view on which virtual elements are overlaid.

Also, the rules for designing the content for AR mode (camera view with overlaid content) differ substantially from designing the content for websites or mobile applications. What combination of text and image might be most suitable for the users to engage the most with the content? We might expect that viewing the augmented content might make the users become progressively more used to seeing content overlaid on museum artefacts or when exploring a new area while travelling. Would they adopt the virtual content as part of their viewing and, as a consequence, feel impoverished when not having access to it in certain situations?

Overlaying of the physical environment with virtual annotations has been referred to as *augmentation*. This can entail augmentation of the products (for instance overlaying a Lego box with an image of how the Lego construction will look like when built) or the person herself. Research so far has shown that consumer enjoy such visual simulation and that they also find it useful when shopping (Javornik et al. 2016), discovering a touristic or cultural site (Kourounthanassis et al. 2015; Leue et al. 2015) and learning (Chang et al. 2014). The perceived value of such augmentation can be related to the quality of virtual augmentation—for example, a suitable alignment of the physical and the virtual, the quality of the content or the system itself (Jung et al. 2015). That can be especially important for certain types of AR apps like virtual try-on, while Pokémon Go was rather based on an overlay instead of on perfect alignment. With the increased level of quality of emerging AR apps, the expectations of users with regards to such alignment might increase.

Designing AR experience in a store or in a museum for people to take part thus always requires taking into account the elements that will signal to the user that they can step into an AR experience. What will be used as triggers? If there is a virtual try-on mirror situated in a store, how will the shoppers understand that the mirror will augment their reflected image? What is required for the set up of an intuitive experience with a mirror, be it in a museum or in a store? Is it more suitable to allow for an element of surprise when a person suddenly sees herself in the mirror with a virtual hat on, or should the person first approach the mirror and initiate the overlay by a movement or by tapping on the screen? If so, how can it be ensured that many people would not just walk by? Is it a role of store assistants or museum curators to point the technology to the visitors? If the human interaction is a crucial element, then further research is needed about how it can be best integrated in the experience. Would it rather be the role of advertisement and PR to raise the profile of stores or spaces where AR installation can be sought out? If so, how to combine the promotion through additional advertising channels with this novel technology? Some screens are so huge that they immediately attract the crowd because they simply can't be overlooked, but the cost associated with such set-up is not compatible with the wide public deployment.

As already underlined by Scholz and Smith (2016), *engagement* with AR can take different forms. The users can engage with content, other users and brands or institutions behind the AR. Qualitative research for example should unveil what meanings users attach to these experiences. Does AR enhance cognitive engagement and facilitate decision-making? In what way do AR set-ups allow users to perform better in specific tasks or lead to behavioural change by visualizing certain content in a manner that it makes a difference? Moreover, interacting with installations or technologies in public spaces often caries a social component– such as the honeypot effect where those passing by are drawn to observe or to take part in the experience, but also elements of social embarrassment, feeling uncomfortable about knowing that others are observing you. The social component in AR experiences needs to be explored further.

Research shows that the younger generation no longer distinguishes between digital and physical content. If AR use shall continue to rise, perhaps the generation post-Y might no longer draw clear distinctions between virtual when overlaid on the surrounding and the physical surroundings. But currently, it is more crucial to investigate what is the perception of such augmentation and what are the potential consequences. In our recent study, we for instance show that such visualization can facilitate an artistic process and allow users to view themselves as opera characters (Javornik et al. 2017). To which extent will the augmentation increase imagination and creativity and to which extent will it actually have the opposite effects? In what ways can AR empower human activities without making the users relying too much on its visualisation techniques? (Fig. 1).

The impact on the subsequent behaviour is one of the most under-investigated areas in AR and user behaviour. Once the episode of interaction is completed, it is crucial to understand what difference it made in the long run. Did the AR app increase the amount the users were willing to spend on a purchase or did it convince

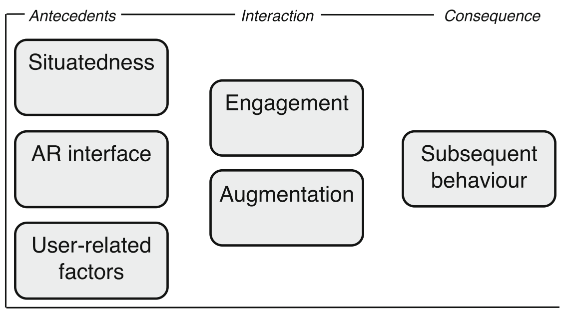


Fig. 1 Framework of AR experience in public (adapted from Javornik et al. 2017)

them into buying an item? Chang et al. (2014) demonstrate direct impact of AR on learning and art appreciation when visiting a gallery. More such studies are required to unveil if AR installations can truly make a difference in for instance how visitors relate to cultural events in the long run and if AR can actually modify how we perceive our skills or if it can impact certain attitudes and beliefs that would lead to positive behavioural change. In the following two cases, two AR public installations are shortly discussed in the view of this framework.

4 Charlotte Tilbury's Magic Mirror

Virtual try-ons are proving to be increasingly more popular additions to retail environments. Make-up artist Charlotte Tilbury set up one such "Magic Mirror" in her flagship store in Westfield that allowed the visitors to try on ten of the artist's signature looks (Arthur 2016). Charlotte Tilbury is positioned as an up-market brand that offers high quality make-up and the retail stores reflect the luxury brand image.

As seen in the Fig. 2, the virtual try-on mirror was situated in a manner that it appeared as a part of the store. Such integration in terms of style and aesthetics allowed for a wholesome retail experience for visitors, as the mirror was embedded as one leg of the retail journey. Furthermore, looking at oneself in the mirror with make-up is an activity that does not need to be learnt, as it's a rather intuitive reaction for shoppers to do—which allowed for appropriate situatedness and interaction triggers.

The fact that the visitor could only try the ten predefined looks poses an interesting question about the level of interactivity and personalization and branding strategy. This allowed the brand to visualize the combination of products of their own choice and retained control over the displayed images. Such a set up can represent a certain advantage, as it prevents the shoppers from designing looks that the make-up artist would not perceive to be of sufficient quality or appropriate

Fig. 2 Magic Mirror in Charlotte Tilbury store in Westfield (London). (Copyright Holition Ltd)

appeal. Furthermore, the ten signature looks are associated with celebrities and represent an important asset to the brand image, therefore the mirror permits the brand to raise profile and increase the awareness and knowledge with the shoppers. Finally, the signature looks—The Ingénue, The Golden Goddess, The Uptown Girl, The Rebel, The Glamour Muse, The Vintage Vamp, The Bombshell, The Dolce Vita, The Rock Chic and The Sophisticate—add elements of storytelling to the virtual try-on.

Moreover, such a set-up simplifies the interaction, as the mirror interface does not require any other features in addition to the buttons for the ten looks. On the other hand, the set up limits further interactions with the mirror in terms of personalizing the looks and trying on a palette of products, as is usually the case for virtual mirrors.

More investigations would require insights into the following questions: what role does such particular set-up of the mirror play in the decision-making process? In what manner does the mirror change consumer experience in the store? What impact does it have on product attitude, especially given the fact that the products were presented as parts of a signature look? Does the mirror enhance interactions with shop assistants or interactions among the shoppers themselves?

Semi-public space such as retail make such set ups less challenging in terms of controlling the external influence and contextual factors. Similar was not the case for the Christmas campaign set up by Blippar, designed for a public site of Covent Garden.

Fig. 3 The shoppers and store assistant in front of the Charlotte Tilbury Magic Mirror (Copyright Holition Ltd)

5 Blippar Christmas Covent Garden Campaign

In the period leading up to Christmas 2016, Blippar launched an app that would augment the visit of Covent Garden. Designed as a gaming application, its purpose was to engage the visitors into a game of collecting eight different reindeer (Fig. 4). When all the reindeer were collected, the user could enter a prize draw to win £200 voucher for dining at a popular Covent Garden restaurant. Coupled with the prize were also other promotional offers that one could benefit from when scanning the tag “Exclusive rewards”, related to specific stores at Covent Garden.

Besides the game, there were also other features, such as visualization of the reindeer Rudolph flying towards the sky and sparkling, as well as an appearance of The Northern Lights (Fig. 4, Right). In order to access all this content, the visitor had to download the Blippar app and “blip” (i.e. scan) the markers that were organised either as labels on windows of stores or cafés or at some other prominent places. As the notion of “blipping” might not have been familiar to the visitors, additional instructions were required in such instance. The experience designers solved this issue by printing the instructions in large font next to the blipping images (Fig. 3 and 4).

The content of this particular campaign was aligned with the time and the place—Covent Garden being a popular destination by many during Christmas period. Seeing Rudolph in the sky with Aurelia Borealis enhanced the magic of the visit at that time of the year. Furthermore, the central Covent Garden area was closed for traffic therefore the visitors had the chance to stop in front of different points without jeopardizing their

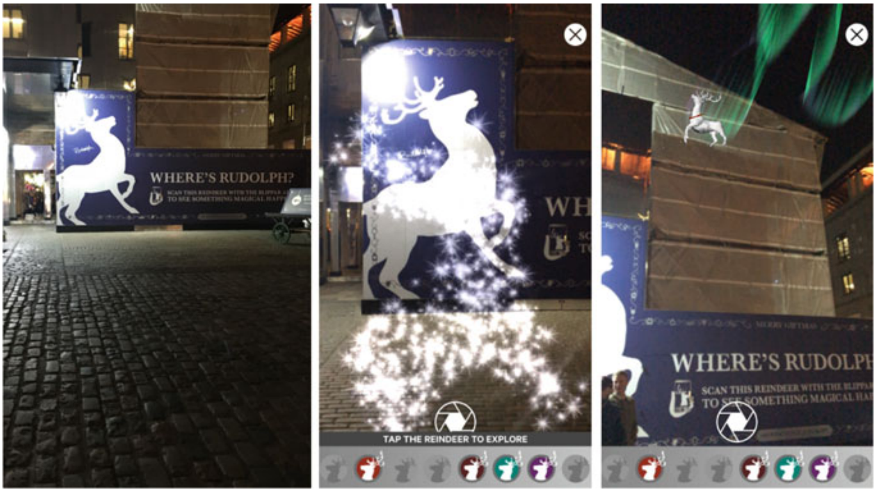


Fig. 4 Cardboard with Rudolph that was augmented once it was "blipped"

safety. Also, the site is a popular destination among families, thus the gaming element resonated well with children.

Some of the related challenges of such a set up have to do with the fact that "blipping" is not an intuitive experience (i.e. not something many visitors are used to doing) and therefore a certain amount of explaining is required for the visitors to take part in the experience. A user study would be relevant to explore to which extent the visitors perceived the experience to be easy and intuitive and if the app had an impact on the character of the Covent Garden visit experience. Were these perceptions different across demographic groups and did they differ depending on the user being on her own or with friends and family?

Designing such an experience in a public space (and not semi-public) carries numerous challenges. For example, the labels for blipping should be easily accessible, but should at the same time not create awkward social situations, where others visitors might mistake the "blipping" for someone taking a photo of them while they are enjoying their coffee (Fig. 5). The blipping should not obstruct other people's activities, which is why the alignment of the digital/virtual and the physical requires such attention with AR experience in public.

Also, further research would be required to understand the perceived appeal of the interface design. Which were the successful solutions of the user interaction and which points created a bottleneck, if any? Moreover, did the gaming elements in some way enhance the visits, both on social and/or individual level? And, most importantly from the commercial point of view, to which extent did the exclusive rewards offer drive the shopping and purchase behaviour? Finally, did the user acquire interest and desire for such a "blipping" experience also in other contexts—if so, which ones and for what purpose?

Fig. 5 One of the labels on the window for the visitors to "blip" and collect reindeer

6 Conclusion

This paper outlines the main dimensions of AR experience with a special emphasis on public interactions. By doing so, it contributes to the field by pointing out the relevance of elements such as *situatedness*, design of *interface features* for the AR mode, *augmentation* and some others. The placement of AR in the physical surrounding and the manner in which virtual overlay relates to the physical context carries high importance for the quality of AR experience. The adoption of AR is starting to come of age and such holistic approaches can help the designers, researchers, marketers and others to seize the potential or AR and deploy it in efficient and appropriate manners.

Acknowledgements The author wishes to thank Prof Yvonne Rogers, Dr Morgan Harvey, Dr Ana Moutinho and Holition Ltd for all the invaluable discussions related to this line of research.

References

Arthur, R. (2016). *Charlotte Tilbury's new virtual "Magic Mirror" serves as active Make-Up Selling Tool.* Forbes. Retrieved January, 2017, from http://www.forbes.com/sites/rachelarthur/2016/10/21/charlotte-tilburys-new-virtual-magic-mirror-serves-as-active-make-up-selling-tool/#5de13d242812 .

Azuma, R., Behringer, R., Julier, S., & Macintyre, B. (2001). Recent Advances in Augmented Reality. *IEEE Computer Graphics and Applications, 21*(6), 34–47.

Calder, B. J., Malthouse, E. C., & Schaedel, U. (2009). An Experimental Study of the Relationship between Online Engagement and Advertising Effectiveness. *Journal of Interactive Marketing, 23*(4), 321–331.

Cecchinato, M. E., Cox, A. L., & Bird, J. (2014). *"I check my emails on the toilet" Email Practices and Work-Home Boundary Management.* Paper presented at the MobileHCI 2014 Workshop on Socio-Technical Practices and Work-Home Boundaries.

Chang, K. E., Chang, C. T., Hou, H. T., Sung, Y. T., Chao, H. L., & Lee, C. M. (2014). Development and behavioral pattern analysis of a mobile guide system with augmented reality for painting appreciation instruction in an art museum. *Computers & Education, 71,* 185–197.

Chuah, S. H. W., Rauschnabel, P. A., Krey, N., Nguyen, B., Ramayah, T., & Lade, S. (2016). Wearable technologies: The role of usefulness and visibility in smartwatch adoption. *Computers in Human Behavior, 65,* 276–284.

Dennis, C., Merrilees, B., Jayawardhena, C., & Tiu Wright, L. (2009). E-consumer behaviour. *European Journal of Marketing*, *43*(9/10), 1121–1139.

Hern, A. (2017). *I tried to work all day in a VR headset and it was horrible.* The Guardian. Retrieved January, 2017, from https://www.theguardian.com/technology/2017/jan/05/i-tried-to-work-all-day-in-a-vr-headset-so-you-never-have-to.

Javornik, A., Rogers, Y., Moutinho, A. M., & Freeman, R. (2016). Revealing the Shopper Experience of Using a " Magic Mirror " Augmented Reality Make - Up Application. *Proceedings of the 2016 ACM Conference on Designing Interactive Systems,* (871–882).

Javornik, A., Rogers, Y., Gander, D., & Moutinho, A. (2017). MagicFace : Stepping into character through an augmented reality mirror. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems '17.* ACM.

Jennett, C., Cox, A. L., Cairns, P., Dhoparee, S., Epps, A., Tijs, T., et al. (2008). Measuring and defining the experience of immersion in games. *International Journal of Human Computer Studies, 66*(9), 641–661.

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.

Kourouthanassis, P., Boletsis, C., Bardaki, C., & Chasanidou, D. (2015). Tourists responses to mobile augmented reality travel guides: The role of emotions on adoption behavior. *Pervasive and Mobile Computing, 18,* 71–87.

Leue, M. C., Jung, T., & tom Dieck, D. (2015). Google glass augmented reality: Generic learning outcomes for art galleries. In *Information and Communication Technologies in Tourism 2015* (463–476). Springer International Publishing.

Lunney, A., Cunningham, N. R., & Eastin, M. S. (2016). Wearable fitness technology: A structural investigation into acceptance and perceived fitness outcomes. *Computers in Human Behavior, 65,* 114–120.

Pagani, M., & Malacarne, G. (2017). ScienceDirect Experiential Engagement and Active vs. Passive Behavior in Mobile Location-based Social Networks: The Moderating Role of Privacy. *Journal of Interactive Marketing, 37,* 133–148.

Pagani, M., & Mirabello, A. (2011). The Influence of Personal and Social-Interactive Engagement in Social TV Web Sites. *International Journal of Electronic Commerce, 16*(2), 41–68.

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*: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.

Rehrl, K., Häusler, E., Leitinger, S., & Bell, D. (2014). Pedestrian navigation with augmented reality, voice and digital map: final results from an in situ field study assessing performance and user experience. *Journal of Location Based Services, 8*(2), 75–96.

Rogers, Y., Scaife, M., Harris, E., Phelps, T., Price, S., Smith, H., Muller, H., et al. (2002). Things aren't what they seem to be: innovation through technology inspiration. *Proceedings of the conference on Designing interactive systems processes practices methods and techniques DIS 02,* (373–378).

Rohm, A. J., Gao, T., Sultan, F., & Pagani, M. (2012). Brand in the hand: A cross-market investigation of consumer acceptance of mobile marketing. *Business Horizons, 55*(5), 485–493.

Scholz, J., & Smith, A. N. (2016). Augmented reality: Designing immersive experiences that maximize consumer engagement. *Business Horizons, 59*(2), 149–161.

Song, J. H., & Zinkhan, G. M. (2008). Determinants of Perceived Web Site Interactivity. *Journal of Marketing, 72*(2), 99–113.

Sundar, S. S., Jia, H., Waddell, T. F., & Huang, Y. (2015). Toward a theory of interactive media effects (TIME): Four models for explaining how interface features affect user psychology. *The Handbook of the Psychology of Communication Technology*, 47–86.

van Noort, G., Voorveld, H. A. M., & van Reijmersdal, E. A. (2012). Interactivity in Brand Web Sites: Cognitive, Affective, and Behavioral Responses Explained by Consumers' Online Flow Experience. *Journal of Interactive Marketing, 26*(4), 223–234.

Wouters, N., Downs, J., Harrop, M., Cox, T., Oliveira, E., Webber, S., Vetere, F., et al. (2016). Uncovering the Honeypot Effect: How Audiences Engage with Public Interactive Systems. *Designing Interactive Systems '16*: pp. 5–16.

A Conceptual Uses & Gratification Framework on the Use of Augmented Reality Smart Glasses

Philipp A. Rauschnabel

Abstract Augmented Reality (AR), the integration of virtual objects into the physical world, is about to become real. Microsoft Hololens and other devices termed as 'augmented reality smart glasses' (ARSG), allow its users to augment their subjective perceptions of the reality. However, not much is known about consumers react to this new form of wearable media technology. Against this background, this article reviews the scarce body of ARSG literature, supplements it with established findings from Uses & Gratification Theory (U&GT) and related research streams to propose a conceptual model. In doing so, this article enhances our understanding of AR, and ARSGs in particular, by proposing the role of existing and novel constructs to the stream of U&GT and AR research. The chapter closes with a discussion of promising avenues for future research on ARSGs and other head-mounted displays.

Keywords Augmented reality smart glasses · Head-mounted displays · Uses and gratifications theory (U&GT) · Fashnology · Wearable technology

1 Introduction

Smart mobile technologies and continuous access to the Internet have become an integral part of our daily lives. Popular apps allow us to check in on Facebook, to tag friends, or to 'instantly' upload photos on Instagram and other mobile social media services. All of these activities are examples of how recent technologies move the virtual world and the real world closer together.

P.A. Rauschnabel (✉)
College of Business, University of Michigan-Dearborn, Dearborn, MI, USA
e-mail: prausch@umich.edu

T. Jung and M.C. tom Dieck (eds.), *Augmented Reality and Virtual Reality*,
Progress in IS, DOI 10.1007/978-3-319-64027-3_15

However, the next groundbreaking technology is right around the corner: media-technologies that integrate virtual holographic objects realistically into a user's perception of the real world, often discussed as "Augmented Reality" or "Mixed Reality". These holograms can be used on basically any recent smart mobile device. The new technology of "augmented reality smart glasses" (ARSGs) offers users the opportunity to integrate virtual 3D-elements even more realistically into their field of vision (Ernst et al. 2016; Rauschnabel et al. 2016a). While prior research has provided important contributions both to augmented reality and wearable technologies (e.g., Chuah et al. 2016; Javornik 2016a, b), ARSGs remain an under-researched but relevant area. For example, Google, Alibaba, and other firms have recently invested $800 million of venture capital into a startup called *Magic Leap*, which specializes in ARSGs. Likewise, other companies including Amazon.com, Microsoft, and Samsung have announced or already launched their ARSGs. Market research reports confirm the game-changing potential of this development with promising numbers. For example, PricewaterhouseCoopers recently concluded that a life-changing wearable future is "right around the corner," (PWC 2014, p. 4) and a Goldman Sachs (2016, p. 4) research study determined realistic chances that AR would become "the next big computing platform, and as we saw with the PC and smartphone, we expect new markets to be created and existing markets to be disrupted." Google Glass was one example of a famous ARSG with little success, but prior research lacks providing any potential explanations as to why consumers did not adopt it as expected. Indeed, Stockinger's (2016), Delphi-Study and Javornik's (2016) research agenda conclude that AR, for consumer markets, is highly relevant but challenging.

This conceptual article[1] suggests Uses & Gratification Theory (U&GT) as a promising starting point to understand AR, and ARSGs in particular. Based on this proposition and taking into account prior research on ARSGs and related fields, I propose a theoretical framework to study the adoption and use of ARSGs. The objective therefore is to conceptualize how ARSGs can address fundamental human needs, and which factors need to be incorporated in understanding the psychological mechanisms that explain consumers' reactions to them. As a result, this proposed model provides scholars and other ARSGs enthusiasts a comprehensive overview of potentially relevant factors that can explain how and when consumers react to ARSGs. By doing so, this chapter also intends to inspire future research in this still futuristic topic.

[1]Please note that this conceptual article is part of a project from which an empirical paper was presented at the 3rd international AR/VR conference in Manchester, UK, Feb 23, 2017. The empirical paper is currently under review in an academic journal. Although distinct, the empirical paper builds on this chapter and thus might share similarities.

2 Theory and Prior Research

2.1 Augmented and Virtual Reality

AR aims to integrate virtual elements, such as holograms or other information, into a user's perception of the real-world (Javornik 2016a, b). For example, virtual mirrors are large screens in stores in which customers can see themselves wearing different clothes in different contexts (Anderson et al. 2013). Likewise, AR apps such as Pokémon Go for mobile devices allow users to experience AR independent from their location (tom Dieck and Jung 2015; Rauschnabel et al. 2017). However, pretending that virtual elements (e.g., Pokémon) are 'really existing' is potentially unrealistic when looking "through" a screen of a mobile device. ARSGs, however, are worn like regular glasses and integrate virtual information realistically into the user's field of vision (Rauschnabel et al. 2016; Rauschnabel et al. 2015). This allows a hands-free use which makes the AR experience more realistic than AR among mobile hand-held devices. To operate, various sensors (e.g., laser, gyroscope, cameras, microphone, GPS, etc.) capture the real world, and an integrated computer module processes this information and integrates virtual information. Figure 1 shows schematically the functionality of AR, and ARSGs in specific. Here, a woman is wearing an ARSG-device and looks at a carpet. The device processes the environment and realistically integrates a 3D hologram—a cat. Thus, the users 'sees' a cat sitting on the carpet.

2.2 Fashnology: Wearable Devices

ARSGs are, as any wearable device, not just 'used' but also 'worn', and thus, share several psychological similarities with fashion accessories. In fact, many wearables share prototypical similarities with 'non-smart' counterparts. For example, a smartwatch is worn like a regular watch, and some of them even look very similar to prototypical 'traditional watches' (e.g., Samsung Gear 3), whereas others look distinct (e.g., Apple Watch). To study wearables in general more effectively, research has discussed the term "fashnology," a combination of fashion and technology, as an overarching study concept (Rauschnabel et al. 2016). For example, Chuah et al. (2016) show that people who perceive smartwatches as a technology (vs. fashion) evaluate them as more useful (vs. visible). Likewise, Rauschnabel et al. (2016) propose that consumers who mentally categorize ARSGs as a fashion accessory tend to evaluate them more based on visible aspects, whereas those who categorize them as a technology incorporate usefulness judgements more. In addition, a finite mixture model among a large-scale US sample shows that about three quarters of the American population are 'fashnologists', and thus incorporate both fashion and technology criteria to assess ARSGs.

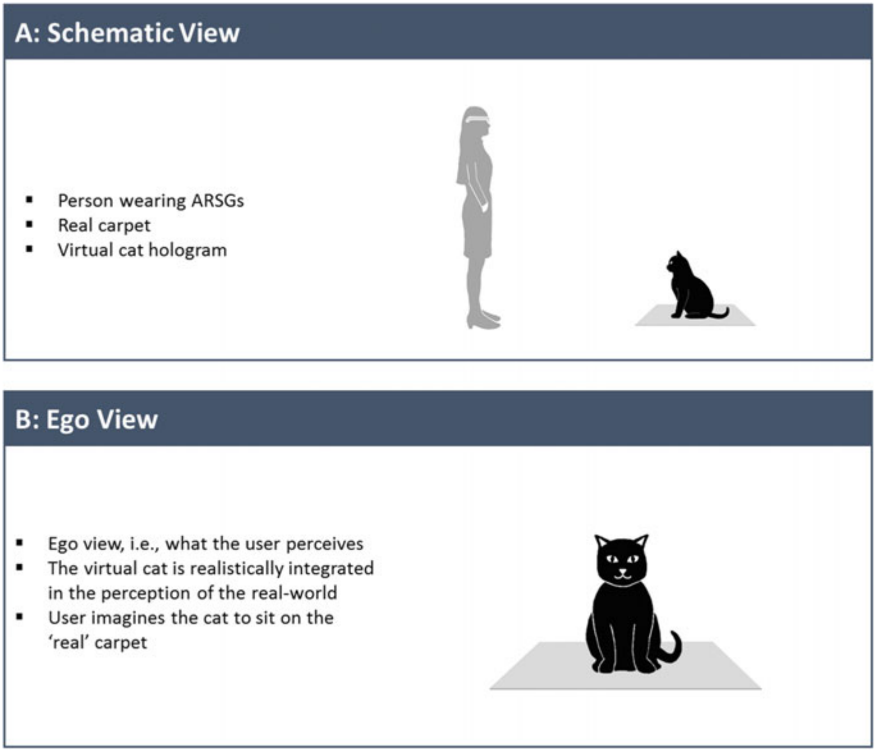


Fig. 1 Schematic characteristics of ARSGs: *gray* = real, *black* = virtual (*Source* http://www.connectedscience.de/reprint with permission)

In sum, it is important to note that ARSGs are a combination of Augmented Reality (i.e., reality *plus* virtuality), and fashnology (i.e., fashion *plus* technology). Figure 2 summarizes these specific ARSG characteristics schematically.

2.3 Uses and Gratification Theory (U&GT)

Traditionally, media researchers proposed that mass media are powerful and influential, whereas consumers are passive. U&GT scholars took a different approach. Rooted in media and communication science, U&GT addresses the central question: Why do people use particular media? U&GT is based on various assumptions, such as that audiences behave in a goal-oriented manner and proactively choose the media to consume in order to address particular human needs (Katz et al. 1973; Rubin 2002). Although individuals' needs often vary based on their individual characteristics (e.g., demographics, personality, etc.), Katz et al. (1973) provide a systematization of five broad categories of media-related needs:

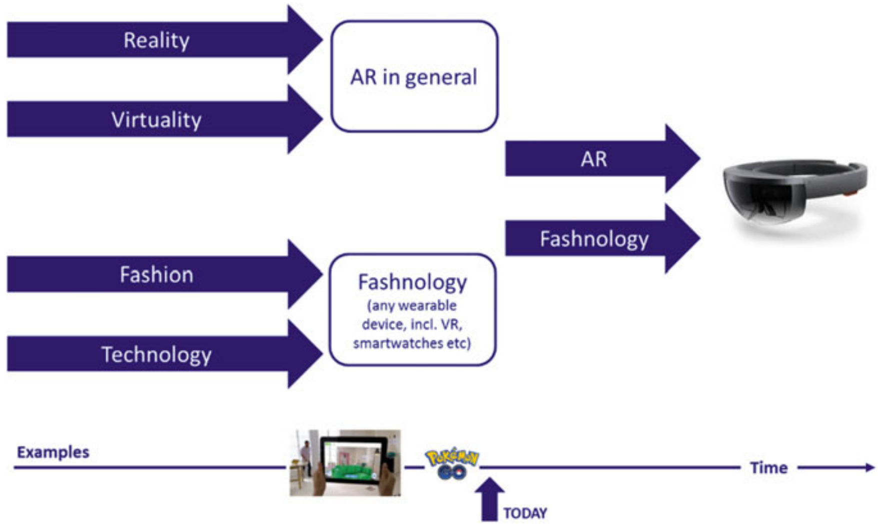


Fig. 2 ARSGs combine fashion and technology as well as the real-world with the virtual world

(1) cognitive needs, such as information gathering and understanding of particular phenomena,
(2) tension-release needs, such as escapism or diversion,
(3) affective needs, such as emotional experiences,
(4) social integrative needs, such as creating new and maintaining existing social relationships, and finally
(5) personal integrative needs, such as enhancing once status, confidence, or credibility (e.g., confidence building, credibility).

Despite the fact that U&GT is not without criticism (Ruggiero 2000), it remains one of the most widely applied theories in media research (Rubin 2002). For example, scholars have applied its framework to study various forms of media and technologies, including social media (Leung 2013) and online games (Wu et al. 2010). In addition, the flexibility of U&GT has allowed researchers to link it with other theories to investigate other innovative devices and services (Nysveen et al. 2005), such as ARSGs (Rauschnabel et al. 2016a). Certainly, many of the studied U&GT variables have counterparts in other domains. For example, what technology acceptance scholars term "usefulness" or "performance expectancies" (e.g., Venkatesh et al. 2012; King and He 2006; Ratten 2009) describes the extent to which a user of a technology believes that the use of a particular technology improves his or her task-performance. U&GT scholars use similar constructs that reflect utilitarian gratifications (Katz et al. 1973). Likewise, 'enjoyment' in the TAM domain describes how much "fun" a person experiences from using a technology (King and He 2006). Enjoyment is an example of a hedonic gratification in U&GT research that addresses tension-release needs (Rubin 2002).

3 Literature Review

Not many studies have investigated the adoption of ARSGs. Most of them build on prior technology acceptance research. These studies showed that factors such as perceived usefulness, enjoyment (Rauschnabel et al. 2016), social norms (e.g., Rauschnabel and Ro 2016; Weiz et al. 2016), image-related factors (Rauschnabel and Ro 2016; Rauschnabel et al. 2016), or the potential to substitute real physical objects through holograms (Ernst et al. 2016) are impactful in shaping consumers' reactions to ARSGs. Eisenmann et al.'s (2014) Harvard Business case study provides a comprehensive overview of factors that influence consumers' reactions to Google Glass. Findings of this case study also include "practical" factors such as specific display characteristics or battery. Likewise, other publications have discussed the potential of data leaks and thus, threats to a user's privacy (Hein and Rauschnabel 2016); however, most these early studies did not identify any significant risk factors, except Rauschnabel et al. (2016) who found that people tend to care more about the privacy of the people that surround them rather than about their own self privacy. Few studies have also investigated other potential risk factors (Rauschnabel et al. 2016; Stock et al. 2016), and discussed topics such as distraction, information overload, health risks and so forth. However, most of these studies conclude that risks factors, at least in the current stage of the lifecycle, are less important. As with smartwatches and other wearable devices, ARSGs also include a substantial amount of 'fashion'. A study by Rauschnabel and colleagues (2016) has investigated why and when consumers perceive ARSGs as fashion, technology, or both ('fashnology'). Finally, Hein et al. (2017) took a different approach and studied the role of ARSGs from a society perspective. A core finding is that people tend to associate various societal risks (e.g., public privacy, loss of social cohesion) and societal benefits (e.g., social progress potential), which impact the anticipated success (i.e., whether people think that ARSGs will be successful) and the desired success (i.e., whether people want that ARSGs are successful in the future).

4 A Conceptual Model for Augmented Reality Smart Glasses

U&GT, as outlined above, is based on the assumption that an individual's personal motivational factors drive his or her media usage behavior. Katz et al.'s (1973) proposed five broad categorizations of needs that are linked to media use. Based on

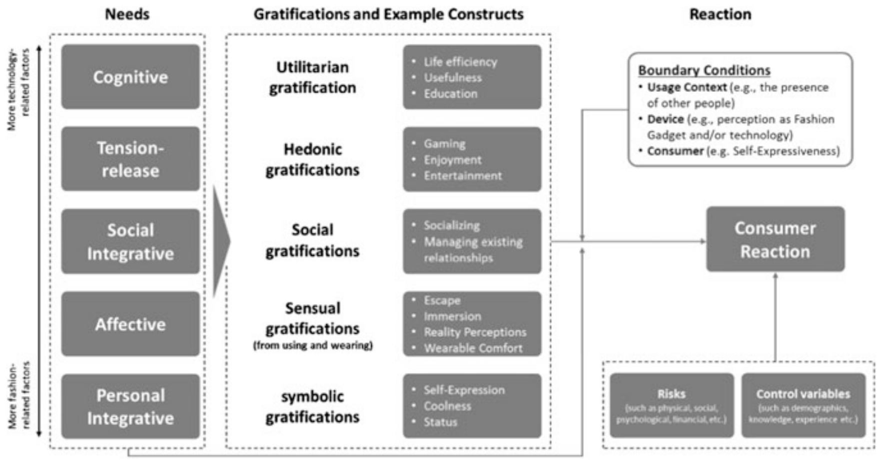


Fig. 3 Conceptual model

that, I propose a conceptual model (see Fig. 3) to theorize specific factors related to ARSG usage. The model starts on the left side with an overview of the five categorizations of needs (e.g., cognitive), where each of them is conceptually linked to a broader category of gratifications (e.g., utilitarian) consisting of examples of several specific factors (e.g., life efficiency). These gratifications can be predominantly obtained from the device itself (upper factors) or from the medium (i.e., AR; bottom factors). In addition, the model proposes that the strengths of these effects might differ based on the usage context (existence of other people or not), the device (fashion, technology, or fashnology), and the user/consumer (e.g., self-presentation). In addition, the model proposes that the degree to which a human need is satisfied determines the importance of specific gratifications.

4.1 Cognitive Needs and the Role of Utilitarian Gratifications

One reason people consume particular media, such as newspapers, is to gratify their cognitive needs. These can include various specific gratifications such as finding relevant information or organizing one's lives. This idea is conceptually linked to the broad construct of perceived usefulness in the literature on technology acceptance (Venkatesh et al. 2012) which reflects workers or users' evaluations of a technology in terms of increasing their (work/life) efficiency. Once more apps are available, ARSGs can offer numerous utilitarian benefits. The current overview provides some examples of promising utilitarian gratifications:

- **Work and life efficiency** are utilitarian gratifications similar to performance expectancy (Venkatesh et al. 2012) or perceived usefulness (King and He 2006) that cover the degree to which a user believes that using ARSGs can help him or her accomplish certain personal or job-related tasks more efficiently. Both of these constructs are typically increased by access to **real-time information**. For example, Hein and Rauschnabel (2016) discuss the idea that ARSGs can support workers with information from Enterprise Social Networks. Consumers can have access to anything they need, such as emails, chats or navigation systems. Likewise, police officers could use face recognition or lie detector apps to identify suspicious people. Salespeople could use emotion scanner apps to learn more about a negotiation partner's preferences in real-time.

- **Information gathering and education** cover the potential to use ARSGs for learning and decision making purposes. For example, a user can learn new languages. Users can also explore museums, buildings and cities using ARSGs. Whenever a user looks at a particular object, the app can integrate relevant information for him or her.

4.2 Tension-Release Needs and Hedonic Gratifications

People often use media to satisfy a variety of tension-related needs. These technologies are typically associated with a particularly high "hedonic value"—that is, media that delivers what people in everyday language term as "fun." Psychological research has shown that hedonic gratifications are associated with various positive outcomes such as the reduction of boredom or pleasure (Close and Kukar-Kinney 2010; Klinger 1971). Therefore, it is not surprising that research on the use of media and technology concludes that hedonic factors are an important determinants of use (Nysveen et al. 2005; Taylor et al. 2011; Venkatesh et al. 2012). Examples of specific hedonic gratifications associated with ARSGs are:

- **Enjoyment**, an established construct in U&GT research but also in the technology acceptance literature (Venkatesh et al. 2012), is defined as "the extent to which the activity of using a specific system is perceived to be enjoyable in its own right, aside from any performance consequences resulting from system use" (Venkatesh 2000, p. 351). Enjoyment reflects the potential that a user can distract him/herself from everyday activities, particularly through the use of ARSGs in general. AR scholars have studied and shown the importance of AR in various settings (Leue et al. 2015; Jung et al. 2015; tom Dieck and Jung 2015).
- Related to that, **Gaming** is a construct that describes the use of (AR) games on ARSGs (Rauschnabel et al. 2015). For example, Robo Raid is a game that can be played on HoloLens where virtual robots attack a user who has to shoot them.
- **Entertainment**, on a broader level, also includes examples of watching movies or performing various tasks to be entertained. For example, a YouTube app could offer access to millions of clips, or a Netflix app access to a large database of movies. These examples show that ARSGs can potentially address several needs which traditionally TV or Radio have addressed. In contrast to enjoyment,

entertainment is focused more on a particular task associated with a particular app, whereas enjoyment can also result just from the use of the device alone.

4.3 Affective Needs and Sensual Gratifications

"Sensual gratifications" cover all benefits that users experience from the stimulation of various human senses. As ARSGs are worn and used, these gratifications can derive from wearing or using. Whereas wearing is solely mostly linked to feeling, the use—depending on the app—can stimulate visual and acoustic senses, too. Some examples include:

- **Wearable comfort** (sense: touch), which is based on the assumption that consumers react more positively to ARSGs when wearing them feels comfortable. This evaluation of the overall wearable comfort is influenced by physical characteristics of the device, such as the size, the weight, pressure, temperature, and so forth. Most readers will probably have a favorite pullover or pants that just 'feels good'. The same might be true for ARSGs. Some people might like the feeling of wearing them, whereas others might feel it distracting, impractical and uncomfortable. Most likely, this wearable comfort is driven by physical characteristics of the device itself.
- ARSGs can allow users to **alter their environment in a desired way** (sense: seeing). For example, they can place art and other things that users cannot have in real-life (e.g., expensive luxury accessories or things that do not exist in reality, such as fantasy creatures). For example, a user could alter his/her home into a 'Harry Potter-like' environment where 'magic' furniture and other objects/creatures from the movies can be virtually integrated.

4.4 Social Integrative Needs and Social Gratifications

Social factors are influential drivers in explaining various forms of human behavior, including consumption, technology use and media choice. In this article, social gratifications explain various factors that are associated with social relationships.

- **Socializing**, such as using ARSGs in order to get in touch with other people, is one example of a social gratification. It is very likely that within the next few years, dating apps will appear and other apps that can connect individuals to each other. Prior research has linked this and similar gratifications with the use of social media and other technologies (Sheldon 2008). Another possible way is that ARSG users can connect to each other in community-like organizations (Felix 2012; Muniz and Schau 2005). Especially in the very early stage (i.e., now), there are already online communities where users with similar interests share their experiences with ARSGs—for example, Hololens groups on Facebook.

- Visible consumption objects, especially new technologies such as ARSGs, might have the potential to serve as a "**conversation starter**." As in the early age of smartphones (i.e., the iPhone 1), owning a new device stimulated interest (and thus, questions) from people unfamiliar with the new technology. The difference between this factor and the aforementioned socializing construct is that 'conversation starter' results more from owning the device and happens predominantly in the 'real-world,' whereas socializing arises from particular apps and thus happens in the 'augmented world'.
- Related to that, the **management of existing relationships** is a promising area for ARSG-apps. For example, there are videos on YouTube in which base jumpers document their 'view' of the jump, probably with the intention to share these moments with friends. Sharing moments with friends is something people always want to do (e.g., showing photos from a holiday trip), and ARSGs facilitate the integration of friends into one's view in real-life. It is also likely that online social networks will be extended into AR, where ARSGs can make thi experience more realistic than other mobile devices. Just recently, Mark Zuckerberg (the founder and CEO of Facebook) stated: "One day, we believe this kind of immersive, augmented reality will become a part of daily life for billions of people."

4.5 Personal Integrative Needs and Impression Management

Most people have a keen interest to present themselves in a positive manner to others. Researchers from numerous disciplines have shown that this motivation drives their behavior in various ways. ARSGs are worn like regular spectacles, which makes them even more visible and self-defining than many other consumption objects. In social interactions, faces play an especially important role (Bloch and Richins 1992) so that "even simple changes to a face, such as wearing different types of eyeglasses or removing them, might influence how someone is perceived" (Forster et al. 2013, p. 1).

- **Impression management** is one of the main factors why many people use particular media and technologies for symbolic reasons, such as reassuring their societal status or power, and/or to gain credibility among others (Hollenbeck and Kaikati 2012; Venkatesh and Davis 2000). Specific examples include following brands on social media (Hollenbeck and Kaikati 2012) or check in on social media for image building (Luarn et al. 2015). Innovative technologies that are highly visible to others are thus generally associated with many positive attributes (e.g., 'innovative'). For example, Chuah et al. (2016) show that consumers prefer smartwatches that are visible to others. This impression management can also be applicable to more specific images, such as a particularly popular or even cool and trendy image ("**coolness**") or a high **social status**.

- It is also important to consider **normative factors** in the acceptance of ARSGs. The technology acceptance literature in general (e.g., Venkatesh et al. 2012), and on ARSGs specifically (e.g., Rauschnabel and Ro 2016), have studied injunctive norms. These type of norms describe normative expectations about a user's peers. A similar construct are descriptive norms. Descriptive norms describe the idea that people are more likely to adopt ARSGs when they expect that it will grow in popularity and eventually become commonly ubiquitous (Rauschnabel et al. 2015). Our recent research suggests that descriptive norms, at least in the current stage in the product lifecycle, are more influential than injunctive norms.
- '**Fashion Match**' is a novel term in this research that addresses the matching potential of ARSGs to a user's typical clothing style. For example, sporty ARSGs (such as the sporty Everysight Raptor Glasses) might not be preferred in everyday life by a person with a more elegant or conservative clothing style. However, it is likely that fashion match needs to be studied in future research through the lens of fit (i.e., similarity) and complementarity (i.e., an ARSG device complements particular fashion items in a way that the user's overall appearance is enhanced).

4.6 Boundary Conditions

The aforementioned list provides a systematization of factors that can be used in ARSG research. However, it is important to note that these effects might differ when particular boundary conditions exist. Methodologically speaking, these effects could be moderated by various variables. The model is based on the idea that several categories of moderators exist, such as usage context, individual, and technology related factors.

- **Usage context factors** are about the specific context in which ARSGs are used. For example, it is likely that the presence of other people matters. That is, people might incorporate symbolic factors more when they are in public than in situations where they are alone. Similarly, when using ARSGs in a work-related context, utilitarian gratifications might matter more than symbolic ones.
- **Individual factors** are factors that describe the user itself. Beside demographic variables, personality traits, needs, (other) motives, attitudes and other individual-level factors might determine the weight of each of the factors on evaluations. This might also include the cultural background of a user (Gong and Stump 2016). For example, more individualistic personalities might focus more on self-expressive gratifications, whereas collectivistic individuals might value the socializing benefits more.

- **Technology related** moderators are another relevant moderator in the proposed framework. For example, as stated in Rauschnabel et al. (2016), the design of a device might impact consumers' in terms of 'fashnology', which can then serve as a moderator in the propose model.

4.7 Risk Factors

Although the focus of U&GT (and thus also this chapter) are gratifications, it is important to note that people also integrate various risk factors in their decision making. With regards to ARSGs, our research has identified numerous risk factors, and some of them are:

- **Privacy**, as people are afraid of threatening their own, as well as other peoples' privacy. Research has shown that both risks are highly salient among consumers. Recent research did not confirm that when it comes to ARSGs, people care about their privacy, but care about public privacy (Rauschnabel and Ro 2016; Hein et al. 2017).
- Another risk factor is related to **health risks** in general. This includes the fear that ARSGs can hurt a user's eyes, electro smog that can cause brain cancer, that distraction could lead to physical injuries, and finally, that seeing and interacting with objects that do not exist can impact a user's psychological well-being. It is important to note that, to the best of my knowledge, the actual risk of these factors has not yet been determined in the academic literature. Similarly, not much research has been done to investigate how the perception of these risks impacts consumers' decision making.
- Especially in the very early beginning of a product lifecycle, consumers have very little information about the future of a technology. In addition, prices are usually very high (e.g., the first version of HoloLens was sold for more than $3,000). Therefore, **financial risks** are potential factors that decrease the favorability of consumers' evaluations. In interviews, many consumers shared their fear that the HoloLens and other devices might not work properly, and that new standards would be established in a few years so that current devices would be useless in a few years. Likewise, wearing a novel device—especially in public contexts—can be associate with very high **social risks**, e.g., the fear that other people react negatively (which is related to the normative factors discussed above).
- Another category of risks that we identified in qualitative, yet unpublished, research are **society consequences**. As discussed in Hein et al. (2017), consumers associate ARSGs with various positive and negative consequences for societies. Consumers tend to integrate these factors also into their personal decision making. For example, in a qualitative study in the US, one respondent stated that a risk of ARGSs is the "distinguishing the rich from the poor," and others criticized that societies are already too technology-focused. These quotes

imply that consumers are likely to avoid ARSGs because—in their view—adopting them would support a negative societal trend. On the contrary, it is worth noting that other consumers also discussed positive societal consequences, such as help for visually impaired people, the reduction of crime and new jobs.

4.8 Control Variables

Robust models typically include control variables, such as age and gender. For ARSGs, additional control variables could increase the robustness and generalizability of a model, if sample size allows. Examples include whether respondents are used to wearing any form of glasses or wearable devices, their knowledge about and attitude towards new technologies in general, but also specifically about ARSGs. Another control variable could be a proxy for user friendliness (e.g., perceived ease of use).

4.9 Dependent Variables

Depending on the studied context, the proposed model allows researchers to study a variety of different variables. Adaptions of established constructs include the attitude towards ARSGs or towards using them, purchase intention, or usage intention. Models can be refined by incorporating various types of these variables and their interplay, but also usage intention in different contexts. This is an alternative to the inclusion of moderators (as proposed in this article) and might be particularly relevant if respondents might or might not use the same ARSG in different contexts—such as at home, in public, or at the workplace.

5 Discussion

As shown in the Introduction section, ARSGs are very likely to become the next major step in the evolution of smart wearable technologies. While market research predictions are highly promising, scant research attempting to understand the people that end up using it (i.e., consumers) exists. Taking into account the established U&GT framework (Katz et al. 1973), I address this fundamental research gap by proposing a conceptual model that links basic human needs to gratifications associated with ARSGs.

The proposed framework includes various examples of specific gratifications that scholars can implement in empirical studies. Does it thus make sense to include each of these gratifications in a questionnaire? Definitely not. Restrictions of the survey length as well as a study focus on a specific application might impact the consideration set of gratifications. In addition, too many similar constructs in a model can lead to estimation problems because of multicollinearity or cross-loadings of items. On the other hand, the proposed framework should also be more seen as a systematic source of inspiration. It is likely that additional gratifications exist that are of particular relevance for a specific research context. Therefore, additional exploratory research, such as netnography (Bartl et al. 2016) or other forms of qualitative research, can be beneficial. For example, as marketers have a keen interest in using innovative media to place their brand messages (Wang et al. 2009), brand-related measures might need to be incorporated.

It is also important that ARSGs are a very novel form of device and thus, the wording of items might need to be adjusted to the study context. This means that established statements need to be revised and/or extended. Pre-studies with consumers (e.g., factor analyses based on survey data, or card sorting tasks) and experts are a useful approach to validating adopted scales.

Finally, the challenge of ARSG research in the current stage of the product lifecycle is whether scholars should expose respondents to real devices, or work with a fictitious context. There are several pros and cons to both approaches. Using a fictitious context can be explained quite realistically and can at least be used to measure consumers' general interests in ARSGs. The existence of useful videos, descriptions and photos of ARSGs can provide users a realistic picture of the processes, and implementing them in (online) surveys allows to survey a large amount of people. On the contrary, evaluating a technology solely based on an explanation might be biased and less realistic. However, having respondents actually use ARSGs for a sufficient amount of time before surveying them, is time consuming and thus might limit the sample size.

The proposed model can serve as a source of inspiration for managers in several ways. App developers can be guided by the proposed needs and factors to identify specific needs and expected gratifications that their apps can satisfy. In other words, the proposed framework can serve as a source of inspiration in the idea generation phase of app developers. For manufacturers of ARSG devices, the proposed model highlights the role of the fashion-related factors, and the importance of emphasizing particular aspects in their market communication (e.g., focus on design or functionality). In line with this, this article echoes the idea that a context-specific targeting might be an effective strategy (e.g., one device for work and one device for leisure). This is already reflected in various existing real-life examples. For example, Epson positions their Moverio glasses as a manufacturing device, whereas Everysight Raptor are positioned for cycling.

6 Concluding Remarks

Many scholars from various disciplines including communication science, human–computer interaction, marketing, MIS, engineering, and others conclude that ARSGs are a highly relevant and interesting study object. However, one crucial success factor (maybe even the most crucial one) is that people accept and use them. In this chapter, I introduce and propose U&GT as a starting point for further contributions in this field. Scholars, educators and managers are inspired to consider the proposed framework when addressing one or several of the questions:

- How can businesses benefit from ARSGs? In particular, how can ARSGs improve internal processes (e.g., logistics, marketing) but also communication with external audiences (e.g., customers)?
- How could branded apps for ARSGs look like?
- How can business models for free ARSG apps (‘freemium’) look like?
- How can ARSGs solve major societal problems, such as poverty, obesity or social isolation?
- What laws and government decisions are needed to reduce the risks of ARSGs?

Acknowledgements I thank Young Ro for feedback on this article, as well as the conference chairs, reviewers and participants of the 3rd International AR VR conference, Manchester. In addition, I thank Christina Philipp and www.connectedscience.de for additional feedback and support.

References

Anderson, F., Grossman, T., Matejka, J., & Fitzmaurice, G. (2013, October). YouMove: enhancing movement training with an augmented reality mirror. In *Proceedings of the 26th annual ACM symposium on User interface software and technology,* (311–320). ACM.

Bartl, M., Kannan, V. K., & Stockinger, H. (2016). A review and analysis of literature on netnography research. *International Journal of Technology Marketing, 11*(2), 165–196.

Bloch, P. H., & Richins, M. L. (1992). You look “mahvelous”: The pursuit of beauty and the marketing concept. *Psychology & Marketing, 9*(1), 3–15.

Chuah, S. H. W., Rauschnabel, P. A., Krey, N., Nguyen, B., Ramayah, T., & Lade, S. (2016). Wearable technologies: The role of usefulness and visibility in smartwatch adoption. *Computers in Human Behavior, 65*(5), 276–284.

Close, A. G., & Kukar-Kinney, M. (2010). Beyond buying: Motivations behind consumers’ online shopping cart use. *Journal of Business Research, 63*(9), 986–992.

Eisenmann, T., Barley, L., & Kind, L. (2014). Google Glass. *Harvard Business School Case Study.*

Ernst, C. P. H., Stock, B., & dos Santos Ferreira, T. (2016). The Usage of Augmented Reality Smartglasses: The Role of Perceived Substitutability. *AMCIS2016 Proceedings.*

Felix, R. (2012). Brand communities for mainstream brands: the example of the Yamaha R1 brand community. *Journal of Consumer Marketing, 29*(3), 225–232.

Forster, M., Gerger, G., & Leder, H. (2013). The Glasses Stereotype Revised. *The Jury Expert, 25*(2), 1–6.

GoldmanSachs (2016). *Virtual & augmented reality*. Retrieved March, 2016, from http://goldmansachs.com/our-thinking/pages/technology-driving-innovation-folder/virtual-and-augmented-reality/report.pdf.

Gong, W., & Stump, R. L. (2016). Cultural values reflected in the adoption of social networking sites. *International Journal of Technology Marketing, 11*(3), 360–378.

Hein, D. W., & Rauschnabel, P. A. (2016). *Augmented Reality Smart Glasses and Knowledge Management: A Conceptual Framework for Enterprise Social Networks*. In: Rossmann, A, Stei, G. & M. Besc, (Eds.) *Enterprise Social Networks* (pp. 83–109). Springer Fachmedien Wiesbaden.

Hein, D. W., Jodoin, J. L., Rauschnabel, P. A., & Ivens, B. S. (2017). Are wearables good or bad for society?: An exploration of societal benefits, risks, and consequences of augmented reality smart glasses. In *Mobile Technologies and Augmented Reality in Open Education* (1–25). IGI Global.

Hollenbeck, C. R., & Kaikati, A. M. (2012). Consumers' use of brands to reflect their actual and ideal selves on Facebook. *International Journal of Research in Marketing, 29*(4), 395–405.

Javornik, A. (2016a). 'It's an illusion, but it looks real!'Consumer affective, cognitive and behavioural responses to augmented reality applications. *Journal of Marketing Management, 32*(9–10), 987–1011.

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

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.

Katz, E., Haas, H., & Gurevitch, M. (1973). On the use of the mass media for important things. *American sociological review*, 164–181.

King, W. R., & He, J. (2006). A meta-analysis of the technology acceptance model. *Information & Management, 43*(6), 740–755.

Klinger, E. (1971). Structure and functions of fantasy.

Leue, M. C., Jung, T., & tom Dieck, D. (2015). *Google glass augmented reality: Generic learning outcomes for art galleries.* In Information and Communication Technologies in Tourism 2015 (463–476). Springer International Publishing.

Leung, L. (2013). Generational differences in content generation in social media: The roles of the gratifications sought and of narcissism. *Computers in Human Behavior, 29*(3), 997–1006.

Luarn, P., Yang, J. C., & Chiu, Y. P. (2015). Why people check into social network sites. *International Journal of Electronic Commerce, 19*(4), 21–46.

Muniz Jr, A. M., & Schau, H. J. (2005). Religiosity in the abandoned Apple Newton brand community. *Journal of consumer research*, *31*(4), 737–747.

Nysveen, H., Pedersen, P. E., & Thorbjørnsen, H. (2005). Intentions to use mobile services: Antecedents and cross-service comparisons. *Journal of the Academy of Marketing Science, 33* (3), 330–346.

PWC. (2014). *The Wearable Future*. PWC Consumer Intelligence Series: Research Report. https://www.pwc.com/us/en/technology/publications/wearable-technology.html

Ratten, V. (2009). Adoption of technological innovations in the m-commerce industry. *International Journal of Technology Marketing, 4*(4), 355–367.

Rauschnabel, P. A., Brem, A. & Ro, Y. K. (2015a). Augmented Reality Smart Glasses: Definition, Conceptual Insights, and Managerial Importance. Working Paper, The University of Michigan-Dearborn, MI, USA.

Rauschnabel, P. A., Brem, A., & Ivens, B. S. (2015b). 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,* 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.

Rauschnabel, P. A., Hein, D. W., He, J., Ro, Y. K., Rawashdeh, S., & Krulikowski, B. (2016). Fashion or Technology? A Fashnology Perspective on the Perception and Adoption of Augmented Reality Smart Glasses. *i-com: Journal of Interactive*. *Media, 15*(2), 179–194.

Rauschnabel, P.A.; He, J.; Ro, K. Krulikowski, B. (2016): Drivers and Barriers of Augmented Reality Smart Glasses, *Working Paper, University of Michigan: Ann Arbor, Dearborn, Flint*.

Rauschnabel., Rossmann., & tom Dieck. (2017). An Adoption Framework for Mobile Augmented Reality Games: The Case of Pokémon Go, *Computers in Human Behavior*, forthcoming.

Rubin, A. (2002). The uses-and-gratifications perspective of media effects. In J. Bryant & D. Zillmann (Eds.), *Media effects: Advances in theory and research* (2nd ed., pp. 525–548). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Ruggiero, T. E. (2000). Uses and gratifications theory in the 21st century. *Mass communication & society, 3*(1), 3–37.

Sheldon, P. (2008). The relationship between unwillingness-to-communicate and students' Facebook use. *Journal of Media Psychology, 20*(2), 67–75.

Stock, B., dos Santos Ferreira, T. P., & Ernst, C. P. H. (2016). Does Perceived Health Risk Influence Smartglasses Usage?. In *The Drivers of Wearable Device Usage,* (13–23). Springer International Publishing.

Stockinger, H. (2016). The future of augmented reality-an Open Delphi study on technology acceptance. *International Journal of Technology Marketing, 11*(1), 55–96.

Taylor, D. G., Lewin, J. E., & Strutton, D. (2011). Friends, fans, and followers: do ads work on social networks? *Journal of Advertising Research, 51*(1), 258–275.

tom Dieck, M. C., & Jung, T. (2015). A theoretical model of mobile augmented reality acceptance in urban heritage tourism. *Current Issues in Tourism*, *1*:1–21.

Venkatesh, V., & Davis, F. D. (2000). A theoretical extension of the technology acceptance model: Four longitudinal field studies. *Management Science, 46*(2), 186–204.

Venkatesh, V., Thong, J. Y., & 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.

Wang, Y., Wang, K. L., & Yao, J. T. (2009). Marketing mixes for digital products: a study of the marketspaces in China. *International Journal of Technology Marketing, 4*(1), 15–42.

Weiz, D., Anand, G., & Ernst, C. P. H. (2016). The Influence of Subjective Norm on the Usage of Smartglasses. In *The Drivers of Wearable Device Usage* (1–11). Springer International Publishing.

Wu, J. H., Wang, S. C., & Tsai, H. H. (2010). Falling in love with online games: The uses and gratifications perspective. *Computers in Human Behavior, 26*(6), 1862–1871.

Exploring the Early Adopters of Augmented Reality Smart Glasses: The Case of Microsoft HoloLens

Mahdokht Kalantari and Philipp Rauschnabel

Abstract Not much research has been done to understand how consumers react to wearable technologies that mix virtual and real worlds in glasses-like wearable devices. Drawing up on various technology acceptance and media theories, the authors develop a model to understand how people react to Augmented Reality Smart Glasses (ARSGs) using the example of Microsoft HoloLens. Results show that consumer's adoption decision is driven by various expected benefits including usefulness, ease of use, and image. However, hedonic benefits were not found to influence the adoption intention. In addition, this research shows that the influence of the descriptive norms on the adoption intention outperforms the influence of the injunctive norms, which are established drivers of technology acceptance research. Theoretical and managerial implications of these findings are discussed.

Keywords Hololens · Augmented reality smart glasses · Mixed reality · Head mounted display · Acceptance · TAM

1 Introduction

Wearable technologies are currently receiving tremendous interest among all consumer segments. Market trends show an increasing growth in the sales of smartwatches, fitness trackers and VR glasses. CCS Insight (2016), a leading market research company in the wearables-related sector, has forecasted that in 2020, 411 million smart devices will be sold, worth a staggering $34 billion. According

M. Kalantari (✉)
Wayne State University, Michigan, USA
e-mail: maddie@wayne.edu

P. Rauschnabel
University of Michigan Dearborn, Michigan, USA
e-mail: prausch@umich.edu

T. Jung and M.C. tom Dieck (eds.), *Augmented Reality and Virtual Reality*,
Progress in IS, DOI 10.1007/978-3-319-64027-3_16

to their forecast, shipments for AR and VR headsets will grow 15 times to 96 million units by 2020, at a value of $14.5 billion. Scholars are making first attempts to investigate these recent trends from an academic standpoint to understand why and how users react to wearable technologies (Rauschnabel and Ro 2016; Leue and Jung 2014). These devices are the next step in providing information, including virtual realities, realistically and they are more easily accessible to users. For example, rather than taking a smartphone out of one's pocket to read a text message, the message can be conveniently displayed on a user's wrist. Likewise, VR allows users to perceive themselves as being a different person in a different place (Craig 2013), making animations much more realistic than traditional screen-based technologies.

Recently, manufacturers announced their efforts to enter consumer markets with a novel technology that is termed 'Augmented Reality Smart Glasses' (ARSGs), which—broadly speaking—realistically integrates virtual objects into a user's view field in glasses-like devices. While Google Glass, one of the first commercially launched ARSGs, has received a lot of media attention, its success in consumer markets was limited. However, recent studies suggest that other devices such as Microsoft HoloLens are much more promising due to their holographic possibilities. In contrast to Google Glass, HoloLens does not have just one prism that overlays information; HoloLens realistically integrates 3D information into a user's perception of the real-world which no other commercially available technology can offer so far.

There is still a lack of understanding about the factors that drive consumer's acceptance and resistance to ARSGs. This is probably due to the novelty of AR in general and ARSGS in particular, but as initial research suggests, it may also be due to the fact that the existing theories are difficult to apply to ARSGs. Thus, in order to extend our understanding of consumers' adoption of ARSGs, we aim to answer the following two research questions using Microsoft HoloLens, the first commercially available holographic ARSG:

- RQ1: How do consumers perceive ARSGs, in particular Microsoft HoloLens?
- RQ2: Which factors influence the adoption of ARSGs, in particular Microsoft HoloLens?

To answer these research questions, we first review the relevant literature on technology acceptance and ARSGs consumer research. Based on this review, we propose a framework consisting of various benefits, risks, technology factors and norms as antecedents to ARSG adoption. We then test the proposed model using the example of Microsoft HoloLens. Results from descriptive analyses and a regression model indicate various, yet unknown, factors that explain how consumers react to ARSGs. These findings provide several contributions to the literature on ARSGs, wearables, and research about norms.

2 Theory and Prior Research

2.1 Augmented Reality and ARSGs

Initially, computer-related technologies were predominantly used in work-related contexts as task-oriented devices. Manufacturers quickly realized the potential of computer applications and the internet in personal settings; hence, information technology rapidly diffused to consumer markets. With the rise of mobile technologies, an 'always and everywhere online mentality' became ubiquitous (Ratten 2009). Recently, companies have developed a new generation of mobile devices that can be fixed to a user's body—wearables. Most wearables come in the form of accessories, with prominent examples being the Apple Watch (smartwatch) and the Fitbit (smart bracelet).

During recent years, a new generation of applications have been developed that integrate virtual elements with the physical environment. According to Craig (2013), Augmented Reality (AR) is defined as a "medium in which digital information is overlaid on the physical world that is in both spatial and temporal registration with the physical world and that is interactive in time". For example, smartphone users can use the Wikitude smartphone app and view a famous building. Wikitude then automatically includes relevant Wikipedia information in the user's viewfield. Thus, in contrast to VR,[1] AR is not closed off from reality, but melds the real and virtual worlds together (Javornik 2016a; Scholz and Smith 2016). Likewise, AR has been studied and applied in various contexts, such as tourism (Jung et al. 2015), museums (Tom Dieck and Jung 2015), retailing (Spreer and Kallweit 2014; Rese et al. 2016) and others (Stockinger 2016; Javornik 2016a, b).

Current developments in IT aim at combining AR with wearables in glasses-like devices. Microsoft HoloLens, Google Glass (now: Project Aura), Everysight Raptor, ODG R-7 and Epson Moverio are prominent examples of these developments, and Samsung, Zeiss, Amazon and other firms have filed patents for and announced the launch of smart glasses.

2.2 Technology Acceptance Research

Since the advent of computer technologies, researchers have been studying the dynamics and the influential factors on individual's acceptance of information technologies. Although various theories and approaches have been suggested in the field of information systems to address this issue, the Technology Acceptance

[1]With VR-devices (e.g. Oculus Rift), users immerse themselves in a virtual world that shuts out the external environment, totally immersing the user in the virtual reality.

Model (TAM) has received the highest level of attention and application among the researchers (Davis 1989; King and He 2006).

TAM is a simple, parsimonious and powerful model to explain the use of a new technology (King and He 2006). TAM is rooted in behavioural research about attitude and behaviour formation (e.g., Theory of Reasoned Action) and psychology research about behaviour regulation and change (e.g., Social Cognitive Theory) (Davis 1989; Davis et al. 1989). TAM proposes that the individuals' behavioural intention to adopt/use a new technology is determined both by perceived ease of use, defined as "the degree to which a person believes that using a particular system would be free of effort" (Davis et al. 1989), and perceived usefulness, defined as "the degree to which a person thinks that using a particular system would enhance his or her job performance" (Davis et al. 1989). Furthermore, many studies indicate that perceived usefulness partially mediates the relationship between perceived ease of use and behavioural intention.

Although the parsimony of TAM is considered as a prominent strength for this model, it is also commonly criticized because this model neglects the various aspects of decision making across different technologies (Bagozzi 2007). Researchers have tried to extend TAM by including other parameters such as task (Chau and Lai 2003), social (Venkatesh and Davis 2000; Lewis et al. 2003), and demographics (Venkatesh and Morris 2000). A famous example is the proposal of the unified theory of acceptance and use of technology (UTAUT, Venkatesh et al. 2003) that integrates TAM with seven other decision making theories. Empirical testing results suggested a complex model with the addition of two determinants including social influence and facilitating conditions, and four moderators of key relationships.

TAM and its extensions have been valued for their application flexibility in different contexts. In particular, these models allow researchers to include variables that are only relevant in specific contexts. Therefore, in this paper, we use TAM as our framework and extend it with factors that are specifically relevant to the context of ARSGS. Particularly, as discussed in the model development section, we extend and apply TAM to ARSGs by integrating benefits, risks, technology factors, and social norms.

2.3 *Prior Research on ARSGs*

Scholars from various disciplines, including engineering (Chi et al. 2013; Behzadan et al. 2008), business (Rauschnabel and Ro 2016), MIS (Ernst et al. 2016), tourism (Jung and Han 2014), and others have studied various aspects and applications of ARSGs. For the purpose of this study, research that focuses on consumer acceptance is particularly important. Table 1 summarized these studies.

Table 1 Prior consumer- and acceptance research on ARSGs

Study	Research questions	Theory	Findings
Rauschnabel et al. (2015)	How does personality relate to consumer's reaction to Google Glass?	Big five theory, technology acceptance research	Personality predicts awareness of google glass and moderates the relationship between TAM-related factors and ARSG adoption
Rauschnabel and Ro (2016)	What drives the adoption of Google Glass?	Technology acceptance research	Perceived usefulness, ease of use, injunctive norms, and consumers' level of technology innovativeness drive consumers' evaluation and intended adoption of Google Glass
Eisenmann et al. (2014)	How do consumers react to Google Glass?	Exploratory case study	The study explores various facets of consumers' reactions to Google Glass, including design, functionality, barriers, and potential use cases, among others
Ernst et al. (2014)	Do consumers intend to substitute real objects with virtual, holographic ones?	Technology acceptance research	Substituting real things with holograms makes consumers more likely to adopt ARSGs because it makes ARSGs more useful and enjoyable
Stock et al. (2016)	Do health risks and enjoyment influence the intended use of HoloLens?	Technology acceptance	The negative effect of health risks on the intention to use HoloLens is not significant. However, higher levels of health risk lead to lower levels of perceived enjoyment, a predictor of intended use of HoloLens
Weiz et al. (2016)	Do perceived usefulness and injunctive norms determine the adoption of Google Glass?	Technology acceptance	There was no direct effect of injunctive norms on actual usage of Google Glass, but they were indirectly related via perceived usefulness
Hein and Rauschnabel (2016)	Can ARSGs be used in enterprise social networks?	Technology acceptance research on an individual and firm-level	The authors provided a conceptual model that identifies firm-level and individual-level factors that affect the implementation and individual's active and passive use of ARSGs in enterprise social networks

(continued)

Table 1 (continued)

Study	Research questions	Theory	Findings
Rauschnabel et al. (2016)	Are ARSGs fashion or technology?	Technology acceptance research, fashion research, categorization research	Most consumers perceive ARSGs as a combination of fashion and technology (Fashnology). Categorization is driven by familiarity with ARSGs in general
Hein et al. (2016)	How do consumers evaluate the societal consequences of ARSGs?	Exploratory	This study identifies several societal benefits and risks that drive consumers anticipated and desired diffusion of ARSGs
Leue et al. (2015)	How does google glass enhance visitors' learning outcomes in art galleries?	Exploratory	Interviews with participants indicated that google glass enhances the learning outcomes of visitors by making connections between art pieces and providing a deeper perspective as well as helping the visitors personalize their tours based on their interest in specific themes
tom Dieck et al. (2016)	What are the requirements of visitors of museums and art galleries for the development of wearable ARSGs applications?	Exploratory	Study findings reveal that the important factors in developing and implementing wearable AR applications in museums and art galleries are: content requirement, functional requirement, comfort, experience and resistance

3 Model Development

Figure 1 provides an overview of the proposed model. Inspired by the extant technology acceptance literature (e.g. King and He 2006; Davis et al. 1989; Venkatesh et al. 2012) and prior research on ARSGs (e.g., Rauschnabel et al. 2015, 2016; Ernst et al. 2016), the model proposes that consumer's intention to adopt ARSGs is driven by the benefits and risks of using them, other characteristics of the technology, and social norms. In the subsequent sections, we will provide hypotheses addressing each of these categories of antecedents.

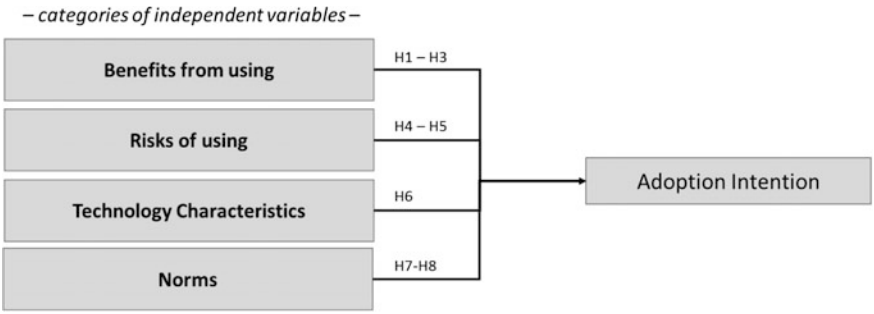


Fig. 1 Model overview

3.1 Benefits from Using

The technology acceptance literature argues that expected or perceived benefits from using a technology typically drive the adoption (King and He 2006; Venkatesh et al. 2012). We propose that three particular benefits are relevant in understanding consumers' adoption of HoloLens:

First, perceived usefulness, a powerful construct in the technology acceptance literature (King and He 2006) is proposed to influence the adoption intention. ARSGs, including HoloLens, can be used in various ways to increase a user's efficiency in accomplishing their tasks. For example, Hololens can be used for getting step-by-step remote instructions from an expert on a variety of issues from home repair to medical instructions. Hololens can also be used to build different types of 3D holographic models in the physical space for various design purposes. Another application of Hololens is helping users visualize how new furniture and/or decorations will look like in their homes. Hololens can also substitute physical screens and monitors as users can have a number of virtual screens with different sizes (Ernst et al. 2016). The other advantage of Hololens in comparison to physical screens is that users can watch movies or browse the internet on virtual screens no matter where they are in their homes and/or offices.

H1: Perceived usefulness is positively related to consumer's intention to adopt ARSGs.

Likewise, the technology acceptance literature proposes two other constructs that are likely to determine consumers' intended adoption of ARSGs: hedonic motivation and image.

The construct 'hedonic motivation' is defined as the extent to which using a technology is perceived as enjoyable and fun. Hololens offers several uses and applications that can appeal to a user's hedonic needs and motivations. Hololens can turn monotonous tasks into a game for the users. For example, they can replace the physical world around them with an interactive and scrolling scenery as they jog on a treadmill. Hololens also offers a selection of mixed reality games that make use of the user's physical environment and have spatial sounds to guide the user through the game. Hololens provides users with the capability to combine gestures, voice, and the HoloLens gaze feature to create 3D objects. Users can also create short clips with special effects that can be viewed on Hololens.

H2: Hedonic motivation is positively related to consumer's intention to adopt ARSGs.

As ARSGs are not just used but also worn, the literature on Fashnology also proposes that factors related to other people seem to matter (e.g., Rauschnabel et al. 2016). For example, Chuah et al. (2016) show that the level of visibility of smartwatches drives consumers' adoption of them. In this study, we extend this research stream and propose that the image of wearing ARSGs matters. Inspired by the TAM literature (Venkatesh and Davis 2000), we define image as the extent to which using ARSGs is "perceived to enhance one's social status in one's social system" (Moore and Benbasat 1991) is perceived to impact the positive image of the user.

H3: Image is positively related to consumer's intention to adopt ARSGs.

3.2 Risks of Using

Technology acceptance scholars have identified various risks as relevant to people's adoption and use of technology. We propose that this is also true for ARSGs. In particular, two risk factors seem to play an important role: First, the general risk of using ARSGs from a technological perspective, as proposed by TAM Scholars (King and He 2006), and second, the risk of threatening a user's privacy (Rauschnabel and Ro 2016).

The first risk that we incorporated in our analysis is the technology risk. According to Featherman and Pavlou (2003), perceived technology risk has various aspects: psychological risk, risks due to uncertainties in purchase decision, and physical risk. Psychological risk addresses the potential anxiety or disappointment that can occur after the consumer purchases the technology. Risks that are due to the uncertainties in purchase decision are financial risk, time loss risk and technology performance risk. Consumers may feel that they have invested their money and time in purchasing a technology that does not meet their needs. Moreover, the technology may fail to perform as expected. Physical risk refers to the risk of personal injury after using the technology. In particular, these wearable technologies can affect a user's vision and mobility. ARSGs overlay information and holographic objects on a person's field of view which in turn leads to limiting the view to some extent and potentially causing distraction. ARSGs generally require that users shift their focus quickly from the real world in the distance to the overlaid information and objects; therefore, some users may have difficulty adjusting focus. Users may also get distracted by the virtual objects and hence have longer reaction times than usual. An example of this hazard can be wearing ARSGs while driving which may lead to misjudging the speed of other cars and underestimating reaction times.

The second risk factor is particularly important as ARSGs are equipped with cameras, microphones and other sensors (Hein et al. 2016). This allows ARSGs to technically capture, process, and share the personal interactions of a user with third parties, such as hackers. Not surprisingly, media have also elaborated on this criticism, and scholars have discussed this issue conceptually. Recently, Rauschnabel et al. (2016a, b) analysed the impact of these risk factors on users' adoption intention and did not find a significant effect to confirm this empirically; however, a replication using a different research design could help with generalizing or falsifying this finding.

Therefore, we proposed that both risk factors—technology risk and privacy risk—are negatively related to HoloLens adoption

H4: Perceived technology risk is negatively related to consumers' intention to adopt ARSGs.
H5: Perceived privacy risk is negatively related to consumers' intention to adopt ARSGs.

3.3 Technology Characteristics

We also propose that several characteristics of ARSGs determine the intended use. One of the main factors in the original TAM model that has been known for its influence on adoption behaviour is perceived ease of use of the technology. The TAM scholars have widely studied the role of perceived ease of use as a determinant to adoption and use. Reviewing these studies shows that there is a general consensus in the scientific community that perceived ease of use has either a direct or indirect effect on consumers' behavioural intention to use new technologies in various contexts. This finding has also been supported in technology acceptance studies in the context of wearable technologies (Lee 2009; Leue and Jung 2014; Rauschnabel and Ro 2016). Therefore, we propose that perceived ease of use is also positively related to adoption intention in the context of Augmented Reality Smart Glasses.

H6: Perceived ease of use is positively related to consumers' intention to adopt ARSGs.

3.4 Norms

It is a widely replicated finding that people's behaviour is strongly influenced by other people. TAM researchers have established a construct called 'social influences' in their models which reflects an injunctive normative belief. Injunctive normative beliefs describe the extent to which a person believes that other people expect a person to engage in particular behaviours (Cialdini et al. 1990)—here: to adopt HoloLens (H7).

However, the literature on social norms also proposes a second type of norm: descriptive norms. With regards to ARSGs, descriptive norms describe the expected social conformity of using them—in other words, they indicate if a person believes that using ARSGs will be somehow common among his or her peers (H8).

With very few exceptions, most prior research on TAM and ARSGs have focused on injunctive norms; however, especially in the early stage of the product lifecycle, a comparison of the two types of norms provides an interesting contribution to the literature. Therefore, we propose:

H7: Injunctive norms are positively related to consumers' intention to adopt ARSGs.
H8: Descriptive norms are positively related to consumers' intention to adopt ARSGs.

4 Methodology and Research Design

One hundred and sixteen students of a North American university took part in an online survey on 'new media and technologies' for extra credits. The sample consists of 43% females, and respondents' average age was 23.2 (SD = 5.1). The study started with a short, approximately 2-minute video by Microsoft that explains Hololens followed by the constructs of interest and demographic variables.

Where possible, we used existing scales from the literature and adapted them to the context of HoloLens. We used 7-point Likert scales ranging from 1 = totally disagree to 7 = totally agree. All items and references are presented in the appendix. All coefficient alphas exceeded the recommended thresholds of .7, indicating sufficient reliability, as shown in Table 2 (diagonal). All the items were aggregated composite mean scores. Table 1 also presents the mean values, standard deviations, and correlations between the constructs.

Table 2 Correlations and descriptive statistics

		M	SD	1	2	3	4	5	6	7	8	9
1	Perceived usefulness	5.34	1.26	.93								
2	Hedonic motivation	5.65	1.26	.44**	.89							
3	Image	5.76	1.72	.35**	.15	.91						
4	Technology risk	3.78	1.30	−.22*	−.04	−.16	.89					
5	Privacy risks	4.57	1.51	−.16	−.02	−.11	.60**	.93				
6	Ease of use	4.98	1.28	.36**	.25**	.07	−.12	−.17	.94			
7	Injunctive norms	3.63	1.46	.43**	.16	.25**	−.19*	−.19*	.48**	.93		
8	Descriptive norms	3.38	1.45	.30**	.15	.38**	−.13	−.13	.27**	.53**	.95	
9	Adoption intention	3.49	1.49	.48**	.17	.42**	−.31**	−.21*	.41**	.55**	.63**	.88

**$p < .01$; *$p < .05$/diagonal: Cronbach's alpha

5 Results

RQ1 focuses on how consumers evaluate HoloLens. Table 1 presents the descriptive statistics, particularly mean and standard deviations. Results show that the surveyed respondents tend to evaluate the benefits substantially higher (perceived usefulness: m = 5.3; hedonic motivation: m = 5.65; image: m = 5.76) than the risks (technology: m = 3.78; privacy: m = 4.57). Respondents also expect that HoloLens is easy to use (m = 4.98), and evaluate them low in terms of social norms (injunctive: m = 3.63; descriptive: m = 3.38). Interestingly, the standard deviation is particularly high for image (SD = 1.72), indicating that HoloLens is associated with a very positive image for some respondents, and a very negative one for others.

With regards to RQ2, we applied using multiple regression analyses. The results are outlined in Table 2 and visualized in Fig. 2. An inspection of VIF factors did not indicate any concerns with multicollinearity (all VIF < 3), and the overall model fit F-test indicates an R squared significantly above zero ($p < .001$) (Table 3).

6 Discussion and Conclusion

This is one of the few studies that investigates consumers' acceptance of a novel technology: Microsoft Hololens, a recently launched ARSG device. Drawing up on established technology acceptance theories and taking into account the ARSG

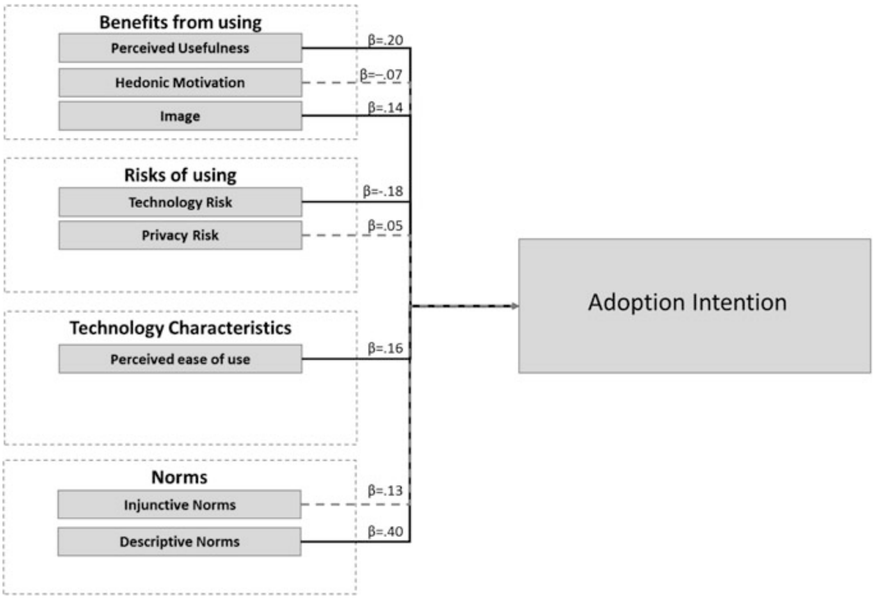


Fig. 2 Visualization of the results

Table 3 Regression analysis

	β	t	p
Perceived Usefulness	**0.20**	**2.49**	**0.01**
Hedonic Motivations	−0.07	−0.98	0.33
Image	**0.14**	**2.00**	**0.05**
Technology Risk	**−0.18**	**−2.21**	**0.03**
Privacy Risk	0.05	0.65	0.52
Perceived ease of use	**0.16**	**2.08**	**0.04**
Inductive Norms	0.13	1.59	0.12
Descriptive Norms	**0.40**	**5.09**	**0.00**
R Squared R Squared (adjusted)	.57 (p < .001) .543		

specific characteristics, this research proposes and empirically tests a model consisting of eight hypotheses to explain consumers' intended adoption of ARSGs. The results of this study show that perceived usefulness, image, ease of use, and descriptive norms are positively related to adoption intention whereas technology risks are negatively related to adoption intention. No significant effect was found for hedonic motivations, privacy risk, and inductive norms. Descriptive analyses also show that consumers tend to see more benefits than risks of ARSGs. Findings of this research have important implications for theory and practice as discussed below.

6.1 Theoretical Implications

The first theoretical contribution of this study is a comprehensive framework of antecedents to ARSG adoption. While prior research has often focused on a small number of factors (e.g., Weiz et al. 2016; Ernst et al. 2016; Rauschnabel et al. 2015), the model in this study incorporates benefits, risks, technology factors, and norms. By doing so, this study provides a much more comprehensive overview of factors relating to the adoption of ARSGs than proposed in the existing research. Counter-intuitively, the coefficient of hedonic motivation did not approach significance. This is surprising, as consumers generally value new technologies for being 'fun' to use (Venkatesh et al. 2012). A potential explanation is that hedonic motivations behave similarly to other antecedents in Rauschnabel and Ro (2016) by focusing on the evaluation of the device, rather than the behavioural intention.

The second contribution of this research is the focus on risks. Prior research on ARSGs has predominantly focused on benefits (e.g., Rauschnabel et al. 2015; Tom Dieck et al. 2016) or other established TAM factors (Rauschnabel and Ro 2016). Results of this study confirm Rauschnabel et al.'s findings (2016a, b) that people's perception of the privacy risks do not seem to matter in their intention to adopt. In addition, this study shows that general technology risks can affect the adoption intention. That is, while this research replicates the counter-intuitive finding that privacy risks are less crucial, it also shows that general risk factors matter. More research is needed to better understand the nature and antecedents to these risk factors.

The third contribution is the distinction of the descriptive versus injunctive norms (Cialdini et al. 1990). Prior research, including numerous TAM studies in related disciplines have predominantly looked at injunctive norms (e.g. Venkatesh et al. 2012). In this study, we integrated injunctive and descriptive norms. Results indicate that, at least in this study, descriptive norms seem to be more relevant in explaining the adoption intention. This is an important contribution for ARSG research, but also for the TAM domain as a whole. Findings suggest that scholars should consider descriptive norms in addition to injunctive norms.

Finally, most prior research has focused on Google Glass (Rauschnabel et al. 2015; Rauschnabel and Ro 2016; Eisenmann et al. 2014) or ARSGs in general (Rauschnabel et al. 2016). So far, not much research has studied ARSGs using the example of Microsoft HoloLens. Compared to HoloLens, Google Glass has a plain design, only one prism and is not able to realistically integrate 3D Holograms into a user's perception of the reality. HoloLens, however, offers these features, but in a much more 'bulky' device.

6.2 Managerial Implications

This study also provides a number of implications for ARSG manufacturers and app developers. In particular, in order to foster the adoption of ARSGs, manufacturers should focus on utilitarian benefits, ease of use, and the reduction of technology risks. Utilitarian benefits can be promoted by showing how a user's life can be improved in terms of efficiency—potential examples include opportunities for collaboration, organizer functions and so forth. In order to improve user-friendliness, app developers and manufacturers need to understand users' expectations of how to operate this novel form of media technology. So far, Microsoft HoloLens uses a variety of operation methods (voice commands, hand gestures, and mouse-like clicker devices) to provide users with options when it comes to working with Hololens. More challenging might be the way to reduce the technology risk as a whole. Therefore, Manufacturers should understand the factors that determine this overall risk.

In addition to that, focusing on descriptive norms in communication could be a promising strategy. Manufacturers can provide information about how our lives could look like in the future or communicate summaries of the promising forecasts in their advertisements.

6.3 Limitations and Future Research

Like any other study, this research has some limitations. First, the relatively small group of participants consisting of US students might limit the generalization and extrapolation of the findings to other consumer groups. In addition, the focus on HoloLens, the first commercially available 3D ARSG is a strength in terms of managerial implications because findings can be influenced by Hololens-specific usage circumstances. Finally, similar to most prior studies on ARSGs (see Table 1), we also provided respondents with only a description of ARSGS rather than an exposure to the real product. However, in contrast to most prior studies, we showed respondents a realistic video instead of a textual and abstract description of the ARSG concept. While some findings (e.g. a non-significant effect of privacy; see Rauschnabel and Ro 2016) were replicated, other findings remain surprising. For example, hedonic benefits did not impact adoption intention, but in Rauschnabel et al. (2016) they were found to influence usage intention. More research is needed to study the influence of these factors on various outcomes (e.g. usage intention in different contexts, adoption intention, attitude towards using, and so forth). This study found that technology risk is a crucial driver of ARSG adoption. This is an important contribution as prior research has not yet studied risk factors intensely. While this study confirms that technology risks matter, a subsequent follow up question remains unanswered: What exactly is technology risk when it comes to ARSGs? Future research therefore should focus on assessing the risks of ARSG usage. Lu et al. (2005) provided a first multi-dimensional assessment of technology risks. Extending this to Fashnology—or in particular ARSGs—could lead to important contributions to the technology and Fashnology literature.

References

Bagozzi, R. P. (2007). The legacy of the technology acceptance model and a proposal for a paradigm shift. *Journal of the association for information systems, 8*(4), 3.

Behzadan, A. H., Timm, B. W., & Kamat, V. R. (2008). General-purpose modular hardware and software framework for mobile outdoor augmented reality applications in engineering. *Advanced Engineering Informatics, 22*(1), 90–105.

CCS Insight (2016). Wearables Momentum Continues. Retrieved Janurary, 2017. from http://www.ccsinsight.com/press/company-news/2516-wearablesmomentum. continues.

Craig, A. B. (2013). *Understanding augmented reality: concepts and applications*. Newnes.

Chau, P. Y., & Lai, V. S. (2003). An empirical investigation of the determinants of user acceptance of internet banking. *Journal of organizational computing and electronic commerce, 13*(2), 123–145.

Chi, H. L., Kang, S. C., & Wang, X. (2013). Research trends and opportunities of augmented reality applications in architecture, engineering, and construction. *Automation in construction, 33,* 116–122.

Chuah, S. H. W., Rauschnabel, P. A., Krey, N., Nguyen, B., Ramayah, T., & Lade, S. (2016). Wearable technologies: The role of usefulness and visibility in smartwatch adoption. *Computers in Human Behaviour, 65,* 276–284.

Cialdini, R. B., Reno, R. R., & Kallgren, C. A. (1990). A focus theory of normative conduct: recycling the concept of norms to reduce littering in public places. *Journal of Personality and Social Psychology, 58*(6), 1015.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS quarterly*, 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*(8), 982–1003.

Eisenmann, T., Barley, L., & Kind, L. (2014). Google Glass. *Harvard Business School Case Study*

Ernst, C. P. H., & Stock, B. (2016). *& dos Santos Ferreira, T.* The Role of Perceived Substitutability: The Usage of Augmented Reality Smartglasses.

Featherman, M. S., & Pavlou, P. A. (2003). Predicting e-services adoption: a perceived risk facets perspective. *International Journal of Human-Computer Studies, 59*(4), 451–474.

Hein, D. W. E., Jodoin, J., Rauschnabel, P. A., & Ivens, B. S. (2017). *Are Wearables Good or Bad for Society? An Exploration of Societal Benefits, Risks and Consequences of Augmented Reality Smart Glasses.* In Kurubacak, G. & Altinpulluk, H. (Eds.) *Mobile Technologies and Augmented Reality in Open Education*,. …….:IGI Global

Hein, D. W., & Rauschnabel, P. A. (2016). Augmented Reality Smart Glasses and Knowledge Management: A Conceptual Framework for Enterprise Social Networks. In *Enterprise Social Networks* (83–109). Springer Fachmedien Wiesbaden.

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

Javornik, A. (2016b). It's an illusion, but it looks real!'Consumer affective, cognitive and behavioural responses to augmented reality applications. *Journal of Marketing Management, 32*(9–10), 987–1011.

Jung, T. H., & Han, D. I. (2014). Augmented Reality (AR) in Urban Heritage Tourism. e-Review of Tourism Research.

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.

King, W. R., & He, J. (2006). A meta-analysis of the technology acceptance model. *Information & Management, 43*(6), 740–755.

Lee, H. M. (2009). A study on the acceptance of wearable computers based on the extended technology acceptance model. *The Research Journal of the Costume Culture, 17*(6), 1155–1172.

Leue, M. C., Jung, T., & tom Dieck, D. (2015). Google Glass augmented reality: Generic learning outcomes for art galleries. In *Information andCommunication Technologies in Tourism 2015*, (463–476). Springer International Publishing.

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

Lewis, W., Agarwal, R., & Sambamurthy, V. (2003). Sources of influence on beliefs about information technology use: An empirical study of knowledge workers. *MIS Quarterly, 1,* 657–678.

Lu, H. P., Hsu, C. L., & Hsu, H. Y. (2005). An empirical study of the effect of perceived risk upon intention to use online applications. *Information Management & Computer Security*, *13*(2), 106–120.

Moore, G. C., & Benbasat, I. (1991). Development of an instrument to measure the perceptions of adopting an information technology innovation. *Information systems research, 2*(3), 192–222.

Ratten, V. (2009). Adoption of technological innovations in the m-commerce industry. *International Journal of Technology Marketing, 4*(4), 355–367.

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.

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,* 635–647.

Rauschnabel, P. A., Hein, D. W., He, J., Ro, Y. K., Rawashdeh, S., & Krulikowski, B. (2016a). Fashion or Technology? A Fashnology Perspective on the Perception and Adoption of Augmented Reality Smart Glasses. *i-com*, *15*(2):179–194.

Rauschnabel, P. A.; He, J.; Ro, K. Krulikowski, B. (2016b): Expected Benefits and Perceived Risks of Augmented Reality Smart Glasses, Working Paper, University of Michigan: Ann Arbor, Dearborn, Flint.

Rese, A., Baier, D., Geyer-Schulz, A., & Schreiber, S. (2016). How augmented reality apps are accepted by consumers: A comparative analysis using scales and opinions. *Technological Forecasting and Social Change*. ……..

Scholz, J., & Smith, A. N. (2016). Augmented reality: Designing immersive experiences that maximize consumer engagement. *Business Horizons, 59*(2), 149–161.

Spreer, P., & Kallweit, K. (2014). Augmented reality in retail: assessing the acceptance and potential for multimedia product presentation at the PoS. *Transactions on Marketing Research, 1*(1), 20–35.

Stock, B., dos Santos Ferreira, T. P., & Ernst, C. P. H. (2016). Does Perceived Health Risk Influence Smartglasses Usage?. In *The Drivers of Wearable Device Usage* (pp. 13–23). Springer International Publishing.

Stockinger, H. (2016). The future of augmented reality-an Open Delphi study on technology acceptance. *International Journal of Technology Marketing, 11*(1), 55–96.

tom Dieck, M. C., & Jung, T. (2015). A theoretical model of mobile augmented reality acceptance in urban heritage tourism. *Current Issues in Tourism*, *1*:1–21.

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

Venkatesh, V., & Davis, F. D. (2000). A theoretical extension of the technology acceptance model: Four longitudinal field studies. *Management Science, 46*(2), 186–204.

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, 1,* 115–139.

Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: Toward a unified view. *MIS Quarterly, 1,* 425–478.

Venkatesh, V., Thong, J. Y., & 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.

Weiz, D., Anand, G., & Ernst, C. P. H. (2016). The Influence of Subjective Norm on the Usage of Smartglasses. In *The Drivers of Wearable Device Usage* (pp. 1–11). Springer International Publishing.

Functional, Hedonic or Social? Exploring Antecedents and Consequences of Virtual Reality Rollercoaster Usage

Timothy Jung, M. Claudia tom Dieck, Philipp Rauschnabel, Mario Ascenção, Pasi Tuominen and Teemu Moilanen

Abstract During the last years, various media technologies such as Augmented Reality (AR) and Virtual Reality (VR) have gained increased attention in consumer markets and tourism. For theme parks, especially those with rollercoasters, wearable VR devices are expected to be associated with various benefits for tourists' experience. Therefore, adventure park managers with VR rollercoasters have a keen interest in understanding the drivers and psychological mechanisms of their visitors, especially those associated with economic benefits. Against this background, this study provides a conceptual model grounded in the VR and AR literature. The model is then tested in a Finnish amusement park with a VR switchback, and analysed using structural equation modelling. Result show that entertainment value and service quality drive satisfaction and subsequently word of mouth, but results do not confirm the importance on visitors' willingness to pay an extra fee for a VR experience. However, this economically crucial variable is determined by social

T. Jung · M.C. tom Dieck (✉)
Faculty of Business and Law, Manchester Metropolitan University,
Manchester, UK
e-mail: c.tom-dieck@mmu.acuk

T. Jung
e-mail: t.jung@mmu.acuk

P. Rauschnabel
Department of Management Studies, College of Business,
University of Michigan – Dearborn, Dearborn, MI, USA
e-mail: prausch@umich.edu

M. Ascenção · P. Tuominen · T. Moilanen
Experience and Wellness Economy Unit/Haaga Campus,
Haaga-Helia University of Applied Sciences, Helsinki, Finland
e-mail: mariopassos.ascencao@haaga-helia.fi

P. Tuominen
e-mail: pasi.tuominen@haaga-helia.fi

T. Moilanen
e-mail: teemu.moilanen@haaga-helia.fi

T. Jung and M.C. tom Dieck (eds.), *Augmented Reality and Virtual Reality*,
Progress in IS, DOI 10.1007/978-3-319-64027-3_17

presence of other people, indicating that visitors are willing to pay for experiencing an immersive experience with other people. Theoretical and managerial implications are derived, and avenues for further research discussed.

Keywords Virtual reality · Tourism experience · Theme park

1 Introduction

The creation of immersive and enjoyable virtual reality (VR) applications for the enhancement of the tourist experience has received increased attention over the last few years which can be largely linked to latest developments in head mounted displays (HMD) (Guttentag 2010; Jung et al. 2016). Within the tourism context, there are two different approaches to VR experiences: 1. Off-site experience and 2. On-site experience. While off-site experiences provide tourists with an opportunity to explore a destination and trip planning, on-site experiences can be an ideal tool to enhance the existing offering (Jung et al. 2017). Hotel chains such as Marriott used VR simulations to show case their hotels around the world and thus, provide potential hotel guests' with intentions to visit (Marriott 2014). On the other hand, Geevor Tin Mine museum is an example of an on-site VR experience whereby visitors had the opportunity to experience an underground mine, which would normally be inaccessible (Jung et al. 2016). Although these use cases exist around the world, tourism research with regards to tourists' behavioural intentions after experiencing on-site VR is still limited.

These new virtual environments have various implications for marketers (Chauhan and Kumar 2012; Stockinger 2016). In particular, for theme parks, especially those with rollercoasters, wearable VR devices are expected to be associated with various benefits for tourists' experience (Baker 2016). Therefore, theme park managers with VR rollercoasters have a keen interest in understanding the drivers and psychological mechanisms of their visitors, especially those associated with economic benefits. Against this background, this study provides and tests a conceptual model grounded in the VR literature.

Furthermore, the competition between theme and amusement parks is fiery, and it is expected that the next battle ground will be about the use of AR and VR technology. In this context, Finland is the first of the Nordic countries to offer rides which combine a rollercoaster with virtual reality. This ride used in this study allowed visitors to experience space scenery, in 360 degrees through a video animation, where they dodged planets at high speed. The music that played in the background was specifically composed for this ride.

During the rollercoaster ride visitors wear a virtual reality headset with a high-quality widescreen image. The VR headset seamlessly combined a real rollercoaster ride with a virtual world. Acceleration and distance sensors were constantly synchronising the 360-degree virtual image as the ride moved around.

Previous studies in the technology adoption context found a number of antecedents that influence users' satisfaction and behavioural intentions including functional benefits, hedonic experience and social experiences (Jung et al. 2015; Rauschnabel and Ro 2016; Algharabat and Zamil 2013). However, research within the VR tourism context is limited. In particular, a focus on positive word of mouth (WOM) and willingness to pay extra after experiencing technologies has reviewed limited attention within the tourism context. This however, is crucial in order to create compelling business cases for tourism companies. Therefore, the proposed model will test these drivers to provide meaningful recommendations.

2 Theoretical Background and Hypotheses Development

Our conceptual model is summarized in Fig. 1 and inspired by prior media and VR research. The model theorizes that consumers' evaluation and reaction to VR rollercoasters is driven by functional, hedonic and social benefits. In particular, the framework proposes specific constructs that address functional, hedonic and social needs which determine visitor's satisfaction, which then indirectly impacts Word of Mouth (WOM) and willingness to pay extra for the VR experience. Inspired by prior technology acceptance and media theories, we also propose that the behavioural variables are also directly influenced by social factors, such as social presence. In the subsequent section, we will derive, define and propose specific constructs and their role in our framework, before empirically testing the model.

2.1 Service Quality and Satisfaction

A recent study, focusing on mobile acceptance, confirmed the link between quality, satisfaction and the intention to re-use mobile services (Ansari et al. 2013). In fact,

Fig. 1 Proposed model

numerous studies (Baker and Crompton 2000; Petrick 2004) were conducted in the tourism context regarding perceived quality and its impacts on tourism businesses and Chen and Chen (2010) suggested that service quality is the key determinant for tourists' perceived quality with a high influence on customer satisfaction.

Therefore, we propose:

H1: Service quality has a positive effect on satisfaction.

2.2 Entertainment and Satisfaction

Theme parks and hedonic experiences go in hand in hand due to the nature of the business and visitor experience (Balloffet et al. 2014). Psychologically, hedonic experiences are linked with various positive outcomes, such as pleasure and reduction of boredom (Close and Kukar-Kinney 2010; Klinger 1971). Therefore, numerous studies on technology acceptance in general (Venkatesh and Bala 2008; Venkatesh et al. 2012), but also in related contexts such as AR technologies (Balog and Primeanu 2010; Olsson et al. 2013) have empirically validated that hedonic factors drive users' evaluation of technologies. Wong and Cheung (1999, p. 328) explored motivations to visit theme parks and confirmed visitors' "need to enjoy the adventure and excitement of the rides and the level of importance assigned to the adventure theme" as one of the key aspects of theme park businesses. This clearly shows the strong importance of hedonic experiences within the theme park context. Adding to this, previous studies found that VR creates enjoyable and entertaining experiences (Jung et al. 2016) and thus, we propose:

H2: Entertainment has a positive effect on satisfaction.

2.3 Social Presence and Behavioural Intentions

The effect of social experiences on behavioural intentions has been well supported by a long stream of technology adoption literature (e.g. Hsu and Lin 2008; Qin et al. 2011; tom Dieck et al. 2017). Also in the context of VR, social presence plays an important role within literature (Jung et al. 2016). Within the present study, social presence can be explained by "whether there is positive interpersonal and emotional connection between communicators" (Cui et al. 2013, p. 663).

Because the use of a rollercoaster is an incident-based activity (rather than adopting or buying a new technology), we propose that social factors especially during the experience matter. Therefore, as studied in the context of VR, social presence plays an important role within literature (Jung et al. 2016). Within the present study, social presence can be explained by "whether there is positive interpersonal and emotional connection between communicators" (Cui et al. 2013, p. 663). People tend to find social interactions generally enjoyable. Consumption experiences, such as brand clubs or communities in the real world or in virtual worlds (e.g. social media) can help consumers to meet these social needs. Virtual experience, especially while riding a rollercoaster, does not allow the creation of 'real' social relationships, and therefore, might trigger more a 'sense of community'. Anyhow, prior research has shown that evoking the feelings of social interactions can evoke positive feelings. For example, people perceive a "sense of community" around brands (Bergkvist and Bech-Larsen 2010) or think of some brands in terms of human attributes (Rauschnabel and Ahuvia 2014). We therefore propose that if using a VR rollercoaster triggers social perceptions, this should lead to a more positive evaluation. Likewise, we also propose a direct effect on the intentional variables. This is, on the one hand, as technology acceptance theories widely replicate that social influences in general are related to intentional variables. On the other hand, prior research has argued that people tend to consume in an 'instrumental' effect (Ahuvia 2015). Following this stream of research, people could be willing to engage in VR rollercoasters because of gratifications from these social factors, rather a higher and more functional level of 'satisfaction'. Therefore, we propose:

H3: Social presence has a positive effect on satisfaction.
H4: Social presence has a positive effect on willingness to pay.
H5: Social presence has a positive effect on word of mouth.

2.4 Satisfaction and Behavioural Intentions

Although it was argued that behavioural intentions or post-purchase intentions are a result of the satisfaction level of consumers, Fishbein and Manfredo (1992) stated that social behaviours are affected by consumer intentions and thus, can be predicted if properly measured. Wang et al. (2004) defined behavioural intentions as consumers' decision to revisit or repurchase with the same supplier, as well as sharing their experiences in their social circles, the concept of WOM. Harrisson-Walker (2001) argued that since many non-informed consumers heavily rely on others' opinions, the process of WOM to tell others about their experience with the result of influencing potential consumers' behaviour has become more important compared to other external marketing strategies. Furthermore, it was found that high quality perceptions had a positive influence on intended behaviour (Zeithaml et al. 1996). In addition, Choi et al. (2011, p. 191), using the technology acceptance model as a theoretical foundation, concluded that "if the users are satisfied with mobile tour services, the possibility to re-use these services will be high" which was supported by Chou et al. (2013) who focused on the expectancy confirmation theory in the mobile application context. Moreover, a research by Ansari et al. (2013) investigating the value, image, quality, satisfaction and behavioural intention, confirmed that satisfaction has strong positive effects on the intention to re-use mobile value-added services. Adding to this, Luarn and Lin (2003) and Vranakis et al. (2012) identified that one of the most influencing factors affecting loyalty in the e-service or mobile context is customer satisfaction. According to Sun et al. (2013), satisfaction results in returning visitors and higher profits. However, limited research has tested these relationships within the VR tourism context. With regards to behavioural intentions, for theme parks, positive WOM and willingness to pay for services are considered immensely important and therefore we propose:

H6: Satisfaction has a positive effect on willingness to pay.
H7: Satisfaction has a positive effect on word of mouth.

3 Methods

3.1 Data Collection

The data collection was conducted in one of the major amusement parks in Finland. Data were gathered from respondents who experienced a VR rollercoaster, using Samsung Gear VR glasses, between September 23 and October 22, 2016. Convenience sampling method was used by sending an e-mail invitation to 1575 adult higher education students. Students, who replied to the call for participation in the study, were informed about the nature of the research project. Thereafter, if they agreed, participants were given ride tickets, and informed to visit amusement park, with one friend, any day of their choice. A questionnaire was handed with ride tickets, and the participants were asked to fill it after the experience. 152 usable responses of the VR enhanced "milky way" rollercoaster experience were collected.

3.2 Measures

If possible, we adopted existing scales from the literature. Scales were measured using a 5-point Likert scale. Higher values indicate stronger agreement or more positive evaluations. All items and references are listed in Table 2. We started our analyses with an inspection of the factorial structure of the constructs. On a global level, CFA results show good psychometric properties (Chi2 = 180.0; df = .120; $p < .001$; CFI = .960; TLI = .950; SRMR = .048; RMSEA = .062). Similarly, fit indices on a local level indicated exceeded the recommended thresholds of .5, .7, and .7 for AVE, C.R. and Cronbach's alpha. In addition, all factor loading exceeded .7 and were significant on a $p < .001$-level. Table 2 shows the measurement items and the fit measures, and Table 1 presents the correlations.

Table 1 Correlation

Matrix	1	2	3	4	5
1. Entertainment					
2. Quality	0.42				
3. Social presence	0.14	0.30			
4. Satisfaction	0.80	0.71	0.15		
5. Word of moth	0.69	0.62	0.26	0.79	
6. Additional payment	0.22	0.27	0.33	0.18	0.35

Table 2 CFA model

Construct and measurement items	δ	CR	AVE
Entertainment (Loureiro 2014)		.90	.70
The rollercoaster VR experience was amusing	.88		
The rollercoaster VR experience was entertaining	.85		
The rollercoaster VR experience was fun	.80		
The rollercoaster VR experience was captivating	.80		
Service quality (Yang et al. 2005)		.83	.62
How do you perceive your rollercoaster facility quality of the linnunrata extra	.74		
How do you perceive your rollercoaster VR quality of the linnunrata extra 1 2 3 4 5	.78		
How do you perceive your overall quality of the Linnunrata extra experience	.84		
Social presence (Cyr et al. 2007)		.84	.64
There was a sense of human contact when I had the rollercoaster VR experience	.84		
There was a sense of sociability when I had the rollercoaster VR experience	.80		
There was a sense of human warmth when I had the rollercoaster VR experience	.76		
Satisfaction (Quadri-Felitti and Fiore 2013)		.88	.71
How do you feel about your overall rollercoaster VR experience? (1 = dissatisfied…5 = satisfied)	.92		
How do you feel about your overall rollercoaster VR experience? (1 = displeased…5 = pleased)	.78		
How do you feel about your overall rollercoaster VR experience? (1 = frustrated…5 = contended)	.82		
Word of mouth (Quadri-Felitti and Fiore 2013)		.94	.83
I want to recommend linnanmäki to others after experiencing the linnunrata eXtra	.94		
I am likely to recommend linnanmäki to others after experiencing the linnunrata eXtra	.93		
How likely is it that you would recommend linnunrata eXtra to a friend, colleague or relative?	.87		
Willingness to pay (Bloemer and Odekerken-Schroder 2002)		.85	.74
I intend to pay extra entrance fee if this VR experience is included	.86		
I am willing to pay extra for additional VR experiences	.86		

4 Findings

4.1 Hypotheses Testing

In order to test the hypothesized effect, we modelled structural relationships between the hypothesized model. In addition, we included age and gender as control variables on the three endogenous variables to parcel out variance from respondents' demographic characteristics. We assessed the structural equation model in Mplus using a maximum likelihood estimator with robust error terms. Results indicate acceptable levels of fit (Chi2 = 217.84; df = 154; $p < .001$; CFI = .958; TLI = .948; SRMR = .059; RMSEA = .057). We will discuss all effects (standardized beta effects) in detail below and summarize the findings in Fig. 2. Results show two significant antecedents of satisfaction, namely quality ($\beta = .488$; $p < .001$) and Entertainment ($\beta = .621$; $p < .001$), supporting H1 and H2. However, results do not support the hypothesized effect for social presence ($\beta = -.077$; $p = .246$). Both control variables were insignificant (age: $\beta = .009$; $p = .871$; gender: $\beta = .024$; $p = .661$). The model explains 84.4% of satisfaction's variance ($p < .001$).

Findings also show that satisfaction is positively related to word of mouth ($\beta = .779$; $p < .001$) but not on willingness to pay ($\beta = .142$; $p = .162$). This supports H7 but not H6. Both word of mouth ($\beta = .174$; $p = .014$) and willingness to pay ($\beta = .323$; $p = .001$) are significantly influenced by social presence, which is in line with H4 and H5. The model explains 22.2% of the variation of willingness to pay, and 69.5% of word of mouth. The control variables were insignificant for word of mouth (age: $\beta = .075$; $p = .340$) but showed that males and older consumers are more likely to pay extra for the VR experience (age: $\beta = .185$; $p = .030$; gender: $\beta = -.187$; $p = .036$).

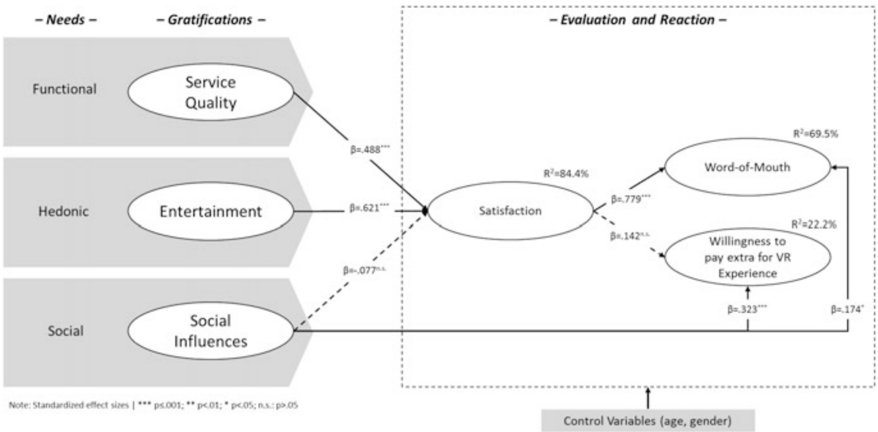


Fig. 2 Summary of the results

4.2 Robustness Tests

To further assess the robustness of the findings, we re-estimated the model with different estimators. We also ran the model without control variables. The effects hold. We also modelled direct effects from entertainment and quality on the intentional variables; they did not reach significance. In sum, findings from the robustness tests lead to the conclusion that the reported results are stable.

5 Discussion and Conclusion

The present study incorporates, extends and modifies previous theories which looked at the relationships between quality, entertainment, social influence, satisfaction and behavioural intention (Ansari et al. 2013; Chen and Chen 2010; Rauschnabel and Ro 2015), theorising (at least) three antecedents of visitors' satisfaction and behavioural intentions to recommend and pay the VR rollercoaster experience. Despite potential benefits of VR applications for enhancing tourist experience, previous research in this context is limited and the present study acknowledges this gap and contributes to the existing pool of knowledge. A number of findings emerged throughout this study that contribute to the literature on VR in several ways.

First, we propose a model that explains the emergence and consequences of users' level of satisfaction with VR experiences. In addition, the study looks at two different but crucial outcome variables: word of mouth and willingness to pay for a VR experience. Results show that word of mouth is mostly driven satisfaction, whereas satisfaction was shown to be non-significant for visitors' intention to pay a for the VR experience. In other words, whether a visitor was satisfied or not did not relate to his or her intention to pay more for the VR experience or not. However, this crucial economic variable was significantly impacted by social experiences.

Second, the proposed model finds two antecedents to satisfaction: service quality and entertainment. In contrast to our hypotheses, social influence does not reach significance. On the one hand, this is somehow similar to the stream of technology acceptance literature, where social norms drive intention but not attitude. A similar effect is observed in this study, where enjoying the VR experience with other people seems not no drive satisfaction (which is similar to the attitudinal variables in the technology acceptance literature), but makes people willing to pay more. The findings also provide several important contributions for managerial practice (Wang et al. 2009). First of all, the findings provide managers with a solid understanding of factors that determine visitors' satisfaction and intentions. Results also show that relying on customer satisfaction measures alone is not sufficient. In particular, managers need to be aware that satisfaction can lead to positive word of mouth, which nowadays can also be documented in 'social media buzz' (electronic word of mouth), which can result in new visitors. However, in order to achieve economic benefits among existing visitors by increasing prices for VR experiences, managers need to stimulate social factors. More research is needed to identify how this can be done (especially in specific VR contexts).

As any study, this research has some limitations that lead to opportunities for further research. For example, the current research was conducted in a single context (one rollercoaster in Finland) and build on a relatively small sample size. These factor might limit generalisability of the findings, and thus, caution must be taken when extrapolating the findings to other contexts. For example, the impact on cultural values could moderate the proposed effects, in a way that people from individualistic versus collectivists cultures value the social aspects differently. In addition, especially for managers, characteristics of the VR app and the rollercoaster that impact the VR experience are crucial. Future research could investigate how effective combinations of VR apps and rollercoasters look like.

In sum, this study—while being one of the first on VR rollercoaster experiences—provides insights into the underlying mechanisms how rollercoasters. The findings provide the basis from further groundwork in the intersection of real-word entertainment and virtual worlds.

References

Ahuvia, A. C. (2015). Nothing matters more to people than people: Brand meaning and social relationships. (pp. 121–149). Brand meaning management.

Algharabat, R. S., & Zamil, A. M. A. (2013). An empirical investigation of 3D-based information systems success for online retailers. *International Journal of Technology Marketing, 8*(3), 316–336.

Ansari, A., Kheirabadi, A., Ghalamkari, S., & Khanjari, A. R. (2013). Investigation the relationship among mobile value-added services quality, customer satisfaction and the continuance intention: Case study, hamrah Avval operator. *International Journal of Information Science and Management, Special Issue ECDC, 2013,* 67–84.

Baker, C. A. (2016). Creative choices and fan practices in the transformation of theme park space. *Transformative Works and Cultures, 22,* 1–1.

Baker, D. A., & Crompton, J. L. (2000). Quality, satisfaction and behavioural intentions. *Annals of Tourism Research, 27*(3), 785–804.

Balloffet, P., Courvoisier, F. H., & Lagier, J. (2014). From museum to amusement park: The opportunities and risks of edutainment. *International Journal of Arts Management, 16*(2), 4–17.

Balog, A., & Pribeanu, C. (2010). The role of perceived enjoyment in the students' acceptance of an augmented reality teaching platform: A structural equation modelling approach. *Studies in Informatics and Control, 19*(3), 319–330.

Bergkvist, L., & Bech-Larsen, T. (2010). Two studies of consequences and actionable antecedents of brand love. *Journal of Brand Management, 17*(7), 504–518.

Bloemer, J., & Odekerken-Schroder, G. (2002). Store satisfaction and store loyalty explained by customer-and store-related factors. *Journal of Consumer Satisfaction, Dissatisfaction and Complaining Behavior, 15,* 68.

Chauhan, R., & Kumar, G. (2012). Virtual business empires at second life. *International Journal of Technology Marketing, 7*(3), 254–266.

Chen, C. F., & Chen, F. S. (2010). Experience quality, perceived value, satisfaction and behavioral intentions for heritage tourists. *Tourism Management, 31*(1), 29–35.

Choi, H. S., Park, J. W., & Park, S. B. (2011). A Study on the Effect of Mobile Tourism Information Services on Tourist Satisfaction and Continual Reuse. *Int. J Busi. Inf. Tech, 1*(3), 189–195.

Chou, C. H., Chiu, C. H., Ho, C. Y. and Lee, C. J. (2013). Understanding Mobile Apps Continuance Usage Behaviour and Habit: An Expectance-Confirmation Theory", Available at. http://www.pacis-net.org/file/2013/PACIS2013–132.pdf. Accessed 14. March 2014.

Close, A. G., & Kukar-Kinney, M. (2010). Beyond buying: Motivations behind consumers' online shopping cart use. *Journal of Business Research, 63*(9), 986–992.

Cui, G., Lockee, B., & Meng, C. (2013). Building modern online social presence: A review of social presence theory and its instructional design implications for future trends. *Education and information technologies, 18*(4), 661–685.

Cyr, D., Hassanein, K., Head, M., & Ivanov, A. (2007). The role of social presence in establishing loyalty in e-service environments. *Interacting with Computers, 19*(1), 43–56.

Fishbein, M. and Manfredo, M. J. (1992). A Theory of Behaviour Change. In Manfredo, M. J. (Ed.), *Influencing Human Behaviour: Theory and Applications in Recreation, Tourism and Natural Resources Management* (pp. 29–50). Sagamore: Champaign.

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

Harrison-Walker, L. J. (2001). The measurement of word-of-mouth communication and an investigation of service quality and customer commitment as potential antecedents. *Journal of Service Research, 4*(1), 60–75.

Hsu, C., & Lin, J. (2008). Acceptance of blog usage: The roles of technology acceptance, social influence and knowledge sharing motivation. *Information & Management, 45,* 65–74.

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. and Chung, N. (2016). Effects of virtual reality and augmented reality on visitor experiences in museum, In Inversini, A. and Schegg, R. (Eds), *Information and Communication Technologies in Tourism* (pp. 621–635). Wien: Springer.

Jung, T., tom Dieck, M. C., Moorhouse, N., & tom Dieck, D. (2017). *Tourists' Experience of Virtual Reality Applications*. Las Vegas: Paper presented at ICCE.

Klinger, E. (1971). Structure and functions of fantasy, Wiley.

Loureiro, S. M. C. (2014). The role of the rural tourism experience economy in place attachment and behavioral intentions. *International Journal of Hospitality Management, 40,* 1–9.

Luarn, P., & Lin, H. (2003). A Customer Loyalty Model for E-Service Context. *Journal of Electronic Commerce Research, 4*(4), 156–167.

Marriott. (2014). Available at: https://travel-brilliantly.marriott.com/our-innovations/oculus-get-teleported.

Olsson, T., Lagerstam, E., Kärkkäinen, T., & Väänänen-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.

Petrick, J. F. (2004). Understanding the relationships of quality, value, equity, satisfaction, and behavioral intentions among golf travellers. *Journal of Travel research, 42,* 397–407.

Qin, L., Kim, Y., Hsu, J., & Tan, X. (2011). The effects of social influence on user acceptance of online social networks. *International Journal of Human-Computer Interaction, 27*(9), 885–899.

Quadri-Felitti, D., & Fiore, A.M. (2013). Destination loyalty: Effects of wine tourists' experiences, memories, and satisfaction on intentions. Tourism and Hospitality Research, 1–16.

Rauschnabel, P. A., & Ahuvia, A. C. (2014). You're so lovable: Anthropomorphism and brand love. *Journal of Brand Management, 21*(5), 372–395.

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,* 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.

Stockinger, H. (2016). The future of augmented reality-an open delphi study on technology acceptance. *International Journal of Technology Marketing, 11*(1), 55–96.

Sun, X., Chi, C. G. Q., & Xu, H. (2013). Developing Destination Loyalty: The case of Hainan Island. *Annals of Tourism Research, 43,* 547–577.

tom Dieck, M. C., Jung, T. H., Kim, W. G., & Moon, Y. (2017). Hotel guests' social media acceptance in luxury hotels. *International Journal of Contemporary Hospitality Management, 29*(1), 530–550.

Venkatesh, V., & Bala, H. (2008). Technology acceptance model 3 and a research agenda on interventions. *Decision Sciences, 39*(2), 273–315.

Vranakis, S., Chatzoglou, P., & Mpaloukas, A. (2012). Customer satisfaction of greek mobile phone services. *International Journal of Managing Value and Supply Chains, 3*(4), 43–54.

Wang, Y., Lo, H. P., & Yang, Y. (2004). An integrated framework for service quality, customer value, satisfaction: Evidence from China's telecommunication industry. *Information Systems Frontiers, 6*(4), 325–340.

Wang, Y., Wang, K. L., & Yao, J. T. (2009). Marketing mixes for digital products: A study of the marketspaces in China. *International Journal of Technology Marketing, 4*(1), 15–42.

Wong, K. K., & Cheung, P. W. (1999). Strategic theming in theme park marketing. *Journal of Vacation Marketing, 5*(4), 319–332.

Yang, Z., Cai, S., Zhou, Z., & Zhou, N. (2005). Development and validation of an instrument to measure user perceived service quality of information presenting web portals. *Information & Management, 42*(4), 575–589.

Zeithaml, V. A., Berry, L. L., & Parasuraman, A. (1996). The behavioural consequences of Service quality. *Journal of Marketing, 60*(2), 31–46.

Urban Encounters Reloaded: Towards a Descriptive Account of Augmented Space

Patrick T. Allen, Ava Fatah gen. Shieck and David Robison

Abstract In this chapter, augmented space is described as the layering of media technologies onto the physical space of the city. The approach assesses salient aspects of the experience of space in everyday life, the city and urban space more generally. The chapter discusses these in relation to the deployment of augmenting technologies and modes of display associated with augmented reality, new and digital media: visual or otherwise. Selected work, carried out in relation to culture, leisure and tourism is assessed. These case studies indicate the potential of augmented reality in areas of a) urban design, b) tourism and heritage, and c) the promotion of cycling for health and the creation of alternative transport infrastructure. The main characteristics of AR and augmented space are presented. This is followed by a discussion and development of hybrid research tools and applied in two case studies with a view to providing a potential roadmap for future work in this area.

Keywords Augmented reality · Augmented space · Ubiquitous and mobile technologies · Human engagement · Media layer

1 Introduction

Our urban encounters with the digital such as those reported in Fatah et al. (2008), Allen (2008) and Robison (2012) have gained in their in urgency largely as a consequence of the popularising of 'real world' augmented reality applications in gaming such as *Ingress* and more recently *Pokemon Go* (Humphery-Jenner 2016). These

P.T. Allen (✉)
School of Media, Design and Technology, University of Bradford, Bradford, UK
e-mail: p.t.allen@bradford.ac.uk

A. Fatah gen. Shieck · D. Robison
The Bartlett School of Architecture, University College London, London, UK
e-mail: ava.fatah@ucl.ac.uk

T. Jung and M.C. tom Dieck (eds.), *Augmented Reality and Virtual Reality*,
Progress in IS, DOI 10.1007/978-3-319-64027-3_18

applications have emphasised the potential for the gamification of real spaces and, like geocacheing and other activities have moved computer gameplay from the console or desktop into the open air. As suggested by its title, the overriding intention of this chapter is to update our current knowledge of urban space and the experience of the city that we argue has come about as a consequence of these new developments. Through the lens of the selected work, we will examine the potential integration of augmented reality into real space as well as some of the consequences of this.

2 The Strange Case of Pokemon Go!

The arrival of *Pokemon Go* in July 2016 was a 'wake up call' for anyone engaged in academic research into augmented reality, in fact, it was a wake up call for anyone in the AR industry. It's immediate popularity overcame all expectations and whilst the hype died down surprisingly quickly, putting one in mind of Gartner's "hype cycle" (Gartner 2016) the sudden spike in interest did, however, give Nintendo a much needed opportunity to reawaken its sales in merchandising. Niantic had already had gamers explore the open air with *Ingress* since November 2012. Pokemon Go's lack of financial sustainability within this new potential market for augmented reality gaming was striking: "By mid-September, daily revenues had fallen from US$16 m per day to US$2 m (excluding the 30% app store fee) and daily downloads had declined from a peak of 27 million to 700,000" Humphery-Jenner 2016). The platform raises interesting safety and risk perception issues. These issues may arise in the need for appropriate warnings about gamer proximity to nearby hazards or, indeed, other game players. Attempts to rectify these are evident in the recent release of *Pokemon Go Plus*, a small piece of hardware that apparently performs the necessary proximity detection to keep the gamer safe. But Tassi (2016) writes that this comes with a significant loss of gameplay and user engagement.

In terms of academic research, the *Pokemon Go* phenomenon raises some tantalizing issues:

- The use of augmented reality in gaming (and the problems associated with this).
- The move of computer games and entertainment media from the desktop and console into the open air.
- The key importance of gamer location and attachment to place through locative technologies such as GPS.
- The 'whole deal' around the use and design of space into which AR is introduced.
- The changing of the experience of *space to experience of place*, whether participants are 'being-in' or 'being-out' of real space and the observation, or otherwise, of spatial constraints and social norms.
- The dynamic relations between the real and the virtual within AR systems.

- The pressing need to consider the body and its movements in public space, as a key component within augmented reality systems.
- Aspects of engagement and gamification in public space through the use of rewards and similar motivating objects.

At the very least, new standards for delivery and new research methods are required.

In what follows, we propose a potential research methodology and an overall argument intended to facilitate a much greater understanding of how augmented reality can be incorporated into real world applications and real spaces, but with awareness of the pitfalls and risk perception variables associated with the introduction of *Pokemon Go* and other ‘AR in the wild’ (Rogers 2011) applications.

Theoretical and conceptual work about augmented space have tended to be presented from the perspective of the generalised application of a wider range of ubiquitous and mobile technologies applied to the experience of the city, as in Manovich’s *Poetics* (2006). Many urban spaces are already augmented with a wide range of ubiquitous and mobile technologies, in addition to other forms of media display, including urban screens, for example and as such can easily be described as “augmented spaces” (Aurigi 2008).

These accounts (Aurigi 2008; Allen 2008; Fatah et al. 2008), give priority to the spatial aspects of the design of these spaces and how any intervention, whether as small scale displays using a handheld device or as large scale media displays, can be integrated into the environment in which it is situated (Allen 2008; Fatah 2009). The debate is about this general shift towards augmentation and the human experience of urban and public space being transformed or disrupted by its introduction. The extent to which this can be seen as transnational and generalized phenomenon is also worth discussion.

The brief case study descriptions later in this chapter have the purpose of developing a theoretical understanding of augmented space alongside discussion of the practical development of mobile apps. We argue that it is necessary to go beyond our current understanding of human-computer interaction and related methodologies to understand technology use in the context of augmented space. User participation and engagement is a key concern because the existing strategies used for empirical work in this area may not be enough to cope with both the complexity of human engagement as well as the global nature of these and other related media.

The design, development and deployment of augmented reality systems and their novel forms of display can be evaluated in terms of their facility to create, develop and promote to particular target groups and audiences. That is to say, the work presented in this chapter indicates the development of alternative research, ones that are not necessarily new but that are being applied in different ways to new contexts and combined into a transdisciplinary research strategy. The methods described in this chapter are being devised in order to shed some light on both participation and engagement in the following areas: audience development for museums and galleries and other similar forms of cultural space outdoors, the promotion of cycling, the development of sustainable transport infrastructure and the promotion of healthy lifestyles. These aspects of our empirical strategy are useful additions to our existing research into the design and use of urban and public space.

3 Some Characteristics of Augmented Space

This section provides a descriptive account of some of the characteristics that are considered critical to the existence of augmented space. As such, it is an account that avoids a straightforward definition of augmented space. Similar to the account of "characteristics of augmented reality" provided by Azuma (1997), where the survey given there avoided a full technical description of AR. Indeed, given the variety of technical systems now used in the development of AR, such an account would be so complex, and, given the general perspective of augmented space provided in this chapter, such a definition might be rendered meaningless. Characteristics that are of importance to the work presented here are similar to Azumi's previous account of augmented reality and include: the combination of the real and the virtual, interaction and presentation in real time, and frequent registering in three dimensions.

As was indicated in the previous section a distinction is made between augmented reality and augmented space. The former of these gives priority to the architectural, urban and lived in space within which any augmentation takes place. Previous research on augmented space has tended to focus on the impact of a range of media technologies onto the experience of urban space and put in the context of the layering of these technologies (see e.g. Allen 2008, 2009; Robison 2012) and how they are superimposed onto the built environment including work on analysing patterns of use associated with the BBC's Big Screen network in the UK and the use of mobile gaming as an encouragement tool for social interaction and language learning when travelling to locations of cultural and historical interest.

3.1 The Site-Specific Nature of Augmented Space

Salient observations that have been generated from a consideration of the characteristics of augmented space in the urban context have been developed over many years and stem largely from an interest in the widespread use of large scale LCD displays into the built environment. Here it has already been established that there is a site-specific and located quality to the medium. It has been argued (Allen 2012) that there is a "site-specific" (Kwon 2002) quality to the manifestation of these screens.

McCarthy argued this in relation to the occurrence of smaller scale video displays and TVs in everyday settings such as shopping malls, in bars etc. (McCarthy 2003). The concept of site specificity was then applied to large scale urban screens and it was established that there was quite a powerful located aspect to both the positioning of the screens and the type of content that was displayed on them, as well as important specifics of the visual design of content (Allen 2008, 2009). Case studies on the screen in city centre of Bradford (ibid), for example, showed important characteristic of augmented space more generally and here it is argued, also becomes an important characteristic of 'applied' augmented in an urban setting. In that instance, the physical location of the screens was key to understanding their function and use within the city centre; their evolution and institutional underpinnings (funding, management and curatorial practices); variability of the local environment; simple physical features such as their height; their proximity to particular shops and spaces—in the case of Bradford's screen, adjacent to a major photography gallery. Anna McCarthy (2003, p. 197) has argued that the relation between television and its integration into public space, into sites such as cafes, shops, information displays, travel interchanges, into a wide variety of public areas and into the built environment in more general, is a site specific relation.

Much research has already taken place in relation to the use of "pervasive technology" and its relations to the design and use of space in the urban context (Fatah et al. 2008) and, more importantly, the new forms of interaction that these "digital flows" can facilitate. All of the research indicated here has attempted to integrate an interest in the use of a range of display technologies, whether large or small scale, with an interest in understanding salient aspects of the design of the built environment and the way that they are used by inhabitants of the city. In this section, therefore, the overriding question is whether AR can be placed within the wider context of the debate concerning augmented space. Is AR destined to become yet another layer to add to an already complex set of technologies and systems that persistently confront inhabitants of the city? This style of approach has already been applied to forms of augmented space through the application of Space Syntax as methodology. "Space Syntax analyses cities as systems of space created by physical artefacts of architecture and urban design" (Fatah et al.2008, p. 4). The tendency in this research is to focus on specific spatial characteristics of a given location and how those digital flows impact upon the space and forms of interaction. This is precisely the methodology to be used in order to understand the use of AR in urban space.

This focus on space and the deployment of pervasive systems into spaces in the city has emphasised a very important relation and this is proximity and the spatial relations that are established between devices and, therefore, between users of the technology, as well as other objects that might be present within the environment that can be detected digitally. "Knowing people's 'Bluetooth trails' can help us identify the direction of the movement of a particular device". Giving rise to a potential understanding of, so called "digital attractors" (Fatah et al. 2008, p. 11).

Proxemic relation as indicated in the above can be reflected in a representational and semiotic context in the sense that the closer that an element is in spatial terms to another, say if this were to people in proximity both holding devices, the likelier they are to be seen as in a relation. They are connected in some way purely by their proximity to one another. It is here that the spatial properties of both the medium but also the surroundings within which consumption or reception takes place and both are bound up with forms of social action. This notion of proxemics, first developed by Hall (1966) and later applied to social semiotics and the multimodal properties of texts, Hodge and Kress (1988) and has found more recent articulation in the analysis of urban space, O'Toole (2004), Alias (2004) and our own work. The application of proxemics and proxemic coding might prove to be fruitful to the integration of augmented reality to urban space in the sense that there are social meanings, perceptions and consequences that are generated or triggered by proximity. Indeed, when applied to some of the spatial and interactive issues associated with *Pokemon Go* it is noteworthy that it is proximity and the need for additional proximity detection devices that has become a potential, if temporary, solution. Furthermore, the focus on proximity, is on the proximity of one device to another, or the implicit proxemic relations that arise from this. Here again, the emphasis is on the embodied characteristics of AR and augmented space in more general.

3.2 Margins of the Body: Augmented Space and Embodiment

The site specific nature of augmented space gives rise to another important characteristic and this is the phenomenon of embodiment (Hansen 2004; Massumi 2002; Allen 2012). It is also a key characteristic that can be applied directly to the understanding of augmented reality. The body itself acts as an interface between the human sensory system and any digital or virtual objects that might be projected into the space inhabited by the user (Fatah 2016).

Emphasising the embodied characteristics of augmented space and augmented reality would, in addition to proxemic relations, seem central to developing an understanding of participation and engagement, or to be more specific about this, there is a pressing need for the development of a theory that has affective reactions—how the body feels or is moved—that are implicit in the relation of the body to its surroundings. Such an approach would have the fascinating consequence of attaching the body to its surroundings, where the deployment of augmented reality can been see to "expand the body's margin of indetermination" (Hansen 2004, p. 7). This style of argument has it that the body is at the very centre of interaction, as the "centre of indetermination" (ibid.), the central component in engagement with its surroundings. In sensory or affective terms, the body's relation to the world around it is simultaneously extended and indistinct through forms of augmentation. Thus, technology and, in particular systems such as augmented reality can be seen to be critical tools that can extend the margin between the body and the world (Kirsh 2013). It is important, therefore, to establish the "framing function" (Hansen 2004, pp. 84–87) of the body introduced above, as a characteristic of augmented space, whereby the position and location of the body in space is fundamental to our understanding of the medium and the technology used to deliver virtual objects into real spaces.

The body is always located in real space-time. This is the case even when the body is engaging with content, virtual objects that are generated from outside of the physical location or projected into it. The body in many discourses, modes of representation, and especially those generated across visual, spatial and tactile modalities, is already and always going to be the ultimate frame for information. This property has another important consequence, it “leads to considering how only a blurred distinction seems to exist between space and information, as elements of space increasingly are powerful conveyors of information—materialized into them —becomes more spatially related” (Aurigi 2008, p. 5). To put this into a more phenomenological context, there is a blurred distinction between the body and the world, and, as in Mark Hansen’s terms, we increasingly see “technology as a means of expanding the body’s “margin of indetermination” (Hansen 2004, p. 10). Furthermore, that proximity, in the way that it was presented earlier as a distinct issue within augmented space, we see the relation of closeness and distance (Hodge and Kress 1988) and its corollary, occur as central to the experience of augmented pace and in a way that emphasise the affective relations between participants and the media or virtual objects that they interact with. Therefore, one of the most critical questions to come out of this brief discussion of embodiment rests on where to locate the body within augmented space. The body itself acts as an interface both on a sensory level in terms of its reception of information from the environment and in terms of how it receives information from devices and displays in an urban environment. Featherstone stresses the “importance of the body as a framer of information and this has become more urgent with digitized media” (Featherstone 2006, p. 2). In fact, the argument seem to have become even more urgent with the deployment of aspects of augmented reality and its use within real open and urban spaces. The framing function of the body, therefore, is key to a more general understanding of human engagement with a whole range of types of new media and is implicit is the case studies that follow.

4 Two Case Studies: A Descriptive Account

This section provides a descriptive account of two interventions into urban space using aspects of AR and conforming very much into our general understanding of augmented space. Both of the case studies are arenas where both practical strategies The Leytonstone Arts Trail was created as part of a collaboration between The Bartlett, UCL and Holition Ltd entitled “Augmented Urban Reality”. It exemplifies many of the characteristics that have been discussed so far in this chapter. First, the trail is an attempt to use augmented reality as part of an integrated set of screen based activities engaged in participants of an arts trail. One important feature is the use of tablets that superimpose an avatar into the space, guide participants through the streets and assist in the finding of objects and other screen based activities that are an integral part of the trail.

One striking feature of this application is the amount of mobility that it affords participants. Positioning of participants has been successful as has the mapping of GPS data to handheld tablets and to virtual objects on screen, the avatar in particular. As such this experience is very much a location based affair and to this effect it most definitely conforms to the characteristics of "site-specificity" as set out the previous section. In addition, in the terms that there are a variety of ways that an experience such as this can be explained using concepts of "embodiment" and framing, not least in terms of the mobility of the body within urban space and the relation set up between the body of the participant, and the virtual actions and reactions of the avatar. Entry points, for example, are a key aspect of the framing of the experience and the proxemic relations that occur as a consequence of this. These case studies are also situations where empirical strategies and specific research agenda can themselves be tested. We ask, to what extent, in the examples that follow, are these interventions located and therefore, site specific. In addition, we need to establish the extent to which the experiences of these space and the interaction with technology and the virtual, are embodied. As argued in the previous section, how are the spatial properties and proxemic relations being managed, whether socially and forms of cultural convention, or through the use of locative technologies such as Bluetooth, GPS or other proprietary technology. A further, leading question is related to how active participation to author AR experiences can be facilitated and to what extent is public led co-creation of AR content used to support agency and thus promote authentic forms of engagement?

4.1 Augmented Urban Reality: The Leytonstone Arts Trail

In the AR View one has the choice to enable or disable a 2D map overlay, registered to the 'real' visualized world. The AR view uses a walking 3D digital character or avatar to guide the user in the exact direction of the selected venue, following the pre-planned route. The avatar responds to the body' movements, altering its pose, speed and animation based on the user's movement and proximity to the destination. The aim is to create new spatial and social narratives and engage people with invisible aspects of their environment through the animated character's movement and behaviour (Fig. 1).

During the Leytonstone Arts Trail more than 130 people downloaded the app and used it as a medium to access more content from the event. During 4 days the researchers engaged with passers-by, introduced the project, and helped them installing the app to their devices. Twenty eight questionnaires were gathered from people that were using the app who gave feedback about the different features, such as the User Interface, the AR navigation and sharing pictures with a Live Gallery. A key element here is the potential for people to share aspects of their experience through the live gallery online which also is on display on a situated urban screen on the Leytonstone High Street and to generate their own narratives associated with the experience.

Fig. 1 Augmented urban space: the leytonstone arts trail, london

Based on feedback received from participants we identified the following aspects:

- *Movement and the urban scale*: The speed of the digital character influences the user experience and its rhythm. Some users adapted their pace to match that of the digital character. Varying speed could in future be explored, such that the digital character moves and adapts smoothly to the user. Although the digital character is aligned and integrated in the real environment, digital cues could be introduced on the AR view to give a more realistic idea about the exact scale of the digital character and the real distance between both the digital one and the user.
- *Hybrid space*: As the digital character moves through an urban space it can trigger things of the digital world that are invisible on the real world. Here, it works as a link between the physical and the digital world, and is constantly calling the user's attention to relevant things and information in the environment.
- *Multimodal interactions*: Some users said it would be interesting to have different animations, audio cues or immediately changing to different modes of display. With regards to the mobile devices used, some tablet users said that they would prefer a lighter, more discreet and portable device like a mobile phone instead of a heavy and attractive tablet, in particular because of handling and safety issues.

- *Awareness of the actual environment*: This seems to be a very important aspect. Possible risk might not be noticed, such as when crossing a road. The digital character could give a warning or a hint on the screen when getting closer to cross the road.

One key element of this experience is the orientation: contrary to the conventional 2D maps, where a user might feel lost if he or she doesn't know the area or has difficulty orienting, the immersive 3D mediated experience supports natural navigation "it shows me buildings around me… it takes me into a place where I'm very oriented"; "it was a brand new way of navigation to me… there was a restaurant, and without the app I would never thought of entering".

Three crucial moments of interaction were identified during the navigation experience. The first moment is related with initial interaction and engagement with the experience, the point where the user might not know that a digital character will guide him or her. The second moment is during the entire route and the third moment is when the user reaches the destination. In addition, there are important issues around when the user engages with the avatar, further ways of engaging with the avatar could be explored, especially during the first moments of engagement because there are times when users started their navigation of the route but were looking in the opposite direction. Entry points are a key element of this and have been explored elsewhere in relation to static 2D interaction but could easily be applied to real-world 3D interactions. When reorientation of the device is required, there needs to be some system for making the user aware of this at these critical moments and entry points. During the second moment, adding further personalised features to the interaction especially to the avatar, where they might be spoken to directly with personalised data, thus drawing the user's attention to information about the surrounding area and relevant places to visit. Some participants expressed a desire to customise the avatar. The last moments of the trail could be explored with a different animation of the avatar, adding audio or changing to a different mode of display. In addition, many participants expressed a desire to still be able to refer to a 2D map as part of the display and providing an unrestricted view of the surrounding area and much in that same way as with the traditional printed map that was a central part of previous ways of presenting the Arts Trail to participants.

In summary, the approach to AR offered within the Leytonstone Arts Trail offered a digital platform that facilitates various urban encounters and ways that participants could engage with both virtual and real world content. This is part of ongoing work that addresses highlights participant's engagement and strategies for orienting participants to key parts of the experience of an Arts Trail. More generally, as part a longer term research strategy issues of navigation, wayfinding and facilitating meaningful connections between participants and the built environment and how this can be enriched with digitally augmented spatial and social narratives. The argument at this point is that there are many opportunities available, such as the one described in the case study above, whereby AR and augmented space can intensify a participant's sense of place.

4.2 Cycling Go!

Cycling Go! combines playing a computer game with riding a bike. If an analogy were needed, imagine Super Mario Kart meets Strava meets Pokémon Go! It may sounds engaging, but perhaps a little dangerous? The point, however, is the opposite, this game is proposed as a means to make cycling safer *and* to support local sustainable travel initiatives. The spatial, pleasurable sensation you get when riding a bike, even at a moderate, non-risky pace, is already more immersive than playing a sit-down screen-based game, simply because it's *real* and it is embodied. In addition, the intention to augment cycling in this manner would, in our view, take social gaming to an entirely new level, and would certainly take the current gaming environments indicated by the like of *Ingress* and *Pokemon Go* to another level in terms of both user engagement and participation in the outdoors. This is aside from any additional benefit gained from other social and cultural benefits associated from cycling and the development of alternative transport infrastructures.

Cycling Go! (see Fig. 2) specifically aims to increase the take-up of cycling (as an alternative to car travel for distances under five miles) but with a strategic initial

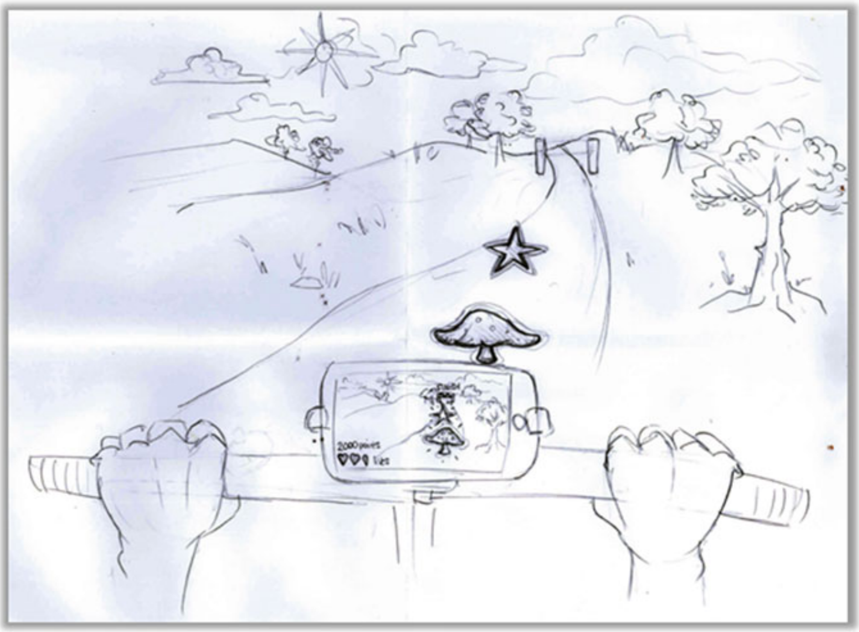


Fig. 2 Initial concept sketch showing objects that can be 'collected' by the cyclists on off-road route sections. (Drawing courtesy of Tom Martyn)

focus on usage of key routes, already built at great expense and in the face of challenging circumstances. These routes have been designated by cycling groups, travel planners, Sustrans and the project's' supporters, CityConnect as key to the Bradford District's 2016–2020 cycling strategy.

A game framework is currently in the planning stages, whereby, content and user administration structures are being created that allows multiple routes, stories and levels (in any city) to be added by others without a high level of technical knowledge. Behind this are two fully working story missions, aimed at key target groups for the take-up of cycling with institutional support from local cycling campaigns groups and the local authority and university (University of Bradford and Bradford Metropolitan District Council) providing a base for user engagement (staff, students and local inhabitants) in addition to the development of targeted research initiatives and infrastructure projects. In this sense design and innovation is quite straightforward as, in the first instance, it 'piggybacks' on both the hype and the more substantive potentials from AR and gamification, such as *Pokemon Go!* As well as the use of fitness and mapping apps and combines these in order to develop strategies for engagement and the encouragement cycling within urban space.

The major strength of this style approach and the motivation for integrating aspects of AR into this form of engagement with urban space, through the creation of a cycling app, is not just about the testing and further development of the core technology, the real strength of this and associated project lies in its ability to engage with its target audience in meaningful ways. *Pokemon Go!* Could in fact be played on a bike but this was certainly not what the designers had in mind when creating it. Indeed, it actually ceases to function once the rider goes beyond a certain speed (because the current system determines that you are a car) and trying to catch a Pokemon, using two fingers to interact with the screen and aim whilst cycling is frankly very dangerous.

Features of the game in the current prototyping phase are as follows: Adventure story introduction and mission objectives built into journey; Collect virtual items for points (e.g. stars and mushrooms); Position checkpoints on the route (gain points for passing regularly); Upload/add media features for players; Share achievements and play via Facebook and Twitter leaderboards; Team play: compete against another workplace, school, class or group; Unlock cultural interest/engagement points (and visit stops); Safety bonus points and messages; Ghost mode—compete with follow a fellow cyclist or 'cycle ghost' (previous cyclist who has used the route); Link to Strava routes; Report route issues pot-holes and obstacles to local authority; Allow tracking of cyclists by app administrators; Open source add-level functionality available via GitHub and others; Cycling "Treeple" (special game story characters) to interact with enroute (Fig. 3).

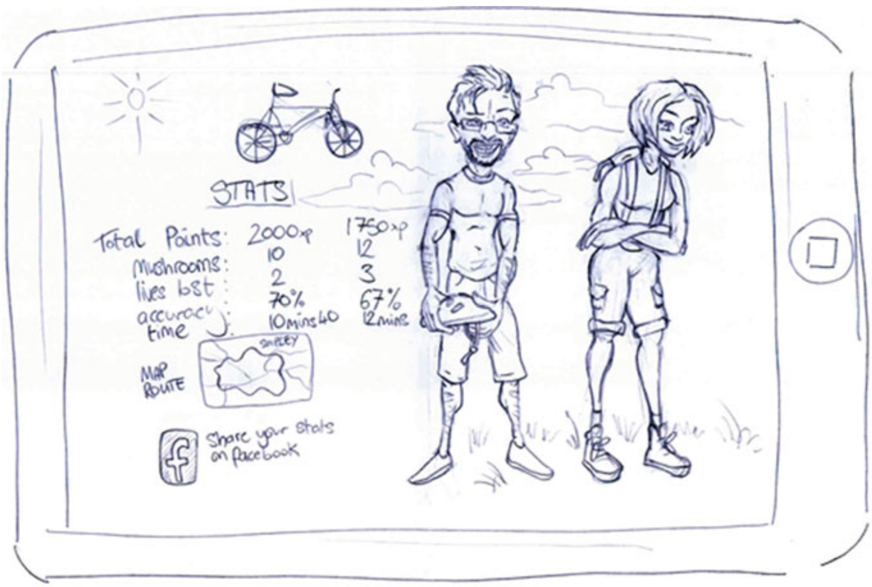


Fig. 3 Early concept sketch of ‘Treeple’ game characters and stats. (Drawing courtesy of Tom Martyn)

5 Conclusion

There are both technical and social aspects to both of the characteristics of augmented space as discussed earlier and both have been highlighted in the descriptive account given in the case studies. In terms of methodology, a mixed, transdisciplinary approach is critical to developing an understanding both the transformative and disruptive potential of these spaces. Such spaces are ultimately, forms of “multimodal text” (Allen 2008) and the multifaceted nature of these spaces needs to be taken into account at the outset, not just in terms of their potential to accommodate for, or become platforms for the delivery multimodal content, but much more than this. The spaces themselves, as stated, are forms of multimodal text that integrates and combine multimodal properties in and of themselves. This is evidenced, for example, in the need to understand the proxemic relations that occur as a consequence of the application of AR into real public space. Proximity and the spatial as well as social meanings that arise from this most basic characteristic of augmented space is a multimodal principle *par excellence*. These characteristics, therefore, require a transdisciplinary approach to research from the outset and an approach that prioritises space and its use.

Both case studies have also exemplified important aspects of AR and its impact on the experience of real public space. As a consequence of these initial investigations we continue to advocate a perspective that integrates AR into a wider set of consideration and as part of a more general approach to urban and architectural spaces that have a range of media technologies superimposed onto them (Julier et al. 2016; Fatah et al. 2010). What, for some years now, we have labelled "augmented space". In addition, prioritising the spatial aspects of the design of augmented space has yielded some useful insights into how we are to conceptualise these spaces and not least the need to drive our understanding and the research that informs this by asking the extent to which such spaces are both site-specific and embodied. To put this another way, an understanding of the variable nature of the space in which augmentation occurs is critical. So too is how the body both relates to the space around it as well as how embodiment, as a set of theoretical concerns, can and should, be used to explain important aspect of interaction and engagement. In addition, and this is most striking, there is an important quality in both AR and augmented space where there is the potential to provide an enhanced a sense of place and this can be achieved by bringing participants to a greater attachment to location rather than dissociating participants from their surroundings as is so often assumed.

Further work in this regard is planned using many of the principles set out in this chapter and, at the time of writing, projects with both regional and global organisations in the museum sector, namely The Bronte Parsonage Museum, West Yorkshire and Regency House Museum, Brighton, are being scoped out as part of more general strategies for audience development and public engagement in the tourism and leisure sectors. We have argued that there is a pressing need to go beyond the use of tools most commonly associated with Human Computer Interaction in investigating the use of AR systems in public space. Indeed, some of the methodological distinctions made in this chapter are specifically intended to do this. For example, how can active participation to author AR experiences be facilitated and to what extent is public led co-creation of AR content used to support agency and thus promote authentic forms of engagement? This is where our work will lead us. That is, to a more nuanced and deeper understanding of human engagement with AR systems and augmented space in more general.

References

Alias (2004). "A semiotic study of Singapore's Orchard Road and Marriot Hotel", in O'Halleran (ed.), *Multimodal discourse analysis.* Continuum.

Allen, P. (2008). "Framing, Navigation and the Body in Augmented Public Spaces", Aurigi (ed.), *Augmented urban spaces.* Ashgate Press: London.

Allen, P. (2009). "Place and Locality in Augmented Public Space": A case study on the site-specific nature of urban screens, *Proceedings of the IEEE*, Cyberworlds 20, E09.

Allen, P. (2012). *"Framing the Media Architectural Body". Proceedings of the ACM*. Media Architecture Biennale: Aarhus.

Aurigi, A. (Ed.). (2008). *Augmented Urban Spaces*. London: Ashgate Press.

Azuma, R. (1997). "A Survey of Augmented Reality", *Presence: Teleoperators and virtual environments, 6*(4), 355–385.

Fatah, A. (2009). "Towards an Integrated Architectural Media Space: The Urban Screen as a Socialising Platform", In S. McQuire, M. Martin, and S. Niederer. (eds.), *Urban screens reader*, Institute of Network Cultures: Amsterdam.

Fatah, A Penn, A and O'Neill, E (2008). "Mapping, sensing and visualising the digital co-presence in the public arena" In Timmermans, H and de, VB, (eds.), *Design & decision support systems in architecture and urban planning.* (pp. 38–58). TU/e: Leende.

Fatah gen. Schieck, A. (2016). Living architecture: Currencies between architectural project pedagogy and Time-based media performance. *aae 2016 Research Based Education.* Bartlett School of Architecture.

Fatah gen. Schieck, A, O'Neill, E and Kataras, P (2010). "Exploring Embodied Mediated Performative Interactions in Urban Space", *UbiComp'10,* September pp. 26–29, 2010, Copenhagen, Denmark. ACM 978–1-60558-843-8/10/09.

Featherstone, M. (2006). Body Image/Body without image, *Theory, Culture and Society*, number 23, SAGE.

Gartner (2016). 3 Trends appear in the gartner hype cycle of emerging technologies, 2016. http://www.gartner.com/smarterwithgartner/3-trends-appear-in-the-gartner-hype-cycle-for-emerging-technologies-2016/. Accessed 20. March 2017.

Hall, E. (1966). *The hidden dimension*. US: Random House.

Hansen, M (2004). *New Philosophy for New Media*, MIT Press.

Hodge, R., & Kress, G. (1988). *Social Semiotics*. Cambridge: Polity.

Humphery-Jenner, M. (2016). "What went wrong with Pokemon Go? Three lessons from plummeting numbers". https://theconversation.com/what-went-wrong-with-pokemon-go-three-lessons-from-its-plummeting-player-numbers-67135. Accessed 18. Oct. 2016.

Julier, S., Fatah gen. Schieck, A., Blume, P., Moutinho, A., Koutsolampros, P., Javornik, A., Kostopoulou, E. (2016). *VisAge: Augmented reality for heritage*. PerDis 2015, Oulu, Finland.

Kirsh, D. (2013). Embodied cognition and the magical future of interaction design. ACM Trans. Computer-Human Interaction 20 (1)

Massumi, B. (2002). *Parables of the virtual*. Durham and London: Duke University Press.

Kwon, M. (2002). *One place after another: Site-specific art and locational identity*, MIT Press.

Manovich, L. (2006). The poetics of augmented space. *Visual Communication Journal, SAGE, 5* (2), 219–240.

McCarthy, A. (2003). *Ambient television: Visual culture and public space*. Durham and London: Duke University Press.

O'Toole, M (2004). "Opera Ludentes: The Sydney Opera House at work and play" In O'Halleran (eds.), *Multimodal discourse analysis.* Continuum.

Robison, D. (2012). "Learning on Location with Ami: The Potentials and Dangers of Mobile Gaming for Language Learning", In *Left to my own devices: Learner autonomy and mobile-assisted language learning* (pp 67–88). BRILL.

Rogers, Y. (2011). Interaction design gone wild: Striving for Wild Theory. *Interactions, 18*(4), 58–62.

Tassi, P. (2016). "What Mystery 'Pokémon GO' Device Is Nintendo Making Now?", https://www.forbes.com/sites/insertcoin/2017/02/03/what-mystery-pokemon-go-device-is-nintendo-making-now/#4840872a15ea. Accessed 03. Febr. 2017.

The Hollywood Reporter (2016). http://www.hollywoodreporter.com/lists/pokemon-go-guide-game-tips-real-life-hazards-910304/item/players-lured-by-armed-robbers-910332. Accessed 07. Dec. 2016.

Part IV
Augmented and Virtual Reality in Healthcare and Defence

Blending the Best of the Real with the Best of the Virtual: Mixed Reality Case Studies in Healthcare and Defence

Robert J. Stone

Abstract The resurgence of interest in the fields of Virtual, Augmented and, more recently, *Mixed Reality* (VR, AR and MxR) is—as was first witnessed in the 1990s—demonstrating the challenges and pitfalls facing interactive systems developers and adopters when confronted with a myriad of potential "high-tech" solutions from an increasingly saturated product marketplace. Adding to the confusion is the increase in appearance of regular online news features and commentaries claiming, for example, that AR is, or will be "superior" in some way to VR (and vice versa), or that MxR will outperform both. Yet, despite this confused state of affairs, there has, over the past two to three decades, been a growing body of evidence confirming that the disciplines of Human Factors (HF) or Human-Centred Design have an indispensable role to play in the choice and subsequent exploitation of these technologies for a wide range of real-world applications. This paper sets out to emphasise the importance of adopting HF techniques and knowledge when developing VR, AR and MxR, and presents a number of relevant MxR case studies in defence and healthcare to support the key premises presented.

Keywords Mixed reality · Defence · Healthcare · Simulation-Based training · Human factors

1 Introduction

It cannot have gone unnoticed that, over the past five years or so, there has been a significant flurry of activity across the globe relating to the "re-birth" of Virtual Reality (VR). At defence, aerospace, automotive and creative media conferences and exhibitions, and on technology-focused Internet sites, the future of human-computer interaction, it is claimed by many, will be driven by the availability and affordability

R.J. Stone (✉)
Department of Electronic, Electrical & Systems Engineering,
University of Birmingham, Birmingham, UK
e-mail: r.j.stone@bham.ac.uk

T. Jung and M.C. tom Dieck (eds.), *Augmented Reality and Virtual Reality*,
Progress in IS, DOI 10.1007/978-3-319-64027-3_19

of sophisticated, (often outlandish) wearable devices and advanced human interface technologies, all allegedly capable of “immersing” end users—be they gamers or developers of “serious” industrial applications—into believable computer-generated synthetic environments.

Whilst the hype and unsubstantiated claims of vendors of VR technologies need to be treated with considerable caution, it is important to realise that there have been many world-wide initiatives that have demonstrated the potential of VR, either as a credible technology in its own right, or as part of a *blended* solution with other forms of media, to deliver affordable training and visualisation solutions to many end user groups and organisations. In the domain of defence training, for example, projects undertaken during the UK’s Human Factors Integration Defence Technology Centre (HFI DTC) programme (2003–2012; Barrett et al. 2006) delivered many important concept capability demonstrators based on commercial off-the-shelf (COTS) VR hardware and software technologies. These demonstrators included submarine spatial awareness training (*SubSafe*; e.g. Stone et al. 2009), pre-deployment counter-improvised explosive device awareness (Stone 2012), subsea mine countermeasures detection and reporting (Stone et al. 2016) and a remote driving and manipulation skills trainer for the UK’s *CUTLASS* bomb disposal system (Fig. 1; Stone 2012).

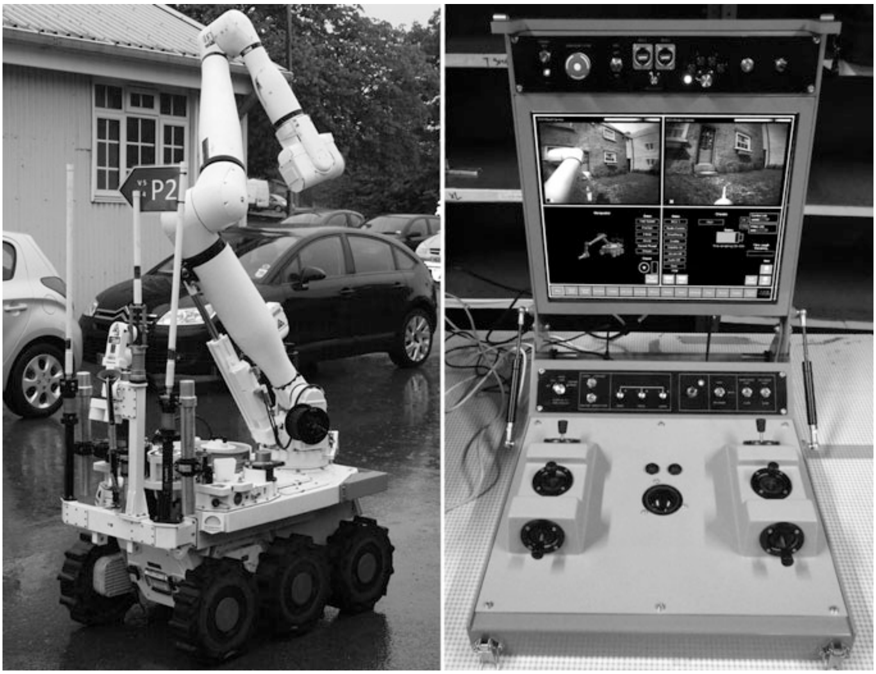


Fig. 1 CUTLASS Bomb disposal system (*left*) and remote skills training simulator (*right*)

The VR projects undertaken during the HFI DTC programme also demonstrated that, despite the many claims and examples of "immediately available" innovative training systems one sees at defence exhibitions and in Internet postings, any novel training solution should always be subjected to a rigorous Human Factors (HF) or Human-Centred Design (HCD) treatment during the system development process (e.g. ISO 2010), including a strong stakeholder engagement (particularly during early periods of training observation and briefings and, later, in the evaluation of prototype test beds).

1.1 From VR to AR and MxR

Despite its prominent historical role in the ever-expanding timeline of interactive technologies, VR is not, of course, the only (predominantly but not exclusively) visual computing technique to experience extensive global interest of late. Augmented Reality has many parallels with its VR counterpart (especially in terms of the display and data input hardware exploited during real-time interaction, and the sources of data used to generate the virtual content). However, unlike VR, AR scenes are typically presented in the form of virtual objects and behaviours (and, indeed, other forms of media, including video) that attempt to augment the real-world scene and provide additional information to the end user. AR relies on dedicated software tools and location recognition techniques in order to register virtual objects accurately with the real-world views, and there are a number of techniques for achieving this (including the use of fiducial markers, computer vision and methods based on user location detection via Global Positioning Systems GPS).

Another variation on the theme of VR, and one that is, at the time of writing, attracting a strong and growing international following, is *Mixed Reality* (or MxR). MxR is a form of AR, but, rather than superimposing computer-generated material onto real-time images of the world, MxR attempts to exploit the existence of real-world objects in order to enhance the believability, and indeed usability, of those computer-generated or virtual elements, which are typically "projected" onto (sometimes described as "anchored to") specific objects using AR-like techniques. MxR anchor objects can be as advanced as deactivated items of equipment or machinery, even complete rooms or temporarily-erected enclosures. Alternatively, they can be as basic as boxes, wall- and ceiling-mounted frames, or tables. The table-centric set-up shown in Fig. 2, for instance, depicts an MxR concept for a system supervision and surveillance station for the *Mayflower Autonomous Ship* project, scheduled to undertake a transatlantic crossing in 2020 as part of the 400-year anniversary of the original *Mayflower* sailing in 1620 (http://www.telegraph.co.uk/science/2016/12/28/mayflower-set-sail-400-years-pilgrim-fathers-landed-america/ [03 January 2017]). On an even smaller scale, familiar objects, from inert interactive devices (mice, keyboards, steering wheels, etc.) to 3D-printed "tangible" shapes—controls, wands, simple cylinders and cuboids—can be used to enhance real-time user interaction in an MxR environment. One very important

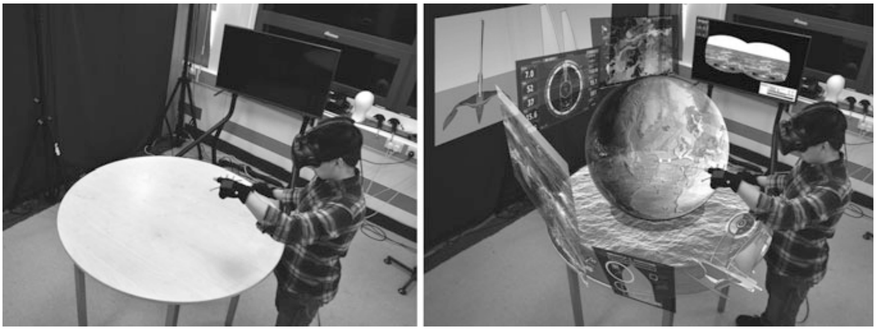


Fig. 2 MxR Command table concept for the *Mayflower Autonomous Ship*

feature of MxR environments is that, by virtue of their exploitation of physical objects in the real world, they can help overcome technological limitations by providing of credible haptic feedback experiences for VR and AR users.

As is the case with AR, an effective MxR environment requires careful consideration and implementation of the method by which the location and orientation of the end user's body, head and hands, not to mention the real-world objects with which s/he is interacting, are spatially registered and tracked in real time. Also, as the success of an MxR implementation depends upon providing an intuitive degree of freedom of movement for the end user—from whole-body postural changes to head and arm movements crucial for detailed scene interpretation and interaction—the use of wearable technologies, especially head-mounted displays (HMDs), becomes an important consideration. However, as is the case for both VR and AR, the use of such wearable technologies must be considered carefully, from both a technical and HF perspective, paying attention to the inevitable compromises to interaction they impose and the health and safety implications that typically accompany them.

2 The Importance of Human-Centred Design

The success of projects involving the exploitation of novel interactive technologies, especially in the rapidly evolving domains of VR, AR and MxR, depends upon a wide range of factors, not least important of which is the need for close participatory involvement on the part of stakeholders and end users, and a strong underpinning HCD theme, ensuring that the hardware and software technologies selected deliver usable and meaningful training experiences. In particular, for all projects in the interactive technology domain, the author and his team follow the guidelines laid down in International Standard ISO 9241, Ergonomics of Human-System Interaction, in particular Part 210: *Human-Centred Design for Interactive Systems* (ISO 2010). Whilst not specifically written for the VR/AR/MxR domain, Part 210 presents a range of guiding principles, each of which has relevance to the development of interactive technology projects. They include the importance of gaining an early understanding of end users' tasks and their contexts of use, for example via observations and briefings, and the involvement of all "stakeholders" in regular technology evaluations, throughout the entire lifecycle of the system under development.

Experience has also shown that early engagement with all stakeholders in a wide range of simulation-based training applications is an essential component of the system design and interactive technology selection process. Observation of the interplay between trainees, instructors and their place of training is crucial to the definition of appropriate levels of *fidelity* within the simulation, which are then used to describe the extent to which a VR, AR or MxR simulation represents the real world, including natural and man-made environments, systems and, increasingly, the inclusion of participants or *agents*. There are two important variations on the theme of fidelity. *Physical* fidelity (or "engineering fidelity", after Miller (1954)) relates to how virtual environments and their component objects, including interface hardware elements, mimic the appearance and operation of their real-world counterparts (Stone 2012). In contrast, *psychological* fidelity is the degree to which simulated tasks reproduce behaviours that are required for the actual, real-world target application. Psychological fidelity has also been more closely associated with positive transfer of training than physical fidelity and relates to how skills and/or knowledge acquired during the use of the simulation—attention, reaction times, decision-making, memory, multi-tasking capabilities—manifest themselves in real-world or real operational settings.

3 Mixed Reality Case Studies

There now follows a small selection of early and recent projects from the domains of healthcare and defence, each resulting in an MxR implementation following the undertaking of early HF observations and related HCD activities.

3.1 Early Mixed Reality Examples I—Surgical Skills Training

One of the earliest examples of an MxR solution for training, MIST_{VR}, evolved from a project sponsored in 1994 by the UK's Wolfson Foundation and Department of Health. The overarching aim of this research was to assess the potential of emerging VR technologies to deliver cost-effective training for future surgeons. In collaboration with clinical subject matter experts, a series of observational HF analyses were undertaken during surgical procedures, each of which were used to isolate eight key task sequences common to a wide range of laparoscopic

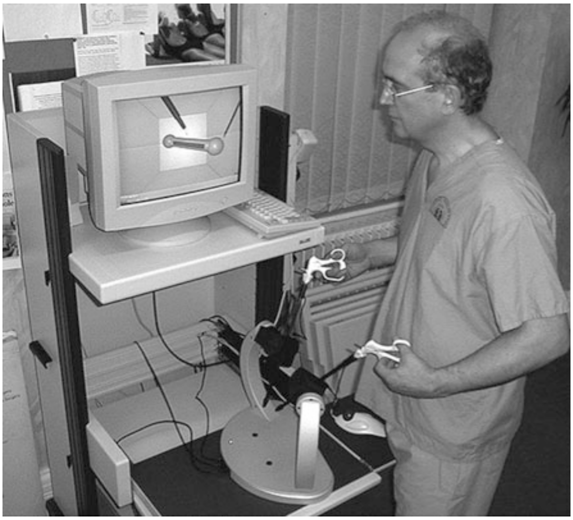


Fig. 3 $MIST_{VR}$ surgical trainer

cholecystectomy (gall bladder removal) and gynaecological interventions (Stone 2011, 2016). The analyses also helped to define how those sequences would be modified or constrained by such factors as the type of instrument used, the need for object or tissue transfer between instruments, the need for extra surgical assistance, and so on. As a result of these early analyses, it was decided that $MIST_{VR}$'s virtual content should be designed to foster—and objectively assess—laparoscopic skills. This, it was further concluded, would be achieved *not* by training on realistic human body representations (with which the trainee was already familiar, not to mention the fact that such high-fidelity simulations were unachievable given the technology of that time), but on carefully selected task 'primitives', abstracted from the theatre observations (including simple spheres, blocks, cylinders and wireframe task volumes of low 'physical' fidelity). In addition, and moving more into the realm of Mixed Reality (MxR), it was recommended that interaction with the abstracted visual elements of $MIST_{VR}$ should be achieved using a physical, electronically-tracked laparoscopic instrument module, as shown in Fig. 3.

3.2 Early Mixed Reality Examples II—Military Part-Task Training

Two further studies that are directly relevant to the earlier summary of fidelity in VR, AR and MxR systems design, and to the importance of exploiting HF knowledge and techniques, concern the development of the first Royal Navy Close-Range Weapons Simulators installed at the land training base of HMS Collingwood (Stone and Rees 2002; Stone 2012, Case Study 6) and the Helicopter

Voice Marshalling (HVM) Simulators, installed at RAF Shawbury and Valley (Stone and McDonagh 2002; Stone 2012, Case Study 21).

The Close-Range Weapons Simulators (CRWS) project provides a good example of how real equipment—in this case deactivated weapons removed from the original shore-based training establishment of HMS Cambridge—were used to augment the VR experience. Observations of training procedures at HMS Cambridge drove the choice of a head-tracked HMD-based solution for the VR system, based on the interactions of gunners with their weapons and other ship-board personnel. However, the techniques by which the weapons were physically moved during operation dictated that an MxR training solution was essential. To operate the 20 mm cannon, the gunner is strapped into the shoulder rests and uses his full body weight in order to move the weapon in azimuth and elevation. For the 30 mm cannon, the gunner sits within a small open cabin and operates the azimuth, elevation and firing functions of the weapon via a small control panel. These features also drove the choice of a partially face-enclosing HMD, the Kaiser XL-50, which, at the time, afforded a degree of unobscured real-world peripheral vision to the wearer (Fig. 4, left image).

The RAF HVM simulators were originally designed to train *Griffin* (Bell 412) helicopter aircrew to monitor safety- and mission-critical aspects of the external environment through an open rear cabin door, verbally relaying important flight commands and situational awareness information to the pilot in order to guarantee an accurate and safe approach of the aircraft to a landing site or target object. As with the CRWS systems described above, early HF observations of the HVM Aircrew during flight operations suggested that an MxR solution was essential, combining the presentation of virtual images representing a variety of training scenarios using a partially face-enclosing HMD (as with the CRWS solution) together with a simple wooden framework, the dimensions of which were based on the rear door area of the *Griffin* Helicopter (Fig. 4, right image pair). Furthermore, the wooden frame also supported the accurate positioning of safety handholds

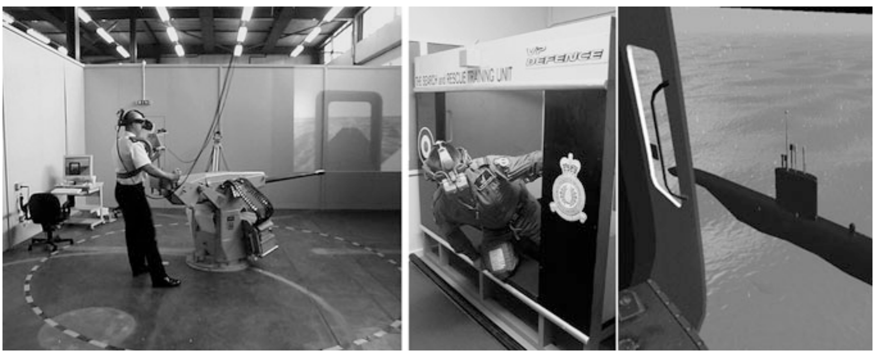


Fig. 4 Royal Navy weapons trainer (*left*) and RAF voice marshalling simulator (*right*)

above and either side of the door, as found in the real aircraft, together with a mounting block for the purposes of attaching a standard issue RAF safety harness.

3.3 Current Mixed Reality Example I—Advanced Human Interfaces for Military Command & Control

A paper by Knight and Stone (2014) reviewed a wide range of MxR concepts proposed between 2000 and 2013 for future military command and control environments. These concepts included fixed-location facilities consisting of large group displays, interactive surfaces or "tabletops", advanced workstations based on "digital desks" and a variety of wearable 3D displays. The review also presented findings from HF studies of future interaction modalities, including motion tracking, gesture recognition, gaze control and tangible interfaces, all of which have the potential to support the manipulation of digital content in an MxR system. The authors further concluded that, whilst the technologies reviewed supported enhanced situational awareness through improved access and presentation of information, as well as better control of digital content through intuitive interaction, more research was required to generate relevant and appropriate HF guidelines for their application so that they could be implemented successfully in an MxR command and control environment.

An opportunity to demonstrate the power of MxR in "blending the real with the virtual" came about as the result of a BAE Systems-sponsored concept demonstrator, developed to evaluate advanced human interaction techniques in future military command and control. This demonstrator is based around a central "command table", as illustrated earlier in the *Mayflower Autonomous Ship* concept (Fig. 2), with the user's location, body motion and gestural inputs being tracked using a 12-camera OptiTrack motion capture system. The captured data dictate the location and real-time update of simulated volumetric scenarios covering the surface of the otherwise empty circular table, together with "free-floating" display panels containing additional textual, symbolic, graphical and video information (Fig. 5; Stone 2016).

In Fig. 5, the user views the real world, 3D scene and floating panels via an Oculus Rift DK2 HMD, modified with a Ximea xiQ USB Camera (1280 × 1024 CMOS sensor) to provide an AR solution. The user can translate, rotate and zoom into/out of the command table scenario in real time using "sweeping" gestures and can also select and direct any of a range of land, air and sea assets using "drag"-like gestures (similar to those used with Smartphones and tablets).

One example of a simulated volumetric scenario developed for the early evaluation of the MxR concept is based on an aerial 3D representation of a peaceful protest being staged outside a fictional mansion house hosting a "G8 Summit". The scenario is animated such that, following the departure of a splinter group from the immediate protest area, the situation develops into an insurgent attack. As the attack

Fig. 5 MxR command and control interactive table prototype

Fig. 6 MxR command and control city attack scenario

develops, information is presented to the end user via both the volumetric display (e.g. depicting the availability and location of manned and unmanned ground and aerial assets), and a number of free-floating display panels, some of which relay images from ground-based cameras (police-worn, social media-sourced, robotic patrol systems, etc.). Another scenario is based on a small city (Fig. 6), this time presenting information relating to an insurgent vehicle attack and the predicted early environmental consequences of detonating the contents of the vehicle (canisters displayed in the form of a simulated point cloud scan as if from an advanced 3D "keyhole" sensor, mounted onboard a small Unmanned Air Vehicle (UAV)).

More recently, and as part of two UK Ministry of Defence research programmes—ASUR (Autonomous Systems Underpinning Research) and MarCE (Maritime Collaborative Enterprise), the command and control concept demonstrator has been extended to conduct further HF investigations. The focus of the ASUR project—a "Low Infrastructure, Low Cost, High Mobility Mixed Reality-enabled UAV

Ground Station"—relates to the design and evaluation of multi-UAV ground control hardware and features within an MxR environment. This project includes the development of novel methods of presenting and interacting with UAV ground control data, including the use of special-purpose, 3D printed "tangible" interface objects (e.g. Paelke et al. (2012a); Weiss et al. (2010); Zuckerman and Gal-Oz (2013)). One example of such a novel method involves the integration into larger-scale and less-detailed virtual terrain models of virtual site models and associated hostile assets, processed automatically from aerial video captured from small UAVs. In the future, such a process could be carried out in near-real time by "sacrificial drones", deployed from high-altitude platforms, with important data being collected before the drone is destroyed or loses power. The MarCE project has similar ambition, but focuses on the development of a "Maritime Air Defence Operations Room of the Future", within which a single Commanding Officer may be placed whilst in charge of fighting the air battle for an entire naval task group.

3.4 *Current Mixed Reality Example II—Medical Emergency Team Trainer*

During one demonstration of the MxR Command Table described above to a military audience, representatives from the Royal Centre for Defence Medicine (RCDM) suggested that such a facility could possibly used in the future to plan specific deployments for Medical Emergency Response Teams (MERTs). The MxR scenarios could, it was suggested, be of considerable use in improving the situational awareness (e.g. Norri-Sederholm et al. 2014) of those military and medical personnel deploying to an incident via helicopter, helping them (for instance) to understand in advance the topography and nature of the terrain—and potential threats—surrounding the landing site. During subsequent discussions, the potential for MxR techniques to deliver realistic forms of pre-deployment training for defence medics was put forward and it was suggested that a short concept capability demonstrator, similar in scope to the command table studies, be developed for evaluation. In the event, and following training observations undertaken at the Tactical Medical Wing (TMW) of RAF Brize Norton, the focus of the demonstrator changed from one emphasising pre-deployment situational awareness training to one reproducing the high-tempo in-flight experience of dealing with casualties brought onboard (pre-hospital emergency care).

The observational sessions were conducted using the TMW's ground trainer, in essence a fixed-base wooden replica of rear cargo/passenger cabin of the CH-47 *Chinook* helicopter (Fig. 7), with each training trial covering casualty recovery from the field to the helicopter, in-flight primary care, and casualty transfer to ground medical teams with hand-over briefings. Two sub-teams of trainee paramedics were involved in each 15–20 min session, and basic adult and child

Fig. 7 RAF Brize Norton's fixed-base *Chinook* MERT trainer

mannequins (Laerdal SimMan® "patient simulators") provided the focus for manual handling and medical procedures.

These observational sessions were extremely valuable. Space does not permit a detailed coverage of the HF outcomes of the sessions; these can be reviewed in Stone et al. (2017). However, it became very clear from the outset that, for the same Human Factors reasons highlighted in the MxR projects described earlier, a totally VR-based training system would not be capable of replicating the levels of task and context fidelity required for effective MERT training. In particular, the constraints imposed by the physical context in which MERT trainees were performing—the aircraft cabin frame, the presence of casualties and a huge collection of onboard medical and life support equipment—would be impossible to reproduce credibly using current VR technologies and techniques. Furthermore, a VR approach to such a complex training environment would, most likely, deliver distracting simulation artefacts, such as portions of the trainees' virtual bodies disappearing through the hull of the *Chinook*, or tracking mismatches between their real and virtual hands and the 3D casualty representation. For these reasons, it was decided that an MxR solution, based on a transportable and reconfigurable physical enclosure, would be developed. This reasoning also drove an early decision to procure a physical synthetic body in order to provide a meaningful and realistic sense of haptic feedback to the simulation users.

The enclosure takes the form of an inflatable "tunnel"-like structure (Fig. 8, left image), the internal dimensions of which closely match the width and height of the *Chinook* cabin. Three windows are provided on each side of the enclosure, and these can be left open or covered as necessary. The ribbed nature of the enclosure was designed not only to reproduce the beam structures within the *Chinook* cabin, but also to provide rigid fixing points for medical equipment when inflated. The enclosure is inflated using a single hand-held air blower and can be erected and

Fig. 8 Inflatable MERT MxR prototype training enclosure with task-relevant space-filling objects (*left*) and *SIMBODIE* casualty mannequin (*right*)

deflated in around 20 min. Once inflated, appropriate space-filling items have been added, including a stretcher, simple seating, cabin wall webbing and replica weaponry, all sourced from online vendors, and relevant additional items of equipment have been provided by the RCDM sponsors (including a medical 'Piggot Pouch', various Bergen back-packs and an intravenous drip set-up).

To simulate accurate—and believable—anatomical and physiological characteristics of a virtual casualty, not to mention supporting the haptic sensations involved with processes such as cannulae and catheter insertion, intubation procedures, wound attendance, and so on, a TraumaFX male *SIMBODIE* mannequin was procured. The mannequin (Fig. 8, right image) is constructed using soft silicone with moveable joints. Additional features include modifications to allow the placement of intraosseous needles, sites for intravenous access, detachable lower limbs to simulate traumatic amputations and adhesive patches mimicking gunshot and laceration wounds.

The computer-generated elements of this MxR demonstrator also take the form of a variety of online-sourced assets, including the virtual *Chinook* helicopter (which required considerable remedial modelling to deliver an environment acceptable to RAF and RCDM stakeholders) and 3D models of the space-filling items listed above, together with Royal Anglian/Royal Marine soldiers and RAF pilots. Once modified to a level suitable for real-time rendering as fully-textured and animated VR scenarios, all 3D assets were integrated within the Unity Game Engine, ready for display and interaction using a variety of hardware devices.

To provide a realistic view of the world external to the virtual *Chinook*, rather than generating a large terrain database in 3D, a 4K aerial video sequence was captured using a DJI *Inspire 1* drone flown under manual control in an elliptical flight path for approximately 4 km over a remote area of Dartmoor, with the onboard gimballed camera facing rearwards. To create a view as if looking towards the ramp area from within the virtual *Chinook* cabin, a video projection billboard was created within Unity, located at an apparent distance of 25 m from the rear of the helicopter in virtual space (Fig. 9). Similar video footage was used to simulate views from the side windows of the cabin. To add to the in-flight illusion, particle effects were used to simulate engine exhaust and mist passing the side windows and rear door of the helicopter, and high-quality *Chinook* engine sound effects were integrated with the visual flight sequence, provided to the development team by Boeing Defence UK Limited.

The interactive hardware components of the MxR MERT trainer changed significantly during the course of this early demonstrator project (for details, see Stone et al. 2017). In summary, early quality and accuracy concerns with the head-mounted display (a Razer OSVR HDK1) and motion capture technology (an OptiTrack V120 Trio—a significantly scaled-down version of the OptiTrack Flex 13 MOTIVE motion capture system described in Sect. 3.3 of this chapter) were addressed following the commercial launch of the HTC Vive HMD and integral “Lighthouse” position tacking modules. Unfortunately, however, the hand controllers delivered with the Vive are still, at the time of writing, inadequate, in that they do not provide an intuitive means of interacting directly with the physical

Fig. 9 Virtual *Chinook* interior showing billboarded external video scene

characteristics of the physical *SIMBODIE* mannequin. Close attention is being paid to online announcements of novel developments in input devices, especially with glove-based technologies (such as that under development by the Netherlands-based company Manus), as, depending on their hand and finger movement registration accuracies and their ability to integrate with existing motion capture devices (such as the recently announced Vive tracker units by HTC), they are most likely to deliver a credible and intuitive method of undertaking simulated medical interventions with synthetic human bodies.

4 Conclusions

The development and delivery of VR and MxR systems for advanced visualisation and training applications over the past two decades have been instrumental in developing Human Factors guidelines and procedures of relevance to a wide range of interactive technology projects, emphasising the importance of defining the knowledge, skillls and abilites (KSAs) of the end user population, together with any constraints imposed upon them by the contexts in which they operate. The results of the international research studies based on the MIST_{VR} trainer, for example, are still used today to illustrate the importance of generating an early understanding of users' KSAs and work environments when defining the task and context fidelities necessary to guarantee successful VR training outcomes. From an MxR perspective, incorporating a realistic instrument frame into the design of the MIST_{VR} hardware generated positive feedback from trainees and instructors and did much to accelerate their acceptance of MIST_{VR} as a surgical skills trainer. Eventually, MIST_{VR} became a de facto part-task surgical skills trainer, adopted by the European Surgical Institute in Germany and marketed as a surgical training product by Mentice of Sweden.

Similar success stories and lessons learned resulted from the early RN weapons and RAF helicopter training projects described in Sect. 3.2 of this chapter, and these form as important a contribution to current HF guidelines as the MIST_{VR} experience (e.g. Stone 2012). For example, just one year after the installation of the CRWS system in 2001 (the original cost of which was around £730,000), some impressive usage statistics began to emerge. For example, 55 training courses were held, with a total gunnery student throughput of 329. These figures by far exceeded the number of students undertaking the hands-on courses held at the original coastal training base and the downtime avoided due to foul range/bad weather was a contributory factor at around 33%. In addition, and based on a typical year of live firing at the coastal training establishment, 39,000 live rounds were saved (representing a cost saving of around £1.5 million), and the saving in flight time resulting from the aerial towing of targets for gunnery practice amounted to 384 h (at a cost of £4936 per hour, this equated to a monetary saving of £1.9 million). Finally, instructor feedback from annual Gibraltar live firing trials suggested that those participants who had been exposed to the CRWS system demonstrated superior marksmanship qualities compared to those who had not. The training outcomes recorded from the HVM courses were less significant, although the aim of completely replacing legacy classroom training techniques, based on scale dioramas, model helicopters and the practice of placing trainees into supermarket shopping trolleys, "propelled" by blindfolded instructors during hangar-based exercises, was successfully achieved. Furthermore, given that the provision of a cost-effective means of providing remedial training for students close to failing was a major requirement placed by the RAF on the development team, this, too, was successfully achieved. Releasing aircraft for such training would, at the time, have incurred flying costs in excess of £2500 per unit. The final cost of providing *three* HVM MxR trainers to the RAF in 2002 amounted to £240,000—the equivalent of just 96 hours flying time.

However, there is still much to do from an HCD standpoint, especially at a time when novel interactive technologies are appearing on the market at a rate that far exceeds anything witnessed in the 1990s and early 2000s. For example, rather than providing concrete results of immediate relevance to the VR/AR and MxR development communities, the more recent projects described in this paper have, as a result of early, quite informal HF evaluations, generated more research questions than were first anticipated. The command and control studies, for instance, have demonstrated significant gaps in the international HF knowledge base, particularly with regard to such issues as the design of graphical representations of platforms (air/land/sea/subsea), multi-layer/multi-level tracks, environmental effects and trends, threats, topographical overlays and so on that are appropriate for viewing using MxR, static/swept volume volumetric or holographic display set-ups. Very few papers have been found that contain usable information relating to such basic issues as the appropriateness of 2D versus. 2.5D versus. 3D, and the use of colour, shape and motion coding in the design of symbols or realistic icons, even "symbicons" (Smallman et al. 2001), for complex and dynamic visualisation applications. Many other questions relating to the use and usability of these technologies have also arisen and include the design of appropriate gestures for target acquisition, asset direction, menu selection and multimodal data "drill-down", together with optimum design characteristics of tangible interface devices and system requirements for multiple user interaction.

The MERT MxR simulation study has also generated a number of important challenges, such as the demand for new techniques for integrating high-fidelity physical mannequins, such as the *SIMBODIE* illustrated above, into a virtual aircraft or vehicle, to support realistic training for hands-on medical interventions. The MERT project will also require a novel approach to allowing real trainees to interact with their virtual counterparts—paramedic avatars, force protection and pilot avatars—especially during high-tempo training involving the recovery of casualties into the body of the rescue platform whilst under fire or when experiencing other mission constraints.

Many challenges lie ahead, yet there is little doubt that the interactive technology market will continue to produce a growing range of products for the VR, AR and MxR sectors for the foreseeable future. Some will be instant successes; many, many others will be short-lived. Whether or not the market lives up to the multi-billion dollar expectations and predictions of some of the more recent (and often unbelievable) market surveys remains to be seen. One thing is clear, however; that, despite the significant advances witnessed over recent years in these fields, the human-centered lessons from the past three decades of trial, error, partial adoption and failure must be learned. Visualisation and training solutions based on VR, AR and MxR technologies must be designed in conjunction with their end users, identifying the skills that need to be trained or the knowledge that has to be imparted. Only then can one hope to deliver solutions that are based on appropriate and meaningful content, fidelity and interactive technologies, as opposed to demonstrations that may look impressive, futuristic and may stand out in press releases or at exhibitions, but fall significantly short of delivering a high impact outcome for their target end users.

References

Barrett, G., Baber, C., Stanton, N. A., MacLeod, I., Newman, P., & Stone, R. (2006). From wearable computers to surgical training: The human factors integration defence technology centre. *Journal of Defence Science, 10*(4), 177–185.

ISO (International Standards Organisation; 2010). BS EN ISO 9241–210:2010—Ergonomics of Human-System Interaction; Part 210: Human-Centred Design for Interactive Systems. BSI Group.

Knight, J. F. & Stone, R. J. (2014). An Overview of Human-Machine Interface Research Relevant to Virtual and Mixed Reality Environments for Command and Control. Unpublished Technical Report for BAE Systems. *Future Mission Systems 2035* Project.

Miller, R. B. (1954). Psychological considerations in the designs of training equipment, wright air development center, wright patterson air force base, Ohio: Defense Technical Information Center.

Norri-Sederholm, T., Kuusisto, R., Kurola, J., Saranto, K., & Paakkonen, H. (2014). A Paramedic Field Supervisor's Situational Awareness in Prehospital Emergency Care. *Prehosp Disaster Med., 29*(2), 1–9.

Paelke, V., Nebe, K., Geiger, C., Klompmaker, F. & Fischer, H. (2012). Multi-Modal, Multi-Touch Interaction with Maps in Disaster Management Applications, In *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Science*, Volume XXXIX-B8, 22nd ISPRS Congress, Melbourne. pp. 55–60.

Smallman, H. S., St John, M., Oonk, H. M., & Cowen, B. (2001). 'Symbicons': a hybrid symbology that combines the best elements of symbology and icons. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 45*(2), 110–114.

Stone, R. J. (2011). The (Human) science of medical virtual learning environments. *Philosophical Transactions of the Royal Society B., 366*(1562), 276–285.

Stone, R. J. (2012). Human factors guidance for designers of interactive 3D and games-based training systems, *Human Factors Integration Defence Technology Centre Booklet*. http://www.birmingham.ac.uk/Documents/college-eps/eece/research/bob-stone/human-factors-guidance.pdf. Accessed 06 Jan. 2017.

Stone, R. J. (2016). Getting VR right then and now … The indispensable Role of human factors and human-centred design. *Presence, 25*(2), 151–160.

Stone, R. J., Caird-Daley, A., & Bessel, K. (2009). *SubSafe*: A games-based training system for submarine safety and spatial awareness. *Virtual Reality, 13*(1), 3–12.

Stone, R. J., Guest, R., Mahoney, P., Lamb, D. & Gibson, C. (2017). A 'Mixed Reality' simulator concept for future medical emergency response team training, *J R Army Med Corps*. http://jramc.bmj.com/cgi/content/abstract/jramc-2016–000726. Accessed06 Jan. 2017.

Stone, R. J. & McDonagh, S. (2002). Human-Centred development and evaluation of a helicopter voice marshalling simulator, In *Proceedings of I/ITSEC 2002*. Orlando: 3–5 December. http://www.iitsecdocs.com/volumes/2002 Accessed 06 Jan. 2017.

Stone, R. J. & Rees, J. B. M. (2002). Application of Virtual Reality to the Development of Naval Weapons Simulators, In *Proceedings of I/ITSEC 2002*. Orlando: 3–5 December, 2002. http://www.iitsecdocs.com/volumes/2002. Accessed 06 Jan. 2017.

Stone, R. J., Snell, T. & Cooke, N. (2016). An Inexpensive Underwater Mine Countermeasures Simulator with Real-Time 3D After Action Review, *Defence Technology*. 12(5), 367–379. http://www.sciencedirect.com/science/article/pii/S2214914716300654. Accessed 06 Jan. 2017.

Weiss, M., Hollan, J. D., & Borchers, J. (2010). Augmenting interactive tabletops with translucent tangible controls. *Tabletops-Horizontal interactive displays* (pp. 149–170). London: Springer.

Zuckerman, O., & Gal-Oz, A. (2013). To TUI or not to TUI: Evaluating performance and preference in Tangible vs. *Graphical User Interfaces, International Journal of Human-Computer Studies., 49,* 803–820.

How Augmented Reality and Virtual Reality is Being Used to Support People Living with Dementia—Design Challenges and Future Directions

Jason Hayhurst

Abstract The number of people worldwide that suffer with Dementia is estimated at 46 million people and is set to increase to 131.5 million by 2050 at a combined cost estimated at $818bn. Caring for our elderly population living with dementia raises issues over resources in terms of financial aid and time. This paper reviews from existent research projects how Virtual Reality (VR), and Augmented Reality (AR), have been used as cognitive aids to the person living with Dementia (PwD), specifically in the early stages of the condition. The purpose of these interventions being to provide PwD with strategies to maintain their independent living. Within VR and AR, gamification approaches have also been used to provide support through the delivery of calming experiences, use as memory aids, and also cognitive stimulation. VR has also been used as a learning tool enabling carers to gain a better understanding to the challenges PwD face every day. The end of this paper identifies a number of design challenges that exist going forward and includes possible future directions that may be taken.

Keywords Dementia · Augmented reality · Virtual reality · Design challenges · Future directions

1 Introduction

Dementia is a term that describes the symptoms that occur when the brain is affected by certain diseases or conditions (Alzheimers Society 2016). This umbrella term includes the most common cognitive diseases such as Alzheimer's disease. Symptoms of Alzheimer's can include increased loss in concentration and memory, increasing difficulties with the planning of tasks and activities and changes in mood or personality (NHS 2015). Clearly the effects on patients and carers can be significant as the symptom progress and this may also impact on how the sufferer can

J. Hayhurst (✉)
Faculty of Arts, Culture and Education, University of Hull, Hull, UK
e-mail: j.hayhurst@hull.ac.uk

T. Jung and M.C. tom Dieck (eds.), *Augmented Reality and Virtual Reality*,
Progress in IS, DOI 10.1007/978-3-319-64027-3_20

cope with independent living in their own home. A Yougov poll commissioned by the Alzheimer's Society in 2014 found that 85% of people would want to stay living at home for as long as possible if diagnosed with Dementia although only 47% agreed that they thought they would be able to stay at home (Alzheimer's Society 2014). The number of people worldwide that suffer with Dementia is estimated at 46 million people and is set to increase to 131.5 million by 2050, at a combined cost estimated at $818bn (Prince et al. 2015). In the UK the government announced in 2015 the UK's first Dementia Research Institute will receive up to £150 m to encourage research in this area (Prime Ministers Office 2015).

In order for people living with Dementia (PwD) to maintain their independence there is a need for assistive technologies (AT). These technologies can help improve the quality of life (QOL) although it remains difficult to scientifically prove that an increase in QOL has taken place (Peterson et al. 2012). Despite this many AT products claim to increase QOL for PwD. This need to develop ICT environments with an aim to increase QOL in our ageing population also sits within Ambient Assisted Living (AAL) and within Europe there are initiatives such as the Active and Assisted living programme encouraging collaborations with universities and industry to provide innovative solutions for our ageing population (AAL-Active and Assisted Living Programme 2016).

What are the needs?

PwD's do not have the exact same symptoms as one another and there are differences between early stage onset through to end of life. As people decline in the condition so too can their ability to interact with some AT's. Furthermore, support is needed to assist carers to help the adoption of AT's. In the past the focus of Gerentechnology (the research of technology to assist the older population) for dementia has been on the PwD with less focus on the family carers (Kort 2014). There are three main stakeholders in the design of AT for PwD, the carers, the health professionals and the PwD themselves.

Some of the traits of Dementia include short term memory loss or episodal memory recollection from a distant period of time in their life. Spatial memory and navigation therefore become challenging which can lead to PwD getting lost. Navigating public spaces can be a problem when things like puddles can appear as holes in the ground Within the home environment PwD sometimes experience difficulties remembering lists of instructions. They can suffer with blind spots and sometimes have difficulty with hand to eye co-ordination.

AAL often makes use of interventions with smart technologies. These technologies are often combinations of sensor devices such as Bluetooth Low Energy, RFID and wearable technologies (Bossen et al. 2015). These technologies help safety aspects within the home such as appliance power management through to memory and cognition, socialising, leisure and telemedicine. The AT that have been developed focus on providing prompts and reminders with context based on sensors.

This conference paper is not an exhaustive review of all VR and AR assistive technologies for PwD. The papers purpose is to highlight areas where this technology has been developed through to design challenges and future directions.

2 Virtual Reality AT for Dementia

There a number of VR applications developed for PwD. The purpose of this section is to discuss some of the types of applications developed from carer training to immersive PwD applications. This should provide an insight into some of the uses of VR within Dementia.

Figure 1 shows a framework for the different categories of VR applications appropriate to Alzheimer's Disease (AD) (Garcia-Betances et al. 2015). The framework provides a sensible classification of current applications of VR within AD.

The use of VR to construct virtual environments (VE) can provide carers with a greater understanding of how the physical home environment can be challenging to PwD. This is demonstrated at the Alzheimer's Dementia Experience (Alzheimers Australia 2013). The virtual reality experience makes use of Epic Unreal Game engine and Microsoft Kinect sensors along with surround sound. This innovative use of game technology allows actors to virtually walk through a home environment whereby design issues cause cognition stress such as patterned carpets appearing as though bugs are running on the floor. A second actor plays the part of the carer reacting to the PwD. This experiential learning is carried out in order for carers to explore how best to support PwD to help improve their quality of life (QOL). This VE has since been repurposed into a mobile application to work with Google Cardboard known as EDIE (Alzheimers Australia 2016). Using serious

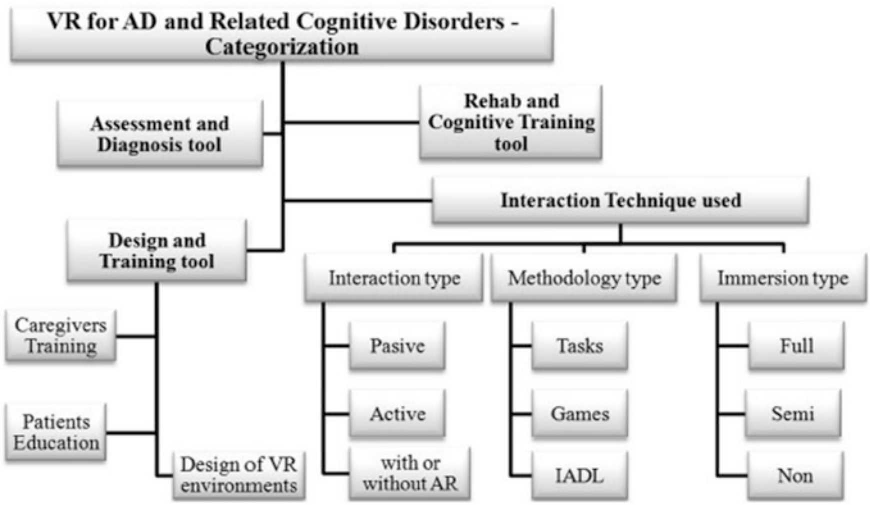


Fig. 1 Categorisation of VR technology applications for alzheimer's disease. (Garcia-Betances et al. 2015)

games as an educational tool in this manner enables carers to gain an insight into living with dementia that may otherwise be difficult to understand. It also means that new carers can appreciate the impact of Dementia in a faster manner than previously possible.

Alzheimers Research UK (2016) have also developed some VR applications to help raise awareness about some of the problems PwD experience when navigating their way home. The second experience they have produced makes use of game engine graphics to demonstrate the challenges faced when carrying out seemingly simple tasks such as making a cup of tea. Both experiences can be viewed via 360-degree video but also via google cardboard on an android phone app. The game engine experience demonstrates the realism that some game engines can now provide in terms of the graphical VE.

The use of VR has also extended beyond caring but also as an aid to designing a Dementia friendly home environment (Alzheimers Australia 2016). This application provides the users with a VE of a home where design issues can be highlighted. The aim is to help homes to be modified to take account of the needs of PwD and make the home more dementia-friendly.

Manera et al. (2016) conducted a feasibility study with image-based rendered virtual reality in patients with mild cognitive impairment (MCI) and Dementia. MCI is a precursor condition that affects a person's memory or thinking. People with MCI are more likely to develop Dementia (Alzheimers Society 2015). The study was designed as an attentional task to train selective and sustained attention using images of a crowd of people. Participants were asked to select people from the crowd according to specific conditions. This was tested with a VR and a paper version of the task in a single-session within-subjects design. A common misconception with AT is that elderly patients do not enjoy technology interventions. The results showed that participants were highly satisfied and interested in the task with more participants preferring the VR based task compared to the paper based version. The mean age of participants was 75. This intervention shows that the elderly population can be motivated to engage with technology even within virtual reality environments.

Some VR applications for PwD are fully immersive whereas others make use of screens and Microsoft Kinect sensors to enable PwD to have a level of interactivity in the VE. One example is a VR application called the Virtual Forest developed for Alzheimer's Australia. The forest presents a park-like setting with a river and a bridge. The seasons change with a clap of the hands and PwD navigate the VR by waving their hands. This experience appears to engage PwD, and carers have described the VE as having a calming experience 'settling' PwD. The platform was developed using the Epic Unreal Engine. Using a Kinect to provide a semi immersive experience may well suit a care home environment as opposed to having to hand out VR eyewear.

3 Augmented Reality AT for Dementia

AR removes some of the boundaries in place with VR in that the virtual layer can be provided wherever the person is or is moving too. This therefore presents opportunities for development within Dementia AR and there have been a range of interventions with PwD in this area. Some of the AR applications focus on wayfinding outside the home through to memory palace experiences within the home. In terms of headsets, there has been some bespoke depth sensing glasses developed whereas some applications make use of tablet or smartphone devices. There has also been some use of Internet of Things (IoT) devices and wearables including Bluetooth Low Energy (BLE) beacons to help position PwD with their environment.

Within nursing, an application has been developed called GhostHands in which a student can view an experts augmented hands modelled in real time providing procedural guidance (Scavo et al. 2015). Within Dementia, PwD can sometimes forget how to carry out routine tasks. Sometimes this results in the incorrect sequence of steps or the omission of something quite essential. If we consider the growing need of an ageing population then assistive technology used this way could be operated remotely by carers in order to assist PwD stay at home longer.

Bolestsis and McCallum (2016) developed an AR based gaming experience using Cognitive Augmented Reality Cubes (CogARC). The physical cubes were viewed through a tablet held in place with a physical bracket. PwD could then view different games that encouraged pattern and colour matching with the cubes. The research presents CogARC as a cognitive screening tool for elderly people over 60 years old. The design iterations of the application experienced some interaction issues such as cube recognition and a delay between the real movement of the physical object and the display on the screen. Some of these issues were overcome using Unity Game Engine and an extension known as Vuforia Unity Extension. Another issue was the limit of the gaming stage i.e. (10-inch Tablet Screen). Challenges relating to depth perception were experienced when looking through the screen.

An interesting combination of AR and Bluetooth beacons have been developed in order to provide a system known as a Memory Palace (Morel, Bormans, & Rombouts). This system encourages caregivers and PwD to attach beacons to items of significance in the home environment. They then use a mobile application to assign media to the item of interest including images, audio, video etc. The PwD can then use the phone and app to walk around the house with memory replays as they pass near to a tagged object. The implementation did require the caregiver to be involved in the creation of the object memories and the PwD did find the application more useful as an aid to converse about a particular memory.

An AR based system known as Kognit proposes a future platform that uses bespoke depth sensing AR glasses to focus on body sensor interpretation, activity recognition and as a pro-active episodical memory aid, including assistance and monitoring of activities such as the taking of medication and drinking water (Sonntag 2015). This particular system extends AR with Artificial Intelligence in order to provide prompts at appropriate points around the home and outdoors.

The above future platform is extended in an innovative design project described as “The adventures of Gladys in (an augmented) wonderland” (Raleigh 2016). This research presents a set of design principles to address the design challenges of dementia experience within public places. The concept in this research is based around an augmented reality based device named as Public Realm Orientation Device (Pro-d). The proposal is to encourage the development of an AR device that also has depth sensing technologies in order to provide context sensitive information when a PwD is walking in a public space. This could be to identify hazards and keep the PwD safer when navigating outdoors.

4 Benefits of VR/AR

In a society where our elderly population is growing significantly we have to find ways to help our aged people. Technology can provide an intervention that may help the elderly stay at home longer without the need to move into a care home environment.

Indeed VR has already been researched in terms of its use in pain management (Montaño et al. 2011). Investigators in this research state that as the field of VR for pain management develops treatments may reduce the need for narcotics in patients. For PwD it has been commented that VR can be used to decrease stress and anxiety levels which may again reduce the need to medicate. This in turn could have a significant cost reduction in pharmaceutical drugs.

In addition, it may also be possible for VR/AR applications to provide healthcare professionals with further information about the PwD within the home. Physical movement data, how many times VR help has been sought, through to results of serious game challenges may aid professionals in their understanding of the individual patient. In a similar manner, it may help reduce pressures caregivers.

Making use of mobile AR can be used in physically able PwD whilst stimulating their cognitive abilities. As the Dementia progresses then it may be useful to consider the use of VR as a cognitive stimulant. The use of music as a therapy to stimulate cognition has been shown to have a positive impact on PwD disruptive behaviour and anxiety (Zhang et al. 2017). As music stimulates cognition through hearing so too can it be argued that VR/AR can do the same through vision. The effect could be further enhanced with levels of interactivity.

5 Technology Design Issues

There are a number of issues when designing assistive technology for PwD. The first is the consideration of the stakeholders. Often the AT requires a level of technical intervention to either setup the application or indeed use it. This therefore requires caregivers or family members to be able to use any application in order to support the PwD in its use or adoption.

Furthermore, designers of AT should consider a user centred approach with any design. One AT may be appropriate for that PwD but not necessarily another. There is a danger that designers of AT use a “One Size Fits All” approach. Any intervention of AR/VR should be designed to consider the needs of the PwD and consideration should be given to the notion that their needs may differ over time depending on how their Dementia is affecting them at that particular time. This maybe one of the reasons that a number of the VE used within VR are generic but more research into differences in VE may be needed in order to compare bespoke designed VE and the impacts on PwD.

If we consider the meaning of stimuli and its impact on the engagement of PwD. Interventions that involve objects or tasks with meaning specific to the PwD will be more likely to engage with that person (Cohen-Mansfield et al. 2010). Within the sphere of AR/VR this could translate to VE’s that are context-aware to any PwD resulting in a more immersive adoption of any intervention.

There is a challenge in relation to developing immersive VE that are specific to PwD. If for example, we developed memory stimulating VE that can be considered as psychosocial interventions. For example, “one of the primary goals of reminiscence theory are to facilitate recall of past experiences so to promote intrapersonal and interpersonal functioning and thereby improve well-being” (Kasl-Godley and Gatz 2000). Therefore, a VE designed to invoke meaningful memories in a PwD and result in a reduction in anxieties could in fact result in increased stress depending on the individual. Validation therapy is also something that a VR/AR application could be developed to support. This theory encourages carers/family members to follow the the PwD objectives her and now and not ask why. So what may seem as irrational behaviour i.e. “Look at that plane flying across in front of us” is not challenged as not existing. Instead a conversation is started that discusses the type of plane etc. A VE could be an effective mechanism for this type of therapy assuming that relevant content is available.

Some AT technologies report the positioning of the PwD within the home environment either as a datapoint or through a series of video/image captures. One of the challenges is therefore how we ensure that PwD maintain a level of privacy within their home and indeed from any aggregated data used by health care professionals. This could be more relative to patients making use of mobile based AR applications rather than static VR applications.

A number of AT including AR and VR report to enhance PwD quality of life (QOL). However, there appears to be a lack of standards in relating QOL to AT in this sector. This can therefore make it harder for PwD and carers to compare products available to them. Technology based QOL metrics would also make future research including AR/VR impact to be more objectively assessed. A factor that may be particularly important to government backed projects in this sector.

Interventions of AR and VR that rely on IoT, wearable devices and physically installed items in the home could be a barrier to the adoption by PwD. Where possible we should be working with technology that is pervasive and not necessarily bespoke for the PwD. This is equally important to enable updates for platform software to be more readily available. In addition, consideration needs to be given if we are relying on eyewear. If a platform relies on this and a PwD doesn't remember or indeed wish to wear it, then the project could fail and no benefits experienced by the PwD. However, wearable devices that measure heart rate for example could have an impact on any AR/VR intervention if the purpose is to be an assistive aid.

Ethical clearance for research is also problematic with PwD. Obtaining informed consent is clearly easier for early stage dementia than in later stages. However, within the UK the National Institute for Healthcare Research (NIHR) there is a network of PwD that are willing to be involved in research (National Institute for Health Research 2017). This provides a positive opportunity to overcome challenges in recruitment for potential AR/VR projects.

6 Future Possibilities

The use of VR/AR has a number of positive possibilities particularly as the technology itself matures. The mobile capabilities of AR and related technologies make this AT more useful to early stage sufferers. The AR platform can be used to encourage PwD to become active and stimulate their cognition. Whereas VR can also be used be used to stimulate PwD that are in the later stages of Dementia, either as fully immersive, or semi-immersive experiences. In addition, a greater level of context aware delivery applications could make use of wearables as a trigger or prompt to using AR/VR.

Whilst some of the AR applications presented here appear to be futuristic proposals, the pace of technology appears to offer the opportunity to develop some of these applications, and yet at the same time avoid the need for bespoke hardware to be developed. A google based technology known as Project Tango widens the scope of what can be achieved within the AR space. The hardware developed within this project combines depth sensing, motion tracking and area learning to provide real time mapping of the environment. Although this technology platform is relatively new in terms of consumer based available hardware it does seem to offer a platform fot5frc r AR/VR developers to integrate with the use of a game engine. This could lead to some interesting experiences in the space of Dementia research. Indeed, this technology could bring life to some of the aspects of the Gladys in Wonderland project documented earlier in this paper.

The use of more relevant VE to the PwD is an area being considered by the author of this paper. What if we could create a memory palace type experience using the Project Tango device? This device can monitor motion tracking and also use depth sensing to enable AR based VE to be used in a gamification activity. The concept is to allow both PwD and family members to contribute media assets that could be attached as interactive objects around the home. This could encourage activity by the PwD and stimulate cognition. The additional advantages are that movement around the home could also be monitored which could be useful data to health care professionals. If we consider the AR based game Pokémon Go. This game encourages mobility in order to capture Pokémon monsters and level up. In a home or care environment, AR could be used to stimulate cognition and activity in a similar functional manner.

In addition, AR could be used in order to provide remote assistance in functional tasks in the home. If we consider a system similar to the Ghost Hands discussed earlier in this paper we could see a future where social care call centres provide remote assistance at the point needed by PwD. Even the most basic task such as making a cup of tea has a number of steps. Confusion in self-management and care could ultimately contribute to a decision to move a PwD to a care environment. With AR, remote operators could help PwD carry out basic tasks and help reduce anxiety.

7 Conclusion

This paper explains some of the issues that PwD face with Dementia and an overview of AT within the VR and AR space. Whilst it is not an exhaustive account of AR and VR within the Dementia space it does provide examples of intervention types within the area of VR and AR. There appears to be more AT research in the area of VR than AR despite the mobility that the latter provides. The issues of special awareness and navigation could be enhanced with the intervention of AR applications providing longer independence and quality of life that PwD seek. As PwD decline in cognitive abilities then the use of VR either as a full immersive or semi immersive VE can provide cognitive stimulation. The VR examples in this paper show that the use of VR as training aid to caregivers should help more people understand the needs of PwD which may lead to improved levels of care. More user-centred design is required to provide VE that have more relevancy to PwD as this can lead to a greater level of immersive experience and engagement. VE Designers have to understand the psychosocial interventions can be problematic which need consideration with the design of VE for both AR and VR. Furthermore, a greater clarity is required to standardise the QOL metrics that apply to AT in order for PwD and caregivers to understand which may be the most appropriate to their needs.

In a world with ever increasing levels of elderly people the intervention of AT with AR and VR could help enable greater levels of support without necessarily increasing the number of caregivers. Assistive support could be pushed out through

AR at the point that it is needed. Recent developments in technology may provide more scope to develop user centred AT that is simpler to roll out in terms of home delivery which may lead to a greater acceptance of this technology by PwD.

References

AAL-Active and Assisted Living Programme. (2016, 12 30). *About*. Retrieved 12 30, 2016, from Active and Assisted Living Programme. http://www.aal-europe.eu/about/.

Alzheimers Australia. (2013, 10 1). Virtual Dementia Experience. Melbourne, WA, Australia.

Alzheimers Australia. (2016, 3 16). *3D Dementia Friendly Home App To Assist Carers and Empower People Living With Dementia*. Retrieved 1 10, 2017, from Alzheimers Australia: https://vic.fightdementia.org.au/vic/3d-%E2%80%98dementia-friendly%20home%E2%80%99-app-to-assist-carers-and-empower-people-living-with-dementia.

Alzheimers Research UK. (2016, 6 1). *A Walk Through Dementia*. Retrieved 1 10, 2017, from A Walk Through Dementia. http://awalkthroughdementia.org/.

Alzheimers Society. (2016). *Types of Dementia*. Retrieved 01 13, 2016, from https://www.alzheimers.org.uk/site/scripts/documents.php?categoryID=200362.

Alzheimers Australia. (2016, 9 22). Cardboard VR App For Smartphones enables reality of dementia through EDIE's eyes. Melbourne, WA, Austrailia.

Alzheimer's Society. (2014). *Most people want to stay at home if diagnosed with dementia but less than half know how*. Retrieved 01 13, 2016, from https://www.alzheimers.org.uk/site/scripts/press_article.php?pressReleaseID=1138.

Alzheimers Society. (2015, 8 1). *What is mild cognitive impairment (MCI)*. Retrieved 1 6, 2017, from Alzheimers Society. https://www.alzheimers.org.uk/site/scripts/documents_info.php?documentID=120.

Alzheimers Society. (2016). *Alzheimers Society*. Retrieved 01 13, 2016, from https://www.alzheimers.org.uk/site/scripts/documents_info.php?documentID=120.

Bolestsis, C., & McCallum, S. (2016). Augmented Reality Cubes for Cognitive Gaming: Preliminary Usability and Game Experience Testing. *International Journal of Serious Games, 3*(1), 3–18.

Bossen, A., Kim, H., Steinhoff, A., Streiker, M., & Williams, K. (2015). Emerging roles for telemedicine and smart technologies in dementia care. *Smart Homecare Technology and TeleHealth, 2015*(3), 49–57.

Cohen-Mansfield, J., Thein, K., Dakheel-Ali, M., & Marx, M. S. (2010). The underlying meaning of stimuli: Impact on engagement of persons with dementia. *Pschiatry Res, 177*(1–2), 216–222.

Garcia-Betances, R. I., Arrendondo Waldemeyer, M. T., Fico, G., & Cabrera-Umpierrez, M. F. (2015, 5 12). A succint overview of virtual reality tehcnology use in Alzheimer's disease. *Frontiers in Aging Neurosience, 7*(80), 1–8.

Joseph, R. G. (2016). *Agnosia*. Retrieved 01 13, 2016, from http://brainmind.com/Agnosia.html.

Kasl-Godley, J., & Gatz, M. (2000). Psychosocial Interventions for individuals with dementia: An Intergration of theory, therapy, and a clinical understanding of dementia. *Clinical Psychology Review*, 755–782.

Kort, H. M. (2014). Demenita and Dementia Research. *Gerentechnology, 12*(3), 125–126.

Manera, V., Chapoulie, E., Bourgeois, J., Guerchouche, R., Renaud, D., Ondrej, J., … Robert, P. (2016, 3 18). A Feasibility Study with Image-Based Rendered Virtual Reality in Patients with Mild Cognitive Impairment and Dementia. *PLOS One, 11*(3).

Montaño, Z., Li, A., Chen, V. J., & Gold, J. (2011). Virtual reality and pain management: current trends and future directions. *Pain Management, 1*(2), 147–157.

Morel, A., Bormans, K., & Rombouts, K. (n.d.). Memory palaces to improve quality of life in dementia. *2015 Conference on Raising Awareness for the Societal and Environmental Role of Engineering and (Re)Training Engineers for Participatory Design (Engineering4Society)* (pp. 80–84). Belgium: IEEE.

National Institute for Health Research. (2017, 1 1). *Researchers*. Retrieved 1 1, 2017, from Join Dementia Reserarch: https://www.joindementiaresearch.nihr.ac.uk/content/researchers.

NHS. (2015). *Symptoms of Dementia*. Retrieved 01 13, 2016, from http://www.nhs.uk/Conditions/dementia-guide/Pages/symptoms-of-dementia.aspx.

Peterson, C., Prasad, N., & Prasad, R. (2012). The future of assistive technologies for dementia. *Gerontechnology, 11*(2), 195.

Prime Ministers Office. (2015). *PM announces funding for UK's first Dementia Research Institute*. Retrieved 01 13, 2016, from https://www.gov.uk/government/news/pm-announces-funding-for-uks-first-dementia-research-institute.

Prince, M., Wimo, A., Guerchet, M., Ali, G.-C., Wu, Y.-T., & Prina, M. (2015, 09 01). *World Alzheimer Report 2015: The Global Impact of Dementia.* Retrieved 01 13, 2016, from http://www.alz.co.uk/research/world-report-2015.

Raleigh, J. (2016, 6). The adventures of Gladys in (an augmented) wonderland. *Australian Journal of Dementia Care*, 27–29.

Scavo, G., WILD, F., & Scott, P. (2015). The GhostHands UX: telemonitoring with hands-on augmented reality instruction. *Intelligent Environments (Workshops)*, (pp. 236–243).

Sonntag, D. (2015, 9). Kognit: Intelligent cognotove engancement technology by cognitive models and mixed reality for dementia patients. *AAAI Fall Symposium Series*.

Zhang, Y., Cai, J., An, L., Hui, F., Ren, T., Ma, H., et al. (2017). Does music therapy enhance behavioral and cognitive function in elderly dementia patients? A systematic review and meta-analysis. *Ageing Research Reviews, 35,* 1–11.

Part V
Augmented and Virtual Reality Design & Development

Testing the Potential of Combining Functional Near-Infrared Spectroscopy with Different Virtual Reality Displays—Oculus Rift and oCtAVE

Aleksandra Landowska, Sam Royle, Peter Eachus and David Roberts

Abstract The aim of this pilot study was to assess the pros and cons of combining mobile neuroimaging with two different styles of highly immersive displays: one that is worn on the head; and the other that is entered. Specifically wearable Functional Near Infrared Spectroscopy (fNIRS) was combined with both an Oculus Rift and surround immersive projection technology (IPT). The first experiment assessed signal to noise ratio (SNR), freedom of movement and motion artefacts in both systems combined with fNIRS. Second experiment involved measuring hemodynamic response from the prefrontal cortex in IPT. Findings suggest that fNIRS is compatible with both approaches and the majority of movement they support. This work opens the door to measuring close to surface medium resolution neural response, to virtual stimuli in which people can naturally look and walk around. This has potential to improve ecological validity in applications range from neuroscience research to exposure therapy.

Keywords Virtual reality · fNIRS · Brain imaging · Prefrontal cortex · Emotional regulation

A. Landowska (✉) · S. Royle · P. Eachus · D. Roberts
School of Health Sciences, University of Salford, Salford, UK
e-mail: A.Landowska@edu.salford.ac.uk

S. Royle
e-mail: W.S.S.Royle@salford.ac.uk

P. Eachus
e-mail: P.Eachus@salford.ac.uk

D. Roberts
e-mail: D.J.Roberts@salford.ac.uk

T. Jung and M.C. tom Dieck (eds.), *Augmented Reality and Virtual Reality*,
Progress in IS, DOI 10.1007/978-3-319-64027-3_21

1 Introduction

Recent rapid technological advances in Virtual Reality (VR) and brain imaging offer opportunities for researchers in the field of neuroscience to investigate brain response in highly controllable and repeatable settings. VR allows for the creation of more naturalistic environments which facilitate ecological validity (Bohil et al. 2011). Traditionally neuroscience used standard desktop displays in order to present stimuli and investigate underlying brain response. This approach however is highly artificial and does not resemble real life situations. Previous neuroscientific studies demonstrated that the human brain responds differently to static emotional 2D images than to interactive emotional 3D environments (Dores et al. 2014). Therefore, there is a need to develop more ecologically valid combinations of VR displays and brain imaging methods. This would allow improved neuroscientific research unobscured by the limits of screens.

When combining VR with neuroimaging, maintaining quality of the measurement without sacrificing naturalness of movement and response is challenging. The aim of this pilot study was to assess the pros and cons of combining mobile neuroimaging with two different styles of highly immersive displays: one that is worn on the head; and the other that is entered. Specifically, wearable Functional Near Infrared Spectroscopy (fNIRS) was combined with both an Oculus Rift and surround immersive projection technology. The scope was to investigate neural activity in the prefrontal cortex related to emotional regulation in VR, as well as Signal to Noise Ratio (SNR), motion artefacts (noise in a data caused by body movement), peripheral signal interference, and comfort of use. The classic VR experiment—The Pit Room (Meehan et al. 2002) was employed in order to trigger an emotional response to VR using an IPT system. Meehan's PIT Room experiment which involves exposure to virtual heights, demonstrated that exposure to stressful VR induces emotional response, even in healthy participants. This response was measured by heart rate, electrodermal response, and self-report (Meehan et al. 2002).

2 Literature Review

Many recent studies combined neuroimaging techniques with VR in research on human cognition and performance, such as human navigation and driving behaviour (Carvalho et al. 2006), social interaction (King et al. 2006), spatial memory (Burgess et al. 2001), violent behaviour (Mathiak and Weber 2006), or emotion (Baumgartner and Valko 2006). Most of these studies employed Functional Magnetic Resonance Imaging (fMRI) or Electroencephalography (EEG). The former offers high spatial resolution, while the latter offers better temporal resolution (Ferrari and Quaresima 2012). However, lying within a huge and noisy fMRI scanner restricts freedom of movement and could possibly evoke anxiety in some participants (Irani et al. 2007). Recently, improvements have been made making EEG systems more compact, wireless and portable. This allows EEGs to be combined with VR systems in which people can more freely move (Török et al. 2014). The most challenging disadvantages of EGG are its susceptibility for motion artefacts, and electronic signal interference. fNIRS provides a tool for acquiring brain scans that sits between the spatial resolution of fMRI and temporal resolution of EEG, within VR (Irani et al. 2007).

fNIRS was combined with a VR display for the first time by Holper and colleagues (2010) as a tool for monitoring virtual motor rehabilitative training. Other recent studies showed fNIRS can be used in combination with VR in balance control (Moro et al. 2014), or navigation learning (Ayaz and Shewokis 2011). However those studies did not use fully immersive systems and did involve freedom of movement within VR. This pilot study tested the potential of utilising technologies which would facilitate naturalness of response while measuring neural activity from the prefrontal cortex.

The most commonly used VR systems are Head-mounted Displays (HMDs) and Cave Automatic Virtual Environments (CAVEs) (Cruz-Neira et al. 1992). The former allow people to look around a virtual scene, typically from a fixed or highly constrained position. The latter, allow a small space within the scene to be moved around, potentially with others. Some HMD's allow a degree of movement similar to smaller CAVE's. However this study compares extremes: an HMD that does not support natural walking; and a large IPT that allows a small group to move around an object the size of a car.

Traditional HMD's restrict motion by being tethered to a computer with cables. While wireless versions are coming to market, having the real world completely hidden makes walking dangerous. While Augmented Reality is set to resolve these issues, commercial technology is in its infancy and there are times when the real world should be hidden. Another disadvantage of HMD's is that others and one's own body are hidden. This may potentially impact on the feeling of presence in an alternate reality, as well as cause cybersickness (Malik et al. 2014). CAVE-like systems offer a solution by immersing a user into a room-sized VR simulation which supports natural locomotion and interaction in the space, without losing the sight of one's own body or others. On the other hand, CAVE-like systems are generally more expensive, especially in terms of space usage, and do not fit easily into many settings, such as a clinic for example.

Previous neuroimaging studies demonstrated that the prefrontal cortex plays a crucial role in emotional reappraisal and cognitive regulation of emotion (Grimm et al. 2006). In particular, neuroimaging studies performed on healthy participants found increased activity in the medial prefrontal cortex (MPFC) and dorsolateral prefrontal cortex (DLPFC) during perception of fearful pictures (Lange et al. 2003), emotional reappraisal (Ochsner and Gross 2005), or suppressing negative mood during decision making (Beer et al. 2006). Comparatively, studies performed on patients with depression and anxiety disorders demonstrated hypoactivation in the MPFC and DLPFC could indicate deficits in emotional regulation (Duval et al. 2015).

3 Method

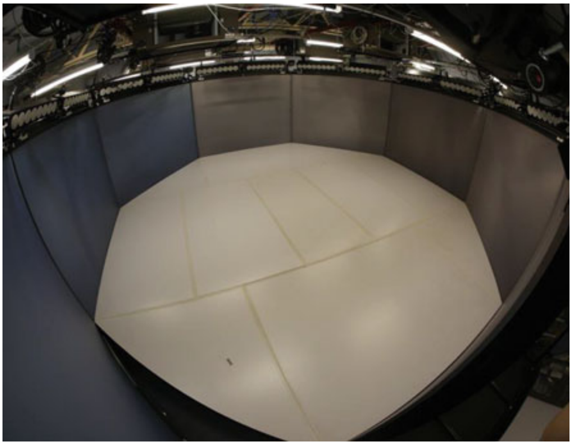
This pilot study tested the potential of combining the wearable fNIRS device—NIRSport, with two VR display systems: a CAVE-like (IPT) system—Octave, and a custom fNIRS-adapted Oculus Rift DK2. The aim was to test the feasibility of the protocol in terms of the design, integration of technology, and signal to noise ratio. The approach was to combine VR display systems in which participants can move freely while neural indexes of the signal quality can be measured. Another objective of this study was to measure brain response to evocative VR in the display which allows the most extensive natural movement.

3.1 Devices

Immersive Projection Technology (IPT) Octave
Octave is an octagonal IPT space approximately 32.6 m^2, which is big enough to allow a small group of people to mingle. Immersive Projection is delivered via the surrounding walls and floor display. There are 8 surrounding wall screens 2600 x 1969 mm with resolution 1400 × 1050 pixels, and 96 Hz refresh rate. There are 14 Christie S+3 K mirage projection units of which 6 project to the floor with 8 rear projection systems utilised for the walls. Octave images are generated by a PC workstation with 2 x Xeon E5-2650, giving 32 threads, 64 GB memory, SSD and 4xNvidia K5000 with a k-sync card running a single desktop through 4 mosaic instances. Parallax is provided by the optical motion tracking system Vicon MX-F40, controlled by a Dell workstation running Windows 7 and Vicon Tracker 2.0, with custom designed optical markers on the glasses. The users in Octave wear XPAND 3D Shutter Glasses Lite RF (X105-RF-X1) with a shuttering frequency 96 Hz. There are no modifications required in order to measure haemodynamic responses to IPT based virtual stimuli utilising the NIRSport system, however the infrared tracking system and electronic light emitting peripheral devices may potentially introduce noise to the fNIRS data (Fig. 1).

Custom Oculus Rift
The Oculus Rift DK consists of a single stereoscopic OLED screen measuring 5.7” corner to corner, with a resolution of 1920 × 1080 (960 × 1080 per eye) pixels producing a 100 degree field of view with a 75 Hz refresh rate. Images were generated using an MSI GS30 2 M shadow laptop with base station, running an Intel i7 5700HQ, giving 8 threads, 16 GB of memory, HDD, and Nvidia GTX 970 graphical processing unit, with Windows 7 operating system. An infrared detector is used to locate the device in space alongside internal gyroscope, accelerometer and mangnetometer solutions. The Oculus Rift DK2 needed adaption to allow space for the fNIRS optodes. Securing straps were changed—it was necessary to remove the ‘over-the-head’ strap of the oculus in order to ensure it was not in contact with probes of the NIRSport system. The remaining straps were removed and replaced

Fig. 1 Octave



with a buckled elastic strap. This helped to avoid issues caused by disturbance of probes when the HMD was put on. Due to the reduction of weight support across the top of the head, the HMDs weight was not being distributed comfortably when worn, with a moderate level of pressure on the end of the nose. In order to increase comfort, the frames of a pair of glasses were incorporated to improve support. Part of the top section of the HMD was cut away and edges were sanded to eliminate sharpness. The section removed was slightly larger than the length of a NIRSport standard probe in order to minimise chances of contact between HMD and probe during use. The lack of support across the forehead caused by removing a section of the HMD led to it leaning back toward the user at an inappropriate angle for use. Angled foam inserts combated this (Fig. 2).

Functional Near Infrared Spectroscopy (fNIRS)
In order to measure changes in cerebellar oxygenation this study utilised the NIRSport system. (NIRsPORT 8-8, NIRx Medizintechnik GmbH, Berlin, Germany) which is a portable, wearable, multichannel fNIRS system consisting of 8 LED illumination sources and 8 active detection sensors. Emitters were placed on positions F3, AF7, AF3, Fz, Fpz, AF4, F4, AF8, while detectors were placed on positions F5, F1, Fp1, AFz, F2, Fp2, F6. Twenty channels were set up covering the prefrontal cortex (Fig. 2). The source—detector distance was 3 cm. Optodes were placed on the participant's head using an EasyCap relative to the international 10/20 system (Jasper 1958). The data was acquired with the NIRStar acquisition Software (v2014 NIRx Medical Technologies LLC) at two near infra-red light wavelengths of 760 nm and 850 nm, with a sampling rate of 7.81 Hz (Fig. 3).

Fig. 2 Oculus Rift DK2 adapted for fNIRS

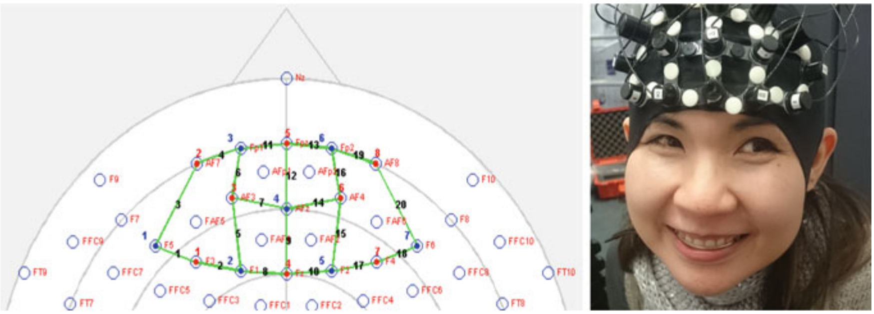


Fig. 3 fNIRS optode placement (*left*); participant wearing fNIRS device (*right*)

3.2 Procedure

Experiment 1

During the first stage of the experiment, both VR displays were combined with the NIRSport and were tested in terms of raw data quality through measuring Signal—To—Noise—Ratio (SNR). Visual inspection of the raw optical densities was carried out using NIRStar Software (version 2014, NIRx Medical Technologies LLC).

During initial investigations of fNIRS data quality in immersive environments, the Oculus Rift was tested using multiple programmes designed to elucidate a variety of movements.

Experiment 2

Further testing involved measuring hemodynamic response in the display which allowed more extensive natural movement—Octave. Eleven volunteers (N = 11, 4 females and 7 males, mean age 33.18, SD = 4.72) were recruited to walk on the virtual plank 6 meters above the floor in Octave. During the task, we recorded brain oxygenation changes from the prefrontal cortex as a neural index of emotional regulation.

Simulation
The scenario was created using Unity 4.3.3 game (https://unity3d.com/). The simulation in Octave was supported by MiddleVR 1.4.2 for unity (http://www.middlevr.com/middlevr-for-unity/).

The environment consisted of two rooms: the training room, which looked like a normal room with a floor and furniture, where participants familiarised themselves with the virtual environment and trained to carry out the task; and the pit room which had no floor but the wooden ledge on which participants stood and looked down into the pit room (which looks like an ordinary room with a floor and furniture) approximately 6 m below the plank.

3.3 Task

Prior to the experiment participants were allowed to familiarise themselves with the virtual environment and practice carrying out the task for about 5 min. During the experiment they were asked to perform a simple walking task. In the training room, (Fig. 4 right), the participant walked on the floor. In the pit room (Fig. 4 left), the participant walked on the virtual plank.

3.4 Design

The experiment employed a within-subject design. Each participant performed a task under two experimental conditions—training room and pit room. There were 10 trials split equally between the training room and pit room, with each trial lasting 30 s. A 30 s baseline was recorded prior to the first stimuli onset. During this participants were instructed to step on the actual floor outside of the simulation area in the training room, stay still, close their eyes, clear their mind and relax. After the

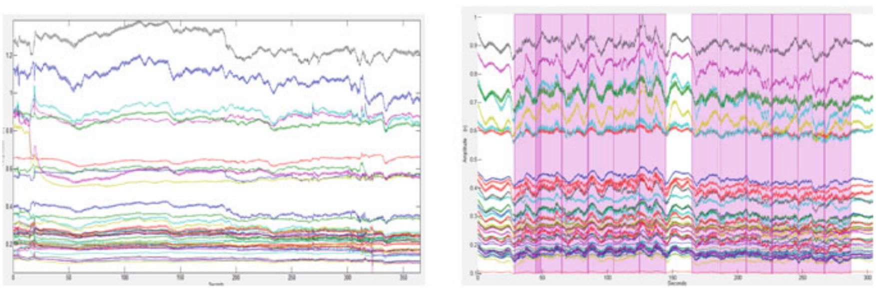


Fig. 4 Example time series acquired from combining fNIRS with custom oculus rift DK2 (*left*) and octave (*right*). Noise appears as rapid changes (such as spikes and steps)

baseline, participants heard pre-recorded audio instructions generated in random order, to move either to the training room or move to the pit room. The whole experiment lasted 330 s. We employed an event-related design where participants spent 30 s in the training room and 30 s in the pit room. There were no breaks between conditions.

3.5 Data Analysis

Raw time series were assessed in NIRStar Software (version 2014, NIRx Medical Technologies LLC) by calculating a SNR and performing visual inspection of the raw optical densities using the function 'check raw data' within the software. To calculate SNR, the relative coefficient of variation (CV) was calculated for each channel. Data with CV over 15% was removed from the analysis. Raw data was converted to average haemoglobin concentration changes using the modified Beer–Lambert law for each channel, each subject, and each condition. fNIRS data was preprocessed and analysed using NIRSLab (NIRx Medical Technologies version 2014). Oxy- (HbO) and deoxy—(HbR) haemoglobin time series were band-pass filtered with low cut-off frequency 0.01 Hz and high cut-off frequency 0.2 Hz to remove drifts and noise from the data. Many previous studies have shown that HbO correlates with BOLD signals better than the HbR (Hoshi et al. 2001), therefore this study focused on HbO for further analysis.

Statistical data analysis was performed using NIRSLab—SPM (SPM8). Data was modelled with GLM. Two regressors were generated by convolving the weighted task time series with the canonical hemodynamic response function provided by SPM8 (Friston et al. 1996). Discrete cosine transform basis functions were used for temporal filtering, and precoloring HRF was used for the serial correlations. On the next level analysis T-contrasts were created for HbO changes to generate statistical parametric maps of activation for two regressors: training room, and pit room, for each channel and each subject. SPM T-maps were generated by using two contrasts: training room-pit room and pit room-training room, and thresholded at $p < 0.05$ (corrected).

At the group analysis, SPM group ΔHbO T—statistics were calculated to identify the channels significantly activated with a significance level threshold set at $p < 0.5$ (corrected) according to the false discovery rate method FDR used in fMRI studies (Singh and Dan 2006). The estimated anatomical locations of each channel were determined using anatomical locations of international 10-10 system cortical projections of EEG sensors (Koessler et al. 2009; Okamoto and Dan 2005).

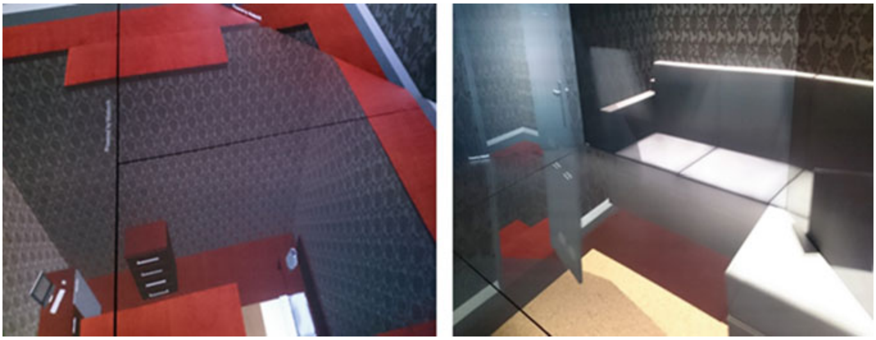


Fig. 5 Pit room experiment—view into the pit room (*left*), view in the training room (*right*)

4 Findings

4.1 SNR and Motion Artefact Analysis Results—Experiment 1

Figure 5 shows example raw time series data from a single subject acquired from both the Oculus—fNIRS test, and Octave—fNIRS test. SNR tests demonstrated that there was no significant signal interference from either VR.

Due to motion artifacts, 5% of the data was removed from the Oculus—fNIRS test, and 50% from Octave—fNIRS test.

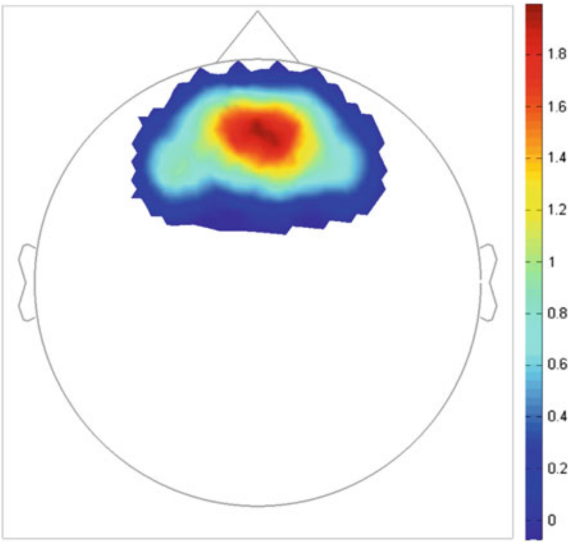
4.2 SPM Results—Experiment 2

Figure 6 shows the results for SPM group analysis (Pit room versus Training room). SPM contrast for group analysis (Pit room versus Training room) at the significance threshold level $p < 0.05$ (corrected) revealed no significant results. However, results showed a trend toward increased HbO in MPFC (channel 12, $t(4) = 1.99$, $p = 0.1175$, two-tailed) and DLPF (channel 15, $t(4) = 1.81$, $p = 0.1445$, two-tailed) when participants exposed to the virtual heights in the Pit Room in comparison to the Training Room.

5 Discussion and Lesson Learned

The main concern in this pilot study was possible interference between the display system, including its motion tracking equipment, and the fNIRS. We were particularly concerned that the near infrared light from motion tracking system in the

Fig. 6 SPM T-map of ΔHbO in the pit room versus training room. The t-value (unthresholded) is indicated by a *colour* scale



Octave and Oculus Rift would be picked up by the infrared sensors of the fNIRS. By measuring SNR and motion artifacts, this was proved an ungrounded assumption for both VR displays (Fig. 5).

Although fNIRS is less susceptible to motion artifacts than EEG and fMRI, still it is sensitive to sudden excessive movement. As an objective of this study was promoting freedom of movement in VR, the level of motion impact was investigated. On the one hand the Oculus Rift caused less motion artifacts, but it restricted freedom of movement to the head. Therefore motion artifacts were likely to have been caused primarily by optode displacement during putting the device on. On the other hand combining fNIRS and Octave caused more motion artifacts due to both the nature of the display system, as well as the experimental task itself. The data analysis revealed motion artifacts in the signal when people leant forward excessively. This was potentially a problem given the task encouraged this. However, such a level of bend did not arise from the experimental protocol, but rather participants wanting to experiment with the experience. Moreover, this study investigated how much movement is too much to keep data motion artefact free. While it was possible to remove such data, it is better practice to exclude all the data from the session.

Initially the measurement system was highly unstable. This came from the desire to maximise freedom of movement and approach. Physiological data can be communicated wirelessly from the sensors to the computer; however several technological issues, such as the data collection laptop overheating, and software crashes, were related to the high system requirements for brain data acquisition which requires a high-end laptop. The solution was to put the brain data acquisition laptop in a mesh backpack.

Table 1 Advantages and disadvantages in combining fNIRS with HMDs and IPT (Results of this study displayed in Italic)

Oculus	Octave
Movement restricted to that of the head	Allows movement around the space
Single user	Allows a group of people to mingle
Hides the presence of others	Doesn't hide presence of others
Doesn't allow natural embodiment	The user can see their own body
No risk of infrared light inference	*Higher risk of infrared light inference*
HMD can cause minimal motion artifact due to the sensor displacement	*IPT can cause motion artifact due to the freedom of movement within VR space*

The adaptations made to the Oculus Rift DK2 would be harder to achieve with the newer commercial versions of the Oculus. These contain wiring through the headband. It is important to note that the adapted Oculus Rift was a prototype. Further work needs to be carried out to fully integrate HMD based VR with neuroimaging methodologies. A potential solution is to utilise 3D printing techniques to incorporate an EEG/fNIRS cap into a specially designed HMD.

In conclusion, combining fNIRS with both VR displays offers new opportunities for the researchers. Both VR systems have their own pros and cons (summarised in Table 1). Therefore the selection of appropriate display should be determined by the experimental design and the research question.

6 Conclusions

Virtual Reality offers a solution for bridging the gap between ecological validity and controllability (Rey and Alcañiz 2010). Both ecological validity and controllability are important in VR and in neuroscience research, and applications that combine the two. This study proposed and tested a solution that integrates wireless brain imaging and two VR displays—a large IPT VR solution in which users can move more freely—Octave, and a custom fNIRS-adapted Oculus Rift. The results of our pilot study suggested trends that indicate the potential for this integration of technology to evoke emotional response within VR. We have demonstrated the feasibility of the study and resolved all technical problems.

Although this pilot study did no obtain statistically significant results due to the sample size, it identified promising trends showing that VR can trigger emotional regulation response which can be measured by a wireless brain imaging device. Results of our study demonstrated trends in increased haemoglobin oxygenation (HbO) in right MPFC and right DLPFC indicating emotional regulation processes in the brain when participants were exposed to evocative virtual stimulus. These results are consistent with previous neuroimaging studies using fMRI (Quirk and Beer 2006). However, this study did not constrain the natural movement of the participant in one of its conditions.

This pilot study lead to a further developed investigation. Since the reported investigation was conducted, the data collection for the full experiment with a larger sample was completed, and analysis is underway. This work opens the door to measuring close to surface medium resolution neural response, to virtual stimuli in which people can naturally look and walk around. This has the potential to improve ecological validity in applications ranging from neuroscience research to exposure therapy.

References

Ayaz, H., Shewokis, P. A., Curtin, A., Izzetoglu, M., Izzetoglu, K., & Onaral, B. (2011). Using MazeSuite and functional near infrared spectroscopy to study learning in spatial navigation. *JoVE (Journal of Visualized Experiments), 56,* e3443–e3443.

Baumgartner, T., Valko, L., Esslen, M., & Jäncke, L. (2006). Neural correlate of spatial presence in an arousing and noninteractive virtual reality: an EEG and psychophysiology study. *CyberPsychology & Behavior, 9*(1), 30–45.

Beer, J. S., Knight, R. T., & D'Esposito, M. (2006). Controlling the integration of emotion and cognition: the role of frontal cortex in distinguishing helpful from hurtful emotional information. *Psychological Science, 17*(5), 448–453. doi:10.1111/j.1467-9280.2006.01726.x.

Bohil, C. J. C., Alicea, B., & Biocca, F. a F. (2011). Virtual reality in neuroscience research and therapy. Nature Reviews. Neuroscience, 12(12), 752–62. http://doi.org/10.1038/nrn3122

Burgess, N., Maguire, E. A., Spiers, H. J., & O'Keefe, J. (2001). A temporoparietal and prefrontal network for retrieving the spatial context of lifelike events. *NeuroImage, 14*(2), 439–453. doi:10.1006/nimg.2001.0806.

Carvalho, K. N., Pearlson, G. D., Astur, R. S., & Calhoun, V. D. (2006). Simulated driving and brain imaging: combining behavior, brain activity, and virtual reality. CNS Spectrums, 11(1), 52–62. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/16400256.

Cruz-Neira, C., Sandin, D. J., DeFanti, T. A., Kenyon, R. V., & Hart, J. C. (1992). The cave audio visual experience automatic vortual environment. Portal.acm.org. Retrieved from https://www.evl.uic.edu/documents/cacm92-cave-cruz-neira.pdf.

Dores, A. R., Barbosa, F., Monteiro, L., Reis, M., Coelho, C. M., Rebeiro, E., et al. (2014). Amygdala activation in response to 2D and 3D emotion- inducing stimuli. *PsychNology Journal, 12*(1–2), 29–44.

Duval, E. R., Javanbakht, A., & Liberzon, I. (2015). Neural circuits in anxiety and stress disorders: a focused review. *Therapeutics and Clinical Risk Management, 11,* 115–126. doi:10.2147/TCRM.S48528.

Ferrari, M., & Quaresima, V. (2012). A brief review on the history of human functional near-infrared spectroscopy (fNIRS) development and fields of application. *NeuroImage, 63*(2), 921–935. doi:10.1016/j.neuroimage.2012.03.049.

Friston, K. J., Holmes, A., Poline, J. B., Price, C. J., & Frith, C. D. (1996). Detecting activations in PET and fMRI: levels of inference and power. *NeuroImage, 4*(3 Pt 1), 223–235. doi:10.1006/nimg.1996.0074.

Grimm, S., Schmidt, C. F., Bermpohl, F., Heinzel, A., Dahlem, Y., Wyss, M., et al. (2006). Segregated neural representation of distinct emotion dimensions in the prefrontal cortex—An fMRI study. *NeuroImage, 30*(1), 325–340. doi:10.1016/j.neuroimage.2005.09.006.

Holper, L., Muehlemann, T., Scholkmann, F., Eng, K., Kiper, D., & Wolf, M. (2010). Testing the potential of a virtual reality neurorehabilitation system during performance of observation, imagery and imitation of motor actions recorded by wireless functional near-infrared spectroscopy (fNIRS). *Journal of Neuroengineering and Rehabilitation, 7*(1), 57. doi:10.1186/1743-0003-7-57.

Hoshi, Y., Kobayashi, N., & Tamura, M. (2001). Interpretation of near-infrared spectroscopy signals: a study with a newly developed perfused rat brain model. Journal of Applied Physiology (Bethesda, Md. : 1985), 90(5), 1657–1662. http://www.ncbi.nlm.nih.gov/pubmed/11299252.

Irani, F., Platek, S. M., Bunce, S., Ruocco, A. C., & Chute, D. (2007). Functional near infrared spectroscopy (fNIRS): an emerging neuroimaging technology with important applications for the study of brain disorders. *The Clinical Neuropsychologist, 21*(1), 9–37. doi:10.1080/13854040600910018.

Jasper, H. H. (1958). The ten-twenty electrode system of the International Federation. *Electroencephalography and Clinical Neurophysiology, 10*(2), 371–375. doi:10.1016/0013-4694(58)90053-1.

King, J. A., Blair, R. J. R., Mitchell, D. G. V., Dolan, R. J., & Burgess, N. (2006). Doing the right thing: a common neural circuit for appropriate violent or compassionate behavior. *NeuroImage, 30*(3), 1069–1076. doi:10.1016/j.neuroimage.2005.10.011.

Koessler, L., Maillard, L., Benhadid, A., Vignal, J. P., Felblinger, J., Vespignani, H., et al. (2009). Automated cortical projection of EEG sensors: Anatomical correlation via the international 10-10 system. *NeuroImage, 46*(1), 64–72. doi:10.1016/j.neuroimage.2009.02.006.

Lange, K., Williams, L. M., Young, A. W., Bullmore, E. T., Brammer, M. J., Williams, S. C. R., et al. (2003). Task instructions modulate neural responses to fearful facial expressions. *Biological Psychiatry, 53*(3), 226–232. doi:10.1016/S0006-3223(02)01455-5.

Malik, S. H., Blake, H., & Suggs, L. S. (2014). A systematic review of Cybersickness. *British Journal of Health Psychology, 19,* 149–180. doi:10.1145/2677758.2677780.

Mathiak, K., & Weber, R. (2006). Toward brain correlates of natural behavior: fMRI during violent video games. *Human Brain Mapping, 27*(12), 948–956. doi:10.1002/hbm.20234.

Meehan, M., Insko, B., Whitton, M., & Brooks, F. P. (2002). Physiological measures of presence in stressful virtual environments. Proceedings of the 29th Annual Conference on Computer Graphics and Interactive Techniques—SIGGRAPH '02, 645. http://doi.org/10.1145/566570.566630.

Moro, S. B., Bisconti, S., & Muthalib, M. (2014). A semi-immersive virtual reality incremental swing balance task activates prefrontal cortex: A functional near-infrared spectroscopy study. *NeuroImage, 85,* 451–460. doi:10.1016/j.neuroimage.2013.05.031.

Ochsner, K. N., & Gross, J. J. (2005). The cognitive control of emotion. *Trends in Cognitive Sciences*. doi:10.1016/j.tics.2005.03.010.

Okamoto, M., & Dan, I. (2005). Automated cortical projection of head-surface locations for transcranial functional brain mapping. *NeuroImage, 26*(1), 18–28. doi:10.1016/j.neuroimage.2005.01.018.

Quirk, G. J., & Beer, J. S. (2006). Prefrontal involvement in the regulation of emotion: convergence of rat and human studies. *Current Opinion in Neurobiology, 16*(6), 723–727. doi:10.1016/j.conb.2006.07.004.

Rey, B., & Alcañiz, M. (2010). Research in Neuroscience and Virtual Reality. In Virtual Reality (pp. 377–394). http://doi.org/10.5772/13198.

Singh, A. K., & Dan, I. (2006). *NeuroImage, 33*(2), 542–549. doi:10.1016/j.neuroimage.2006.06.047.

Török, Á., Sulykos, I., Kecskés-Kovács, K., Persa, G., Galambos, P., Kóbor, A.& Honbolygó, F. (2014). Comparison between wireless and wired EEG recordings in a virtual reality lab: Case report. In 5th IEEE International Conference on Cognitive Infocommunications, CogInfoCom 2014—Proceedings (pp. 599–603). http://doi.org/10.1109/CogInfoCom.2014.7020414.

Telethrone Reconstructed; Ongoing Testing Toward a More Natural Situated Display

John O'Hare, Allen J. Fairchild, Robin Wolff and David J. Roberts

Abstract The concept of supporting ad hoc or dynamic membership tele-present meetings through pulling up a chair is novel. In real world business situations, people pull up a chair after catching the eye of someone already seated. Telethrone is a situated display on a chair which allows multiple correct views of a remote collaborator. The system has been expanded to support informal meetings where chairs can be moved around. This is facilitated through the novel integration of a 3D reconstructed model of a person, with live viewpoint dependent rendering onto a retro-reflective surface. This removes the need for painstaking alignment of multiple cameras and projectors each time a chair is moved. A between subjects experiment tested accuracy of reconnected mutual gaze mediated by part of the system. Subjectively easier and harder situations are compared. Specifically best and worst cases, both in terms of orientation of eyes in the reconstructed head, and angle of observer gaze onto the display. Discussion compares results to experiments that used other systems to attempt to convey eye gaze by different techniques. This research builds toward a scalable system for ad hoc business meetings; a paradigm poorly supported by current video conferencing. It is also applicable to supporting conversations between seated people in any scenario where seats might be moved, for example in interaction between client and therapist in tele-therapy.

Keywords Tele-presence · Situated display · Gaze · Retroreflective projection technology · Non-verbal cues · Multi-view

J. O'Hare (✉) · A.J. Fairchild
School of Computer Science and Engineering, University of Salford, Salford, UK
e-mail: j.ohare@salford.ac.uk

A.J. Fairchild
e-mail: a.j.fairchild1@salford.ac.uk

R. Wolff
Deutschen Zentrums Für Luft- Und Raumfahrt, Linder Höhe, 51147 Cologne, Germany
e-mail: Robin.Wolff@dlr.de

D.J. Roberts
School of Health Sciences, University of Salford, Salford, UK
e-mail: d.j.roberts@salford.ac.uk

T. Jung and M.C. tom Dieck (eds.), *Augmented Reality and Virtual Reality*,
Progress in IS, DOI 10.1007/978-3-319-64027-3_22

1 Introduction

The vision of this work, from tele-presence artist Paul Sermon, is of pulling up a chair after catching someone's eye; in teleworking just as the real world. The approach is to project various viewpoint dependent renders of the remote participant onto a chair that reflects each render in a separate retro-projection frustrum. The original Telethrone (O'Hare et al., 2016) was a chair covered in a retro-reflective material onto which 2D video streams showing the remote person from different perspectives were projected. The retroreflective material allows viewers from each pulled up chair to have their own perspective view. With chairs evenly distributed around the Telethrone, it should in principle also be possible to support mutual awareness between a telepresent seated person and a person walking past. *withyou* (Roberts et al. 2015, Fairchild et al. 2017) was a telepresence system that recreates a 3D CGI copy of a remote person that can be viewed from any perspective but was derived from multiple discrete 2D video streams. Before integration of *withyou*, the mona lisa effect meant that a pulled chair would need to exactly align to a remote camera if mutual gaze were to be supported. However, there are shortcomings of both the retro-reflected material and of free-viewpoint video, that might impact on estimation of gaze. Specifically, the retro-reflective material suffers image bleed between spatial channels, and free-viewpoint video introduces artifacts. As one descrete step in development we present an early prototype and pilot that test these combined shortcomings do not prohibit reasonable gaze estimation (Fig. 1).

Example of potential utility
To intuitively outline the utility of the new system to business users a hypothetical meeting is convened to discuss whether a project is likely to overrun. This meeting comes about without warning; an executive in the company is in the building on other business and gets into a conversation in the social space with a developer. The product owner who might be expected to oversee such matters is offsite but can be present through a single Telethrone which is installed in the space. The executive

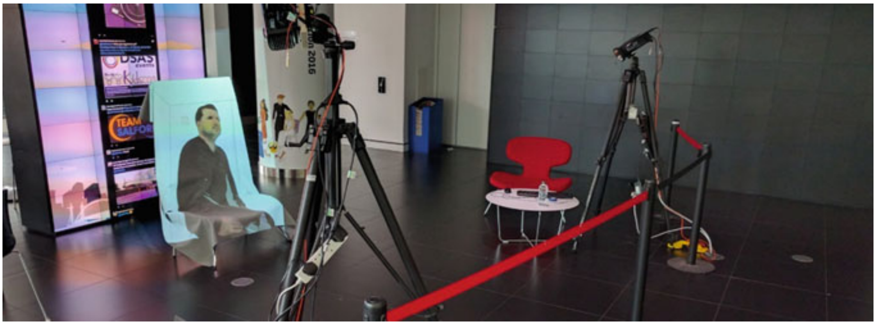


Fig. 1 Experimental deployment in a semi-public space, testing elements of the system

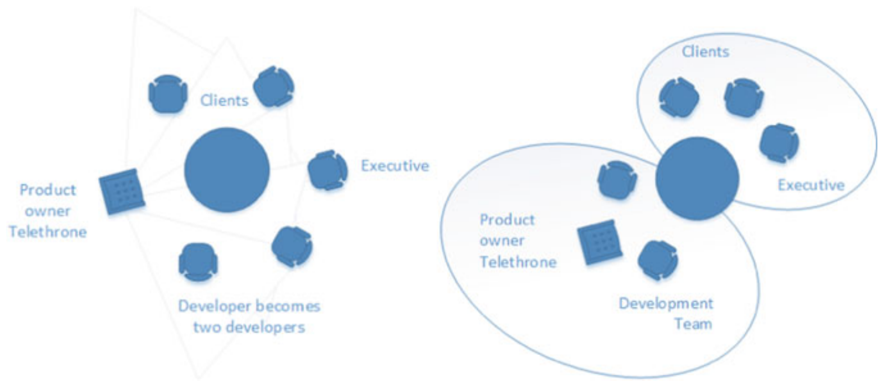


Fig. 2 A normal ad hoc business meeting evolves over time and is supported by the Telethrone (square chair)

invites two clients to join him. As the meeting begins another developer from the product team passes and is signalled to join by the tele-present product owner. Now five people are physically present in the space, while one is tele-present. The members of the meeting sit down and naturally cluster into two contiguous groupings: The two clients and the executive, and the three members of the product team. This distribution can be seen in Fig. 2. As the meeting evolves it becomes necessary for the product team to clarify a technical point amongst themselves. In the posited Telethone supported meeting it is possible for the two developers to form a 'huddle' with the product owner. This meeting sub group can fork the conversation, while the clients and executive continue with other matters. The described Telethrone system with tracking of the chairs and 3D reconstruction of the associated viewpoints can support this evolution of a meeting.

2 Literature Review

Communicating both attention and appearance has been a long standing challenge to computer supported collaborative working (Roberts et al. 2015). Telepresence solutions aimed at collaborative working have traditionally attempted to join remote spaces so that people in each can look into the other, seeing each other, at best, as if through a window (Roberts et al. 2015). Immersive Collaborative Virtual Environments (ICVE) have been used to join remote spaces so that they coincide (Roberts et al. 2003), and free-viewpoint video has been combined with immersive projection technology to allow people to move around spaces, seemingly together (Roberts et al. 2015). In ICVE's people in each space can have the appearance and feeling of moving around the other, however, true identity and facial expression are hard to communicate without restricting movement (Roberts et al. 2015).

Situated displays have attempted to give the impression of placing people within each other's room by contextualising the display, or engineering it such that the background of the remote setting is omitted (Oyekoya et al. 2012). In approaches to date, situated displays and capture equipment cannot be moved without painstaking alignment of cameras and projectors across the two spaces.

Human acuity in judgement of the eye gaze of others is high (Symons et al. 2004). This keen sense of gaze is important for group social interaction (Colburn et al. 2000). Gaze awareness does not just mediate verbal communication, but rather, is a complex channel of communication in its own right (Vertegaal et al. 2001) (Otsuka et al. 2005). It also governs those who are involved in the communication at any one time (Roberts et al. 2013). Physical communication channels extend beyond the face (Nguyen and Canny 2009) and include both micro (shrugs, hands and arms), and macro movement of the upper body (Ekman 1993). These conversational hand gestures augment verbal communication (Krauss et al. 1996). In multi-party conversation, body torque (the rotation of the trunk from front facing) can convey aspects of attention and focus (Schegloff 1998). Several decades of research and commercial activity in telecommunication and telepresence have failed to fully support transmission of all aspects of interpersonal communication (Roberts et al. 2015). Some non-verbal communication is supported in video-conferencing (VC) with limited success. The Mona Lisa effect means that in most systems both directional eye gaze and mutual eye gaze are unsupported (Vishwanath et al. 2005) (Loomis et al. 2008) as anyone looking into a camera appears to be making eye contact with all of the observers at the other end of the video channel. Commercial systems such as Cisco Telepresence Rooms cluster their cameras above the centre of three screens for meetings using their tele collaboration product. They admit that this only works well for the centrally seated observer and the brain must compensate for this (Wolff et al. 2008; Roberts et al. 2015). Therefore, in camera based telecommunication systems the angle offset from a camera "should be at most 1.2 degrees in horizontal direction, and 1.7 degrees in vertical direction to support eye contact" (Bock et al. 2008), otherwise the offset effect should be corrected. Nguyen and Canny demonstrated the Multiview system (Nguyen and Canny 2007) and observed similar task performance in face-to-face meetings based on trust tasks, while a similar approach without spatial segmented views of the remote participant was seen to negatively impact performance. They also found that "upper-body framing improves empathy measures" (Nguyen and Canny 2009). Pan, Steptoe and Steed found similar results with their spherical display, with a decrease in trust toward avatar mediated conversation when viewing 2D displays at oblique angles (Pan et al. 2014). Kim et al. demonstrate the Telehuman system, capable of conveying both the appearance and the direction of attention of a figure projected into a tube in 2D and 3D (Kim et al. 2012). There are several methods of reconstructing the human form as a computer model in real time. It is possible to create geometric models of the human form using a technique called shape from silhouette (Grau et al. 2007) in which multiple viewpoints from cameras allow algorithmic generation of a visual hull (Franco and Boyer 2003). 3D video has been successfully integrated into ICVE systems that use projectors to surround the user with a virtual environment (Roberts et al. 2015). Both spatiality and appearance of the remote collaborator are maintained, supporting complex interaction (Roberts et al. 2015). Situated displays place a representation of the remote user into a space, theoretically allowing all participants to physically interact with the 'contextual configurations' around them (Goodwin 2000). This is a relatively new field of research that includes Telepresence robots (Lee and Takayama 2011), Telehuman (Kim et al. 2012), head in a jar implementations such as SphereAvatar (Pan and Steed 2012), and Gaze Preserving Situated Multi-View Telepresence System (Pan et al. 2014). Telehuman is especially pertinent and brings the whole body of a standing remote user into a space via a cylindrical display with a single tracked observer viewpoint. Situated displays seek to embed the represented participant within the spatial and contextual framework of the conversation such that referential cues are better supported. This has many implications, but chief amongst these is support for a spatially faithful conversational environment supportive of gaze. SphereAvatar demonstrates that there are problems with accurate mapping, distortion, projection, and movement of the captured participants outside the limits of the capture volume (Oyekoya et al. 2012). Retro-reflective materials such as Chromatte(tm) cloth reflect light back along the angle of incidence (Tachi 2003). An everyday application of such material is high visibility jackets. They have previously been researched by Tachi for mutual tele-existence (Tachi et al. 2004). In their system the motion of users is mirrored by a tele-operated robot to which a retro-reflected view of the remote user's head is projected (from the head of the onlooking user). Krum et al. describe the REFLCT system (Krum et al. 2012) which uses large retro-reflective surfaces to "provide[s] users with a personal, perspective correct view of virtual elements that can be used to present social interactions with virtual humans". They also use helmet mounted projectors and describe a military training application in a large volume which allows faithful transmission of attention and gestures from the virtual to the real. They also briefly describe augmenting a facial mannequin by projecting onto retro-reflective projection technology (RPT) adhered to the surface. Importantly the material negates much of the effect of surface normals thereby presenting even light reflection regardless of deformations in the surface. They also point out that the optical characteristics of the material maintain polarisation and so could support passive stereoscopy. Room2room from Microsoft labs (Benko 2016) demonstrates the utility of projecting onto furniture. The system uses a Kinect 2.5D camera to capture a remote participant, and an overhead projector combined with a Kinect to projection map a viewpoint correct image of the tele-present person onto a complex surface such as a chair. However, this is a single static view-point. The literature does not explicitly engage with the potential for inviting passing parties to join a conversation. Additionally, there is poor support for dynamic shifts in seating within a meeting. The original Telethrone (O'Hare et al 2016) was a situated display with fixed positions at both locations. It was thus similar to SphereAvatar (Pan and Steed 2012) and Gaze Preserving Situated Multi-View Telepresence System (Pan and Steed 2014). In the paper it was argued that projection of a person onto furniture was likely to be less odd (or perhaps uncanny) and more familiar than seeing a head in a jar as with SphereAvatar, or a person in a tube as in Telehuman (Kim et al. 2012). The original Telethrone was tested with two spatially distinct moving images projected from live IP based video feeds but found the results for eye gaze reconnection inconclusive (O'Hare et al. 2016). *'withyou'* is an experimental capture and playback system which uses the octave multimodal suite (Roberts et al. 2015). This system uses shape-from-silhouette reconstruction (Duckworth and Roberts 2012) to send a full 3D video polygonal hull to another rendering location. Previous tests on the system suggested that the capture and playback made it possible to judge the eye gaze of the reconstructed subjects to within limits which underpin social interaction (Roberts et al. 2013). It was developed onward for a mixed reality system with multiple sites collaborating on shared data (Fairchild et al. 2017).

3 Methods

In order to assess if the 3D reconstruction and eye gaze elements (Roberts et al. 2015) work with the Telethrone (O'Hare et al. 2016) a limited experiment is undertaken where the chair is decoupled from the projector in order to check whether the system allows gaze discrimination. This experiment was inspired by (Kim et al. 2012) and (Roberts estimating eye gaze). By testing the harder case of gaze estimation as someone walks past, also gives some level of confidence that gaze would be supported if a chair was pulled to any point, the simpler case. The experimental setup demonstrates the feasibility of components of the system. This is an iterative step towards a complete system with multiple mobile chairs facing a Telethrone.

3.1 The Telethrone System

The new Telethrone concept moves toward simple support for social space deployments, engaging attention outside of the meeting group. Dynamic group membership might involve both someone walking toward or past and or pulling up a chair. The technology approach was to combine the earlier Telethrone situated display and *withyou* telepresence system. By doing so virtual cameras join the sets of real cameras and real projectors, removing the need for the two to have the same spatial arrangement. Viewpoint is rendered according to position of onlooker. This means tracking someone walking past, or tracking a seat that is moved up.

Further refinements of the *withyou* capture system have been undertaken for integration with Telethone. Better projection gives higher effective pixel density across the board. Vertical and horizontal resolution is around twice that previously available for the face and eyes throughout the capture and display pipeline. A new texturing technique is also employed which picks and applies the best texture for the viewpoint.

Additionally, the texturing camera is at eye level, which distortion demonstrated in (Roberts et al. 2015). The Telethrone image generator reconstructs a visual hull then the appropriate textures are selected and blended depending on the viewing angle supplied by the Vicon optical tracking system and associated VRPN software network transmission.

3.2 Experiment

The captured subject in Fig. 3 was asked to focus their attention away from their body centreline to marked points in the octave either 45 degrees to their right (best case condition) or 66.5 degrees to their right (worst case condition). This seemingly over accurate angle was chosen at it is a clearly seen location in the geometry of the capture system and was selected as the maximum one might expect to deviate from the body centreline in social conversation.

This reconstruction system has not previously been tested when projecting onto RPT so repeating an element of the *withyou* experiment in a way which tests the optical characteristics of the Chromatte cloth provides a firm foundation for further investigation. The captured model was played back through the two projectors seen in Fig. 1. The furthest projector was set to display a static frame of the reconstructed subject with them appearing to look directly at the projector, which would be a seat in the full Telethrone system. This provides an image on the surface which scatters 5% of incident light in all directions. This ghostly overlay is visible as an overlay on the other projected images (O'Hare et al. 2016). Walking participants are head tracked as they try to align to the eye gaze of a static reconstructed model that continuously adjusts for their head position. This is similar to methods employed in "Estimating the gaze of a virtuality human" (Roberts et al. 2013) and Telehuman (Kim et al. 2012).

Fig. 3 Capture of the subject in the octave system

3.3 Hypotheses

H1: that the ability of the experimental participants to judge the gaze direction of the reconstructed avatar is statistically similar to comparable experiments in literature in a best case experimental condition. Eyes are rendered in the centre of the head and directed toward the centre of the retro-reflected light cone. No discernible crosstalk from the second projector is visible in this condition.

H2: that the ability of the experimental participants to judge the gaze direction of the reconstructed avatar is significantly worse than the best case condition in a 'worst case' experimental condition. Head, body and eyes are all unaligned with respect to one another and the attention is directed to the edge of the retro-reflected light cone ensuring that cross talk occurs between the projectors.

3.4 Variables

The independent variable is how much the confederate deviates their view from their body centreline, alongside how central to the retro-reflected light cone their deflected view is.

In the best case condition the capture gaze, eyes and head are aligned. The reconstructed eye vector is central to the cone of reflected light from the Telethrone surface resulting in a clear image.

In the worst case condition the capture is combined head and eye gaze with the reconstructed eye vector to the edge of the cone of reflected light from the Telethrone surface. This increases the effect of the crosstalk.

The dependent variable is the angle offset from the correct simulated view vector which the participants settle on during the experiment.

3.5 Participants

n = 39 participants were recruited for a between subjects experiment with two conditions from Social VR 2016 workshop at MediaCityUK in Salford in line with ethical approval CST 15/03. The first 19 subjects performed the best case condition, while 21 subsequent attendees performed the worst case scenario.

3.6 Scope

In the current Telethrone prototype the projector is mounted behind and above the head of the seated onlooker as they view the Telethrone. This position generates a tracked viewpoint update. The whole system can be moved around the floor on wheels to take up a different viewpoint on the Telethrone. The prototype chair with these tracked projectors is currently unwieldy, so for the purposes of the experiment we tested a component where the tracking was decoupled from the projection. This allowed the participants to move unencumbered when finding their position of mutual eye gaze. This tests the readiness of the reconstruction for the broader Telethrone system. The utilisation of a static model, streamed from disk ensures repeatability.

3.7 Procedure

Each participant wore a tracked hat which presented their location to the renderer and the logging system. They were instructed to stand between the two projectors facing the Telethrone. In this location they were presented with a blend of two spatially distinct views onto the Chromatte cloth. They were requested to walk slowly along a line demarked by a barrier (shown in Fig. 1). This took them into the projection frustum of the projector displaying the reconstructed and tracked image, which was continuously rendered as perspective correct based upon the VRPN tracking data. The effect was that the participants gradually felt that they are walking more into the head and eye gaze of the projected subject (Fig. 4).

Fig. 4 Participant wearing the tracked hat, front view (*LHS*) and looking to the right (*RHS*). When they were satisfied that they were in the correct position, they signalled to the experimenter who immediately stopped the data logging to record their position.

4 Findings

For the best case condition n = 18 the deviation from correct angle is Mdn = −0.78 M = −0.50 StDev = 6.28 Q1 = −4.00 Q3 = 2.46. Shapiro-Wilk significance of 0.087 suggests that the data is normally distributed. For the worst case n = 21 the deviation from correct angle is Mdn = 8.27 M = 7.74 StDev = 4.48 Q1 = 3.78 Q3 = 10.86. Shapiro-Wilk significance of 0.419 indicates that the data is normally distributed.

Wilcoxon ranked signed comparison between conditions shows significant difference between accuracy in best and worst cases z = −2.765 p = 0.006 while an independent sample t-test likewise shows a difference with t = −4.769 p = 0.000. Fig. 5 shows box plots comparing the two conditions.

5 Discussion and Conclusion

All statistics were performed in SPSS comparing within the experiment and against the most similar experiments, Telehuman (Kim et al. 2012) and "Evaluating the gaze of a virtuality human" (Roberts et al. 2013). Differences in the final positions shown in Figs. 6a and b is potentially explained by the additional difficulty in resolving the eye component of the model (Fig. 7). All subjects stopped short of the correct position. Roberts et al. used an earlier version of the free viewpoint reconstruction system and projection into an immersive environment (Roberts et al. 2015).

When comparing to their paper 'estimating the gaze of a virtuality human' median and standard deviations were used to create box charts from the original data (Fig. 8). The rightmost bar labelled WORST is the worst case condition from the experiment while the bar to its immediate left R0L, the most analogous

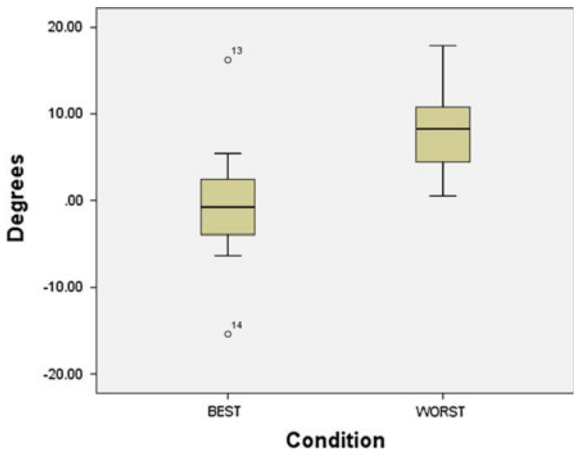


Fig. 5 Accuracy of the two conditions compared as a box plot. In the best case condition the median accuracy is very close while worst case consistently undershoots the target

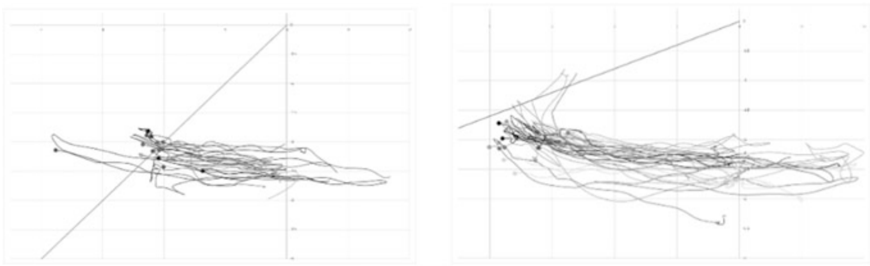


Fig. 6 The walking tracks of the 18 participants in 6a and the 21 participants in 6b trying to resolve the gaze deflected 45 and 66.5 degrees from the vertical axis respectively. Participants started on the right hand side and stopped at the dots to the left. Axes are meters. The positions for the worst case condition are all short of the line

(a) Best case condition (b) Worst case condition

Fig. 7 Best case view onto the Telethrone from 7a: 45 degrees from front head and eyes aligned, no image cross talk and 7b: 66.5 degrees from front, head and eyes not aligned, cross talk from the other spatial segment is visible

condition from the Roberts paper to WORST. R0L in Roberts et al. has eyes aligned forward in the head, and the head turned away from the body. R’RL in Roberts is eyes, head, and body not aligned. The left most bar labelled BEST is for the experimental best condition while the second bar R’RL is for the most analogous condition to BEST in Roberts et al. “estimating the gaze of a virtuality human”. The best case condition is analogous to Telehuman in their reported ‘looking at’ scenario where participants had to decide where they were being looked at. Telethrone has higher mean accuracy in the best case condition with 0.85 degrees compared to 5.2 degrees. Telehuman has a far better STDEV at 0.89 compared 6.27. The standard deviation of Telehuman is potentially lower as many more experimental runs were performed. Plots are both positive and negative rather

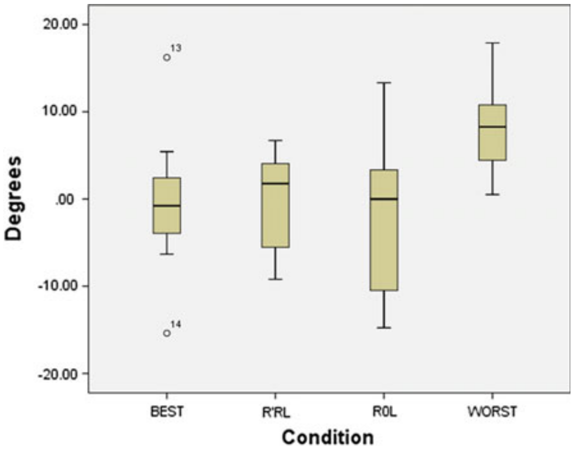


Fig. 8 Comparing to "Estimating the gaze of a virtuality human"

than absolute values as reported in Roberts' paper to examine directionality of the system. The mean angle of deviation of the Telethrone system in the best case condition compares well to Telehuman with a higher mean accuracy, and a standard deviation in the same range as the offset reported in Telehuman. Without access to the detailed Telehuman data it is hard to make detailed comparison. It is notable that the maximum negative deviation for the best case condition is less than the lower quartile deviation from the analogous condition in Roberts et al.'s experiment. Better quartile ranges in both best and worst case condition are suspected to be due to the better texturing method and higher resolution. Subject 14 complained that the system did not work for him and he could not seem to resolve the gaze at all. He made three passes through the correct eye vector. It is interesting that he was the tallest participant with the tracking data showing him to be approximately 15 cm taller than the mean height of 1.55 m for the group. While height might be a factor subject 13, the other outlier visible as a dark spot in the centre of Fig. 12a, was close to the mean height at 1.50 m.

The novel contribution of the paper is the presentation of an updated version of the Telethrone system, with tracked 3D video augmenting the spatial segmentation, as well as an experiment which builds toward a deployable system. In the experimental results the best case scenario compares well against "Estimating the gaze of a virtuality human" in the similar R0L condition, and against Telehuman in the 'Look at' condition. This satisfies H1 and clears the way for further integration with the Telethrone prototype and a behavioural test with multiple participants. In particular it is suspected that the better texturing approach gave higher accuracy and smaller inter quartile ranges over previous experiments. The worst case scenario satisfies the H2 assertion that the accuracy would be compromised with deflected eye gaze and cross talk. While this data demonstrates less accuracy it is by no means a broken system for the support of directional gaze. Given the properties of the retro-reflective material, the approach is locally scalable with up to 5 onlookers limited by the optical characteristics of the material (only 5 spatial segments are provided). Up to 6 Telethrones per site (6 connected sites of all Telethrones) are theoretically possible provided that multiple tracked and positioned avatars can be projected from a suitable high resolution projector taking in all seats from each Telethrone. Telethrone appears to support small ad hoc group meetings with dynamic participation and sub groups within a group. The simplicity of the system, its affordability, flexibility, and scalability seem to be appropriate for high traffic social spaces which is a less researched application for telepresence displays.

References

Bock, S. W., Dicke, P., & Thier, P. (2008). How precise is gaze following in humans? *Vision Research, 48*(7), 946–957.

Colburn, A., Cohen, M. F., & Drucker, S. (2000). The role of eye gaze in avatar mediated conversational interfaces. Sketches and Applications, Siggraph'00.

Duckworth, T. W., & D. J. Roberts. (2012). 3DRecon, a utility for 3D reconstruction from video. Joint Virtual Reality Conference of ICAT, EGVE and EuroVR

Duckworth, T., & Roberts, D. J. (2014). Parallel processing for real-time 3D reconstruction from video streams. *Journal of Real-Time Image Processing, 9*(3), 427–445.

Ekman, P. (1993). Facial expression and emotion. *American Psychologist, 48*(4), 384.

Fagel, S., Bailly, G., Elisei, F., & Lelong, A. (2010). October. On the importance of eye gaze in a face-to-face collaborative task. In *Proceedings of the 3rd international workshop on Affective interaction in natural environments* (pp. 81–86). ACM.

Fairchild, A. J., Campion, S. P., García, A. S., Wolff, R., Fernando, T., & Roberts, D. J. (2017). A mixed reality telepresence system for collaborative space operation. *IEEE Transactions on Circuits and Systems for Video Technology*, *27*(4), 814–827.

Goodwin, C. (2000). Action and embodiment within situated human interaction. *Journal of Pragmatics, 32*(10), 1489–1522.

Grau, O., Thomas, G. A., Hilton, A., Kilner, J. & Starck, J. (2007), May. A robust free-viewpoint video system for sport scenes. In *3DTV Conference, 2007* (pp. 1–4). IEEE.

Kim, K., Bolton, J., Girouard, A., Cooperstock, J., & Vertegaal, R. (2012). May. TeleHuman: effects of 3d perspective on gaze and pose estimation with a life-size cylindrical telepresence pod. In *Proceedings of the SIGCHI Human factors* (pp. 2531–2540). ACM.

Krauss, R. M., Chen, Y., & Chawla, P. (1996). Nonverbal behavior and nonverbal communication: What do conversational hand gestures tell us? *Advances in Experimental Social Psychology, 28,* 389–450.

Krum, D. M., Suma, E. A., & Bolas, M. (2012). Augmented reality using personal projection and retroreflection. *Personal and Ubiquitous Computing, 16*(1), 17–26.

Lee, M. K. and Takayama, L., 2011, May. Now, I have a body: Uses and social norms for mobile remote presence in the workplace. In *Proceedings of the SIGCHI conference on human factors in computing systems* (pp. 33–42). ACM.

Loomis, J. M., Kelly, J. W., Pusch, M., Bailenson, J. N., & Beall, A. C. (2008). Psychophysics of perceiving eye-gaze and head direction with peripheral vision: Implications for the dynamics of eye-gaze behavior. *Perception, 37*(9), 1443–1457.

Maimone, A. and Fuchs, H., 2011, October. Encumbrance-free telepresence system with real-time 3D capture and display using commodity depth cameras. In *Mixed and augmented reality (ISMAR), 2011 10th IEEE international symposium on* (pp. 137–146). IEEE.

Nguyen, D. T., & Canny, J., 2007, April. Multiview: improving trust in group video conferencing through spatial faithfulness. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 1465–1474). ACM.

Nguyen, D. T., & Canny, J. (2009). April. More than face-to-face: empathy effects of video framing. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 423–432). ACM.

O'Hare, J., Bendall, R. C. A., Rae, J., Thomas, G., Weir, B., & Roberts, D. J. (2016). Is this seat taken? behavioural analysis of the telethrone: A novel situated telepresence display. The Eurographics Association.

Otsuka, K., Takemae, Y., & Yamato, J. (2005). October. A probabilistic inference of multiparty-conversation structure based on Markov-switching models of gaze patterns, head directions, and utterances. In *Proceedings of the 7th international conference on Multimodal interfaces* (pp. 191–198). ACM.

Oyekoya, O., Steptoe, W., & Steed, A. (2012). May. SphereAvatar: A situated display to represent a remote collaborator. In *Proceedings of the SIGCHI conference on human factors in computing systems* (pp. 2551–2560). ACM.

Pan, Y., & Steed, A. (2012). October. Preserving gaze direction in teleconferencing using a camera array and a spherical display. In *3DTV-Conference: The true vision-capture, transmission and display of 3D video (3DTV-CON), 2012* (pp. 1–4). IEEE.

Pan, Y., Steptoe, W., & Steed, A. (2014, April). Comparing flat and spherical displays in a trust scenario in avatar-mediated interaction. In *Proceedings of the 32nd annual ACM conference on human factors in computing systems* (pp. 1397–1406). ACM.

Pejsa, T., Kantor, J., Benko, H., Ofek, E. and Wilson, A., 2016, February. Room2Room: Enabling life-size telepresence in a projected augmented reality environment. In *Proceedings of the 19th ACM conference on computer-supported cooperative work & social computing* (pp. 1716–1725). ACM.

Roberts, D., Wolff, R., Otto, O., & Steed, A. (2003). Constructing a Gazebo: supporting teamwork in a tightly coupled, distributed task in virtual reality. *Presence, 12*(6), 644–657.

Roberts, D., Duckworth, T., Moore, C., Wolff, R., & O'Hare, J. (2009, October). Comparing the end to end latency of an immersive collaborative environment and a video conference. In *Proceedings of the 2009 13th IEEE/ACM international symposium on distributed simulation and real time applications* (pp. 89–94). IEEE Computer Society.

Roberts, D. J., Fairchild, A. J., Campion, S. P., O'Hare, J., Moore, C. M., Aspin, R., et al. (2015). withyou—an experimental end-to-end telepresence system using video-based reconstruction Selected Topics in Signal Processing. *IEEE Journal of, 9*(3), 562–574.

Roberts, D. J., Rae, J., Duckworth, T. W., Moore, C. M., & Aspin, R. (2013). Estimating the gaze of a virtuality human. *IEEE Transactions on Visualization and Computer Graphics*, *19*(4), 681–690.

Steptoe, W., Wolff, R., Murgia, A., Guimaraes, E., Rae, J., Sharkey, P., ... & Steed, A. (2008, November). Eye-tracking for avatar eye-gaze and interactional analysis in immersive collaborative virtual environments. In *Proceedings of the 2008 ACM conference on computer supported cooperative work* (pp. 197–200). ACM.

Symons, L. A., Lee, K., Cedrone, C. C., & Nishimura, M. (2004). What are you looking at? Acuity for triadic eye gaze. *The Journal of General Psychology*, *131*(4), 451.

Tachi, S. (2003, May). Telexistence and retro-reflective projection technology (RPT). In *Proceedings of the 5th virtual reality international conference (VRIC2003)*, vol. 69 (pp. 1–69).

Tachi, S., Kawakami, N., Inami, M., & Zaitsu, Y. (2004). Mutual telexistence system using retro-reflective projection technology. *International Journal of Humanoid Robotics*, *1*(01), 45–64.

Vertegaal, R., van der Veer, G., & Vons, H. (2000, May). Effects of gaze on multiparty mediated communication. In *Graphics interface* (pp. 95–102).

Vertegaal, R., Slagter, R., Van der Veer, G., & Nijholt, A. (2001, March). Eye gaze patterns in conversations: there is more to conversational agents than meets the eyes. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 301–308). ACM.
Vishwanath, D., Girshick, A. R., & Banks, M. S. (2005). Why pictures look right when viewed from the wrong place. *Nature, 8,* 1401–1410.
Wolff, R., Roberts, D., Murgia, A., Murray, N., Rae, J., Steptoe, W., ... & Sharkey, P. (2008, October). Communicating eye gaze across a distance without rooting participants to the spot. In *12th 2008 IEEE/ACM international symposium on distributed simulation and real time applications (DS-RT 2008)* (pp. 111–118). IEEE.

A Survey of Drone use for Entertainment and AVR (Augmented and Virtual Reality)

Si Jung Kim, Yunhwan Jeong, Sujin Park, Kihyun Ryu and Gyuhwan Oh

Abstract This paper explores the use of drones for entertainment with the emerging technology of AVR (Augmented and Virtual Reality) over the past 10 years from 2006 to 2016. Drones, known as UAV (Unmanned Aerial Vehicle) or UAS (Unmanned Aircraft System), is an aircraft without a pilot or a person board also known as an unmanned aircraft. This paper focuses on drones with four sets of rotor blades, known as a Quadcopter, and how they are applied in the field of entertainment and AVR because their usages are getting expanding in science, commercial, or entertainment use. Industries and individuals began to see opportunities of drone technology and these days and it is expanding to the field of creating aerial immersive mixed reality. This paper introduces the overview of drones and characteristics of their usages in the field of entertainment and AVR areas.

Keywords Drone · UAV · Entertainment · Augmented reality · Virtual reality

1 Introduction

The word "drone" has referred to a male honeybee whose only role is to mate with the queen since Old English and it began branching out as a verb, meaning to buzz like a bee. Drone is also known as an unmanned aerial vehicle (UAV), an aircraft without a human pilot aboard and is often controlled by either a human operator or autonomously by onboard computers. So that, in computer science and artificial intelligence studies, they often call a drone as a remotely piloted vehicle (RPV), remotely operated aircraft (ROA), remote control helicopter (RC-Helicopter), or unmanned vehicle systems (UVS) (Eisenbeiss, 2004).

S.J. Kim (✉) · Y. Jeong · S. Park
University of Nevada, Las Vegas, USA
e-mail: si.kim@unlv.edu

K. Ryu · G. Oh
Ajou University, Suwon, South Korea
e-mail: drghoh@ajou.ac.kr

T. Jung and M.C. tom Dieck (eds.), *Augmented Reality and Virtual Reality*,
Progress in IS, DOI 10.1007/978-3-319-64027-3_23

Drones were designed and used for military purposes in the old days, especially during World War I and II. The hot air balloon was the very first attempt for drones. Austria used first unmanned bomb-filled balloons to attack Venice in 1849 (Franke, 2015). Nikola Tesla was the first person who was granted a patent (US Patent # 613809) in 1898 for what was likely the first remote control and unmanned aerial vehicle ever envisioned. The patent was entitled as “Method and Apparatus for Controlling Mechanics of Moving Vessels or Vehicles,” covered any type of vessel or vehicle which is capable of being propelled and directed, such as a boat, a balloon, or a carriage. Tesla was the first person to theorize, envision, and even patent a practical remote controlled robot or an unmanned vehicle, called teleautomation (Drones: a history of flying robots, n. d.).

Drones varied in shapes of airplane and helicopter through World War I and II. However, the drone, which normally has 4 rotors, became a popular choice since it was inexpensive and easy to use (Villbrandt, 2011). The society has begun to become familiar with a new drone technology, and many people started using drones for their own personal purposes resulting in using drones not only for military purpose, but also recreational and commercial purposes. For example Helicam, which is a remote controlled mini helicopter used to obtain aerial pictures or motion images, is widely used in nowadays and we can find its variety of different applications from the world’s largest video website, YouTube.

The largest theatrical Canadian entertainment company, Cirque du Soleil, designed a flying lamp show, called “SPARK”, with Swiss Federal Institute of Technology and ETH Zürich in 2014 (SPARKED: A Live Interaction Between Humans and Quadcopters, 2014). They used multiple drones that are hidden inside each of the lampshades with a performer to show a live interaction between humans and flying robots by telling the story of a lamp repairman who suddenly has to deal with a blown fuse at late night. By this live performance, Cirque du Soleil showed the possibility of applying drone technology into art and entertainment, and furthermore, we see future for drone technology in the performing arts and live entertainment.

In December 2014, the world’s largest non-profit organization dedicated to the advancement of unmanned system and robotics, AUVSI (the Association for Unmanned Vehicle Systems International) and AMA (the Academy of Model Aeronautics) worked on the educational campaign program called, “Know Before You Fly” with the FAA (the Federal Aviation Administration). This campaign educates and provides prospective UAS with the information and guidance they need to fly responsibly (Know Before You Fly’ UAS Safety Campaign Is Taking Flight, 2014). They explain and give examples of commercial and recreational use of UAS and then provide information and guidance so people can fly drones safely and responsibly (Unmanned Aircraft Systems, 2015). Also, the FAA published the rules of drone usage in the U.S. in February, 2015. This standard and safety regulations of drones are not only used in the US, but other counties also began to apply. In Canada, Transport Canada and the Office of the Privacy Commissioner of Canada studied drones and they published safety regulations for using drones in November, 2014 (The Review and Processing of an Application for a Special Flight

Operations Certificate for the Operation of an Unmanned Air Vehicle (UAV), 2014) (Office of the Privacy Commissioner of Canada, 2013).

It comes into request to study and research drones with augmented and virtual reality (AVR) since drones and AVR are becoming popular in public and its usage is greatly increasing for commercial, live shows, gaming, sports, and other entertaining purposes. This exploratory study includes how drones are used in entertainment with the emerging technology of AVR.

2 Objective and Method

The object of the study is to explore how drones are used in the field of entertainment and AVR and address their characteristics. We first classified the notion of entertainment into several different branches such as music, games, reading, performance, sport, and fairs and expositions then conducted multiple times of Internet searches for finding relevant articles. We took the same procedures for AVR. We found a total of 275 sources consisted of 100 general articles, 100 websites, and 75 research papers. Among these, we selected 47 sources that are most relevant to the goal of the study. These were 5 copyrights, 21 research papers, 16 videos, 4 articles, and 1 book chapter. Based on these 47 sources, we categorized the use of drones into three areas—live performance, music, and AVR. The 47 resources were categorized into 19 live shows, 2 music, 26 AVR. An independent coder was recruited and recorded results by using an excel spreadsheet.

3 Drones for Entertainment

3.1 Live Performance

There were 19 live performances that used single or multiple drones as they are listed in Table 1. One of the largest live theatrical producers Cirque de Soleil collaborated with ETH Zürich and produced a live drone show called, ‘SPARKED: A Live Interaction Between Humans and Quadcopters’ in 2014 shown in Fig. 1. In the live show, they put a performer in the middle of the flying drones that are shaped as lamps. The ‘Meet Your Creator—Quadrotor Show’ (Meet Your Creator—Quadrotor Show, 2012) was held at the Saatchi & Saatchi in 2012. They performed with quadrotors that are attached with mirrors and LED on the stage without any human shown in Fig. 2. The performance used multiple drones, meaning that the drones became the live actors of the performance and performed on behalf of the person or with a person while syncing their movements.

Table 1 Drones for live performance

	Title	Type	Year	Details	Note
1.	Aerial display system with floating pixels (Wong et al., 2014)	Patent	2014	Displayed light and floating pixels into drones	Virtual fireworks reproduction
2.	Aerial display system with floating projection screens (Stark et al., 2014)	Patent	2014	Making floating projection screens by using drones	Aerial screening
3.	Aerial display system with marionettes articulated and supported by airborne devices (Trowbridge et al., 2014)	Patent	2014	Controlling marionettes by using airborne drone	Marionettes performance
4.	Visual localization Of unmanned aerial vehicles based on marker detection and processing (Stark and Wong, 2015)	Patent	2014	Using marker detection to visual localize of drones	
5.	Synchronizing the motion of a quadcopter to music (Schöllig et al., 2010)	Paper	2010	Drones dance with music by using motion sense	Drone dance performance
6.	A platform for dance performances with multiple quadrocopters (Schoellig et al., 2012)	Paper	2010	Motion is controlled by music	Drone dance performance
7.	Feasibility of motion primitives for choreographed quadrocopter flight (Schöllig et al., 2011)	Paper	2011	Create a virtual tool for drone motion verification and drone performance	Drone performance
8.	Quadrocopter ball juggling (Müller et al., 2011)	Paper	2011	Quadcopter juggles balls by itself	Drone circus performance
9.	A flying inverted (Hehn and D'Andrea, 2011)	Paper	2011	Drones balance an inverted pendulum	Drone circus performance
10.	Cooperative quadrocopter ball throwing and catching (Ritz et al., 2012)	Paper	2012	Quadcopter throw and receive balls by using nets	Drone circus performance
11.	Quadrocopter pole acrobatics (Brescianini et al., 2013)	Paper	2013	Two quadcopters balance an inverted pendulum and launching it off the vehicle and catching it	Drone circus performance
12.	Dance of the flying machines: methods for designing and executing an aerial dance choreography (Augugliaro et al., 2013)	Paper	2013	Drones fly and dance	Drone dance performance
13.	Quadrocopter ball juggling, ETH zurich (Quadrocopter Ball Juggling, ETH Zurich, 2011)	Video	2011	Quadcopter juggles ball	Drone circus performance
14.	Robot quadrotors perform james bond theme (Robot Quadrotors Perform James Bond Theme, 2012)	Video	2012	Quadcopter perform 007 james bond theme song	Drone music performance

(continued)

Table 1 (continued)

	Title	Type	Year	Details	Note
15.	Meet your creator—quadrotor show (Meet Your Creator—Quadrotor Show, 2012)	Video	2012	Performance using drones, mirrors, and lights	Drone art performance
16.	Quadrocopter pole acrobatics (Quadrocopter Pole Acrobatics, 2013)	Video	2013	Two quadcopters balance an inverted pendulum and launching it off the vehicle and catching it	Drone circus performance
17.	The beautiful choreography of dancing drone lamps, SPARKED: A live interaction between humans and quadcopters (SPARKED: A Live Interaction Between Humans and Quadcopters, 2014)	Video	2014	Performance between a performer and quadcopters that are lampshade	Live performance of human and drone
18.	Flying robot rockstars (Flying Robot Rockstars, 2014)	Video	2014	Flying drones play music instruments	Drone music performance
19.	So you think you can dance? rhythmic flight performances with quadrocopters (Schoellig et al., 2014)	Book	2014	Article about dancing drone and present a set of algorithms that enable quadrotor vehicles and shows flight performance of multiple quadcopter timed to music	Drone dance performance

Fig. 1 SPARKED: A live interaction between humans and quadcopters (“SPARKED,” 2014)

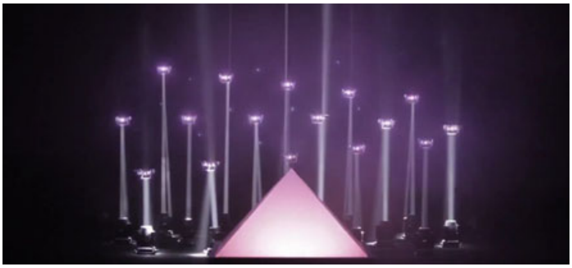


Fig. 2 Meet your creator—quadrotor show (“Meet Your Creator,” 2012)

Table 2 Two sources related to the music of the drone

	Title	Type	Year	Details	Note
1.	Robot quadrotors perform james bond theme (Robot Quadrotors Perform James Bond Theme, 2012)	Video	2012	Playing 007 pames bond theme by using quadrotors	Drone music performance
2.	Flying robot rockstars (Flying Robot Rockstars, 2014)	Video	2014	Flying Drones Play Musical Instruments	Drone music performance

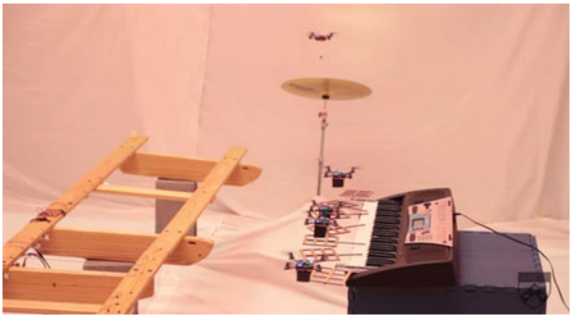


Fig. 3 Robot quadrotors perform james bond theme ("Robot Quadrotors," 2012)

Fig. 4 Flying robot rockstars ("Flying robot rockstars," 2014)

3.2 *Music*

There were two cases used drones in music shown in Table 2. Drones in music are similar to the drones used in the live performances in that both drones perform in front of the audience as human performer. From the 47 sources, only two showed that drone can be used in music. Kumar from the GRASP (General Robotics, Automaton, Sensing and Perception) Lab at the University of Pennsylvania presented drones that play musical instruments in TED 2012 (Kumar, 2012). He introduced the definition and history of a drone as well as showed an example of robotic music that is played by swarm drones as shown in Fig. 3. KMel Robotics that is acquired by Qualcomm presented drones performing music in 2014. There are eight hexacopters playing a single string guitar, a drum, and bells as shown in Fig. 4. These eight hexacopters also performed a live performance in the USA Science and Engineering Festival that was held in Washington, D.C.

4 Augmented and Virtual Reality (AVR) Field

Parrot, a French company introduced a first popular recreational quadcopter called, AR Drone shown in Fig. 5 at the CES 2010 Trade Show held in Las Vegas (CES 2010: Parrot AR. Drone allows video games to become reality, 2010). The user can control the drone using their mobile devices such as a smart phone via an onboard Wi-Fi network. The drone is equipped with two cameras, one on the front and the other on the bottom, and transmits live video to the user's device over the wireless network. It overlays computer graphics such as monsters to shoot at. Airgonay, a French drone club, used the first person view (FPV) flying to turn our imagination into their reality. Airgonay organized a drone racing in a forest for lightweight drones that bob, weave, and generally fly at up to 40 miles per hour, which reminds people of Star Wars: Episode I pod race (FPV Racing drone racing star wars style Pod racing are back, 2014) as shown in Fig. 6. They connected a camera into a wireless video goggles to see an entire eyesight from the drone to make it look like they are really racing. People use drones to film their activities and drones itself can become a tool of playing sports instead of a human player. As mentioned earlier, FPV flying is beneficial in showing people their surrounding environment or scenery and extensively it can also be used for new perspective of tourism. The primary advantage of using drones in tourism is allowing to explore places virtually before they actually visit the location as shown in Fig. 7. Under the concept, people can see and study places that are forbidden and further experience the places virtually (Drones in Tourism, The New Partner for Aerial Videos, 2014).

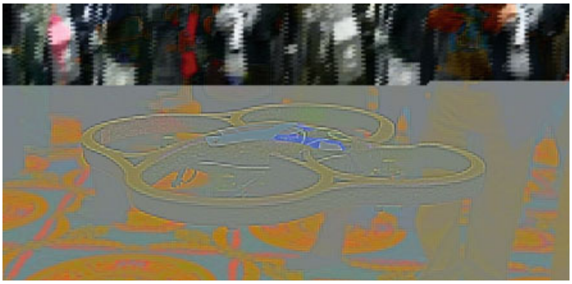


Fig. 5 Parrot's AR. Drone having a demonstration in CES ("CES," 2010)

Fig. 6 Star Wars pod racing using drones ("FPV Racing Drone Racing Star Wars," 2014)

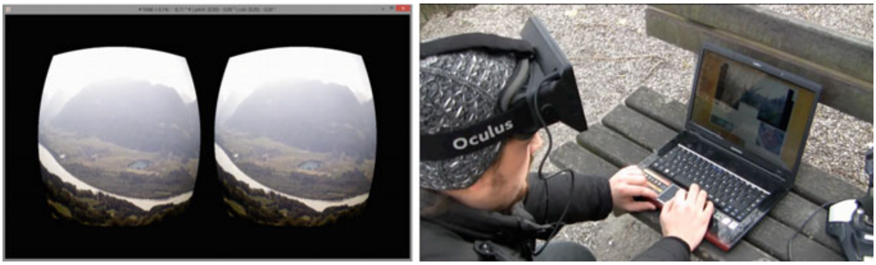


Fig. 7 Using drones for virtual tourism ("Drones in Tourism," 2014)

In the field of AVR, a total of 26 sources were found as they are listed in Table 3. It looks like the applications for AVR with drones have been popular after Parrot introduced their first augmented reality drone, called AR Drone in the CES 2010. Most projects were conducted with augmented reality, not with virtual reality. Drones with AVR are used in a wide range of applications such as agriculture, construction, surveying, and education. There was only one source that introduced

Table 3 26 sources related to drones in the filed of AVR

	Title	Type	Year	Details	Note
1.	CES 2010: Parrot AR. Drone allows video games to become reality (CES 2010: Parrot AR. Drone allows video games to become reality, 2010)	Article	2010	French company Parrot introduced AR. Drone at CES 2010	AR demo
2.	Augmented reality for drones (Augmented reality for drones, 2015)	Article	2015	Integrate augmented reality objects into the video stream of the drones	AR/MR technology
3.	Drones and augmented reality—powerful tools when disaster strikes (Drones and augmented reality—powerful tools when sisaster strikes, 2016)	Article	2016	Use of drones and augmented reality in disaster situations	AR safety map
4.	Air hogs connect: mission drone debuts with augmented reality game (Takahashi, 2016)	Article	2016	immersive augmented reality game	AR/MR game
5.	Video System for Piloting a Drone in Immersive Mode (Seydoux and Florentz, 2016)	Patent	2016	Patent for detecting a change in head direction of a user wearing a virtual reality glasses by an unmanned aircraft	VR technology

(continued)

Table 3 (continued)

	Title	Type	Year	Details	Note
6.	Parrot AR. Drone: augmented reality video games demo (Parrot AR.Drone : Augmented Reality Video Games Demo, 2010)	Video	2010	Parrot 's AR. drone and games with augmented reality	AR/MR demo game
7.	AR. Race: 1,2,3 … GO! (AR. Race: 1,2,3… GO!, 2012)	Video	2012	A video about the game that allows you to enjoy racing with the Parrot's AR. Drones	AR game
8.	NEW GAME—AR. Rescue Free App! (NEW GAME—AR.Rescue Free App!, 2012)	Video	2012	AR. Rescue is a single player augmented reality shooting and piloting game	AR/MR game
9.	AR. Drone localization with visual markers (AR. Drone localization with visual markers, 2013)	Video	2013	Marker-based augmented reality experiment using AR. Drone	AR demo
10.	Star Wars pod racing, using drone (FPV Racing drone racing star wars style Pod racing are back!, 2014)	Video	2014	Experience of Star Wars' aircraft racing using FPV Drone	VR Game
11.	Augmented reality & drones: decrease indoor crashes with SLAM (Augmented Reality & Drones: decrease indoor crashes with SLAM, 2015)	Video	2015	Drone manipulation system through augmented reality	AR demo technology
12.	Augmented reality map for DJI drones—hivemapper (Augmented reality map for DJI drones—Hivemapper, 2016)	Video	2016	Fly with hivemapper for DJI is a map app for DJI's drone	AR map
13.	Walkera aibao drone MR gaming mode operation video (Walkera Aibao Drone MR Gaming Mode Operation Video, 2016)	Video	2016	Virtual and augmented reality game with walkera's aibao drones and exclusive app	AR/VR/MR game
14.	Evaluation of synthetic vision overlay concepts for UAV sensor operations: landmark cues and picture-in-picture (Draper et al., 2006)	Paper	2006	A study on the augmented reality interface of military drone	AR
15.	Flying augmented reality (Koch et al., 2011)	Paper	2011	Visualization of planning models and simulation results by mixed reality methods using drone and pattern recognition	AR/MR simulation technology
16.	Multi-source information fusion augmented reality benefited decision-making for unmanned aerial vehicles (Cai et al., 2011)	Paper	2011	Study of multi-source sensor fusion method of augmented reality for UAV operators	AR technology

(continued)

Table 3 (continued)

	Title	Type	Year	Details	Note
17.	Mixed reality simulation framework for multimodal remote sensing (Burgbacher et al., 2011)	Paper	2011	A study on aerial surveying through drones and simulation of mixed reality	AR/MR simulation technology
18.	Flying a drone in a museum (Thon et al., 2013)	Paper	2013	Creation of augmented reality game using drones based on the arlaten museum in france	AR/VR game
19.	Using drones for virtual tourism (Mirk and Hlavacs, 2014)	Paper	2014	Real-time virtual tour using camera-equipped drones	VR virtual tour
20.	KinecDrone: enhancing somatic sensation to fly in the sky with kinect and AR. Drone (Ikeuchi et al., 2014)	Paper	2014	A study on the experience of virtual reality in the sky using Kinect, Oculus lift and AR. Drone	VR technology
21.	The use of gaze to control drones (Hansen et al., 2014)	Paper	2014	Study of gaze-based control modes for drones	AR/VR/MR demo technology
22.	FlyAR: Augmented reality supported micro aerial vehicle navigation (Zollmann et al., 2014)	Paper	2014	Flight support AR navigation and interface of MUAV	AR demo technology
23.	A virtual reality system to monitor and control diseases in strawberry with drones: A project (Rieder et al., 2014)	Paper	2014	Proposal of strawberry cultivation management system using drones and virtual and augmented reality interface	AR/VR agriculture technology
24.	Mixed reality for robotics (Honig et al., 2015)	Paper	2015	A study on robotic simulation in mixed reality environment using drones	AR/MR simulation technology
25.	Real-time unmanned aerial vehicle 3D environment exploration in a mixed reality environment (Ai et al., 2016)	Paper	2016	Study of human robot interaction system for real-time 3D environment exploration with an UAV via mixed reality environment	AR/VR/MR technology
26.	Quadcopter navigation using google glass and brain computer interface (Zhang and Jackson, 2015)	Paper		Development of a wearable system for drone navigation using google glass	VR

the combination of real images and virtual objects for drones. It was a study for interfacing Air Force's unmanned aerial vehicle, which is slightly different from the concept of current entertainment augmented reality (Draper et al., 2006). Spin Master has launched the Air Hogs Connect Mission Drone shown in Fig. 8, which combines the drone with augmented reality game. It is an immersive augmented reality game experience where players fly drones in an interactive 3D digital universe (Takahashi, 2016).

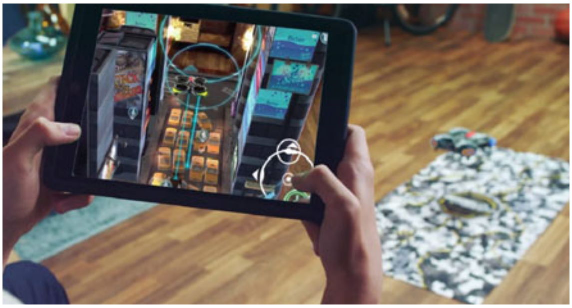


Fig. 8 Augmented reality game air hogs connect: mission drone (Takahashi, 2016)

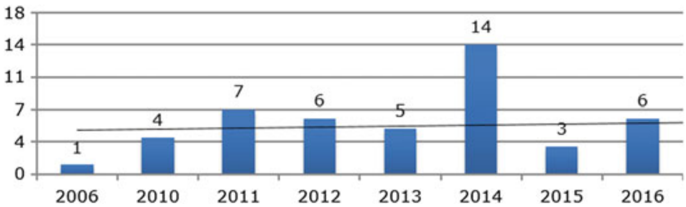


Fig. 9 The use of drones in the field of entertainment and AVR from 2006 to 2016

5 Discussion and Conclusion

The use of drones for entertainment and AVR over the past 10 years from 2006 to 2016 is shown in Fig. 9. There was only one case used drones in 2006, four cases in 2010, seven cases in 2011, six cases in 2012, five cases in 2013, 14 cases in 2014, three cases in 2015, and six cases in 2016. Looking at the trend line displayed in the graph as a solid straight line, it seems that drones are being used more and more over the almost one decade. It is interesting to see why there were more drones used in 2014 compared to the other years. It is our assumption that the TED 2012 introduced drones and their applications and it would influence and trigger the applications of drones for the next years.

We wanted to know how drones were used in the live entertainment. Figure 10 shows the use of them in three different live entertainment areas—Live Shows/Performance, Music, and AVR (Augmented and Virtual Reality). As seen in the figure, drones are used in the field of live shows most, then music, and AVR.

In summary, this paper explored the use of drones in entertainment and AVR. Drones are being used increasingly for live performance and AVR. The use of drones in live entertainment and AVR is no longer a novel approach. However, it is still in early stage as the number of applications are low. It is our conjecture that use of drones will expand explosively, especially for the applications of AVR. It is our belief that the use of drones in entertainment and AVR has great potential and it will become more popular in the field of creative media, interactive tourism, and live entertainment.

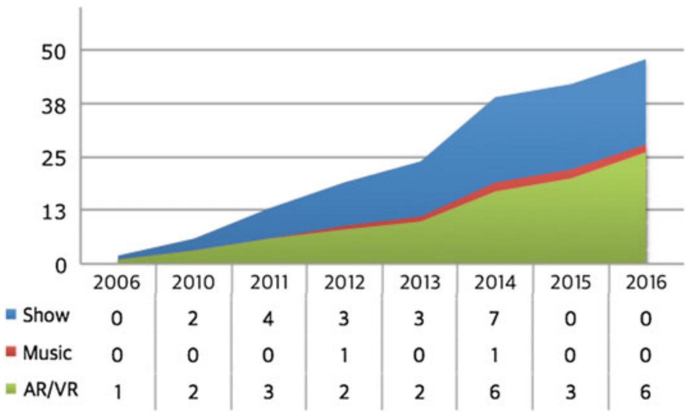


Fig. 10 The use of drones in live entertainment

References

Ai, Z., Livingston, M. A., & Moskowitz, I. S. (2016). Real-time Unmanned Aerial Vehicle 3D Environment Exploration in a Mixed Reality Environment. In *2016 International Conference on Unmanned Aircraft Systems (ICUAS)* (pp. 664–670).

AR. Drone localization with visual markers. (2013). Retrieved from https://vimeo.com/66909596.

AR.Race: 1,2,3… GO! (2012). Retrieved from https://www.youtube.com/watch?v=Faww1TMs2n8.

Augmented Reality & Drones: decrease indoor crashes with SLAM. (2015). Retrieved from https://www.youtube.com/watch?v=qxoXxXxdbOM.

Augmented Reality Map for DJI Drones—Hivemapper. (2016). Retrieved from https://www.youtube.com/watch?v=EaxkIwYxKuk.

Augmented reality for drones. (2015). *Phys.org*. Retrieved from http://phys.org/news/2015–04-augmented-reality-drones.html.

Augugliaro, F., Schoellig, A. P., & D'Andrea, R. (2013). Dance of the flying machines: Methods for designing and executing an aerial dance choreography. *IEEE Robotics and Automation Magazine, 20*(4), 96–104.

Brescianini, D., Hehn, M., & D'Andrea, R. (2013). Quadrocopter pole acrobatics. In *2013 IEEE/RSJ International Conference on Intelligent Robots and Systems* (pp. 3472–3479).

Burgbacher, U., Steinicke, F., & Hinrichs, K. (2011). Mixed Reality Simulation Framework for Multimodal Remote Sensing.

Cai, Z., Chen, M., & Yang, L. (2011). Multi-source Information Fusion Augmented Reality Benefited Decision-making for Unmanned Aerial Vehicles. In *2011 6th IEEE Conference on Industrial Electronics and Applications* (pp. 174–178).

CES 2010: Parrot AR. Drone allows video games to become reality. (2010).

Draper, M., Calhoun, G., & Nelson, J. (2006). *Evaluation of synthetic vision overlay concepts for UAV sensor operations: landmark cues and picture-in-picture*.

Drones and Augmented Reality -Powerful Tools when Disaster Strikes. (2016). Retrieved from http://www.suasnews.com/2016/10/drones-augmented-reality-powerful-tools-disaster-strikes/.

Drones in tourism, the new partner for aerial videos. (2014). Retrieved from https://tourismembassy.com/en/news/tourism-trends/drones-in-tourism-the-new-partner-for-aerial-videos.

Drones: a history of flying robots. (n. d.). Retrieved from http://www.nesta.org.uk/drones-history-flying-robots.

Eisenbeiss, H. (2004). A mini unmanned aerial vehicle (UAV): System overview and image acquisition. *International Archives of Photogrammetry. Remote Sensing and Spatial Information Sciences*, *36*(5/w1).

Flying Robot Rockstars. (2014).

FPV Racing drone racing star wars style Pod racing are back! (2014). Retrieved from https://www.youtube.com/watch?v=ZwL0t5kPf6E.

Franke, U. E. (2015). *Civilian Drones: Fixing an Image Problem?*

Hansen, J. P., Alapetite, A., MacKenzie, I. S., & Møllenbach, E. (2014). The Use of Gaze to Control Drones. In *Proceedings of the ACM Symposium on Eye Tracking Research and Applications* (pp. 27–34).

Hehn, M., & D'Andrea, R. (2011). A flying inverted pendulum. In *2011 IEEE International Conference on Robotics and Automation* (pp. 763–770).

Honig, W., Milanes, C., Scaria, L., Phan, T., Bolas, M., & Ayanian, N. (2015). Mixed Reality for Robotics. In *2015 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)* (pp. 5382–5387).

Ikeuchi, K., Otsuka, T., Yoshii, A., Sakamoto, M., & Nakajima, T. (2014). KinecDrone: Enhancing Somatic Sensation to Fly in the Sky with Kinect and AR Drone. In *Proceedings of the 5th Augmented Human International Conference* (p. 53).

"Know Before You Fly" UAS Safety Campaign Is Taking Flight. (2014). Retrieved from http://www.pobonline.com/articles/97492-know-befor.

Koch, V., Ritterbusch, S., Kopmann, A., Müller, M., Habel5, T., & Both, P. von. (2011). Flying Augmented Reality. In *Proceedings of the 29th eCAADe conference* (pp. 843–849).

MEET YOUR CREATOR—QUADROTOR SHOW. (2012). Retrieved from https://www.youtube.com/watch?v=cseTX_rW3uM.

Mirk, D., & Hlavacs, H. (2014). Using Drones for Virtual Tourism. In *Intelligent Technologies for Interactive Entertainment* (pp. 144–147).

Müller, M., Lupashin, S., & D'Andrea, R. (2011). Quadrocopter ball juggling. In *2011 IEEE/RSJ International Conference on Intelligent Robots and Systems* (pp. 5113–5120).

NEW GAME – AR Rescue Free App! (2012). Retrieved from https://www.google.co.in/search?q=https%3A%2F%2Fwww.youtube.com%2Fwatch%3Fv%3Dp+53V11Ph9sc&ie=utf-8&oe=utf-8&client=firefox-b&gfe_rd=cr&ei=TgRqWbWiM-3x8Afr4Yy4Dw.

Office of the Privacy Commissioner of Canada. (2013). *Drones in Canada*. Retrieved from https://www.priv.gc.ca/media/1760/drones_201303_e.pdf.

Parrot AR.Drone : Augmented Reality Video Games Demo. (2010).

Quadrocopter Ball Juggling, ETH Zurich. (2011). Retrieved from https://www.youtube.com/watch?v=3CR5y8qZf0Y.

Quadrocopter Pole Acrobatics. (2013). Retrieved from https://www.youtube.com/watch?v=XxFZ-VStApo.

Rieder, R., Pavan, W., Maciel, J. M. C., Fernandes, J. M. C., & Pinho, M. S. (2014). A Virtual Reality System to Monitor and Control Diseases in Strawberry with Drones: A project. In *7th International Congress on Environmental Modeling and Software*. San Diego, CA, USA.

Ritz, R., Müller, M. W., & Hehn, M. (2012). Cooperative quadrocopter ball throwing and catching. In *2012 IEEE/RSJ International Conference on Intelligent Robots and Systems* (pp. 4972–4978).

Kumar, V. (2012). Robots that fly … and cooperate. TED Talk.

Robot Quadrotors Perform James Bond Theme. (2012). Retrieved from https://www.youtube.com/watch?v=_sUeGC-8dyk.

SPARKED: A Live Interaction Between Humans and Quadcopters. (2014). Retrieved from https://www.youtube.com/watch?v=6C8OJsHfmpI.

Schoellig, A. P., Augugliaro, F., & D'Andrea, R. (2012). A Platform for Dance Performances with Multiple Quadrocopters. *Improving Tracking Performance by Learning from Past Data*, 147–164.

Schoellig, A. P., Siegel, H., Augugliaro, F., & D'Andrea, R. (2014). So you think you can dance? Rhythmic flight performances with quadrocopters. *Controls and Art* (pp. 73–105).

Schöllig, A., Augugliaro, F., & Lupashin, S. (2010). Synchronizing the motion of a quadrocopter to music. *Robotics and Automation (ICRA)*, (2010 IEEE International Conference on), 3355–3360.

Schöllig, A., Hehn, M., & Lupashin, S. (2011). *Feasiblity of motion primitives for choreographed quadrocopter flight*. In Proceedings of the 2011 American Control Conference (pp. 3843–3849).

Seydoux, H., & Florentz, G. (2016). Video System For Piloting A Drone In Immersive Mode. Washington, DC: U.S. Patent and Trademark Office.

Stark, J. A., & Wong, C. (2015). *Visual localization of unmanned aerial vehicles based on marker detection and processing*. US: Washington, DC: U.S. Patent and Trademark Office.

Stark, J. A., Trowbridge, R. S., & Wong, C. (2014). *Aerial display system with floating projection screens*. US: Washington, DC: U.S. Patent and Trademark Office.

Takahashi, D. (2016). Air Hogs Connect: Mission Drone debuts with augmented reality game. *VentureBeat*. Retrieved from http://venturebeat.com/2016/11/01/air-hogs-connect-mission-drone-debuts-with-augmented-reality-game/.

The Review and Processing of an Application for a Special Flight Operations Certificate for the Operation of an Unmanned Air Vehicle (UAV). (2014). Retrieved from http://www.tc.gc.ca/eng/civilaviation/standards/ge.

Thon, S., Serena-Allier, D., Salvetat, C., & Lacotte, F. (2013). Flying a drone in a museum: An augmented-reality cultural serious game in Provence. In *2013 Digital Heritage International Congress* (Vol. 2, pp. 669–676).

Trowbridge, R. S., Stark, J. A., & Wong, C. (2014). *Aerial display system with marionettes articulated and supported by airborne devices*. Washington, DC: U.S. Patent and Trademark Office.

Unmanned Aircraft Systems. (2015). Retrieved from https://www.faa.gov/uas/.

Villbrandt, J. (2011). *The Quadrotor's Coming of Age*.

Walkera Aibao Drone MR Gaming Mode Operation Video. (2016). Retrieved from https://www.youtube.com/watch?v=z5mkH3zHUFc.

Wong, C., Stark, J. A., & Trowbridge, R. S. (2014). Aerial display system with floating pixels. US: Washington, DC: U.S. Patent and Trademark Office.

Zhang, "Alan" Dingtian, & Jackson, M. M. (2015). *Quadcopter Navigation Using Google Glass and Brain Computer Interface*.

Zollmann, S., Hoppe, C., Langlotz, T., & Reitmayr, G. (2014). FlyAR: Augmented Reality Supported Micro Aerial Vehicle Navigation. *IEEE Transactions on Visualization and Computer Graphics, 20*(4), 560–568.

Augmented Reality for Mobile Devices: Textual Annotation of Outdoor Locations

Slimane Larabi

Abstract For textual annotation of outdoor locations we propose in this paper an augmented reality method for mobile devices based on orientation and GPS measurements and uses a circular string of identifiers as data structure in order to determine what places are seen by the mobile camera. The proposed solution is generic and can be applied in all areas of the world if the required data are available (computed in off-line). The proposed solution has been implemented and served in our university campus for new students to discover all places.

Keywords Augmented reality · Mobile device · Textual annotation · Outdoor location · Circular string of identifiers · Convex hull

1 Introduction

The aim of AR is the intertwinement of digital objects, texts and information with the "original" environment (Liberati 2016). Many AR applications have been developed for mobile devices and devoted to many subjects such as text document, adoption behavior, tourism, events, gamification, smart city, retail and cultural heritage.

Augmenting with text has attracted the interest of many researchers and many systems have been proposed such as the system of Ryu and Park (2016) able to detect text documents in real scenes, to estimate their relative 3D poses to the camera, and to augment them with virtual contents.

Annotation in AR systems has been studied in Wither et al. (2009) showing its usefulness either for adding information in a direct or indirect manner. Many systems of augmented reality (AR) devoted for annotation of building, subway maps, and a museum have been proposed (e.g. Eaddy et al. 2004; Schmalstieg and Wagner 2007; Wither et al. 2009). For the proposed systems, many authors asserted

S. Larabi (✉)
Faculty of Electronics and Informatics, USTHB University, Algiers, Algeria
e-mail: slarabi@usthb.dz

T. Jung and M.C. tom Dieck (eds.), *Augmented Reality and Virtual Reality*,
Progress in IS, DOI 10.1007/978-3-319-64027-3_24

than this orientation measurement is often deviated around tens degrees because of noise, jitter and temporal magnetic influences (Langlotz 2011) and the presence in densely occluded urban environments which decreases the GPS accuracy, this imply that annotations will simply appear on the wrong location.

In other side, using computer vision for visual detection and localization need more advances of this area essentially for illumination changes and accuracy in feature extraction and matching with low complexity of computation needed for mobile devices.

Solutions for this problem have been proposed by several authors. The main idea is to generate panoramas from rotational motion of the device. The panorama is created in a way that allowed users to annotate objects and to be shared with other users visiting the same spot as annotations anchor points were redetected in newly created panoramas by matching small image patches (Langlotz 2010, 2011). In similar work, AR system which allows to users to create content is proposed in Langlotz et al. (2012). To do this, authors propose two different approaches for tracking the device position: in a small workspaces using natural feature-based tracking of a known planar surface and in a large environment using GPS and panorama-based vision tracking.

Our goal is to avoid the complexity of computer vision techniques and the required accuracy for different tasks. We propose an efficient method of low complexity for textual annotating of places using a new concept: circular string of identifiers describing the 360° neighbour of the mobile device. The orientation, the GPS localization are used in order to define the arc of the circular string corresponding to what is seen. From the content of this arc, the annotation is displayed.

We implemented this method in our university campus for helping new students to discover all building and places.

In Section 2 we describe the notion of circular string and how is used to infer the seen places. The Sect. 3 explains the solution for taking into account the motion of the device and the appearance of new places around the device. We describe the obtained results in Sect. 4. Finally, we conclude giving some possible improvements and future works.

2 Coding Seen Places Using Circular String of Identifiers

2.1 Basic Principle

For a given position O representing the mobile device we associate on the map a circle (C) centred on O (see Fig. 1). Any place P_i surrounding the device that can be seen by the camera (when is fixing around it) is projected as an arc on the circle (C) labelled with an identifier (a character) which corresponds to a string annotating P_i.

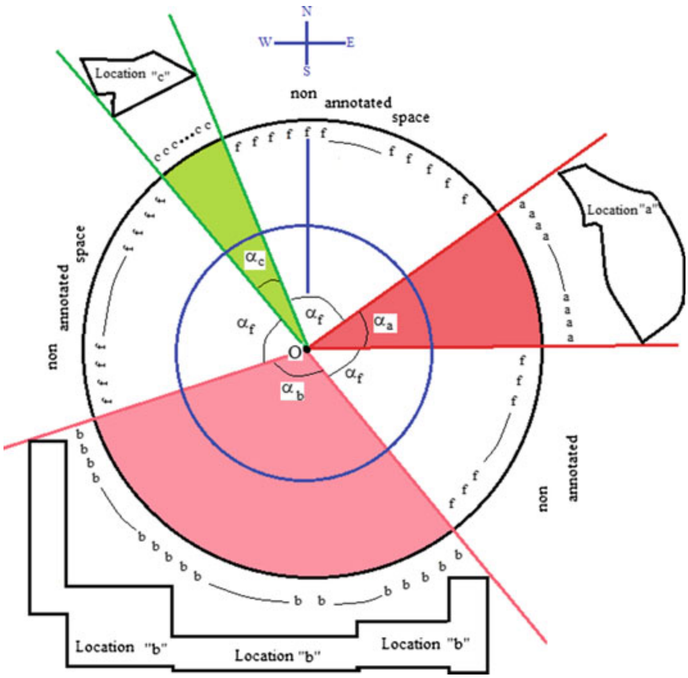


Fig. 1 The circular string of identifiers for a given location O composed here by the characters f (free space), *a* (location "a"), *b* (location "b"), *c* (location "c")

The circle (C) is represented by a circular string "**SeenLocations**" of 360 identifiers. The identifier attached to each arc is duplicated **n** times, where **n** is the length of the arc. The starting identifier in **SeenLocations** coincides with the north direction and that whatever the radius of the drawn circle, the obtained string is the same because the lengths of the different arcs are the same (see the blue circle in Fig. 1). In the example of Fig. 1, the content of this string is:

SeenLocations = "**aaaa…aaaa** ***ffff…ffff*** **bbbb…bbb** ***ffff…fff*** **ccc…cccc** ***ffff…ffffffff***", where ***f*** designates the no-annotated free space.

Note here that the dictionary of places (identifier, string for annotation) is build off-line for a given area.

2.2 Determining the Seen Places from

Once the azimuth angle β and the GPS coordinates have been obtained, the optical axis of the camera and the position of O are located on the map (see Fig. 2). The visible space is determined based on the angle β and the field of view $(-\alpha, +\alpha)$ of the camera. This allows defining a substring on the circular string which points

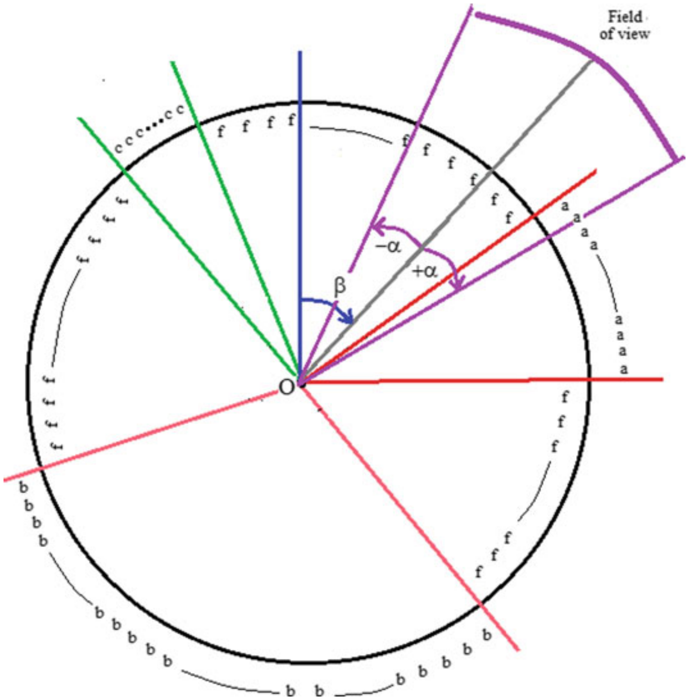


Fig. 2 Substring inference from azimuth angle β and field of view

either completely or partially to seen locations. On the string, the indexes of the substring are $\beta - \alpha$, $\beta + \alpha$. The displayed text will be the strings corresponding to each identifier of the arc. Depending on the content of the substring, the string is displayed as such or preceded by "part of".

3 Updating the Circular String for Moving Mobile Device

3.1 Updating Without Integrating New Places

When the mobile device moves, the associated circular string must be modified because any selected substring of identifiers will not refer necessarily to the correct place. We assume that the device is moving from O to $O^{'}$ (see Fig. 3), the arc (mn) associated to the place P in the circle (C) corresponds to the arc $(m'n')$ on the circle $\left(C^{'}\right)$ whose length and position may be different.

Let A, B be two of corners delimiting the place P. Let m'', n'' be new located points on $\left(C^{'}\right)$ at the same positions as m, n on (C). The arc $m''m'$ defines the angle α_m is equal to $\widehat{OAO'}$ which is computed using the distances $OO^{'}$, $O^{'}A$, OA. In the

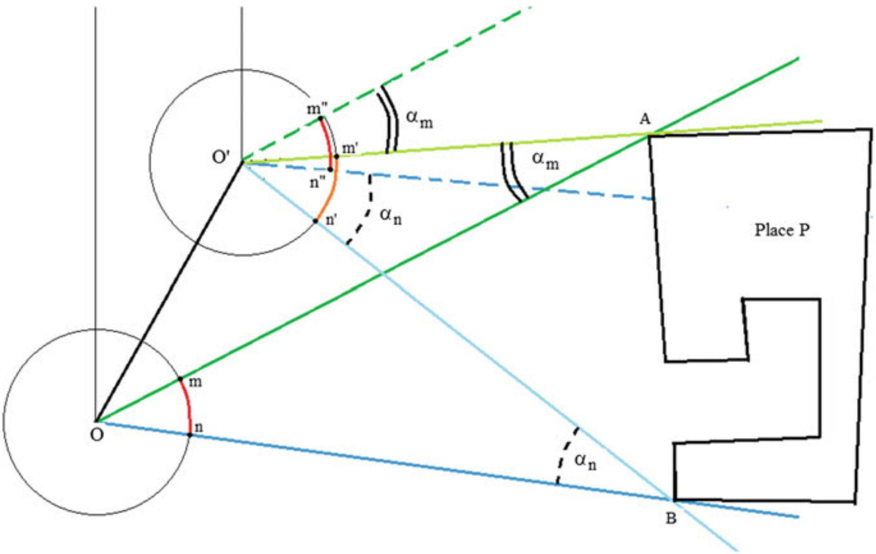


Fig. 3 Variation of the arc of view related to the mobile device motion

same way, the arc $n''n'$ defines angle α_n equal to angle $\widehat{OBO'}$ which is computed using the distances $OO^{'}, O^{'}B, OB$. Consequently, the positions of $O, A, B, O^{'}$ allows computing angles α_m, α_n and then the positions of $m^{'}$, n' corresponding to the seen place on the circular string.

The GPS coordinates of O, $O^{'}$ are communicated by the device (client) to the server, while those of corners A, B are assumed known (extracted and stored off-line from *OpenStreetMap* and Leaflet library). The content of the circular string is updated for each motion of the camera. The next algorithm describes the steps to be performed.

3.2 The Algorithm

Let P_0, P_1, …., P_{k-1} be k places of a given area. $\mathrm{P}_i\left(\mathrm{A}_{\mathrm{i},0}, \mathrm{A}_{\mathrm{i},1}, \ldots., \mathrm{A}_{\mathrm{i,ni}}, id, Str_i\right)$ refers to the place P_i where $\mathrm{A}_{\mathrm{i},0}$, $\mathrm{A}_{\mathrm{i},1}$, …., $\mathrm{A}_{\mathrm{i,ni}}$ define the corners of the convex hull encompassing it, Str_i is the annotation and id the referred identifier on the circular string. The algorithm 1 gives more details how the content of the circular string is updated (see Fig. 4).

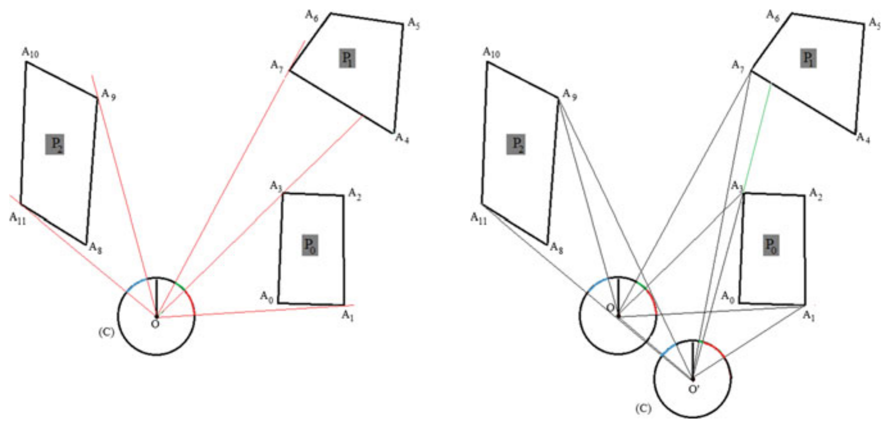


Fig. 4 Applying the algorithm 1 on the area of three places. (*Left*) initializing the circular string, (*right*) updating it

Algorithm 1.
Begin
#Initializing the circular string SeenLocations[i]='f' for i=0 to 359.
For(i=0 to 359) SeenLocations[i] = 'f'
For each place $P_i(A_{i,0}, A_{i,1}, \ldots, A_{i,ni}, id, Str_i)$
{ ***For each*** corner $A_{i,j}$
{
- Compute the associated arc mn on the circle (C) using the rays $OA_{i,j}$.
- ***If*** $\exists l / OA_{i,l} \cap P_j \neq \emptyset$ such that P_j is near to (C) than P_i,
Then consider the ray that links O to the corner of P_j and passes throughout P_i. ***EndIf***

}
Let (pos1, pos2) be the positions of the arc mn on (C).
For(i=pos1 to pos2) SeenLocations[i] =' id'
}

#Updating the circular string
#Let O' be the new position of the camera
For each arc mn of (C)associated to $P_i(A_{i,0}, A_{i,1}, \ldots, A_{i,ni}, id, Str_i)$
{ #Let $A_{i,l}$, $A_{i,r}$ be the corners of projected on the arc mn on (C)
- Compute the new position m' on (C) located so that $mm' = \widehat{OA_{l,l}O'}$
- Compute the new position n' on (C)located so that $nn' = \widehat{OA_{i,r}O'}$
- ***If*** $A_{i,l}$ or $A_{i,r}$ is not a corner of P_i
Then evaluate the new projection on (C)using the nearest place P_j. ***EndIf***

Let (pos1, pos2) be the positions of the arc m′n′ on (C).
For (i=pos1 to pos2) SeenLocations[i] =′ id
}
End.

3.3 Updating with Integration of New Places

When the device is in the same area, it may be sufficient to update the circular string as explained in subsection 3.1. However, when it moves towards another area or when new convex hulls' segments appear, the content of the circular string must be changed by inserting the visible places. Depending on the convex hull encompassing the place P, and on the position of the device's centre O, the corner points of P which will be used are determined depending on the position of O related to convex hull (see Fig. 5). Let $C_{i,4}$, $C_{i,0}$, $C_{i,1}$ be three successive corner points of the convex hull, and let ($F044_0$), (D_1) be the line defined respectively by ($C_{i,4}$, $C_{i,0}$), ($C_{i,0}$, $C_{i,1}$). If the centre O appertains the area delimited only by (D_0), (D_1) and $C_{i,0}$ (see Fig. 5), the corners seen are $C_{i,4}$, $C_{i,0}$, $C_{i,1}$. This reasoning is applied for the current position of the centre O and the area where is located. As example, if the device is in the area delimited by (D_1), (D_4), the corners $C_{i,3}$, $C_{i,4}$, $C_{i,0}$, $C_{i,1}$ are visible.

Our method allow then to infer the circular string giving the new GPS coordinates of the mobile device and the known GPS coordinates of the corner points of all places of the area considered.

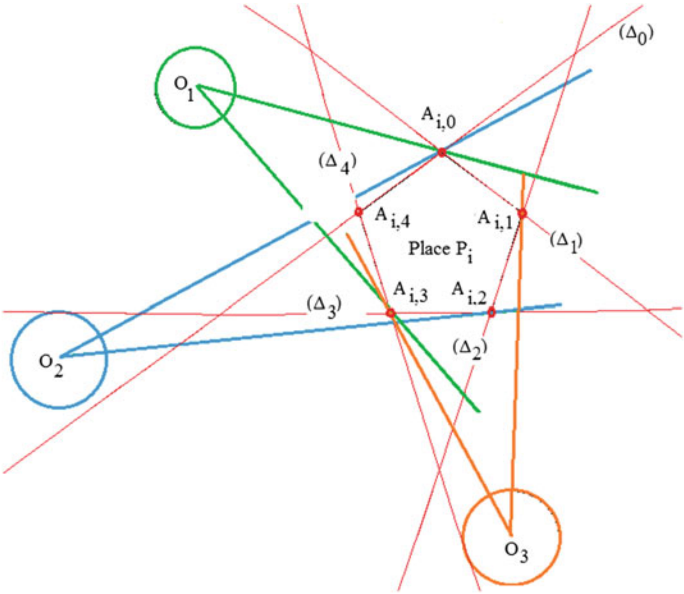


Fig. 5 Used corners in the computation of the arc of view

Fig. 6 The circular string of identifiers on the map for a selected reference point

4 Experiments and Results

We implemented the proposed method on mobile device under the system android. Some reference locations have been chosen in our university and the data related to the circular have been obtained manually and used as input data to the application. We show in Fig. 6 the map (one area of our university) obtained using the library Leaflet and *OpenStreetMap*. A reference point is chosen, the circle is drawn and the different arcs are determined. For each arc is associated an identifier (character) and the circular string is made using the lengths of these arcs. For each identifier is associated a text for annotation.

The selected views are illustrated by Fig. 7 where we can see the images annotated with correct text.

In order to avoid the instability of GPS measure which leads to instability of the text, we considered intervals of values instead of once value.

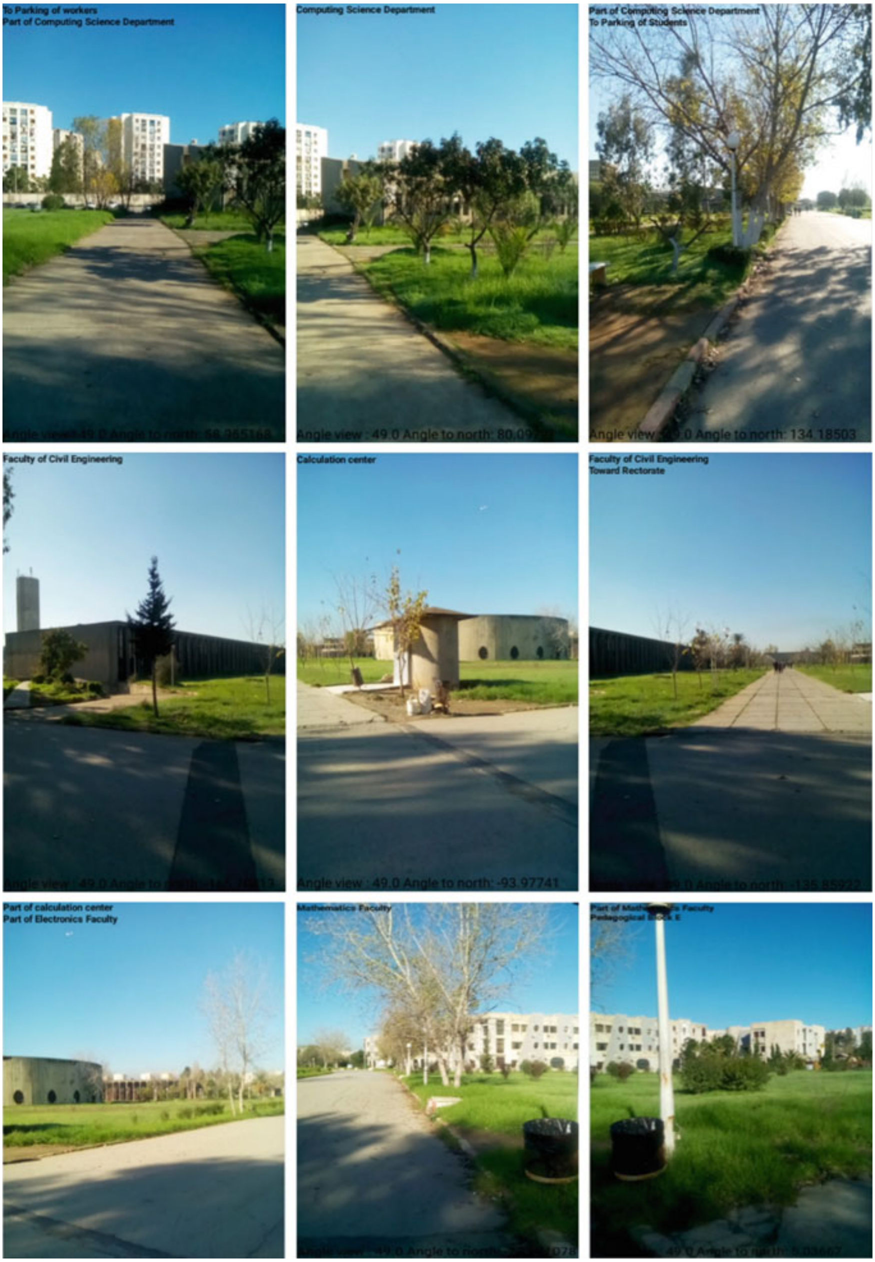


Fig. 7 The annotated locations

5 Conclusion

We proposed a geometry based method for outdoor places annotation. Our method has been implemented and applied to our university campus and served for new students to discover using their mobile devices the different places without help.

The notion of circular string of identifiers introduced for coding the seen places has gave more efficiency to the application in the sense that it is easy to retrieve the places seen entirely or partially. This circular string is also updated for any motion of the device based on stored information of the area. Our next tasks are to deploy this method for tourism areas adding some text explaining the historical monuments and for annotating streets, buildings in any city of the world.

Acknowledgements My acknowledgements to my Master students (MIV) I. MERABTENE, N. BENSAIDANE, M. OUSMER, K. MESSIPSA, M. CHETITAH who have implemented the first part of this work that I gave as project during classes on creative workshop.

References

Eaddy, M., Blasko, G., Babcock, J., & Feiner S. (2004). My own private kiosk: privacy-preserving public displays. In: *Proceedings of the international symposium on wearable computers*, pp. 132–135.

Langlotz, T., Degendorfer, C., Mulloni, A., Schall, G., Reitmayr, G., & Schmalstieg, D. (2011). Mobile Augmented Reality, Robust detection and tracking of annotations for outdoor augmented reality browsing. *Computers & Graphics, 35*(2011), 831–840.

Langlotz, T., Mooslechner, S., Zollmann, S., Degendorfer, C., Reitmayr, G., & Schmalstieg, D. (2012). Sketching up the world: In situ authoring for mobile Augmented Reality. *Pers Ubiquity Computing, 16*(2012), 623–630.

Langlotz T., Wagner, D., Mulloni, A., & Schmalstieg, D. (2010). Online creation of panoramic augmented reality annotations on mobile phones. *IEEE pervasive computing.*

Liberati, N. (2016). Augmented reality and ubiquitous computing: The hidden potentialities of augmented reality. *AI & SOCIETY, 31*(2016), 17–28.

Ryu, H. S., & Park, H. (2016). A system for supporting paper based augmented reality. *Multimedia Tools & Applications, 75*(2016), 3375–3390.

Schmalstieg, D., & Wagner, D. (2007). Experiences with handheld augmented reality. *Proceedings of the international symposium on mixed and augmented reality, 2007,* 3–18.

Wither, J., DiVerdi, S., & Hollerer, T. (2009). Annotation in outdoor augmented reality. *Computers & Graphics, 33*(6), 679–689.

Part VI
Augmented and Virtual Reality in Industry

Augmenting Reality in Museums with Interactive Virtual Models

Theodore Koterwas, Jessica Suess, Scott Billings, Andrew Haith and Andrew Lamb

Abstract Two projects at the University of Oxford extend beyond screen-based interactivity to create physically interactive models of museum objects on smartphones utilising Bluetooth, image recognition and sensors. The Pocket Curator app gives visitors to the Museum of the History of Science the opportunity to recreate a 19th century demonstration of wireless technology in the gallery and to find their latitude with a virtual sextant. The re-sOUnd app transforms phones into historic musical instruments: moving your arm in a bowing motion plays an Amati Violin and blowing into the phone while tilting it up and down sounds a trumpet used by Oliver Cromwell's trumpeter. This paper describes the apps, discusses challenges discovered in testing them with museum visitors, and reports findings from user interviews.

Keywords Museums · Augmented reality · Mobile · Virtual models · Interactivity · Usability · Cultural heritage · Interpretation

1 Introduction

Augmented reality usually refers to a specific mode of interactivity in which a device acts as a lens through which a user experiences their physical environment enhanced with digital content. Two projects at the University of Oxford provide alternative modes of augmented reality through interactive virtual models of

T. Koterwas (✉) · A. Haith
IT Services, University of Oxford, Oxford, UK
e-mail: theodore.koterwas@it.ox.ac.uk

J. Suess · S. Billings
University of Oxford, Oxford, UK
e-mail: jessica.suess@museums.ox.ac.uk

A. Lamb
Bate Collection of Musical Instruments, University of Oxford, Oxford, UK
e-mail: andrew.lamb@music.ox.ac.uk

T. Jung and M.C. tom Dieck (eds.), *Augmented Reality and Virtual Reality*,
Progress in IS, DOI 10.1007/978-3-319-64027-3_25

museum objects. The Pocket Curator app provides visitors to the Museum of the History of Science the opportunity to recreate a 19th century demonstration of wireless technology by ringing a bell in the physical gallery with their phone, and to find their latitude with a virtual sextant. The app was a product of the Hidden Museum project (Suess 2016), which aimed to prototype and test approaches to delivering content via mobile devices to museum visitors in the physical context of the gallery. Our explicit aim was to address the most prevalent concerns about mobile guides in museums: that they are "heads down", isolating, and disconnected from the gallery space and the objects (e.g. Hsi 2003; Boa and Choi 2015). One particularly well received approach was to create experiences that enabled users to interact with the physical space and objects using their devices—experiences that "augment reality" in novel ways. While the Pocket Curator app overlays content on the camera feed, it goes a few steps further, providing the user with an experience of using the object in front of them and causing the environment itself to react. Separately the re-sOUnd app utilises sound and motion to place historic musical instruments in the hands of users: moving your arm in a bowing motion plays a violin and blowing into the phone while tilting it up and down sounds a trumpet. Both apps were iteratively tested with visitors, and the challenges that emerged are applicable to using Augmented Reality in museums and mobile museum guides more broadly.

2 Company Introduction

The University of Oxford is a world-leading centre of learning, teaching and research and the oldest university in the English-speaking world. The role of IT Services is to ensure that the University of Oxford has the modern, robust, reliable, high-performing and leading-edge IT facilities it requires to support the distinctive needs of those engaged in teaching, learning, research, administration and strategic planning. The Gardens, Libraries and Museums (GLAM) of the University of Oxford contain some of the world's most significant collections. While they provide important places of scholarly enquiry and teaching for the University, for the public they also represent the front door to the wealth of knowledge and research curated and generated at the University. The Bate Collection of Musical Instruments has over 2000 instruments from the Western orchestral music traditions from the renaissance, through the baroque, classical, romantic and up to modern times.

3 Project Details

The Pocket Curator app presents seven objects in the Museum of the History of Science (www.mhs.ox.ac.uk). For each object it provides two to three short audio clips and at least one animation, video, or interactive experience.

The museum's Marconi Wireless display features the Marconi Coherer, a mysterious box stuffed with wires and inscrutable antique electronics, and if you look carefully, a bell on the top. Guglielmo Marconi used this device in the first public demonstration of wireless signal transmission. He put the box in one corner of a room and generated a spark in a different corner. The spark would cause the bell on the top of the box on the other side of the room to ring. Pocket Curator enables you to re-enact this demonstration with your phone. It superimposes a line drawing of the box over the camera feed, and when you line up the actual box with the outline, image recognition triggers the next step: the appearance of a "Transmit" button. Pressing the button causes a spark animation and vibration on the phone, and a bell rings out from the Marconi display case holding the real box. Technically the bell is an audio sample triggered over Bluetooth and played though a transducing speaker attached to the top of the case.

The Museum displays a collection of devices used for navigation. One of these, a sextant, may be familiar to some people from films, but few people we interviewed knew how it works. A navigator at sea looks through the scope at the horizon, and using the arm of the sextant adjusts a split mirror so that the sun (or other celestial body) appears in line with the horizon. The track along which the arm moves has degree markings, so the navigator can take a reading of the arc the arm traversed, which corresponds to the angle of the celestial body above the horizon. With this angle reading the navigator can determine the ship's latitude from charts. Pocket Curator simulates this with a virtual model of a sextant. The user holds the phone vertically in front of them. On the screen they see the view through the camera overlaid with a brass ring representing the sextant scope. Within the scope they see an image of the sea, which moves up and and down with the motion of the phone. They centre the sea horizon within the scope, tap a button to set the horizon, and tilt the phone upward until a virtual sun appears. When the sun lines up with the horizon, they tap another button to take a reading. The app shows them the angle they measured along with a short animation of the arm moving on a sextant. They tap the Find Latitude button and see a chart converting their angle measurement, along with a map displaying a line at that latitude. On a given day the app sets the angle of the virtual sun above the horizon so that the measurement they take accurately equates to the latitude of Oxford.

The re-sOUnd app presents historic musical instruments from the Bate Collection of Musical Instruments and the Ashmolean Museum. In addition to offering audio clips of the instruments being played by musicians, the app allows users to play the instruments themselves. Users play wind and brass instruments by blowing into the microphone and tilting the phone up and down to vary pitch. For the Amati Violin, a user holds the phone as if it were the neck of a violin and places their fingers down on the touchscreen as if holding down strings. Moving their arm back and forth in a bowing motion sounds the notes as if bowing the real thing. They can also use interfaces that more directly simulate the instrument, e.g. by covering holes or paddles with their fingers on the touchscreen. Each instrument was sampled in a recording studio so that users hear the real sound the instrument makes.

4 Discussion and Conclusion

The apps were iteratively tested with visitors during development to ascertain both their usability and effectiveness in conveying concepts about the objects. The sextant interactive was developed over several iterations, from a simplified single screen experience to the guided, multi-step experience described above. With the single screen experience, users were shown a map under the scope, with a line indicating latitude which changed as they tilted the phone. It was initially thought this simple, direct association between angle and latitude would convey the concept more clearly than a more complicated process. However, users were not making a strong connection between their experience and how the sextant actually works, e.g. they were not able to describe how tilting the phone corresponded to moving the arm of the sextant. They also missed the correlation between angle and latitude, because in focusing on trying to line up the sun and horizon in the scope, they didn't see the latitude line moving on the map below. This problem of inattentional blindness has also been found in Heads Up Displays (McCann et al. 1993) and Surgical AR applications (Dixon et al. 2013). The second iteration was a two-screen process. On the first screen, the map was replaced with an image of the sextant arm, which moved as the phone tilted, and on the second screen the map and latitude indicator were presented with explanatory text. While this more clearly connected taking an angle reading and finding a latitude, users were still unclear on how it related to the object itself, so a third screen was required. Now, when the user presses a button to set the angle of the sun, the scope is replaced with a message stating the angle they measured, with the sextant arm "set" on that angle, and an animation of the sextant with the arm moving. Users interviewed after the third iteration reported that the connection with the real object was clear, and that they preferred the kinetic aspect of the interactive to a hypothetically proposed demonstration video. They also liked that it got them "behind the glass." One respondent remarked that even though the display wasn't really in her area of interest, the interactive helped grab her interest.

In developing Pocket Curator valuable things were learned about delivering content on mobiles generally (Suess 2016). iBeacons can be effective as an enhancement but not as the only way to access content, and users didn't like QR codes, preferring to simply select content from a menu in both cases. Audio is very effective, but it should answer a question visitors genuinely have about the object rather than what the museum might want to tell them. The longest someone watched or listened to something without looking at the duration (an indicator of fatigue) was 45s. Video is effective when it offers content that can only be experienced visually, such as a demonstration or animation. Talking heads should be avoided unless the presenter is someone the user recognises and cares about.

Because these interactions are novel, users required guidance to use them effectively. The interactives begin with an instructional overlay and a "Start" button, but they need to also intrinsically guide users throughout the process. For the sextant, this was accomplished by breaking down the process into discrete steps and taking visitors through each step with short instructions reinforced by text on the buttons. Timings in the app ensure users don't skip steps, providing the next button only after the user starts the current step. For instance, in step two of the sextant, tilting the phone upward to find the sun, the button to set the "Angle of The Sun" appears only after the user begins tilting the phone upward.

Usability testing for the re-sOUnd app was conducted with 12 visitors over the course of two afternoons in the Bate Collection and Ashmolean. Once users worked out how to hold the phone or were given a hint such as "how would you play a real trumpet", they played the instruments effectively. Showing them a schematic drawing of how to hold and play the instrument was very effective in getting them started, so drawings like these were incorporated into the app.

Further evaluation for re-sOUnd was conducted over several days in the Bate collection and the Ashmolean. 18 visitors were each asked to read about two instruments (control), listen to two instruments (treatment one), and play two instruments (treatment two). The order of activities and instruments were randomized but each instrument was read about, listened to and played an equal number of times over the 18 tests. Users were then asked to take a short survey in which they rated on a 5 point scale the degree to which they felt they learned about each instrument, enjoyed each instrument, and got a "sense" of what it was like to play it. Their responses suggest a correlation between the app giving them a "sense" of playing the instrument and the degree to which they felt they both learned about it and enjoyed it. The survey suggested they enjoyed playing instruments (mean of 3.89) more than reading about them (3.53) and listening to them (3.81). The question regarding how much they learned showed a bias toward reading (3.64) over both listening (3.55) and playing (3.44). The survey also asked more general questions about the app. Respondents agreed the app made them want to look at the real instruments (4.28), want to learn about other instruments in the collection (4), want to learn to play an instrument (3.68), and made the instrument seem more "real" (3.78). They agreed they would recommend the app to a friend visiting the collection (4.33). There are limitations to this evaluation. The general conceptual association between "reading" and "learning" likely skewed responses, and it is unclear respondents made a clear distinction between listening and playing when thinking back on their experience, rating all experiences of hearing the instrument similarly.

Google Analytics in Pocket Curator anonymously tracks when audio, video, and interactives are started and finished by a user. The data show that the sextant interactive is the most started and finished item in the app, and Marconi is second most started and fourth most finished. Both interactives are started and finished more than any individual audio or video clip and the top three audio clips combined. For re-sOUnd, the violin is currently most popular. The apps have only been available for a few months and not widely advertised, so numbers are low, but as the data grows it should indicate user behaviour and preferences in the wild. Combining these data with further surveys and interviews will allow further study of the virtual models approach to augmenting reality.

Acknowledgements Both projects were funded by the University of Oxford's IT Innovation Fund. Pocket Curator was developed in collaboration with staff at the Museum of the History of Science (www.mhs.ox.ac.uk), especially Stephen Johnston. Re-sOUnd was developed in collaboration with the Music Faculty (www.music.ox.ac.uk), the Bate Collection of Musical Instruments (www.bate.ox.ac.uk) and the Ashmolean Museum (www.ashmus.ox.ac.uk), principally Colin Harrison and Sarah Casey. The apps were technically developed by Theodore Koterwas, Andrew Haith and Markos Ntoumpanakis.

References

Boa, R., & Choi, Y. (2015). Using mobile technology for enhancing museum experience: Case studies of museum mobile applications in S. Korea. *International Journal of Multimedia and Ubiquitous Engineering, 10*(6), 39–44.

Dixon, B. J., Daly, M. J., Chan, H., et al. (2013). Surgeons blinded by enhanced navigation: the effect of augmented reality on attention. *Surgical Endoscopy, 27*(2), 454–461.

Hsi, S. (2003). A study of user experiences mediated by nomadic web content in a museum. *Journal of Computer Assisted learning, 19*(3), 308–319.

McCann, R. S., Foyle, D. C., & Johnston, J. C. (1993). Attentional limitations with heads up displays. In R. S. Jensen (Ed.), *Proceedings of the seventh international symposium on aviation psychology* (pp. 70–75). Columbus: Ohio State University.

Suess, J. (2016) *Hidden museum project* http://www.oxfordaspiremuseums.org/blog/hidden-museum-project.

The Augmented Worker

Martin McDonnell

Abstract Virtual reality (VR) is already well established in the aerospace and military sectors, and is becoming commonplace for certain business activities in other sectors such as architecture, automotive, healthcare and retail. Augmented reality (AR) is now also being pioneered for commercial use, with clear benefits identified in layering digital information onto the physical world around workers and practitioners. The Soluis Group has been at the vanguard of these developments, exploring advancements in AR technology and its applications for commercial use. The business has specifically identified the benefits of augmented reality wearables in construction and high-end manufacturing. This led to Soluis working with Crossrail and Innovate UK to explore applications and test AR live on-site. Following delivery of a pioneering proof of concept, it is has become clear that the AR application Soluis developed has considerable benefits to the construction industry, with potential applications in several other sectors.

Keywords Augmented reality · Virtual reality · Manufacturing · Construction

1 Company Introduction

Soluis was founded by Martin McDonnell in the year 2000. Martin's commitment to excellence in design visualisation and graphic presentation has been the foundation of Soluis's approach from the outset, driving it in its aim to deliver world-class 3D visualisation and interactive applications.

Today Soluis Group now comprises of three divisions; Soluis Studios, Soluis Apps and Soluis Interact.

Soluis Studios is at the core of the business, with a wealth of creative talent that delivers the highest level of production across a range of digital media formats. This division aims to develop best-in-class visual media that can then be delivered in an

M. McDonnell (✉)
The Soluis Group and Sublime, Glasgow, UK
e-mail: martin@soluis.com

T. Jung and M.C. tom Dieck (eds.), *Augmented Reality and Virtual Reality*,
Progress in IS, DOI 10.1007/978-3-319-64027-3_26

engaging environment for clients and their stakeholders. This includes content such as film production, motion design, architectural visualisation and character animation.

Soluis Apps provides an in-depth development capability that offers clients the ability to develop bespoke digital applications, and develops key functionality across our range of visual engagement solutions. This includes mobile app development, database integration, web applications and bespoke PC and Mac software.

Soluis Interact was born out of Soluis's appetite to explore the most engaging and interactive presentation of content for clients. This division uses digital content to create compelling environments that can be deployed across a range of platforms such as immersive game environments, virtual reality and augmented reality. Vital to the success of all the work that Soluis Interact delivers, is the high-quality of the core visual content that it creates and presents.

The business has continued to explore new technology, including the ever-evolving computer games technologies, ensuring that the latest solutions are exceeding the expectations of the growing customer base. Today the Soluis Group creates compelling, narrative-driven digital media for clients, deploying virtual and augmented environments into the most effective and engaging medium, whether visualisation, AR, VR or mobile application.

2 Project Details

Over the past four years Martin McDonnell has had the vision to pioneer development of AR wearables that would drive efficiency, safety and create an enhanced, collaborative working environment. In this respect, 'Augmented Worker' is the child of two separate, but related projects that tilted at these aims.

The first of these was Soluis and Carbon Dynamics's 'Fit-Home', which enabled a 'co-design' process using VR. The second was Soluis's Innovate UK funded project to deliver a useable AR prototype for Crossrail:

'Fit-Home'—Martin met Matt Stevenson - owner of DFMA business Carbon Dynamic - at a course at the MIT Sloan School of Management. In early 2015 they decided to combine efforts in researching, developing and testing a software platform that would enhance the design, manufacturing, and assembly processes at Matt's modular construction business.

Using both virtual and augmented reality, Soluis developed applications which allowed Carbon Dynamic to quickly make detailed and informed decisions for the design of their spaces based on direct feedback from end users. The level of detail and feedback gained from using this technology was hugely beneficial to the business, saving time and money and avoiding costly mistakes.

This was achieved through a 'co-design' process enabled by the VR technology. Discovering the benefits in applying VR and AR solutions in the DFMA sector also suggested a wider opportunity for the greater construction industry.

'In-Site'—Later in 2015 Soluis applied for Innovate UK's "IC Tomorrow" competition, that offered the opportunity to work in partnership with Crossrail to investigate real industry uses for augmented and virtual reality. The broader impetus for the project was the desire to explore 'Smart Construction' via new immersive technologies, aiming to deliver improvements in efficiency and safety.

Soluis's winning entry was granted £35,000 to invest in an AR wearables concept and trial it on-site at Crossrail's Liverpool Street site, working in partnership with their contractor, Laing O'Rourke (Fig. 1).

The concept, named 'In-Site' aimed to deliver a leap forward in bringing functional, wearable AR to the construction sector, and perform three basic functions:

1. **Identifying** an asset
2. **Pulling** information about that asset from the cloud (and delivering into the operative's field of view)
3. **Pushing** information about the asset back from the operative to the cloud.

This functionality could be applied across a range of activities at the Crossrail site, however focus was given to two key elements: commissioning and handover stages. This supported enhanced efficiency in logging and reporting on installed assets in Crossrail tunnels, which could be carried out more swiftly, safely, and reliably than previously; by allowing operatives to perform key tasks hands-free and with their heads up.

By leveraging existing BIM assets, and drawing on the latest technological advances in AR, 'In-Site' allows on-site operatives to access information more quickly and efficiently. It allows them to compare real-world assets to expected at a glance, making discrepancies immediately apparent. Overall, this makes

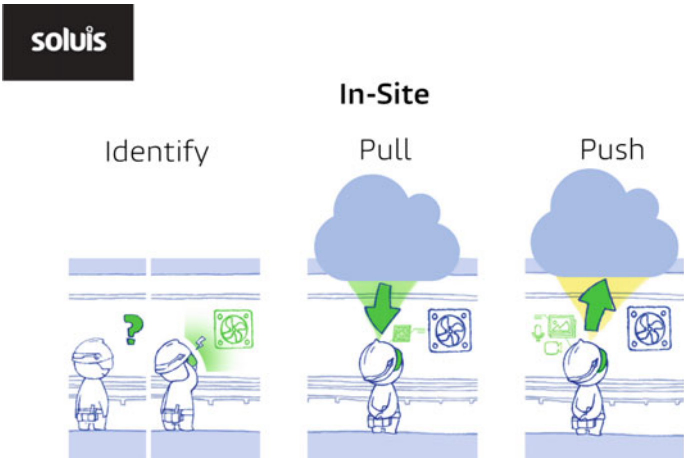


Fig. 1 Diagram of the In-Site application functionality

commissioning and handover significantly more efficient: sign-off can be achieved more quickly with fewer errors and less downtime (Figs. 2, 3, 4 and 5).

The ‘In-Site’ concept was made possible by the advent of wearable devices in PPE-compliant form, together with the availability of legible 3D content and freely available augmented reality engines. Soluis’s experience in construction visualisation and functional AR, the business was well placed in bringing these two areas of new technology together in a successful smart solution.

Fig. 2 The In-Site application used at crossrail’s liverpool street station site

Fig. 3 The In-Site application used at Crossrail’s Liverpool Street station site, by contractor Laing O’Rourke

Fig. 4 The In-Site application used at Crossrail's Liverpool Street station site, by contractor Laing O'Rourke, inspecting assets

Fig. 5 Point of view from user of the in-site application through the DAQRI smart helmet

The additional benefits of the solution, includes the use of a heads-up display for delivering context-appropriate safety information. Prior to conducting asset maintenance or repair, operatives can receive safety notifications, asset status updates, and preview tutorials, all whilst keeping their hands available for the relevant task. The substantial increase in contextual awareness facilitated by heads-up, hands-free reporting could prevent accidents, and potentially save lives on construction sites every year.

The trial process consisted of site engineers at Liverpool Street Crossrail station—Europe's most ambitious piece of engineering—assessing pre-fabricated, installed wall framing assets against an asset management checklist (created in collaboration with Laing O'Rourke's manufacturing wing), filling in this checklist, and saving it to push back to the cloud. Users could also take an image of pieces that were defective and push this information back to the database.

The Crossrail and Innovate UK project demonstrated that the Soluis 'In-Site' application could deliver exceptional benefits in efficiency and safety if further evolved for the construction and manufacturing industry.

The final prototype was delivered in late 2016.

3 Discussion and Conclusion

With the proof of concept for the 'In-Site' application demonstrating the vast benefits and feasibility of the solution, Soluis is now evolving this concept to explore a further range of applications across all stages of the manufacturing process.

The business is now building the tools and platform that will deliver the promise of VR/AR to the construction industry.

What might that promise deliver? Soluis believes the main benefits to be as follows:

- Projects delivered on time and within budget
- Real-time visualisation of projects
- Better collaboration and communication
- Increased safety
- Greater implementation of BIM

The solution and platform that will deliver these benefits, named 'Augmented Worker', is being developed in conjunction with Carbon Dynamic and Advanced Manufacturing Research Centre (AMRC) with an expected advisory board of Autodesk, Microsoft, AECOM, Laing O'Rourke & Doosan Babcock (Fig. 6).

It is envisioned that 'Augmented Worker' will be used throughout the manufacturing process to support workers in the following key areas:

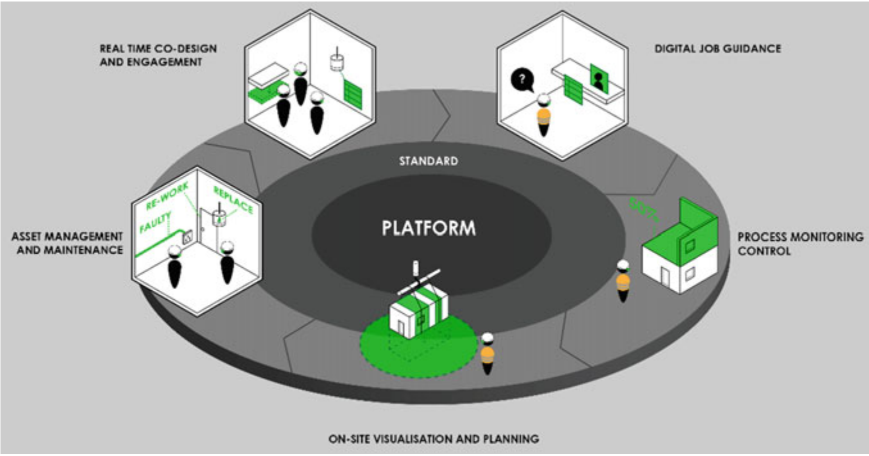


Fig. 6 Diagram of the augmented worker platform

1. **Real-Time Customer Design, Co-Design, and Engagement Tool**
   Benefit: *A project's timeline can be accelerated and therefore costs reduced by having the client and designer create and visualise potential layouts quickly for large-scale developments in augmented or virtual Reality (AR/VR).*
   In a VR environment designers or architects can see (preview) a product or project with the client or customer while in proof-of-concept, and prototyping, in context. A designer and client can immerse in a project and collaboratively manipulate digital objects to suit the needs of the environment and inspect alternative specifications. Taking it further the augmented reality experience can take collaboration on site and render the digital data as spatially referenced 3D models. This can be a valuable way to solicit feedback from users or other stakeholders.
2. **Digital Job Guidance Tool**
   Benefit*: Downtime is reduced due to improved communication flow and with access to a global knowledge base, enabling operatives to communicate with a remote expert and provide instructions or take information directly from a database to use step-by-step guides.*
   Regardless of their locations AR assisted job guidance supports users to more effectively communicate and complete complex tasks in the field. Workers can remotely connect with team members to share their expertise directly on a mobile device or headset. Augmenting and animating key step by step work-flows using text, 3D models, images and videos together with other corporate assets, such as product information, can all be used as collaborative solutions and help the workers understand processes quickly.

3. **Process Monitoring Control Tool**
   Benefit: *The risk of delays and errors are reduced due to rapid and efficient task completion. This is possible due to the ability to track task times, check inventory and even incentivise workers.*
   Process monitoring will assist the user to receive live on-site information, updates on delays, do inventory checks, and automate reorders which can be efficiently communicated to other users either in the field or back in the office.
4. **On-site Visualisation and Planning Tool**
   Benefit: *Increased safety and better prioritisation sequencing with a reduced risk of errors in field service can be achieved with augmented reality by accessing more detailed building information and on-site guides to 'Safety Zones' for machinery.*
   AR assisted on site planning will enable field workers to connect with the environment at a more detailed level. Operatives will have the ability to see real time data on virtual gauges from 'IoT' connected (or smart) products on site. Pre-set 'no go' zones can be seen to provide safer working environments and thermal cameras, built into the headset, will give operatives the ability to visualise, record and analyse temperature data.
5. **Asset Management and Maintenance Tool**
   Benefit: *Users can view assets and associated data for better building management and maintenance. This means reduced downtime, increased safety, fewer errors due to contextual information and increased efficiency.*
   When augmented reality is met with detailed data this can empower a worker like never before. When placing on a headset a worker can obtain timely and accurate information related to maintenance targets based on the BIM representation of a building combined with facilities management systems and other data sources and will allows user to visualise objects they wouldn't normally see, almost as though using x-ray vision.

Acknowledgements Carbon Dynamic (www.carbondynamic.com), especially Matt Stevenson for work on the Fit-Home and Augmented Worker concepts. Innovate UK, Crossrail and Laing O'Rourke for the development of the In-Site proof of concept. The AMRC for support in development of the Augmented Worker concept.

Digital Representation of Seokguram Temple UNESCO World Heritage Site

Jin ho Park and Sangheon Kim

Abstract Seokguram Temple is the most notable heritage site of the Ancient Korea Shilla Dynasty, representing the Buddhist Rock Art with various architectural, mathematical and geometrical skills. Owing to its universal value and a representative masterpiece of Korea Buddhist culture around the world, it was listed as a World Heritage Site in December 1995 under the UNESCO World Heritage Sites. Due to its enormous cultural significance and diverse location, the site witnesses various environmental conditions and tourism pressure which affects its prestigious status and sustainability. Our approach has enabled us to produce a complete various Digital Representations of Seokguram Temple.

Keywords Seokguram temple · 4 K-UHD · CUBEDOM · Head mounted display · Walking VR

1 Introduction

Seokguram Temple is a 1300 year old cave-like Temple in Gyeongju, South Korea, sitting 750 meters above sea level and over looking the East Sea. It was UNESCO World Heritage List in 1995. It embodies some of the finest Buddhist sculptures in the world. Despite the Seokguram Temple's tremendous cultural significance, the Korean public is restricted from close access—as are the large number of tourists who visit the region every year.

So we resolved to give people a way to easily experience and interact with the despite Seokguram Temple its seclusion. They came up with a great solution: to

J.h. Park (✉) · S. Kim
Department of Creative Contents, Sangmyung University, Seoul, Republic of Korea
e-mail: arkology@naver.com

S. Kim
e-mail: enigma92@Smu.ac.kr

T. Jung and M.C. tom Dieck (eds.), *Augmented Reality and Virtual Reality*,
Progress in IS, DOI 10.1007/978-3-319-64027-3_27

Fig. 1 Seokguram temple and it's sculpture

display a complete, full-scale, 3D digital Data of Seokguram Temple. Such a Data would also allow them to preserve the present condition of the Seokguram Temple if they ever needed to restore it from damage in the future (Fig. 1).

2 Seokguram Temple by 3D Scanning

Laser scanning technique is a fast and efficient method that automatically collects 3D coordinates of cultural heritage. Various laser scanners measure the direction of optical lines connecting points on the surface of cultural heritage objects to reference points on the measuring device and produce Cartesian coordinates. 3D scanning approach is a generally accepted technique for the collection of 3D representation of heritage sites.

For this reason, the laser scan technology has been extensively used by measuring 3D surface coordinates to produce a complete 3D digital replica of Seokguram Temple. Particularly, laser scanning technique was used to collect various 3D scan data, featuring high data acquisition rates, good accuracy and high 3D data density. The combination of such data can be optimized to produce geometric accuracy and visual quality of the collected textured 3D models. First, a Leica 3D scanner was used to capture three-dimensional data of the inner Temple. Such data was imported into 3D modeling tools for creating 2D and 3D drawings. A complete 3D model of Soekguram Temple is shown as Fig. 2.

For short-range scan data a Vivid 9i 3D scanner was used. Likewise, respective drawing of the Seokguram Temple was achieved from the long-range scan data as the converted mesh was dense and unclear, and hence the drawings were used to build mesh models. Secondly, the scan data of the whole site were aligned and converted into watertight mesh models. Colors and textures were added to the

Fig. 2 Seokguram temple by 3d scanning

virtual objects. This technique was helpful to handle a large volume of scan data to rapidly create polygonal models and NURBS surfaces after alignment and merging process.

3 Seokguram Temple by UHD Representation

4 K Ultra-High Definition (UHD) Immersive Displays is a 4 K resolution of Full HD that can enable users to perceive a great immersion experience of cultural heritage objects. Another version of digital Seokguram Temple was also presented in the "Silla: Korea's Golden Kingdom" exhibition arranged by the Metropolitan Museum of Art, New York City in the USA.

As shown in Fig. 3, an Ultra-HD TV screen with a UHD native resolution of 3840 × 2160 pixels was used, which offers a great immersive visual experience to the visitors.

4 Seokguram Temple by Projection Mapping Representation

We proposed a projection Mapping-based immersive theatre, so called CUBEDOM as an application for Seokguram Temple. The CUBEDOM is expected to replicate the similar experience as the real Seokguram Temple does, as it may have the same structure and size of Seokguram Temple. The concept drawings of CUBEDOM are shown as Fig. 4.

Fig. 3 Digital Seokguram temple was presented in the "Silla: Korea's golden kingdom (2013. 11. 3 ~ 2014. 2. 29)" Exhibition arranged by the Metropolitan Museum of Art, New York City, USA

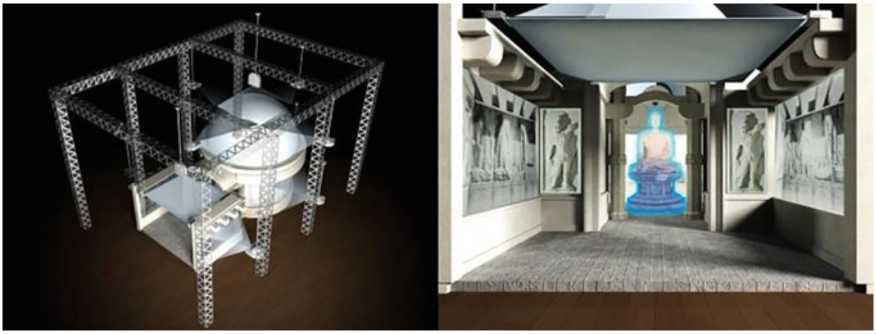


Fig. 4 Projection mapping-based immersive theatre: CUBEDOM

5 Seokguram Temple by HMD (Head-Mounted-Display)

We also proposed a head-mounted display (HMD) system for more immersive and interactive environment. As shown in Fig. 5, the proposed HMD environment may contain gesture-recognition interface to provide user's interaction with a virtual Seokguram.Virtual Reality has been widely used as a tool to create immersive applications for the promotion of heritage sites and allow visitors to perceive VR Contents and internet resources without visiting the site.

The goal of the VR HMD is to achieve an in-depth sense of immersion in which a visitor navigates and interacts with 3D Seokguram objects in a virtual world in the same way that a visitor interacts with the Seokguram of the Real world. we utilized the head mounted display (HMD) called HMD with an Interactive System as a means of presenting the virtual environment to the visitors. HMD is comes with a

Fig. 5 The Oculus rift HMD is shown as an example (Made by indigo entertainment corp)

low price and is commercially available. HMD offers an immersive interactivity and enable the visualization of 3D models of Seokguram Temple.

Our approach has enabled us to produce a complete HMD of Seokguram Temple. The HMD System offers an immersive interactivity and enable the visualization of 3D models of Seokguram Temple. This HMD technology can be used to foster the authenticity of a another World heritage site and enriches the perceived experiences of its visitors.

6 Seokguram Temple by Walking VR

Oculus Rift VR, with its focus on standing or seated experiences mostly. It's no action experiences. But HTC-Vive VR says that real-world moveing is the Good option for VR experiences. usually people walk around in their Walking VR experiences (roomscale VR) spaces. With the release of the HTC-Vive people get basically have room-scale Seokguram Temple VR so people can Real walk around a Seokguram Temple inside with HTC-Vive Controllers with haptic devices. It would be able to interact with the Seokguram Temple sculpture, people would be able to zoom in and zoom out. actually view them as if we were actually standing in front of Seokguram Temple inside. It also you could view them at Seokguram original scale. These Seokguram interactivity provides a new method of VR Seokguram Temple there is no need for glass cases to stop the heritage from being damaged. So we called Seokguram VR Museum. VR Users are encouraged to take control of how they view each Seokguram main Buddha and it's sculpture, and to interact with Seokguram sculpture (Fig. 6).

Fig. 6 Seokguram temple VR experience by walking VR system

7 Conclusions

This paper presents a complete process of 3D Scanning and VR Visualization of a heritage site to its Digital Representation. Using 3D scanning technologies, the three-dimensional data of a heritage site was collected. Various reconstruction techniques were applied to produce 3D models and then VR techniques to demonstrate an accurate representation of a heritage site. In this paper we focus on from 3D Scan to immersive VR HMD, also VR which implies that a Working VR Seokguram Temple. Digital Representation of Seokguram Temple is capable of providing efficient virtual reconstruction environments and an VR Experience in order to increase the realization of cultural heritage site experience.