NEXT GENERATION SHOPPING: EXPERIMENTAL STUDIES ON THE ADOPTION AND DESIGN OF VIRTUAL REALITY SHOPPING ENVIRONMENTS

Zur Erlangung des akademischen Grades eines
Doktors der Wirtschaftswissenschaften

(Dr. rer. pol.)

von der KIT-Fakultät für
Wirtschaftswissenschaften
des Karlsruher Instituts für Technologie (KIT)

genehmigte
DISSERTATION

von
Christian Daniel Peukert (M.Sc.)

Tag der mündlichen Prüfung: 01.09.2020
Referent: Prof. Dr. Christof Weinhardt
Korreferent: Prof. Dr. Orestis Terzidis

Karlsruhe, 2020

KARLSRUHE INSTITUTE OF TECHNOLOGY

Abstract

Department of Economics and Management
Institute of Information Systems and Marketing

Next Generation Shopping: Experimental Studies on the Adoption and Design of Virtual Reality Shopping Environments

by Christian Daniel PEUKERT

In recent years, technological advancements and simultaneously falling prices of virtual reality (VR) technology have led to an increased attention among the wider consumer population. Particularly the retail industry considers the application of VR technology to be an innovative way to approach their customers. Accordingly, first VR shopping environments have already been launched. However, it remains an open question whether and why VR shopping environments will be adopted by end consumers and thus succeed in the long run. To tackle aspects of the latter question, this dissertation takes on an Information Systems (IS) research perspective and sheds light on both, research questions regarding the acceptance (Study 1 & Study 2) and design (Study 3 & Study 4) of VR shopping environments.

Following a structured literature review highlighting the current state of empirical VR research within the IS discipline, the four already published studies will be presented. Since the increased degree of immersion is the key characteristic of today's VR systems, the first study investigates to what extent immersion has an influence on the acceptance of VR shopping environments. The results reveal that immersion has a positive effect on a hedonic, but a negative effect on a utilitarian path, collectively having no impact on the intention to reuse the shopping environment. The negative effect can be explained by low readability – still a technological constraint – of small prints in the VR shopping environment and is expected to diminish as technology evolves. The second study examines the extent to which a real VR experience (versus a presentation of the respective VR environment based on a non-interactive video) is essential to investigate the acceptance of VR shopping environments. The results suggest that a real VR experience is necessary because especially the variables perceived enjoyment and perceived telepresence are systematically underestimated by participants that imagined being in the VR environment based on a video.

The remaining two studies consider how VR environments should be designed in terms of user assistance features. On the one hand, Study 3 evaluates users' preferences with regard to which interactive decision aids or VR specific features consumers expect to be available in VR shopping environments. Study 4, on the other hand, examines the possibility of detecting phases in consumer decision making based on eye tracking data in real time against the backdrop of designing context-aware user assistance systems in the future. The dissertation concludes with discussing the studies' limitations as well as outlining potential avenues for future research.

Acknowledgements

First, I would like to express my gratitude to Prof. Dr. Christof Weinhardt for giving me the opportunity to pursue my research endeavor under his supervision and for his ongoing support on this journey. I would also like to thank all other members of my PhD committee: Prof. Dr. Orestis Terzidis, Prof. Dr. Gerhard Satzger, and Prof. Dr. Steffen Rebennack, for their time spent in reviewing my thesis, their valuable comments, and for the inspiring – partly philosophical – discussions before, during, and after my thesis defense.

Further, I would like to especially thank Prof. Dr. Jella Pfeiffer for her guidance, longstanding cooperation, and continuous encouragement to always go the extra mile. In line with this, I am also grateful that I had the pleasure to work hand in hand with such an experienced team of researchers when tackling the novel field of virtual reality shopping environments: Thank you Anja, Jella, Holger, Martin, and Thies for sharing your research-related expertise, but also knowledge and skills far beyond with me.

A big thanks also goes to my colleagues (or let's better call them friends) at the Institute of Information Systems and Marketing. You have always understood how to keep a sense of humor even in phases of hard work, which has made collaborating with you a unique experience. Even though it was, on the one hand, often sad to say goodbye to successfully graduated colleagues, on the other hand, the circle of friends has steadily expanded with new colleagues starting their PhD activities.

Finally, I am eternally grateful to my friends and family! Thank you for super-charging my batteries whenever I ran out of energy, for always cheering me up in rough times, for the occasional pleasant distractions from work, and above all that you have never stopped believing in me. It's a wonderful feeling to realize having such a great group of people in your back. Above everything, I want to thank my wife, Sina, who accompanied me step by step on my journey as my faithful companion. Thank you for "simply" always being there for me, for making me laugh even in hard times, for giving me a life full of happiness in the hours when the computer was switched off, but also for reminding me that there are sometimes more important things in life than working on the thesis. Now is time to acknowledge your unconditional support – you have achieved all of this together with me! Thank you!

Contents

List of Figures

List of Tables

List of Abbreviations

AGFI	adjusted goodness of fit index
AHP	Analytic Hierarchy Process
AOI	area of interest
AR	Augmented Reality
AV	Augmented Virtuality
AVE	average variance extracted
BC	Bias Corrected
BCa	Bias Corrected and accelerated
CAVE	Cave Automatic Virtual Environment
CB SEM	covariance-based structural equation modeling
CBC	choice-based conjoint
CFA	confirmatory factor analysis
CFI	comparative fit index
CI	Confidence Intervals
CR	composite reliability
DSR	design science research
e-commerce	electronic commerce
EEG	electroencephalogram
ET	eye tracking
FMCG	fast-moving consumer good
HCI	human computer interaction
HMD	head-mounted display
HTMT	Heterotrait-Monotrait Ratio
ICT	Information and Communication Technology
IDA	interactive decision aid
IIMT	interactive information management tool

IS	Information System
KIT	Karlsruhe Institute of Technology
MR	Mixed Reality
MANOVA	multivariate analysis of variance
NeuroIS	Neuro Information Systems
OFD	On-the-fly-detection
PCPM	Paired Comparison-based Preference Measurement
PLS SEM	partial least squares structural equation modeling
RML	robust maximum likelihood
RMSEA	root mean square error of approximation
RQ	Research Question
SEM	structural equation model
SRMR	standardized root mean square residual
TAM	technology acceptance model
TLI	Tucker-Lewis Index
TTS	text-to-speech
UAS	user assistance system
v-commerce	virtual commerce
VFR	virtual fitting room
VR	Virtual Reality
XR	Extended Reality

Part I

Fundamentals

Chapter 1

Introduction

> "It's not about escaping reality, it's about making it better."
>
> Zuckerberg (2017, 14:42)

1.1 Motivation

In recent years, Virtual Reality (VR) has been considered among the most notable evolving technologies in the area of Information and Communication Technology (ICT) (Steininger, 2019; Lee et al., 2020), accompanied with the promise to open up entirely new ways for companies to approach their customers (Yang and Xiong, 2019; Flavián et al., 2019). Although the technology is by no means new (Sutherland, 1965; Sutherland, 1968), its full potential has only recently been unleashed by advances in the VR industry, which significantly intensified the VR experience on the one hand, and lowered the equipment costs on the other hand (Berg and Vance, 2017; McGill et al., 2016). However, the progress was not only favored by the tremendous development of VR hardware (i.e., especially enhancing system performance) and cost reductions, but also by the suppression of negative experiences through VR (literally cyber-/ motion sickness), which led people to discontinue to use VR applications (Fernandes and Feiner, 2016; Wang and Suh, 2019). Accordingly, now VR is "mature, stable, and, most importantly, usable" (Berg and Vance, 2017, p. 1). Decisive for the technological upswing were entrepreneurial efforts (such as investments in research and development, acquisitions, or strategic partnerships) of various tech giants in the field of immersive systems – an umbrella term for VR, Augmented Reality (AR), Mixed Reality (MR) – and the broad rollout of affordable consumer-grade VR hardware by different manufacturers (Cavusoglu et al., 2019; Anthes et al., 2016).

Today's VR systems are mainly based on the application of head-mounted displays (HMDs), which deliver stereo vision and update a person's field of view according to their head movements. Such VR systems offer "a unique way to interact with the ever-growing digital landscape" (Berg and Vance, 2017, p. 1) and therefore allow "people to immersively experience a world beyond reality" (Berg and Vance, 2017, p. 1). However, the opening quotation by Mark Zuckerberg emphasizes that VR shall by no means isolate people (Zuckerberg, 2017). The difference between modern systems and the previous ones particularly lies in the increased degree of immersion that the systems are capable of delivering (Cummings and Bailenson, 2016). Immersion is entirely system-specific (i.e., technological and objectively measurable (Bowman and McMahan, 2007; Slater, 2003)) and has been defined as "the extent to which the computer displays are capable of delivering an inclusive, extensive, surrounding and vivid illusion of reality to the senses of a human participant" (Slater and Wilbur, 1997, pp. 604/605). Nowadays, immersive systems do not necessarily consist solely of visual displays, but also of other sensory modalities that can stimulate human senses (e.g., auditory or haptic feedback), and thus also contribute to immersion (Bowman and McMahan, 2007).[1] According to the system specifications, HMDs can be categorized as high immersive VR, whereas regular desktop applications possess a low degree of immersion. Another characteristic attributed to VR is its ability to induce a sense of telepresence, i.e., the feeling of truly being present in a virtually mediated environment (Steuer, 1992; Klein, 2003). It is widely accepted in literature that immersion (technological) is an integral prerequisite for inducing the perception of telepresence (psychological) (Schultze and Orlikowski, 2010; Sharda et al., 2004), thereby emphasizing that "[tele-]presence is a human reaction to immersion" (Slater, 2003, p. 2). Due to the fact that desktop-based applications can also induce a telepresence perception (Biocca et al., 2007; Klein, 2003), they will be considered as low immersive VR in the course of this thesis.

At present, the most prominent consumer industry making use of the effect of telepresence is the gaming industry, which is why they are seen as pioneers in terms of VR adoption (Hartl and Berger, 2017; Schwarze et al., 2019). The gaming industry, in particular, can be instrumental for the general breakthrough of VR, since the presence of a HMD in a household allows the HMD to be also used for other purposes (i.e., non-gaming applications), but also by other persons living in the same household. From a professional point of view, VR has already been successfully employed for training purposes (e.g., military or medical) and in the context of product design (Berg and Vance, 2017; Bowman and McMahan, 2007). Moreover, therapists apply VR stimuli for phobia treatment (Balan et al., 2019; Strickland et al., 1997).

Another industry seeing potential in the application of VR is the retail industry (Grewal et al., 2017; Martínez-Navarro et al., 2019; Wedel et al., 2020). More than 15 years ago, the application of VR displays has already been mentioned as innovation for the interaction with retailers (Burke, 2002). Indeed, incorporating VR technology into an online shopping ecosystem allows consumers to experience a shopping activity that imitates the one in reality and, at the

---

[1] See Anthes et al. (2016) for a taxonomy of VR hardware (as of 2016). All hardware (input as well as output devices) can potentially impact the overall system's degree of immersion. Further, the applied rendering software needs to be taken into account in determining the level of immersion (Bowman and McMahan, 2007). In addition, Cummings and Bailenson (2016) provide a list of "immersive features" highlighting immersion from another level of abstraction.

same time, provides the advantages of online shopping (Pfeiffer et al., 2020). Thus, a VR-enriched online shopping experience could be created, which might address the existing limitations of electronic commerce (e-commerce) websites. It is a common point of criticism (Tarafdar et al., 2019; Luo et al., 2019; Liu et al., 2019) that "the inability to touch and feel products makes it difficult for people to evaluate product quality" (Suh et al., 2011, p.716), or understand the product, prior to the purchase. This may lead to (product fit) uncertainties, false expectations, and, as a result, product returns (Hong and Pavlou, 2014), which naturally leads to dissatisfied customers in the end. For this reason, it is crucial "to explore innovative ways to create a realistic and immersive online shopping experience" (Liu et al., 2019, p. 824), which some authors have already referred to as "virtual commerce (v-commerce)" (de Regt and Barnes, 2019; Martínez-Navarro et al., 2019). Indeed, Yang and Xiong (2019) have previously shown that the implementation of virtual fitting rooms increases sales while reducing product returns.

In practice, well-known retailers from various industries have tested the use of VR to offer their customers an immersive shopping experience.[2] The provided applications range from initial prototypes to comprehensive shopping environments. Especially in the field of furniture retail, sophisticated VR applications already exist. The Swedish furniture manufacturer IKEA can be considered a pioneer in this respect. Following applications that allow a kitchen to be explored, used and modified in VR (IKEA VR Experience, IKEA VR Pancake Kitchen) or a virtual living space that can be configured in many, albeit predefined, ways (IKEA Virtual Reality Showroom), the IKEA Immerse App is intended to become an integral part of IKEA's omni-channel strategy. The VR application is an extension of the prior mentioned Showroom. It enhances the versatility of the products, the available configurations, and the interaction possibilities, but above all, the realism and the degree of immersion of the whole environment (e.g., real products sounds were recorded and ambient lighting). Moreover, the VR application features seamless integration with IKEA's e-commerce system, which makes it possible to purchase products from the self-made configuration or share the configuration with others. A similar, but less sophisticated VR application (3D room designer) is also offered by the US department store chain Macy's for selected products from their home department.

Furthermore, in 2017, Europe's largest retailer for consumer electronics (the MediaMarktSaturn Retail Group) launched a VR shopping environment named Virtual SATURN, likewise with a direct connection to the existing online shop. During their VR experience, customers can access two environments, a penthouse loft or a space station on the planet Saturn. In both, it is not only possible to browse and inspect products in 3D, but also to get professional advice from employees. Further, the Chinese e-commerce giant Alibaba has also built a VR application (buy+) that teleports customers to famous shopping malls, e.g., Macy's in New York, to shop at and virtually

---

[2] *Note*: In the following, some examples of VR applications in the retail sector are described. References to the applications can be found in Table A.1 Appendix A.

navigate through the site. Interestingly, companies have also joined forces to create first VR environments. For example, this includes the joint virtual shopping environment of Swarovski and Mastercard, whereby products from the Atelier Swarovski Home Décor line are on display in a virtual home. In case a product is appealing, it can be instantly purchased within the virtual environment via Mastercard's digital payment service Masterpass. Moreover, eBay and Myer created a VR environment to shop for products. In contrast to the approaches described so far, this duo moves away from ordinary e-commerce product presentation formats or attempts to replicate reality. Rather, it creates product networks that depict connections between products such as higher-level categories and further adapt according to a person's preferences.

Other companies have taken a different approach, using VR to tell stories or pass on experiences related to the brand. The North Face, for instance, provides 360° videos allowing customers to take part in outdoor adventures. Similarly, Toms shoes tries to convey an experience by supporting their charity campaign – donating a pair of shoes for each purchased pair – with a VR video experience that pictures how people in need receive the donated goods. While Tommy Hilfiger lets customers virtually sit in the front row of their fashion show in their Virtual Reality Catwalk Experience, the car manufacturer Volvo allows customers to virtually test-drive their new models (Volvo Reality).

The aforementioned list is by no means exhaustive, but shows that some of the retail industry's major players have already begun to explore the possibilities of VR.[3] Overall, it can be distinguished between applications that are exclusively provided on the business premises of the respective company (i.e., in-store; e.g., Tommy Hilfiger's VR catwalk experience, Macy's 3D room designer) and the ones that are independently accessible by customers from home (e.g., VirtualSATURN, buy+, IKEA VR experience) – similar to e-commerce websites. In this thesis, the latter are primarily of interest, since the focus is on the potential of VR to enrich the current e-commerce landscape with immersive experiences.

Although first practical VR applications in a shopping context have been launched, they remain largely unexplored in the field of Information Systems (IS) research. In general, the number of articles in top-tier IS journals covering VR related issues is – despite the early call for research by Walsh and Pawlowski (2002, p. 1) titled "Virtual reality: A technology in need for IS research" – quite low. Most studies that mention VR address questions originating from virtual worlds such as Second Life (Franceschi et al., 2009; Schmeil et al., 2012; Chaturvedi et al., 2011; Suh et al., 2011; Nah et al., 2011; Schultze and Orlikowski, 2010), or virtual product experiences in e-commerce settings (Jiang and Benbasat, 2005; Suh and Lee, 2005; Liu et al., 2019; Yang and Xiong, 2019). The previously referenced studies all have in common that they used ordinary desktop computers to display the products or to visualize

---

[3] *Note*: See the recently appeared article by Wedel et al. (2020) for a list of further VR retail applications.

the virtual worlds. However, the degree of immersion of state-of-the-art VR systems is much more pronounced. Only recently, an increased number of studies have been published (e.g., Pfeiffer et al., 2020; Huttner et al., 2019; Schwarze et al., 2019; Balan et al., 2019), which report results of VR experiences based on the application of HMDs. Nevertheless, VR, in terms of highly immersive experiences in virtual environments, remains in a nascent stage of research. This thesis therefore aims at carrying out first attempts in examining the phenomenon of highly immersive VR from an IS perspective with a special emphasis on virtual shopping environments. The next section therefore introduces the underlying research agenda and outlines the related research questions.

1.2 Research Agenda and Research Questions

As outlined in the motivation section, practitioners have already launched first VR shopping environments. Nevertheless, at this stage, it remains widely unknown whether customers will accept VR environments for doing their shopping in the end. However, this represents a fundamental prerequisite for long-term success. Further, the uncertainty about the customers' adoption is also accompanied by the fact that, due to the novelty of these shopping environments, it is largely uncharted territory how the environments need to be designed to meet customers' expectations in the first place. The proximity to e-commerce platforms thereby suggests that both hedonic (i.e., the extent to which the experience is enjoyable) and utilitarian (i.e., the extent to which the environment is useful to complete tasks) factors play a role for both the adoption and the related design.

Hence, the dissertation addresses four Research Questions (RQs) shedding light on perspectives of the acceptance of VR shopping environments (**RQ1** and **RQ2**) and on how VR shopping environments shall be designed with respect to user assistance features (**RQ3** and **RQ4**). In the following, the individual research questions are introduced.

The key difference between today's VR systems and previously available systems is the increased degree of immersion that the technology is capable of delivering (Cummings and Bailenson, 2016). Thereby, Walsh and Pawlowski (2002, p. 305) state that "VR technologies are fundamentally different from other information technologies and hence may require new conceptual models and understandings" and further that "caution must be exercised in assuming that understandings developed around earlier technologies will apply." Recent consumer-grade VR systems employ HMDs to accommodate the visual sense providing a surrounding, panoramic field of view. Thereby the physical reality is visually completely shut out for the user, unlike desktop environments, where physical reality still exists apart of the screen. Furthermore, these systems are highly interactive and are characterized by a high degree of vividness. While customers are accustomed to shopping via webshops, either mobile or desktop-based, shopping in highly immersive shopping environments is a new terrain. Similar to the emergence of e-commerce research almost 20 years ago (e.g., Gefen and Straub, 2000; Gefen et al., 2003; Childers et al., 2001), fundamental questions related to shopping in high immersive VR shopping environments need to be answered first, thus paving the way for further research. One such question is regarding its acceptance. As with any new technology, the key question for the application of VR in a shopping context is whether and why the users accept the technology in the end. Based on e-commerce literature, hedonic as well as utilitarian motives could be decisive predictors of system adoption (Childers et al., 2001; Koufaris, 2002). Although a body of literature that investigates features of VR, e.g., virtual product experiences, in e-commerce settings has been assembled over the years (e.g., Jiang and Benbasat, 2005; Jiang and Benbasat, 2007b; Yang and Xiong, 2019), these articles have in common that they all studied VR in terms of low immersive desktop environments. As a result, the effect of highly immersive VR remains to be determined. Initially, it is hence essential to find out how the degree of immersion (instantiated through consumer-grade VR – high immersion, versus ordinary desktop environments – low immersion) influences acceptance evaluations. The thesis therefore takes the effort to develop and empirically test a research model to theoretically explain how immersion affects system adoption. Hence, the first research question states:

RQ1: *How does the degree of immersion in virtual shopping environments influence system adoption?*

Investigating novel technologies (within this thesis VR) that have not yet fully reached the wider consumer population comes at a price. To obtain empirical data, for instance, on the usability or technology acceptance of a system, larger samples of participants usually need to be invited into a laboratory equipped with VR technology (Hartl and Berger, 2017). Besides high costs for the actual system, the appropriate introduction of the participants into the technology and the secure interaction during experimental sessions requires personnel at all times (Kampling, 2018). In practice, this means that only one participant per session can be handled properly, which therefore entails a high expenditure of time and personnel. For illustration purposes, the data collection in VR for answering the first research question took five weeks (full time) to obtain a sample of 132 valid data sets (Peukert et al., 2019b). In light of the high effort involved, the question arises whether there is also a less costly way to reliably evaluate VR system adoption without having the necessity to bring larger samples into the laboratory. One conceivable way is to only show participants a video shot from a first-person perspective of the respective VR environment and ask them to imagine being in the environment for the purpose of acceptance evaluation. Such a video could be conveniently watched by the participants from home so that a presence appointment in the laboratory would not be necessary. Moreover, from a research perspective, if the proposed approach proves to be promising, acceptance research in the field of VR could be significantly accelerated. Thus, to validate whether a video leads to identical evaluations and could therefore become an alternative method of measurement, the following research question needs to be answered:

RQ2: *Does the acceptance evaluation of VR shopping environments depend on whether users have imagined (based on a video) versus experienced being in the VR environment?*

Particularly in the first study (RQ1), the focus was on replicating reality in the VR application in the best possible manner in order to succeed in systematically manipulating the degree of immersion. However, VR offers far more than a one-to-one replication of reality and is thus capable of creating unique experiences apart from reality (Slater, 2009). Some of VR's advantages specifically originate from, for instance, not being bound by physical laws (Steffen et al., 2019). With regard to the latter, Slater and Sanchez-Vives (2016, pp. 1–2) state that "the real power of VR is not necessarily to produce a faithful reproduction of 'reality' but rather that it offers the possibility to step outside of the normal bounds of reality and realize goals in a totally new and unexpected way." Therefore, it is crucial to find out what kind of features people desire to use in VR on top of what is already possible in reality. Apart from that, it is generally of interest how a VR application shall be overall designed. In the retail sector, it is important that shopping environments are designed in such a way that consumers are not overwhelmed, e.g., by the product range or the complexity of the decisions to be made, which in the worst case can lead to dissatisfied consumers and an abandonment of purchase. This is particularly true for e-commerce websites. To cope with these issues, e-commerce websites draw upon interactive decision aids (IDAs) (Häubl and Trifts, 2000; Groissberger and Riedl, 2017; Pfeiffer, 2012) such as filter mechanisms or sorting functions, different product presentation formats (Jiang and Benbasat, 2007a; Jiang and Benbasat, 2007b), additional product information (e.g., user ratings), or recommendation agents (Xu et al., 2014; Xiao and Benbasat, 2007). In terms of product presentation, high immersive VR shopping environments, in contrast to desktop-based environments, offer the possibility to view products in real scale and dimensionality. Furthermore, other decision support features known from the e-commerce context can also be implemented. While an extensive body of literature on the application of decision support features as well as the design of e-commerce stores exists (e.g., Häubl and Trifts, 2000; Wang and Benbasat, 2008; Wang and Benbasat, 2009; Huang and Benyoucef, 2013), literature lacks similar studies for VR shopping environments. Thus, to gain first insights into how virtual shopping environments should be designed, the following research question is addressed:

RQ3: *Which of the established e-commerce IDAs and VR specific features do customers desire to use when shopping in VR shopping environments?*

Recent technological advances in the area of VR technology do not only allow to implement classical decision support features (e.g., as investigated in RQ3), but also to enhance the degree of intelligence of assistance systems through real-time biosignal processing (Morana et al., 2020). This is possible, since in the meantime, first HMDs have been equipped with eye tracking technology (e.g., HTC's Vive Pro Eye, Microsoft's HoloLens 2, Magic Leap's Magic Leap 1, or Pico's Neo 2 Eye) with the goal of improving system performance and user experience. By means of real-time gaze detection, on the one hand, the so-called *foveated rendering* can be realized, which only renders those parts of the display in highest quality that are currently looked at in order to save computational power (Patney et al., 2016). On the other hand, eye tracking can be used to address the vergence-accommodation conflict (still a crucial limitation of AR and VR systems) through controlling focus-adjustable lenses aiming at reconciling vergence and accommodation (Anthes, 2019).

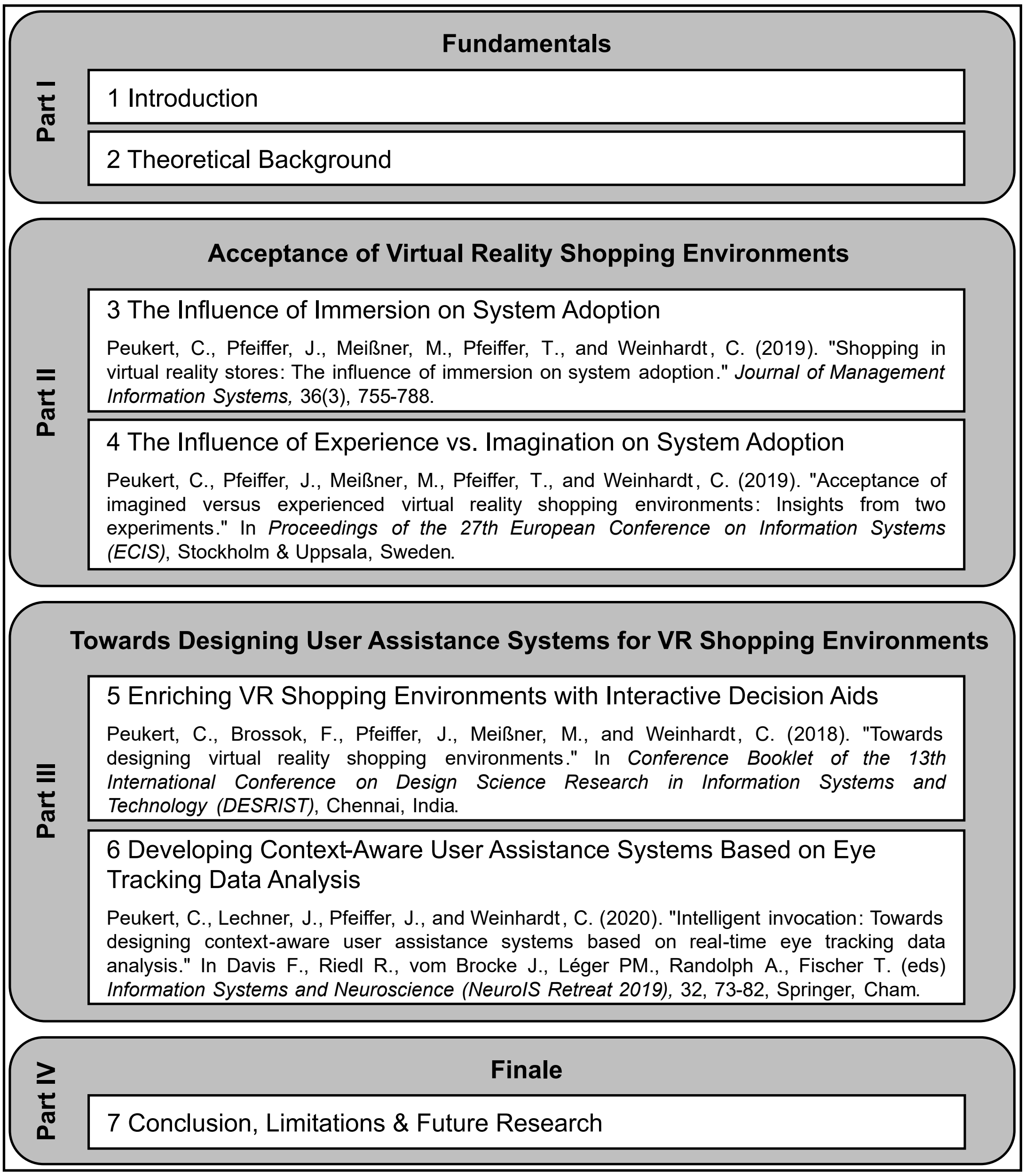
Although the primary reason for the symbiosis between VR and eye tracking technology is for technical reasons, the doors are now also open to using the obtained eye tracking data to feed user assistance systems (UAS) (Pfeiffer et al., 2020). Eye tracking data could, for instance, be used to unobtrusively, i.e., specifically this also means without the necessity of explicit user input/effort (Xiao and Benbasat, 2007), capture the shopping context a consumer is currently facing and as a consequence trigger an intelligent invocation of a decision aid that is meaningful for the specific context. Such a system can be classified as *advanced UAS* based on the definition by Maedche et al. (2016). In literature, approaches already exist, which by means of eye tracking either detect phases in consumer decision making (orientation, evaluation, verification) or classify the shopping motive (based on a post hoc analysis of eye tracking data) (Russo and Leclerc, 1994; Gidlöf et al., 2013; Pfeiffer et al., 2020). The prior mentioned decision phases could potentially mark meaningful points in time for user assistance invocation. For instance, a comparison matrix as IDA is only helpful as soon as one has already put first products under closer consideration (evaluation phase), whereas a filter mechanism supports right from the beginning by reducing the overall complexity of a decision process (orientation phase). Moreover, with respect to regular e-commerce websites: Even though various decision aids are commonly offered (mostly organized in a menu and available throughout the whole decision process), it remains the user's decision when to use which decision aid out of the listed ones (again a decision that needs to be made), even if some are simply not useful at certain times. The described issue could be remedied by a context-aware UAS based on eye tracking that could relieve users of the decision as to *which* kind of help they should use best and *when*. However, it remains to be evaluated whether existing approaches (post hoc) can also be performed in real-time – a necessary precondition to trigger an intelligent invocation. The research question thus states:

RQ4: *Can existing approaches to detect phases in consumer decision making based on eye tracking data be adapted to trigger an intelligent invocation of a UAS in VR?*

Answering these four research questions not only helps to generate a fundamental understanding of how immersive systems affect acceptance evaluations, but also points out initial insights towards how practice-oriented applications need to be designed.

1.3 Structure of Dissertation

The thesis at hand consists of four main parts covering I) general foundations, II) studies on the acceptance of VR shopping environments, and III) approaches that shed light on the potential design of VR shopping environments in terms of UAS. In Part IV), the findings of the previous parts are summarized and directions for future research are outlined. Figure 1.1 provides an overview of the dissertation's underlying structure, thereby disclosing which chapters consist of already published peer-reviewed publications.



Fundamentals

1 Introduction

2 Theoretical Background

Acceptance of Virtual Reality Shopping Environments

3 The Influence of Immersion on System Adoption

Peukert, C., Pfeiffer, J., Meißner, M., Pfeiffer, T., and Weinhardt, C. (2019). "Shopping in virtual reality stores: The influence of immersion on system adoption." *Journal of Management Information Systems,* 36(3), 755-788.

4 The Influence of Experience vs. Imagination on System Adoption

Peukert, C., Pfeiffer, J., Meißner, M., Pfeiffer, T., and Weinhardt, C. (2019). "Acceptance of imagined versus experienced virtual reality shopping environments: Insights from two experiments." In *Proceedings of the 27th European Conference on Information Systems (ECIS)*, Stockholm & Uppsala, Sweden.

Towards Designing User Assistance Systems for VR Shopping Environments

5 Enriching VR Shopping Environments with Interactive Decision Aids

Peukert, C., Brossok, F., Pfeiffer, J., Meißner, M., and Weinhardt, C. (2018). "Towards designing virtual reality shopping environments." In *Conference Booklet of the 13th International Conference on Design Science Research in Information Systems and Technology (DESRIST)*, Chennai, India.

6 Developing Context-Aware User Assistance Systems Based on Eye Tracking Data Analysis

Peukert, C., Lechner, J., Pfeiffer, J., and Weinhardt, C. (2020). "Intelligent invocation: Towards designing context-aware user assistance systems based on real-time eye tracking data analysis." In Davis F., Riedl R., vom Brocke J., Léger PM., Randolph A., Fischer T. (eds) *Information Systems and Neuroscience (NeuroIS Retreat 2019),* 32, 73-82, Springer, Cham.

Finale

7 Conclusion, Limitations & Future Research

FIGURE 1.1: Structure of the dissertation

In Part I, the foundations for the overall research endeavor of the thesis are laid. Following Chapter 1, which introduces the motivation as well as the agenda for the underlying research undertaking, Chapter 2 provides the theoretical background. Besides an introduction of the general terms and concepts in the field of VR, a literature review reports on the current state of research on consumer-centered empirical VR studies within the IS discipline.

Part II comprises two experimental studies (Chapter 3 and Chapter 4, respectively) aiming at addressing questions with respect to the technology acceptance of VR shopping environments. Thereby, the study presented in Chapter 3 investigates how immersion affects system adoption intentions. The reported results stem from a laboratory experiment with two treatments manipulating the degree of immersion of the VR shopping environment under consideration. Chapter 4 comprises a research article that analyzes whether a full VR experience is required for an accurate acceptance evaluation of a VR shopping environment or whether a video shot from a first-person perspective is sufficient for that purpose. This question is addressed by incorporating two sub-studies (one study implementing a basic and another study implementing a more advanced VR shopping environment), which both compare an introduction of the environment based on an online video to a full VR experience in a laboratory.

Part III consists of two chapters each presenting a study in the context of designing UAS for VR shopping environments. While Chapter 5 sheds light on user preferences with regard to the implementation of interactive decision aids in shopping environments, Chapter 6 introduces an approach on how context-aware UAS may be built based on the real-time analysis of eye tracking data, thus taking on a Neuro Information Systems (NeuroIS) research perspective. Thereby, Chapter 5 is based on data collected in an online experiment and Chapter 6 analyzes eye tracking data, which was recorded during the experiment presented in Chapter 3.

Finally, the thesis concludes with a summary of the insights gained by answering the research questions, a discussion of the work's limitations, and an outlook on potential avenues for future research (Part IV comprising Chapter 7).

Chapter 2

Theoretical Background: State-of-the-art of Virtual Reality in Information Systems Research

> "Virtual Reality: A technology in need for IS research"
>
> Walsh and Pawlowski (2002, p.297)

2.1 Virtual Reality: A Short Historical Journey

The term *Virtual Reality* – literarily an oxymoron – has been around for many years, even though its real popularity has only recently reached the general public. Already in the 1990s, ideas existed how VR could enrich e-commerce shopping experiences (Walsh and Pawlowski, 2002) or change our workspaces (Lucas and Baroudi, 1994; Briggs et al., 1997; Nunamaker et al., 1996). At that time, however, it has already been clearly articulated that the lack of available bandwidth could be an impediment to the adoption of VR technology for the time being (Walsh and Pawlowski, 2002). This also led to the fact that, for years, there was no further public interest in this technology. As a result, VR was oftentimes declared dead (Slater and Sanchez-Vives, 2016) even though in 1999 pioneers had already stated to the previous state of technology that "whereas VR almost worked in 1994, it now really works" (Brooks, 1999, p. 16). The breakthrough was not supposed to happen back then, which Slater and Sanchez-Vives (2016, p. 2) attributed to the fact that "the feasibility was not there, or at least not realizable at that time or anywhere near it." Interestingly, they further mention in their 2016 article: "Now though the possibility is real, and for whatever reason now is the time" (Slater and Sanchez-Vives, 2016, p. 2), which – this time – may prove to be true considering the current development.

The new euphoria was sparked by the Oculus Rift Kickstarter campaign (which took place in 2012) with the vision of offering a high-quality HMD affordable for the wider consumer population (Anthes et al., 2016). The campaign reached its initial funding goal (US$250,000) in less than 24 hours and raised over US$2.4 million by the end of the campaign (Anthes et al., 2016; Gleasure and Feller, 2016). Today, Oculus is part of Facebook Inc. as a result of the US$2 billion acquisition in March 2014 – now stronger than ever manufacturing VR headsets for mass markets. Various manufacturers have joined this movement, which is why some title the present time as the *second wave* of VR (Anthes et al., 2016; Schwarze et al., 2019). In 2016, several of the VR HMDs that are still popular today have been released (e.g., models such as the HTC Vive, Oculus Rift, Playstation VR, Google Daydream VR, or Samsung Gear VR), finally marking the time of breakthrough to the end consumer market. Thus, it took almost 50 years from Ivan Sutherland's initial vision of a head-mounted three-dimensional display (also nicknamed as "the Sword of Damocles") to the real marketability of consumer-grade HMDs (Sutherland, 1965; Sutherland, 1968).

After this short historical outline of the development of VR, the next sections are dedicated to introducing the most important theoretical constructs associated with VR and the basics of VR systems. Subsequently, the status of VR research in the IS field will be highlighted within a literature review.

2.2 Immersion, (Tele-) Presence and Related Concepts

Whenever people are talking about VR, the term *immersion* is usually brought up at some point – mostly, however, without clarifying what is meant by it at all. What is generally not a serious concern in everyday conversations may lead to great confusion in the scientific literature if the term is not properly explained. Yet, the term immersion is not applied uniformly in literature and is defined and used differently across scholars (Cummings and Bailenson, 2016). The main dispute is whether immersion is objective (a measurable system configuration, e.g., Slater and Wilbur (1997)) or subjective (an individual's response to a VR system, e.g., Witmer and Singer (1998)). To avoid confusion, it should be made clear at this point that the approach of Slater and Wilbur (1997) is followed within this work, according to which immersion is an exclusively objective measure.

To exemplify the difference between immersion and presence, Slater (2003) uses an analogy to color science: He argues that a color can be unambiguously, objectively expressed through its wavelength distribution. In the same vein, immersion can be objectively assessed. The *perception* of a color, however, is an individual human response and can be influenced by various factors, such as mood. The same appears for the *perception* of presence (i.e., telepresence). Even though a person is facing the same immersive system, the response to it, i.e., the induced telepresence, can be differently perceived across individuals (Slater et al., 1995).

Thus, pursuing a technological perspective, presence is a "human response to sensory immersion" (Schultze, 2010, p. 440), whereby the concepts of immersion as proposed by Slater and Wilbur (1997) represent the antecedents. Or in other words, "[i]mmersion describes the technical capabilities of a system, it is the physics of the system" (Slater and Sanchez-Vives, 2016, p. 5) and presence is an associated subjective correlate to immersion (Slater and Sanchez-Vives, 2016). The relationship between the two variables is proposed as follows: The higher the VR system's degree of immersion, i.e., the more convincing and engaging the generated sensory stimulus, the greater the user's presence perception in the mediated environment (Schultze, 2010; Schultze and Orlikowski, 2010).

The previous section has mainly dealt with the delimitation of the terms *immersion* and *presence*. Up to now, however, no attention has been paid to the technological concepts that constitute immersion. Recalling the definition of immersion by Slater and Wilbur (1997), which has already been quoted in Chapter 1, immersion is composed of technological concepts referring to whether a system is inclusive, extensive, surrounding, and vivid. Likewise, Steuer (1992) introduced the concept of interactivity as predefined by the system's characteristics. In the following, each of these concepts will be briefly explained.

Inclusive. Inclusiveness indicates the ability of a VR system to mask any facet of physical reality (Slater and Wilbur, 1997). In most cases, the concept refers to visual aspects. For example, an HMD covers the entire field of vision so that the physical reality is visually completely shut out. In contrast, in an ordinary Cave Automatic Virtual Environment (CAVE) with three wall-screens (Cruz-Neira et al., 1992), the physical reality remains visually present at the back, which is not covered by any screen. This is even more pronounced for desktop environments, in which physical reality is visually maintained besides the screen and – depending on the screen-size – is almost always visible in the peripheral field of vision. Yet, the concept of inclusiveness also covers other aspects of physical reality besides visual isolation. Among other factors, this includes the suppression of acoustic noise, but Slater and Wilbur (1997) also mention the weight of a HMD as influencing parameter for inclusiveness. Ideally, a HMD would be completely weightless so that users would no longer notice the enduring influence of physical reality (Slater and Wilbur, 1997). Hence, compared to Sutherland's Sword of Damocles (Sutherland, 1968), state-of-the art consumer HMDs would be higher rated with respect to inclusiveness.

Extensive. Extensiveness, on the one hand, describes how many different senses are stimulated, i.e., "displays are more extensive the more sensory systems [...] they accommodate" (Slater et al., 1995, p. 204). On the other hand, it also takes each stimulation's magnitude into account. For example, it is differentiated between whether a system conveys a purely visual experience, or whether the auditory sense is equally addressed. Furthermore, the magnitude of each accommodation can also be determined. Thus, if all other components are considered equal, a system supporting spatialized sound is more extensive than a system that only provides non-spatialized sound and, in turn, possesses a higher degree of immersion (Slater et al., 1995). Whereas the visual and auditory senses have been primarily addressed so far, haptics or even smell may also play a role in the future (Mihelj et al., 2014).

Surrounding. Surrounding describes the extent to which a VR system is capable of creating a holistic 360° experience. It may be a function of whether a system's supported field of view is wide and thus panoramic (e.g., a HMD) or confined to a narrow field of view (e.g., a small desktop screen) (Slater and Wilbur, 1997). However, surrounding is not only limited to the visual sense. To illustrate this, Slater et al. (1995, p. 204) note that systems are surrounding "to the extent that information can arrive at the person's sense organs from any (virtual) direction and the extent to which the individual can turn toward any direction and yet remain in the environment." For instance, with respect to the auditory sense, as the name suggests, a 5.1 surround sound system is more surrounding than a 2.1 sound system focusing on frontal sound. The following example demonstrates the difference to the concept of inclusiveness: A system that is inclusive does not necessarily have to be surrounding and vice versa. Noise-cancelling headphones can completely isolate a person from the physical reality and would hence correspond to the concept of inclusive, but are obviously not surrounding. In the same way, a 5.1 system can be used (surrounding), but as long as one still perceives noise from the physical reality, such as the postman ringing the doorbell, the system is not fully inclusive.

Vivid. According to Steuer (1992, p. 81), vividness is described as "the representational richness of a mediated environment as defined by its formal features; that is, the way in which an environment presents information to the senses." He further argues that vividness can be divided into the factors *breadth* (i.e., whether various senses are simultaneously stimulated) and *depth* (i.e., the specific resolution of each channel) (Steuer, 1992). When examining the conceptualization of Slater and Wilbur (1997), parts of the factor definitions are already included in the extensiveness concept – which is especially true for the factor breadth. With respect to the depth factor, Slater and Wilbur (1997) primarily focus on the naturalness, variety, information content, and richness of the representation. Slater and Usoh (1993) postulate vividness in the sense that, ideally, the transmitted information's quality is so high that the existence of the mediating technology is no longer apparent. Factors that have an impact on vividness range, for instance, from a display's pixel resolution, over rendering parameters up to whether dynamic shadows are supported (Slater and Wilbur, 1997). Until today, the limited display quality of most state-of-the-art HMDs (e.g., limited pixel resolution, screen door effect) still leads to difficulties in readability of small prints in some cases, as can be seen in Chapter 3.

In addition to the outlined concepts, Slater et al. (1995) propose *matching* as further concept covering the extent to which information transmitted via the immersive system (e.g., visually displayed information in the HMD) is in accordance with the user's proprioceptive feedback stemming from body movements. Thus, "[t]he greater the degree of body mapping, the greater the extent to which the movements of the body can be accurately reproduced, and therefore the greater the potential match between proprioception and sensory data" (Slater et al., 1995, p. 204). Likewise, Steuer (1992, p. 86) considers the concept of mapping and defines it as "the ability of a system to map its controls to changes in the mediated environment in a natural and predictable manner." He thereby does not treat it as a stand-alone concept, but as a factor of interactivity alongside *speed* and *range* (Steuer, 1992). Speed refers to the system's response time to any kind of user input (ideally real-time interaction) and range comprises the number of and extent to which parameters of the virtual environment can be modified (i.e., the possible interaction space) (Steuer, 1992). Overall, Steuer (1992, p. 84) defines the concept of **interactivity**, which is composed of mapping, speed, and range as "the extent to which users can participate in modifying the form and content of a mediated environment in real time." In the same way that Slater and Wilbur (1997) underlined the technological perspective from the previously introduced concepts of immersion, Steuer (1992) stresses that interactivity is also predetermined by the properties of the immersive system being used. For the latter reason and also because the concept of interactivity is even more comprehensive than the matching concept by Slater and Wilbur (1997), interactivity will be understood as further concept of immersion within the thesis.[1]

Overall, Slater and Wilbur (1997, p. 605) argue that "[e]ach of these dimensions of immersion has, in principle, associated scales, indicating the extent of their realisation" and further that "these dimensions exist on multiple levels" (Slater and Wilbur, 1997, p. 605). Accordingly, depending on how strong the individual dimensions of immersion are manifested in a system, VR systems can be classified. Several classification schemes are adopted in literature. Some scholars only differentiate between "immersive" and "non-immersive" VR (e.g., Suh and Lee, 2005), others between "fully immersive," "semi-immersive," and "non-immersive" VR (e.g., Gutiérrez et al., 2008; Pfeiffer et al., 2020). However, the categorization by Gutiérrez et al. (2008) is only performed according to the extent to which users still perceive the physical reality during their experience (descending by degree of isolation: HMD fully immersive, CAVE semi-immersive, desktop environment non-immersive). According to Slater and Wilbur (1997), the latter categorization only corresponds to the concept of inclusiveness and disregards all other concepts.

In contrast to the previous distinctions, this thesis will differentiate between high and low immersive VR systems, since desktop-based systems can also convey a feeling of telepresence (Klein, 2003; Kim and Biocca, 1997) and should therefore be categorized as low immersive rather than non-immersive VR.

While immersion manifests the technological description of VR systems, the concept of presence determines VR in the context of the human experience

---

[1] *Note*: Slater and Wilbur (1997) also mention *plot* as further concept referring to whether the implemented virtual environment acts autonomously and has the ability to span an all-encompassing secondary world that follows its own dynamics and storyline. Since the concept is highly software-specific and specifically tailored to any application, it will not be considered further in this thesis.

(Steuer, 1992). Overall, presence is a multi-faceted concept that has been defined, interpreted, and operationalized in various ways in literature and across disciplines (Skarbez et al., 2017; Cummings and Bailenson, 2016; Lee, 2004). For instance, in their seminal work, Lombard and Ditton (1997) identified six different conceptualizations of presence, which are subject to the higher-level definition that presence is "the perceptual illusion of nonmediation" (Lombard and Ditton, 1997, n.a.). Lee (2004, p. 27) defines presence as "a psychological state in which virtual objects are experienced as actual objects in either sensory or nonsensory ways" and differentiates between physical, social, and self presence. Similarly, Kim and Biocca (1997, n.a.) describe telepresence in a sense that a "user of the medium considers the items in the mediated environment as unmediated and reacts directly to the items as if they are physically present objects" further considering telepresence from the two factors, arrival (virtually *now* "being there") and departure (physically *no longer* "being there").

However, as seen, literature is not uniform in the terminology and usage of different presence concepts. In particular for telepresence, which is defined as the "extent to which one feels present in the mediated environment, rather than in the immediate physical environment" (Steuer, 1992, p. 76) multiple terms are more or less used synonymously: virtual presence, VR presence, spatial presence, physical presence, or simply presence, to name a few (Schubert et al., 2001; Sylaiou et al., 2010; Lee, 2004; Sheridan, 1992). Within the thesis, the term telepresence will be applied, which shall refer to the definition by Steuer (1992) and further employ the following aspects as proposed by Slater (1999):

- A feeling of "being there" in the virtual environment
- Dominance of the virtual environment in terms of responsiveness to stimuli compared to the physical reality
- The experience in the virtual environment is memorized as a visit to and not just as an observation of a place

Besides telepresence, particularly social presence is a widely studied construct in the IS field (Gefen and Straub, 2004; Schultze, 2010).[2] While telepresence describes the perception of feeling present in a distant *place*, social presence refers to the perception of being connected to a distant *person*, who is not physically on site (Schultze, 2010). Especially if it is not a single-user VR experience, social presence plays an important role, which will probably become even more important when VR applications become more social, e.g., by means of social shopping or enhanced communication possibilities (Zhang et al., 2020; McGill et al., 2016).

---

[2] *Note*: See the reviews by Schultze (2010) and Skarbez et al. (2017) for an overview of further presence concepts and their definitions.

2.3 Virtual Reality Systems

As sketched in the previous section, VR systems can be distinguished according to their degree of immersion. However, to gain a general understanding of what VR systems are and what not, it is important to delimit VR systems from other immersive systems. Overall, immersive systems are characterized to "purposefully change or enhance the user's perception of reality" (Cavusoglu et al., 2019, p. 680) and comprise MR as well as VR systems.[3] Arguably the best-known concept for distinguishing between different types of immersive Systems is the Reality-Virtuality Continuum by Milgram and Kishino (1994). The continuum considers the *physical* reality at one end and a complete artificially generated environment (*virtual* reality) at the other end. Within this thesis, the definition of *physical reality* according to Pfeiffer et al. (2020, p. 3) is followed, which implies that "[i]n physical reality, we perceive the physical world directly as first-order sensations and actions have direct consequences that follow the laws of physics." Everything that falls between the continuum's endpoints, i.e., everything where "real world and virtual world objects are presented together within a single display" (Milgram et al., 1995, p. 283), is denoted as Mixed Reality (MR). Depending on the proportion and direction of blending, a further distinction is made between Augmented Reality (AR), i.e., virtuality superimposes reality, and Augmented Virtuality (AV), i.e., reality superimposes virtuality (Flavián et al., 2019). It is important to note that the continuum primarily refers to visual sensations. Figure 2.1 illustrates the demarcation of the different systems based on the Reality-Virtuality Continuum (Milgram and Kishino, 1994).

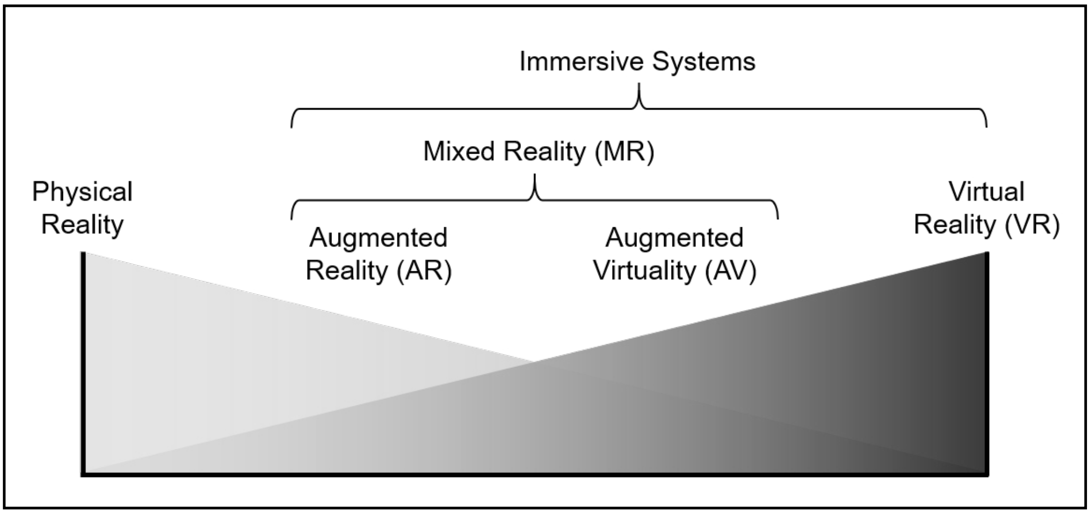


FIGURE 2.1: Reality-Virtuality Continuum (adapted from Milgram and Kishino (1994))

In a general sense, the further one moves to the right of the continuum, the more facets of physical reality are cross-faded by computer-generated virtual stimuli (AR), on the one hand, or the less real objects are superimposed in a

---

[3] *Note*: The term Extended Reality (XR) is synonymously used for immersive systems; the letter "X" in the abbreviation is understood as a placeholder for different system types.

virtual reality (AV), on the other hand. However, as long as facets of physical reality are *deliberately* retained (or displayed), it is – strictly speaking – not a pure VR.[4] To address the continuous improvement of technology, Flavián et al. (2019) propose to extend the Reality-Virtuality Continuum by the dimension of "pure mixed reality," situated between AR and AV, based on the argument that virtual content "is not superimposed on the physical environment (as in AR), but virtual objects are rendered so that they are indistinguishable from the physical world" (Flavián et al., 2019, p. 549). Finally, it needs to be noted that the different types of immersive systems also pursue different goals and serve various fields of application (e.g., see Steffen et al. (2019)).

The continuum is particularly well suited to distinguish VR from other systems. However, a holistic definition of VR requires that the aforementioned concepts of immersion (i.e., including interactivity as well as further sensory modalities) and (tele-)presence are incorporated. For instance, Pfeiffer et al. (2020, p. 3) provide a sound basis for defining VR by referring to VR as "interactive computer-generated multimodal second-order sensations, which users perceive as first-order sensations" encompassing both, technological as well as psychological perspectives. The computer-generated sensation in which the user is immersed in is oftentimes synonymously referred to as "virtual world" or "virtual environment." In this thesis, the term virtual environment is preferably used to avoid any misunderstandings with virtual worlds in the context of social online infrastructures such as SecondLife.

Technically, a VR system usually consists of three major components: A *tracking system* that continuously transmits the position and orientation in space, a *rendering computer* that processes the tracking data, calculates the 3D world accordingly and transmits the rendered sensory information, and a *user interface* that reflects the sensory information back to the user (Blascovich et al., 2002). In essence, two main implementations are established to generate immersive VR experiences, namely HMDs and CAVEs (Loomis et al., 1999; Meißner et al., 2019).

A CAVE comprises multiple wall-sized projection screens arranged in the shape of a cube to create a surrounding virtual experience.[5] During the experience, the user is situated inside the cube and can move freely by natural walking. Motion Trackers thereby align the computer-generated images with the user's current position and orientation (Mihelj et al., 2014). Through the application of special spectacles (e.g., shutter glasses), two images from slightly different perspectives are presented at the same time providing a stereoscopic simulation (i.e., a 3D experience) to the user (Loomis et al., 1999; Meißner et al., 2019). While CAVE-based systems have, due to their high cost and size requirements, not yet attracted much attention in the public (Mihelj

---

[4] *Note*: A special case constitutes a CAVE system, because in a CAVE the own body remains visually "present." Nevertheless, a CAVE is usually classified as a VR system (Cruz-Neira et al., 1992; Pfeiffer et al., 2020).

[5] *Note*: Various setups exist, mostly using five screens (three walls, floor, and ceiling). See Cruz-Neira et al. (1992) and Cruz-Neira et al. (1993) for a comprehensive description of CAVE-based systems.

et al., 2014; Anthes et al., 2016), state-of-the art HMDs have clear focus at the end-consumer market (Anthes et al., 2016).

Instead of requiring a large room-sized static technical setup as for the CAVE, HMD-based systems integrate both, the tracking system and the display, in an increasingly lightweight portable HMD. With regard to the applied display technology, a distinction is made between mobile (stand-alone) HMDs, such as the Oculus Quest,[6] and stationary (wired) systems, such as HTC Vive Pro or Oculus Rift (Anthes et al., 2016). Stationary systems are especially characterized by the higher computing power, whereas mobile systems offer a higher extent of inclusiveness due to the increased freedom of movement. Further, different tracking systems for the HMD can be distinguished with regard to the supported degrees of freedom or, for instance, according to whether inside-out (HTC Vive) or outside-in (Oculus Rift) tracking is applied (Anthes et al., 2016; Pfeiffer et al., 2020). In addition to visual displays, haptic or other sensory *output devices* may also be incorporated into a VR system (Anthes et al., 2016). Moreover, further *input devices* such as controller, navigation (e.g., treadmills), or body- and hand-tracking devices, are potential system expansions (Anthes et al., 2016).

Nevertheless, it must be stressed that HMD-based systems are constantly evolving in various system-specific dimensions such as display resolution, field of view, weight, tracking accuracy and computing power, overall, steadily increasing the degree of immersion that the systems are capable of delivering. This also includes – as described in Section 1.2 – that first hardware manufacturers are integrating eye tracking technology into HMDs expecting to improve system performance (Patney et al., 2016). After having introduced the basics of VR systems, the next section comprises a literature review outlining to what extent VR technology is already used in empirical studies within the IS discipline.

2.4 Literature Review: Studying Virtual Reality in Information Systems Research

Referring to the initial quote – "Virtual Reality: A technology in need for IS research" (Walsh and Pawlowski, 2002, p.297) – it is examined to what extent the call of Walsh and Pawlowski (2002) has been fulfilled by IS researchers so far. To give a general overview of the current state of research on VR in the IS field, a structured literature review is performed. In accordance with the research objective, the literature review is primarily of descriptive nature, hence aiming at summarizing VR articles in the IS field to represent the state-of-the-art (Rowe, 2014; Paré et al., 2015). Therefore, making a theoretical contribution is not the focus of this review. Since the thesis pursues a behavioral research

---

[6] *Note*: Within the thesis, stand-alone solutions only include systems that do not require any additional computer or smartphone. Therefore, smartphone solutions such as Google Cardboard are not considered as stand-alone VR system.

approach, empirical articles focusing on VR from a user perspective are of particular interest.

2.4.1 Methodology

Corresponding to the subject of investigation, the IS discipline is specified as the 'search field'. Following Paré et al. (2015), descriptive reviews do not raise the claim to be exhaustive. Instead, the use of a representative sample of published articles as basis for a literature review is justified. Thus, in this review, all A*, A, and B ranked journals according to the *VHB-Jourqual3: Business and Information Systems*[7] ranking are considered as target source. This results in 36 journals (including the *IS Senior Scholars' basket of eight*) and proceedings of two major IS conferences, namely *International Conference on Information Systems* (ICIS) and *European Conference on Information Systems* (ECIS). To retrieve articles that focus on VR, databases (either popular electronic libraries or archives provided on the journals' websites) covering all outlets were queried using the search term 'Virtual Reality' in title, abstract, or keywords. Overall, the search was not limited to a specific time period since the objective of the review was also to capture the development of the topic's relevance over time. Table B.1 in Appendix B lists the searched journals and provides further information on the search process.

To receive a first impression of the number and content of the hits, the search string was initially only applied to the journals of the *IS Senior Scholars' basket of eight*. The search led to ten hits, which were scanned in detail to determine whether the search process needed to be adjusted. Based on the results, the following study selection criteria were developed:

- Articles shall be of empirical nature (i.e., experimental, survey-based, or interview-based), thereby addressing the use of VR systems.[8]
- Articles shall not exclusively focus on virtual worlds (only if conclusions for behavior in high immersion VR can also be drawn they shall be considered).

Applying the criteria to the previous search results in four articles being sorted out. To illustrate the application of the criteria, they are briefly reviewed for the four papers. The article by Gleasure and Feller (2016), for instance, investigates the evolution of anchor values on crowdfunding platforms based on the case of the Oculus Rift (a VR HMD). Even though they performed a content analysis of postings (empirical), the requirement of direct usage of a VR system was not addressed. Seymour et al. (2018) outline a research agenda for the application of natural face technology for the creation of realistic avatars and its influence on realistic visual presence. Research resulting from the agenda will be highly relevant for the design of VR systems as

---

[7] Retrieved from `https://vhbonline.org/fileadmin/user_upload/JQ3_WI.pdf` (last accessed: 06/26/2020, 2:55 pm)

[8] *Note*: Research-in-progress or short conference articles were therefore only considered if they contained empirical data.

avatars' realism is also a major factor, but since the paper is conceptual in nature, it will not be considered in the review. Both, Schultze (2010) and Schultze and Mason (2012), do not conduct empirical research. While the latter article calls to rethink research ethics in the area of Internet research, the prior article provides a review of studies on avatar-enabled embodiment and presence under the realm of virtual worlds. Further, Schultze and Mason (2012) understand VR as everything that happens in the internet (i.e., virtually) and do not directly relate it to the class of immersive systems.

Next, the search scope was extended to the remaining A and all B ranked outlets. In total, 27 publications were found that matched the search.[9] To determine the relevance of an article, the aforementioned inclusion criteria were checked by scanning title, abstract, and keywords. During this process, further selection criteria were defined to refine the search results to better reflect the review's objectives. Whenever additional criteria were added, all studies were re-examined to confirm their compliance with the criteria. On the one hand, the focus of the articles had to be further specified, and on the other hand, the scope of the term "VR systems" had to be narrowed down:[10]

- Articles shall investigate user behavior and, thus, put the user in the center of the observation, i.e., articles with a strong technology focus are not of relevance (a *real-world task* shall be solved, and not an artificially created one that is designed for the purpose of enhancing overall VR technology).
- Articles shall study consumer-grade VR systems, i.e., systems that are already (or soon to be expected to be) available on the market.[11]

For better comprehensibility, the next section provides a short overview of studies that do not meet the new criteria.

User focus: The following enumeration exemplifies a set of studies that have been excluded since the articles pursue a strong technological focus. For instance, Hsieh (2002) investigates smoothness with respect to frame sets, Frees et al. (2007) develop an approach to increase hand control (i.e., accuracy of hand interactions) in VR, and Kessler et al. (1995) evaluate the precision of sensors of a whole-hand input device. Furthermore, Ware and Balakrishnan (1994) investigate the influence of lag and frame rate on performance in reaching objects, Ware and Rose (1999) examine different forms of virtual 3D object rotations, Watson et al. (1997) observe effects on search performance by manipulating the level of detail through peripheral degradation, and Pollefeys

---

[9] *Note*: For both conferences, ICIS and ECIS, no keyword search was performed because the AIS Library does not support this search specification. Thus, the results for both conferences only rely on the title and abstract search. Further, as many articles originating from the Journal *Communications of the ACM* not necessarily have an abstract, the search was widened to the full-text for this journal.

[10] *Note*: Since the objective is located purely on investigating the development within the IS field, no further forward/backward search was carried out, as for instance suggested by Webster and Watson (2002).

[11] *Note*: The usage of a CAVE is an exception if the application could potentially be also realized via an HMD.

and Gool (2002) describe how to retain 3D models from 2D images. In addition, Sidenmark and Gellersen (2019) study how gaze shifts are performed in VR (i.e., how eye, head, and torso movements are coordinated) and derive interaction design implications based on their results. Although each article has its merit on its own, the articles aimed at advancing the technology and less at understanding the user.

Consumer-grade VR systems: It is remarkable what kind of research has already been conducted in the 90s in the field of VR, but even more what kind of VR systems were used in the studies. Among the noteworthy research is the work by Deering (1995), who introduce a tool called "HoloSketch," which allows to create and manipulate 3D models employing liquid-crystal stereo eyewear (head-tracked), a hand-held 3D wand interaction device and a high-resolution display. Similarly, Ware and Lowther (1997) and Arthur et al. (1993) implement fishtank VR[12], a technology that has never been established, which is why those studies are not considered. Another exotic application is described in a 1993 published paper that consists of a palmtop unit combined with a 6D input sensor to transmit position and orientation information (Fitzmaurice et al., 1993). A recently published study used a bottom-projected table (tabletop) allowing to display 3D objects on horizontal displays that can be used by multiple persons (Nacenta et al., 2016). Further, Basdogan et al. (2000) study the role of haptic feedback in collaborative tasks (however, only in a simple desktop-based system with a haptic input device). It must be noted that VR systems that generate immersion through sight-related (visual) features are primarily targeted as these are (with sound-related features[13]) most pervasive and already mature enough to be accessible to end-consumers (Cummings and Bailenson, 2016). In terms of (visually) low immersive systems (e.g., 3D-rotatable product models shown on an ordinary desktop screen), a less restrictive exclusion approach is adopted since these are already consumer-grade and it is proven that they can also infer a sense of telepresence (Kim and Biocca, 1997; Klein, 2003). However, to reflect this, a distinction between low and high immersive systems is included as a characteristic in the summary of the articles.

2.4.2 Overview of Relevant Studies

All in all, the search resulted in 27 articles considered relevant. Figure 2.2 shows the distribution of studies over the years.

---

[12] *Note*: Fishtank VR systems consist of a desktop computer environment coupled with a head-tracking device (for realizing different perspectives) and hardware that allows to generate stereoscopic vision (Arthur et al., 1993). As a result, 3D objects appear to be situated behind or in front of the screen (Arthur et al., 1993). Due to the similarity of watching a fish tank, Arthur et al. (1993) adopted the term "fishtank VR" to refer to such systems.

[13] *Note*: With respect to auditory features, Cummings and Bailenson (2016) revealed in a meta-analysis that its effect on user presence is negligible compared to effects of visual features (i.e., field of view, stereoscopy, tracking level, update rate).

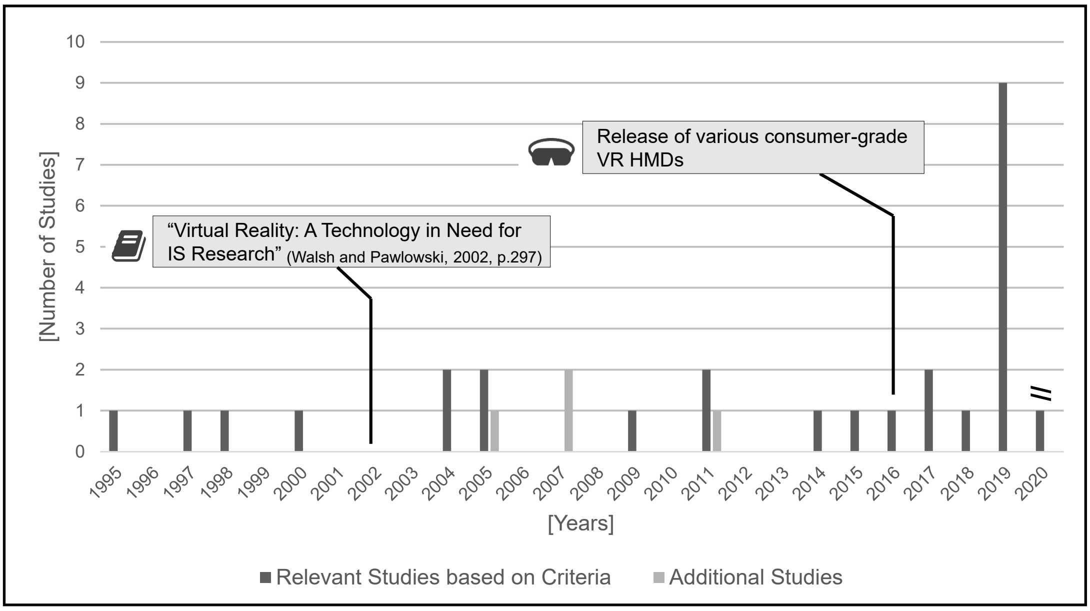


FIGURE 2.2: Distribution of studies over the years. *Note:* Since the search took place until April 2020, the number of studies appeared in 2020 may increase in the course of the year. The light grey bars represent studies, which are essential for the theory development of the Chapters 3 and 4 (see Section 2.4.3 for further information on the studies).

From the distribution of the articles over time, it is striking that one third of the studies was published in 2019.[14] Although the first study dates back to 1995, for a long time, only a few occasional publications appeared. Only from 2014 onwards, a regularity can be recognized (more than 50 percent of the publications originate from 2014 or the following years). Within the graphic, two points in time are marked: The call for IS research in the area of VR by Walsh and Pawlowski (2002) and the year 2016, which marks the release of various consumer-grade VR HMDs. With regard to the former, it can be said – at least on the basis of the publications identified in this review – that not many researchers responded to the call (2 studies were published in 2004 and 2005 each), which is, however, not surprising given the hesitant development of the technology. In contrast, with reference to the latter point in time, numerous studies were published after 2016. Indeed, 11 out of the 14 studies published after 2016 applied one of the HMDs released in 2016. It remains to be seen whether the trend of 2019 will continue in the upcoming years, thus demonstrating that VR has truly arrived in IS research.

---

[14] *Note*: At the time of the search, the journal pre-proof of the study by Lee et al. (2020) was dated 2019. Recently, however, the publication was assigned to a volume for the year 2020. To do justice to the accurate citation, the publication is dated 2020 in the dissertation, but the initial publication date is taken into account in the statistics for the review.

2.4.3 Categorization of Studies

The following subsections shed light on the studies found from various angles to provide a comprehensive overview of the characteristics of studies conducted in the area of VR in IS research. In the beginning, to get an idea of the methodological diversity of the empirical studies, the studies are examined from this point of view, thereby also introducing the characteristics of the respective sample applied. Next, it is considered in which domain (e.g., shopping or entertainment) each study can be located, allowing to identify the primary fields of application of VR in the IS field. In doing so, the individual studies and their main findings are briefly presented domain by domain. Since a high degree of immersion is the main characteristic of recent VR systems, the next section examines whether the studies address a high or low immersive system and, for experimental studies, whether immersion is manipulated between experimental groups. It is also briefly reviewed whether the counterpart of (technological) immersion, (psychological) presence, is measured by the studies, before the actually used VR technology of each study is presented.

Study Method and Sample Characteristics

The methodology applied in the studies can be broken down into three main categories: experiments, surveys, and interviews. However, these categories are not mutually exclusive and might have been applied concurrently (mixed methods approach) or supplemented by additional methods. In addition, some articles report results from more than one study, which may not necessarily be based on the same methodology.[15]

The majority of articles (18) follow an experimental research approach. Most of these articles collected their data exclusively in the laboratory, but some articles also gathered additional observations in the field. With respect to the latter, for instance, Yang and Xiong (2019) report results from two field experiments for the purpose of testing causal effects of different design artifacts, which are complemented by a laboratory experiment to uncover the theoretical mechanisms on which the results can be traced back. Similarly, Pfeiffer et al. (2020) ran one study in the laboratory under controlled conditions and an additional study in the field (a real supermarket) to allow for a comparison between virtual and physical reality. Furthermore, in order to gain additional insights into the observed measures, Wang and Suh (2019) conduct semi-structured interviews subsequent to the laboratory study as a complement. Somehow different is the approach by Peukert et al. (2019a), who investigate to what extent valid results can be obtained via an online survey to assess real VR experiences, thus applying lab experiments and online surveys. To establish a connection to the previous section, it is noteworthy that high immersive experiences have always taken place in a laboratory. Only in the study of Harms (2019), a VR environment was set up in a shopping

---

[15] *Note*: Due to the aforementioned reasons, it is possible that the sums of the individual methods do not correspond to the total number of studies. A detailed overview concerning the methods used in each article can be found in Table 2.1, Table 2.2, and Table 2.3.

mall in addition to a laboratory experiment. However, such an experimental setup is not equivalent to a field experiment. Table 2.1 provides an overview of all studies that conducted an experiment. In the following sections, the remaining content of the table is presented.

The second most common method were surveys (7 articles contain survey data). Again, a primary distinction can be made as to the format of the survey (e.g., online or offline) and how the introduction to the VR application or system took place. The surveys that were conducted online differed in how the topic was introduced. Peukert et al. (2019a), for instance, used a video of a VR experience shot from the first-person perspective and Steffen et al. (2019) showed the subjects promotional videos about VR systems from different manufacturers. Thus, these types of surveys were also referred to as *instructional* surveys (Steffen et al., 2019). Other studies follow a more elaborate approach in order to demonstrate the key characteristics of VR applications to the survey respondents. The researchers rely on so-called *experiential* surveys, which consist of an actual VR experience before answering the survey. This type of survey was carried out either in a laboratory (Steffen et al., 2019; Hartl and Berger, 2017) or in the field (Lee et al., 2020). In contrast, the survey by Sussmann and Vanhegan (2000) was conducted offline by distributing their questionnaire via mail and directly approaching citizens in the city center. Table 2.2 summarizes all studies that collected data by means of a survey.[16]

The remaining category comprises articles that conducted interviews (5 articles contain interview data). The nature of the interviews was partly further specified according to the degree to which they followed a structured procedure. Wang and Suh (2019), Mütterlein and Hess (2017), and Steffen et al. (2019) conducted semi-structured interviews, whereas Schwarze et al. (2019) applied the methodology of conversational interviews. Additional rarely used methods are listed in Table 2.3, which presents all studies that employed interviews.[17]

In general, the distribution shows that experiments are the primary methodology used. Furthermore, even when surveys or interviews are conducted, most of them are preceded by a VR experience. Thus, most articles' evaluations are based on real VR experiences. Having outlined the methodology of the individual studies, the next section examines the characteristics of the samples used.

Besides the study by Balan et al. (2019) and Schwarze et al. (2019), all laboratory studies (i.e., experiments and experiential surveys) employed a student sample.[18] Since Balan et al. (2019) test a VR experience to treat acrophobia, their sample needed to consist of acrophobic persons. Similarly, Schwarze et al. (2019) required a sample of autistic children to pursue their research

---

[16] *Note*: Articles that have already been listed in Table 2.1 were not relisted.

[17] *Note*: Articles that have already been listed in Table 2.1 or Table 2.2 were not relisted.

[18] *Note*: For two lab experiments (Ruddle and Lessels, 2009; Ruddle et al., 2011) no further information was given on the sample origin.

question. Among the subjects who took part in field studies were regular shop clients (Pfeiffer et al., 2020), shopping mall visitors (Harms, 2019), online shoppers (Yang et al., 2012), and museum visitors (Lee et al., 2020). With regard to the interview and survey participants, the following groups were explicitly addressed: media practitioners (Mütterlein and Hess, 2017), VR researchers and tourists (Sussmann and Vanhegan, 2000), employees (Yap and Bjoern-Andersen, 1998), professionals from various industries (Steffen et al., 2019), and virtual world users (Khalifa and Shen, 2004; Krasonikolakis et al., 2014). Table B.2 in Appendix B summarizes the sample characteristics and further provides information on the incentive schemes.

From this it can be deduced that field experiment data of running high immersive VR applications is still completely missing. Furthermore, experiments in high immersive VR were evaluated almost exclusively by students (except the studies of Balan et al. (2019) and Harms (2019)).

TABLE 2.1: Summary of studies – experiments

Author(s) (Year)	Method [Sample]	DO	Brief Description	Main Results	IM	VR Technology	Dependent Variables	Independent Variables	[Moderator/ Mediator]
Balan et al. (2019)	Ex (lab) [4]	T	VR experience to treat acrophobia, which uses physiological data for fear level evaluation/ exposure level adaption	75% of the users obtained a fear level of 0 (complete relaxation) in the end of the game	h	HMD, 2 controller	perceived fear level, physiological data, game level	NA	NA
Harms (2019)	Ex (lab) [44], Ex (in-store) [40]	UX	Automated usability evaluation of VR applications based on the generation of task trees	Approve that proposed usability evaluation technique correctly identifies usability issues. Misunderstandings of users are not detectable.	h	HMD, 2 controller, leap motion hand tracking	usability smells, time spent in scene	Interaction mode (gaze, laser, controller, hand); scene (coffee, copier)	NA
Huotari et al. (2004)	Ex (lab) [84]	IV	Effect of visual integration techniques on cognitive effort in large-screen graphical IS use	Visual integration techniques reduce search and recall errors in large-screen applications compared to traditional diagrams (without technique). No effect between 2D/3D presentation.	l	CAVE	search accuracy, ability to construct memory representations	Presentation form (paper-based, large screen no integration, 2D/ 3D visual integration)	[spatial visualization ability/ spatial recall performance]
Kampling (2018)	Ex (lab) [63]	L	Influence of different hand models on learning performance	Proposes a model for explaining the influence of hand models on learning perfomance	h	HMD	learning perfomance	Controller designs (controller, androgynous hand, glove hand)	[NA/ presence, cognitive absorption]

Author(s) (Year)	Method [Sample]	DO	Brief Description	Main Results	IM	VR Technology	Dependent Variables	Independent Variables	[Moderator/ Mediator]
Kim et al. (2015)	Ex (lab) [60]	NT, L	Evaluation of effects of a finger-walking-based NT on spatial learning	Finger-walking-in-place and full-body-based NTs improve spatial learning compared to joystick navigation. Full-body-based NT leads to significantly higher presence than joystick navigation.	h	CAVE, joystick, tracking system, tablet, 2 smartphones, magnet	spatial learning (route knowledge, survey knowledge), presence	NT (finger-walking-in-place (action-transferred), full-body-based walking, joystick), (balanced for spatial ability)	NA
McGill et al. (2016)	Ex (lab) [24]	E	Investigating the potentials of different VR formats in synchronous at-a-distance media consumption	No difference in social presence was found across formats, but VR cinema and VR 360° are most immersive approaches. More immersive VR conditions were found to be more engaging/ enjoyable.	h	HMD, 24" TV screen, headset, microphone, Microsoft Kinect V2s	TV/media immersion, narrative engagement, social presence/-closeness, emotional connection, synchronization, engagement/-togetherness, speech duration, viewing activity	TV together, TV at-a-distance, VR HMD at-a-distance (TV, cinema, 360° video)	NA
Peukert et al. (2019a)	S1: Ex (lab) [132], Su (online) [62], S2: Ex (lab) [39], Su (online) [45]	Sh	Investigating whether acceptance evaluations differ between true VR experience and imagined experience based on a video	Truly experiencing a VR shopping environment is necessary to accurately evaluate it	h	HMD, 2 controller, desktop screen or laptop	telepresence, enjoyment, ease of use, usefulness, intention to use	VR experience (imagined vs. experienced)	[NA/ telepresence, enjoyment, ease of use, usefulness]

Author(s) (Year)	Method [Sample]	DO	Brief Description	Main Results	IM	VR Technology	Dependent Variables	Independent Variables	[Moderator/ Mediator]
Peukert et al. (2019b)	Ex (lab) [257]	Sh	Influence of immersion on VR shopping store adoption	Positive effect of immersion on hedonic path and negative effect on utilitarian path cancel each other out, hence leading to no effect. Negative effect can be explained by low readability.	h	HMD, 2 controller, 24" desktop screen, mouse	Reuse intention	Immersion (VR shopping environment using a HMD vs. product models in 3D in a desktop environment)	[NA/ telepresence, enjoyment, diagnosticity, usefulness, readability]
Pfeiffer et al. (2020)	S1: Ex (lab) [29], S2: Ex (field) [20]	Sh	Classification of shopping motives based on eye tracking data	80% (85%) prediction accuracy in motive classification in VR (physical environment), similarities between behavior in VR and physical reality.	h	S1: CAVE, flystick	eye tracking measures	2x2 (VR/ reality) x (goal-directed/ exploratory search)	NA
Qiu and Benbasat (2005)	Ex (lab) [72]	Sh	Effects of real-time human-to-human communication by means of text-to-speech (TTS) voice and 3D avatars in e-commerce context	Presence of TTS voice has effect on flow, presence of 3D avatar affects perceived telepresence	l	desktop screen, mouse, keyboard	social presence, telepresence, flow	3D avatar (yes/no), TTS voice communication (text only, TTS voice only, both)	NA
Ruddle and Lessels (2009)	S1: Ex (lab) [30], S2: Ex (lab) [20]	NT	Testing the advantages of walking interfaces in VR with respect to navigation	Walking interface performed significantly better in a search task than rotational body inf. or no body inf.; performance unaffected by environment's level of detail.	h	HMD, 3D mouse, motion tracker, 21" screen, mouse, keyboard	search efficiency, number of collusions, rechecking of objects	S1: body-based inf. (none, rotation, walking); S2: body-based inf. (none, walking)	NA

Author(s) (Year)	Method [Sample]	DO	Brief Description	Main Results	IM	VR Technology	Dependent Variables	Independent Variables	[Moderator/ Mediator]
Ruddle et al. (2011)	S1: Ex (lab) [32], S2: Ex (lab) [44]	NT, L	Comparison of NTs in terms of availability of body-based inf. in virtual environments with varying sizes	S1: Walking interface travelled less distance and explored more efficiently than other groups. S2: Translational body-based inf. (independent whether there is rotational inf.) improves participants' cognitive map.	h	S1/S2: HMD, motion capture system, joysticks, 20" screen, (S1: tracking hall; S2: linear/omnidirectional treadmill)	travel distance, accuracy of cognitive map, travel speed	S1: body-based inf. (none, rotation, walking); S2: body-based inf. (none, rotation, translation, walking)	NA
Slater et al. (1995)	Ex (lab) [16]	NT	Effect of VR NT (walk in place to move forward) on presence perception	Whole-body movement walking simulation method increases presence perception compared to hand-pointing NT	h	HMD, 3D mouse, head-tracking and mouse sensors	ease of navigation, presence	walking technique vs. hand controlled navigation	[NA/ virtual body association, nausea, chosen path]
Suh and Lee (2005)	Ex (lab) [85]	Sh	Influence of VR interfaces on consumer product learning	VR increases consumer product learning. Effects are more pronounced for virtually high than low experiential products.	l	17" desktop screen, mouse, keyboard	consumer learning	interface design (VR/ static) x product type (high/ low experiential product)	[high,low experiential products/ NA]
Suh et al. (2011)	Ex (lab) [92]	Sh	Influence of an avatar's user similarity on usage intention	The more similar the avatar is to the user, the higher is the avatar identification, in turn leading to emotional attachment and diagnosticity. Both, in turn, positively affect intention.	l	19" desktop screen, mouse, keyboard	intention to use avatar	body similarity (high/ low) x facial similarity (high/ low)	[NA/ avatar identification, diagnosticity, emotional attachment]

Author(s) (Year)	Method [Sample]	DO	Brief Description	Main Results	IM	VR Technology	Dependent Variables	Independent Variables	[Moderator/ Mediator]
Wang and Suh (2019)	Ex (lab), In (semi-structured) [20]	UX	Influence of user's behavioral adaptation on cybersickness experience	Demonstration of user adaptation and its potential influence to decrease negative effects (caused by cybersickness) on user experience	h	HMD, 2 controller	cybersickness symptoms, cybersickness triggers, adaptation, overall appraisal about VR usage	(sitting/ standing posture) x (boat task/ sledding task)	NA
Westland and Au (1997)	Ex (lab) [116]	Sh	Comparison of shopping experiences between catalog search, preselected bundle assortment, VR storefront	No difference in spending behavior and number of items purchased across interfaces. Higher search time with VR storefront interface (50 % higher compared to catalog, 212 % to bundle search).	l	desktop, joystick	money spent, time spent, number of items purchased	shopping interface (catalog, preselected bundle, VR)	NA
Yang and Xiong (2019)	S1: Ex (field) [24,435 purch.], S2: Ex (field) [163,944 purch.], S3: Ex (lab) [160]	Sh	Influence of personalized vs. non-personalized virtual fitting room (VFR) designs on sales outcomes	VFR increases sales/ customer satisfaction and decreases product returns, but personalized VFR does not increase sales when conventional product visualizations are available.	l	S1/2: desktop screen, laptop or mobile device, S3: tablet	product sales, customer satisfaction, product returns	S1: VFR (yes/ no), S2: avatar type (non- vs. personalized), S3: (non- vs. personalized VFR) × (non- vs. conventional visual displays)	[S2: Conventional visual displays/ S3: risk, enjoyment, apparel performance, self-discrepancy]

Note: IM=Immersion (h=high, l=low), inf=Information, S=Study; Method: CS=Case Study, Ex=Experiment, In=Interview, Su=Survey; DO=Domain: E=Entertainment,IV=Information Visualization, L=Learning, NT=Navigation Techniques, O=Others, Sh=Shopping, T=Therapy, Tou=Tourism, UX=User Experience/ Usability, VW=Virtual Worlds.

TABLE 2.2: Summary of studies – surveys

Author(s) (Year)	Method [Sample]	DO	Brief Description	Main Results	IM	VR Technology	Dependent Variables	Independent Variables	[Moderator/ Mediator]
Hartl and Berger (2017)	Su (experiential), (lab) [155]	E	Influence of presence and escapism on technology acceptance of VR glasses	Presence affects performance expectancy (moderated by escapism) and hedonic motivation. Performance expectancy, social influence and habit impact behavioral intention.	h	HMD	behavioral intention	(Presence)	[escapism/ performance expectancy, hedonic motivation, effort expectancy, social influence, habit, facilitating conditions]
Khalifa and Shen (2004)	Su (online) [149]	VW	Influence of interactivity and vividness on telepresence and social presence in virtual communities	Both vividness and interactivity significantly affect telepresence and social presence. Vividness has stronger effect on social presence, whereas interactivity has stronger effect on telepresence.	l	NA	telepresence, social presence	(interactivity (dimensions: active control, communication, synchronicity), vividness)	NA
Krasonikolakis et al. (2014)	Su (online) [104]	VW, Sh	Investigates influencing factors for users' store selection and money spending behavior in virtual worlds	Predominant store selection factors are "core store" and "security and privacy" features. Best predictor for spending behavior is visiting frequency/ visiting time of a store.	l	NA	store selection criteria, amount of money spent	(shopper vs. non-shopper, VW visit frequency, difficulty of avatar creation, difficulty of navigating in VW, similarity between virtual/ physical world, time spent in VW, time spent in store)	NA

Author(s) (Year)	Method [Sample]	DO	Brief Description	Main Results	IM	VR Technology	Dependent Variables	Independent Variables	[Moderator/ Mediator]
Lee et al. (2020)	Su (experiential), (field) [269]	Tou	Testing the experience economy theory in a VR museum context	Absorption (education and entertainment) positively affects immersion (escapism and esthetic), and in turn increases the overall VR museum experience and finally visit intention.	h	HMD	museum visit intention	(absorption (education, entertainment))	[NA/ immersion (escapism, esthetic), VR museum experience]
Steffen et al. (2019)	S1: Su (experiential), (lab) [263], S2: Su (instructive), (online) [204], S3: In (semi-structured, qualitative) [18]	O	Development of a framework of generalized affordances for virtually assisted activities	All introduced affordances vary between physical reality and both, VR and AR. Many affordances differ in the ability of AR and VR in terms of their implementation.	h	S1: HMD, S2: desktop screen, laptop or mobile device, tablet, S3: HMD	affordances of VR	(VR, AR, physical reality)	NA
Sussmann and Vanhegan (2000)	Su (distributed via e-mail, approaching citizens in public) [100]	Tou	Influence of VR on tourism	VR will not be a substitute for real holidays, but can be a complement	l	NA	best/ worst features of VR tourism	(VR researcher vs. general public (tourists))	NA

Note: IM=Immersion, S=Study; Method: CS=Case Study, Ex=Experiment, In=Interview, Su=Survey; DO=Domain: E=Entertainment, Inf=Information Visualization, L=Learning, NT=Navigation Techniques, O=Others, Sh=Shopping, T=Therapy, Tou=Tourism, UX=User Experience/Usability, VW=Virtual Worlds.

TABLE 2.3: Summary of studies – interviews

Author(s) (Year)	Method [Sample]	DO	Brief Description	Main Results	IM	VR Technology	Dependent Variables	Independent Variables	[Moderator/ Mediator]
Mütterlein and Hess (2017)	In (semi-structured), multiple cases [5]	E	Investigating potential business model transformation through VR technology in the media industry	Impact of companies that produce/distribute VR content is large, whereas internal use of VR has only small impact	h	NA	NA	NA	NA
Schwarze et al. (2019)	CS, In (conversational), unstructured lab observation, (lab) [5]	T	Investigation whether autistic persons can learn emotion recognition in VR	High motivation and acceptance to use VR for learning emotion recognition, design propositions	h	HMD, 2 controller, headphones	correctly sorted cards (qualitative analysis)	NA	NA
Yap and Bjoern-Andersen (1998)	CS, In (with employees), [NA]	L	Knowledge management and representation via VR/3D technologies	VR/3D technology as important innovation to grasp and share complex expert knowledge and accelerate organizational learning	l	NA	NA	NA	NA

Note: IM=Immersion, S=Study; Method: CS=Case Study, Ex=Experiment, In=Interview, Su=Survey; DO=Domain: E=Entertainment, Inf=Information Visualization, L=Learning, NT=Navigation Techniques, O=Others, Sh=Shopping, T=Therapy, Tou=Tourism, UX=User Experience/Usability, VW=Virtual Worlds.

Study Domains

In order to obtain an overview of the application scenarios in which VR has been studied within the IS field and of what research has already been conducted within those, the individual studies will be aggregated to target domains. For the assignment to and definition of the domains, the author keywords of the studies were used whenever possible. Overall, the following domains were identified (number of studies in brackets; categorization is not mutually exclusive): Shopping (9), Entertainment (3), Therapy (2), Learning (5), Virtual Worlds (3), Navigation Techniques (4), Tourism (2), User Experience & Usability (2), Information Visualization (1), Others (1). In the subsequent sections, each domain is outlined separately.

Shopping. The domain with by far the most articles is the shopping domain, whereby all studies can also be located in the field of e-commerce. Nonetheless, the studies differ according to the object of investigation. While some studies are concerned with virtual product presentation formats (Suh and Lee, 2005; Westland and Au, 1997), others examine the role of avatars' degree of realism (Yang and Xiong, 2019; Suh et al., 2011) or avatars' role in live customer help (Qiu and Benbasat, 2005), and yet other articles study questions regarding the technology acceptance of VR shopping environments (Peukert et al., 2019a; Peukert et al., 2019b). Furthermore, one study takes a deeper look at the classification of shopping motives (Pfeiffer et al., 2020) and another study examines store selection factors in the context of virtual world stores (Krasonikolakis et al., 2014)[19]. Starting with the studies on presentation formats, Suh and Lee (2005) and Westland and Au (1997) look at the effects of different interface designs of low immersive e-commerce websites, wherein Suh and Lee (2005) focus on consumers' product learning and Westland and Au (1997) on consumers' buying behavior. By comparing a static user interface (i.e., in terms of a still image) to an interface showing 3D product presentations, Suh and Lee (2005) show that the latter increases overall consumer product learning and that the effect is more pronounced for virtually high experiential products than for virtually low experiential products. Similarly, Westland and Au (1997) compare three different interfaces (catalog search, preselected bundled assortment, digital storefront), without finding any significant differences in spending behavior or the number of products purchased across the interfaces. However, the search time using the digital storefront was increased (50% to catalog, 212% to bundle) compared to the other interfaces (Westland and Au, 1997).

Closely related to the previous studies are the studies that look at the avatar's degree of realism or the avatar's similarity to the user because products are virtually worn by the avatars and thus also contribute to the product presentation. In this regard, Suh et al. (2011) exemplarily show for apparel shopping that the more an avatar resembles a user (face similarity and body similarity), the higher is the identification with the avatar, which again leads to perceived

---

[19] *Note*: Due to the virtual world context, the study will be introduced in more detail in the section covering the virtual world domain.

diagnosticity and emotional attachment. Both, in turn, impact the intention to use the avatar (Suh et al., 2011). Likewise, Yang and Xiong (2019) explore the use of avatars (personalized and non-personalized) in the area of fashion shopping in so-called virtual fitting rooms (VFRs). Overall, they demonstrate in a field experiment that the general availability of VFRs increases sales and customer satisfaction while reducing product returns. Interestingly, when personalized VFRs in combination with conventional product visualizations are available, sales do not increase, which is explained by the fact that self-discrepancy becomes apparent under this composition (Yang et al., 2012). Instead of addressing product presentations in e-commerce settings, the article by Qiu and Benbasat (2005) is concerned with real-time human-to-human customer communication and consultation. For this purpose, the authors investigate the use of TTS voice technology and 3D avatars and show that whereas the prior has a significant effect on flow, the latter significantly affects perceived telepresence (Qiu and Benbasat, 2005).

The studies by Peukert and colleagues (Peukert et al., 2019a; Peukert et al., 2019b)[20] shed light on questions related to the acceptance of VR shopping environments. Peukert et al. (2019b) examine how the degree of immersion (technically, a low and a high immersive VR shopping environment are compared in a laboratory experiment) influences system adoption. Immersion thereby has a positive effect on a hedonic path, but a negative effect on utilitarian path. As a result, both paths cancel each other out leading to no effect in the behavioral intention. However, the negative effect can be explained by a technological constraint, namely low readability, which is why in future when VR technology is further advanced, the effect of immersion on usage intention may be positive throughout (Peukert et al., 2019b). Against the background of high efforts with respect to costs and required staff when evaluating VR applications, Peukert et al. (2019a) explore the extent to which a real VR experience is necessary to accurately evaluate the acceptance of a highly immersive VR shopping application. By comparing a real VR experience to an evaluation based on a video introducing the VR environment, they show that for an accurate assessment, a real experience is required (Peukert et al., 2019a).

Finally, with the vision to develop innovative decision support systems, Pfeiffer et al. (2020) apply machine learning techniques to classify shopping motives (literally, goal-directed and exploratory search) based on eye tracking data. Thereby, they train and test a prediction model in two studies: one in a VR shopping environment and one in physical reality. Their model reaches an 80% (85%) prediction accuracy in VR (in physical reality) and, furthermore, the best predicting variables largely overlap, which is why the authors suggest that information search behavior may be similar in both environments (Pfeiffer et al., 2020).

Entertainment. The segment that has so far enjoyed the greatest popularity for VR technology is the entertainment industry, which comprises the gaming

---

[20] Friendly spoiler alert: The two studies are presented in Chapter 3 and Chapter 4 in detail, so if you do not want to know the results in advance, I recommend skipping this paragraph!

and media industry. With respect to hedonic information systems, Hartl and Berger (2017) investigated the technology acceptance of VR glasses. For the purpose of giving their respondents an impression of the capabilities of such systems, they viewed 360° contents (a video and a slide-show) and played a game using a HMD within their experiential survey (Hartl and Berger, 2017). They find that the behavioral intention to adopt VR glasses is driven by social influence, habit, and performance expectancy, whereby the latter is significantly influenced by perceived telepresence (users' escapism tendency further moderates this effect) (Hartl and Berger, 2017). Mütterlein and Hess (2017) shed light on the media industry's potential business model transformation through VR. They differentiate between two perspectives, a company internal use of VR (e.g., like conference or collaboration tool) and external use by means of distributing VR content such as videos or games to customers. With respect to the prior, Mütterlein and Hess (2017) predict only a small impact on company's business models; however, for companies that produce and distribute VR content the impact may be large. Looking at the special use case of synchronous at-a-distance media consumption, McGill et al. (2016) investigate the potential use of different VR formats for this matter. With regard to social presence, no statistical differences between all tested formats were found, but specifically a VR cinema and 360° VR video format were rated to be the most immersive (McGill et al., 2016). Moreover, the more immersive VR conditions were perceived to be more enjoyable as well as engaging (McGill et al., 2016). In addition to the presented studies, other studies use a playful environment (serious games) to address real-world challenges (see next section, Balan et al. (2019)).

Therapy. Besides leisure activities as proposed by the aforementioned domain, VR technology is employed in the area of therapeutic treatment. One specific use case is highlighted in the study by Balan et al. (2019) with an application (a game) that shall help people to cope with acrophobia (fear of heights). The game continuously adapts its exposure level to the patient's anxiety. In the end of the game, 75% of the patients obtained a fear level of 0, which corresponds to a complete relaxation (Balan et al., 2019). However, the range of VR applications does not only encompass a wide variety of phobias but, as Schwarze et al. (2019) show, also the treatment of autistic children. In a small sample unstructured lab observation, Schwarze et al. (2019) test the capability of VR technology for emotion recognition learning for autistic children. Overall, they report children's high motivation to use the introduced VR learning application and give design propositions for applications with similar objectives (Schwarze et al., 2019).

Learning. As described in the previous section, VR can potentially not only contribute to emotion recognition learning among autistic children (Schwarze et al., 2019), but also to other forms of learning such as individual learning (Kampling, 2018), organizational learning (Yap and Bjoern-Andersen, 1998), spatial learning (Kim et al., 2015; Ruddle et al., 2011), or consumer product learning (Suh and Lee, 2005). In 1998, Yap and Bjoern-Andersen (1998) outlined VR and 3D technology as important innovations for expert knowledge management and, as a consequence, see VR technology as an accelerator for organizational learning. With a focus on studying VR's ability to improve individual learning, Kampling (2018) investigated the interplay of cognitive absorption and presence on different learning-related outcome variables in a pilot study. His initial findings suggest that presence has a positive impact on cognitive absorption, and both positively influence learner satisfaction (Kampling, 2018). The effects on perceived individual learning, however, point in different directions (Kampling, 2018). While presence has a positive effect on perceived individual learning, cognitive absorption obtains a negative effect (Kampling, 2018).[21]

Virtual Worlds. Despite the strict screening process, three studies relating to virtual worlds remained in the sample. Among them is the study by Khalifa and Shen (2004), who looked at the influence of system design characteristics on presence perception (considering both, telepresence and social presence) in the context of virtual communities. The system design characteristics were instantiated as vividness and interactivity, which both had a significant influence on the two presence perceptions. More specifically, comparing the effects from both, vividness had a stronger effect on social presence, whereas interactivity had a stronger effect on telepresence (Khalifa and Shen, 2004). Furthermore, Krasonikolakis et al. (2014) identify influencing factors for users' store selection decision as well as money spending behavior in virtual worlds. They find that so-called "core store features" comprising product variety and price, convenience related factors, as well as the store atmosphere, and "security and privacy features" are the predominant store selection factors, while visiting frequency and visit duration are the best predictors for users' spending behavior (Krasonikolakis et al., 2014). Since Suh et al. (2011) consider a task-focused virtual world setting, namely, a shopping context, the study has already been addressed in the shopping domain. Nevertheless, because of its affiliation, it should also be mentioned here.

Navigation Techniques. Another stream of research concentrates on investigating the effect of various navigation techniques for locomotion in virtual environments on user behavior. Central to all studies is a comparison between several technology-mediated navigation techniques (e.g., by means of a joystick or "finger-walking" on a tablet (Kim et al., 2015)) to a walking interface that is close to (e.g., physical walking on a treadmill (Ruddle et al., 2011)) or identical to actual physical walking (also referred to as full-body-based walking). With respect to perceived telepresence, full-body-based navigation achieves significantly higher values than a joystick (Kim et al., 2015) or a hand-pointing navigation technique (Slater et al., 1995). The studies of Ruddle and colleagues distinguish whether body-based walking is fully supported, or whether only rotational or translational movements are translated (or none of these) (Ruddle and Lessels, 2009; Ruddle et al., 2011). They find that full-body-based walking significantly improves search task performance in comparison to only rotational or no body-based information (Ruddle and Lessels, 2009)

---

[21] *Note*: Not all studies have been discussed in detail as the missing studies have either already been discussed or will be discussed in a later section.

and that further the search efficiency is increased (less travel distance and higher exploration efficiency) through full-body-based walking (Ruddle et al., 2011). A further research objective was to examine whether navigation techniques affect spatial learning. In this regard, Kim et al. (2015) reveal that finger-walking on a tablet as well as full-body-based navigation, both, improve spatial learning compared to a joystick navigation. Further, according to Ruddle et al. (2011), as long as translational body-based information is available, participants' cognitive map is improved.

Tourism. Two studies were identified that looked at the application of VR in the tourism industry, one of them hypothetical (Sussmann and Vanhegan, 2000) and the other one in an actual use case (Lee et al., 2020). Already in the year 2000, Sussmann and Vanhegan (2000) investigated how virtual holidays by means of VR might affect the travel sector by surveying VR researchers as well as potential tourists. They conclude that VR will not be a substitute for real holidays, but the technology can be a complement (Sussmann and Vanhegan, 2000). In contrast to considering entire vacations, Lee et al. (2020) examine VR experiences in a museum context. Using a HMD in the field, museum visitors of one museum could experience a VR experience about another museum against the backdrop of evaluating the influence of the VR experience on the visiting intention. Their results suggest that absorption (modeled as education and entertainment) has a positive impact on immersion (instantiated as escapism and esthetic), which in turn increases the overall VR museum experience and finally leads to an increased intention to physically visit the museum in future.

User Experience & Usability. The breakthrough of VR is not only related to questions about system costs, but also to factors such as the user experience and the usability of VR applications. Thereby, the evaluation of the usability of applications and especially the detection of usability issues is an important activity to improve the overall system quality. To address this, Harms (2019) proposes and validates an automated usability evaluation technique that identifies usability issues of VR applications. While so-called usability smells can be correctly detected, in particular, misunderstandings of users cannot be revealed (Harms, 2019). Similarly, yet with a stronger focus on user experience, Wang and Suh (2019) study the well-known problem of VR associated with cybersickness. In their study, they introduce "user adaptation" (i.e., by means of repeated VR exposures or through anticipating distracting situations and adapting accordingly) as a potential influencing factor to diminish negative impacts – such as cybersickness – on the general user experience (Wang and Suh, 2019).

Information Visualization. The study by Huotari et al. (2004) is the only attempt in the area of information visualization. Based on the idea to improve the design of graphical information systems, the authors find that visual integration techniques improve search performance in large-screen applications compared to traditional diagrams that do not apply any technique (Huotari et al., 2004). Further, they do not find any effect when comparing 2D to 3D large screen applications (Huotari et al., 2004).

Others. Finally, the study by Steffen et al. (2019) takes on a special role, as it specifically considers in which domains the use of VR (but also AR) is reasonable. Therefore, they develop and validate a framework of generalized affordances for virtually assisted activities, which may guide practitioners in developing immersive systems.

Additional information on the respective tasks (if applicable) that the participants had to accomplish as well as a brief description of the VR environment in which the study took place can be retrieved from the Table B.2 in Appendix B (columns "VR Environment" and "task"). Interestingly, the VR environments almost exclusively aimed at reproducing reality.

The breakdown by domain has shown that VR has been studied in many different application domains, but the main interest has been placed in the shopping context so far. A further classification would also be possible according to the field of investigation and not with respect to the specific application scenario. For instance, all of the following studies focused on technology adoption either from a user perspective (Peukert et al., 2019a; Hartl and Berger, 2017; Peukert et al., 2019b) or a firm-level perspective (Mütterlein and Hess, 2017; Steffen et al., 2019). However, the categorization along the application domains seemed to be most appropriate for the time being.

Study Relation to the Concepts of Immersion and Presence

Immersion gives the possibility to objectively classify a VR system from a technological point of view. A general distinction is made between high and low immersive systems (see Section 2.2). Within this review, the decisive factor for the evaluation is the type of VR system the study *refers* to (i.e., high or low immersion). Overall, 17 studies applied or referred to high immersive systems (HMDs or CAVE), whereas 10 studies considered low immersive systems (desktop environments).

Furthermore, for each of the experimental studies, it was examined whether the treatment manipulation also involved a manipulation of the technological concepts of immersion (i.e., inclusiveness, vividness, extensiveness, surrounding, and interactivity). For 14 studies, a manipulation of at least one technological concept of immersion could be identified.[22] As only a few studies have reported their treatment manipulation in relation to the technological concepts of immersion (e.g., Suh and Lee (2005) and Peukert et al. (2019b)), the experimental design and the description of the independent variables were used as a basis to derive the technological concepts for each study. The majority of studies (13) has manipulated vividness, followed by interactivity (10). Five studies have manipulated all technological concepts of immersion. Additional combinations usually consisted only of interactivity and vividness or one other concept. Figure 2.3 illustrates the identified manipulations for the studies.

---

[22] *Note*: Pfeiffer et al. (2020) do not compare two different systems within their treatments, but a highly immersive system to the physical reality. Their approach is therefore mentioned here, but left out for the further procedure.

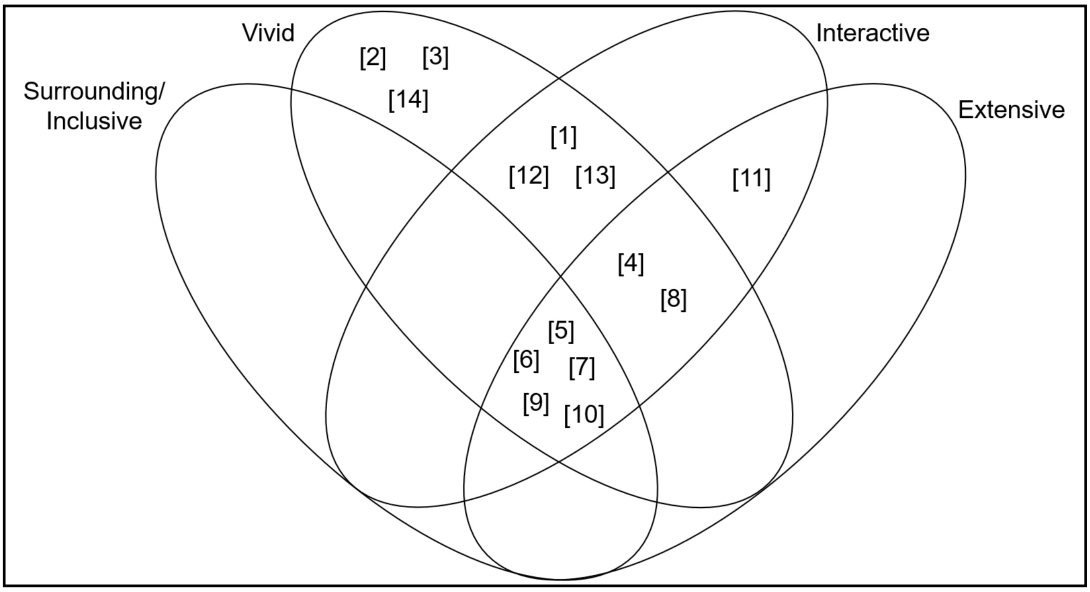


FIGURE 2.3: Studies manipulating the technological concepts of immersion. *Legend*: [1] Harms (2019), [2] Huotari et al. (2004), [3] Kampling (2018), [4] Kim et al. (2015), [5] McGill et al. (2016), [6] Peukert et al. (2019b), [7] Peukert et al. (2019a), [8] Qiu and Benbasat (2005), [9] Ruddle and Lessels (2009), [10] Ruddle et al. (2011), [11] Slater et al. (1995), [12] Suh and Lee (2005), [13] Westland and Au (1997), [14] Yang and Xiong (2019).

However, it remains to be said that most studies have not put the manipulation of immersion at the center of the investigation.

With respect to presence, nine studies have reported data for self-reported presence measures. Thereby, different facets were assessed, mostly referring to either only telepresence (Peukert et al., 2019a; Peukert et al., 2019b; Hartl and Berger, 2017; Slater et al., 1995), or a combination of social presence and telepresence (McGill et al., 2016; Qiu and Benbasat, 2005; Khalifa and Shen, 2004).[23] Here, it must be noted that the construct was not always designated as *tele*presence (e.g., Slater et al., 1995; Hartl and Berger, 2017), but theoretically corresponded to it. Moreover, it was sometimes covered as a subset of a larger scale, which was equivalent to telepresence contentwise (McGill et al., 2016). In addition, two studies (Kampling, 2018; Kim et al., 2015) have drawn on versions of the Witmer-Singer Presence Questionnaire (Witmer and Singer, 1998; Witmer et al., 2005) – although the actual measurement of presence via the questionnaire is partly questioned in the literature (e.g., see Slater, 1999).

Overall, the studies have indicated that higher immersion (Peukert et al., 2019b), an actual vs. an imagined VR experience (Peukert et al., 2019a), higher vividness and higher interactivity (Khalifa and Shen, 2004), the presence of a 3D avatar (Qiu and Benbasat, 2005), and a more natural navigation technique

---

[23] *Note*: The applied presence measures mostly build upon the scale introduced by Kim and Biocca (1997).

(Slater et al., 1995) have a positive impact on the perceived telepresence.[24] With respect to the results obtained by means of the Witmer-Singer Presence Questionnaire, Kim et al. (2015) find a significant effect of the navigation technique (full-body-based walking higher than joystick navigation), whereas Kampling (2018) does not reveal any significant differences from the application of different hand models (HTC Vive controller vs. androgynous hands or glove hands). In addition to the effect of vividness and interactivity on telepresence, Khalifa and Shen (2004) further outline an effect of vividness and interactivity on social presence. However, all other studies that measured social presence do not capture any effect of their treatments on social presence (Qiu and Benbasat, 2005; McGill et al., 2016).

Due to the great diversity of measured variables, only immersion and presence as key concepts in the context of VR (Walsh and Pawlowski, 2002; Slater and Wilbur, 1997) were dealt with in greater detail within this review. All other measured variables can be retrieved from Table 2.1, Table 2.2, and Table 2.3, respectively.

Applied Virtual Reality Technology in the Studies

In contrast to the previous section, which considered the type of immersion referred to in the studies, this section examines the specific VR technology that was actually utilized to run the tested VR systems. Since no technology is explicitly tested within pure surveys or interviews, they are not considered here. In the following, a distinction is made between the applied technology for high and low immersive VR.

With regard to high immersive VR, 14 studies applied HMDs and three studies used a CAVE.[25] In conjunction with the application of the CAVEs or HMDs, most studies reported the use of additional controllers and tracking systems for interaction purposes. Particularly the older studies feature many additional sensors, because at that time, not many sensors were already built into the HMDs and controllers as it is the case today. Some studies have also used headphones to accommodate the auditory sense in addition to the visual one (Schwarze et al., 2019; McGill et al., 2016) and, moreover, the study by Ruddle et al. (2011) used different treadmills (linear and omnidirectional) as walking interface.

Considering low immersive VR, four laboratory studies were conducted in a desktop environment using either mouse and keyboard or even a joystick (Westland and Au, 1997) as input devices. In addition, Yang and Xiong (2019) conducted a set of studies of which two were executed in the field. Therefore,

---

[24] *Note*: Regarding the study by McGill et al. (2016), it was not possible to isolate the factor of telepresence from the applied immersion-media scale. Further, Hartl and Berger (2017) modeled presence in their survey as an independent variable, so that no effect on telepresence could obviously be reported.

[25] *Note*: The numbers indicate that a high immersive VR technology was employed and tested in the study. However, this does not rule out that a low immersive technology was additionally tested, for instance, in another treatment.

the applied technology within the field studies cannot be further specified – the website could have been accessed from both stationary and mobile devices. In their lab study, however, they used a tablet to let participants access the website. Further details regarding the applied VR technology in each study can be found in Table 2.1, Table 2.2, and Table 2.3, respectively.

In each study that included a VR experience, the focus primarily lay on stimulating the visual sense in the best possible manner. The transfer of motion input signals to the visual output plays a major role in generating a realistic visual stimulus matching the motion sequence. In addition to the visual sense, the studies by Kim et al. (2015), Ruddle et al. (2011), Ruddle and Lessels (2009), and Slater et al. (1995) specifically focus on the locomotor system – although the locomotor system is strictly speaking accommodated in any VR experience in which one moves forward through physical walking. Two other studies further address the auditory sense (Schwarze et al., 2019; Lee et al., 2020).

These findings are in accordance with the statement of Vinnikov et al. (2017, p. 2) that mostly "one display mode, normally visual display, is usually well represented, while other modes such as audio and tactile displays are represented with lower fidelity or not at all" and with results of Cummings and Bailenson (2016) that auditory stimuli are not among the main drivers for generating telepresence. If in the future haptic feedback (e.g., the HaptX Glove or the Teslasuit) is converted into consumer technology or even the sense of smell can be addressed, immersive experiences may be further enriched (Mihelj et al., 2014; Gutiérrez et al., 2008), paving the way for fascinating research questions.

NeuroIS Measures

Since the study presented in Chapter 6 is based on NeuroIS measurements (Peukert et al., 2020), it shall be considered whether NeuroIS measurements are already applied in the area of VR. Based on the underlying study set of this review, the use of NeuroIS measurements in VR is relatively rare. Only the articles by Pfeiffer et al. (2020) (mobile eye tracking in physical/ virtual reality) and Balan et al. (2019) (electroencephalogram (EEG), galvanic skin response, heart rate) gather neurophysiological data within their experiments. While Pfeiffer et al. (2020) analyze eye tracking data post hoc, Balan et al. (2019) access the data during the experiment to adaptively adjust the task's difficulty level. However, in the near future, when eye tracking technology may already be built into HMDs (Pfeiffer et al., 2020; Peukert et al., 2020), the number of studies obtaining NeuroIS measures (at least eye tracking) is likely to increase.[26]

---

[26] *Note*: Sidenmark and Gellersen (2019) and Vinnikov et al. (2017) also apply eye tracking. However, the articles were removed in the course of the inclusion criteria refinement.

Additional Studies of Relevance for the Thesis

For the scope of the thesis, further articles that are relevant for the theory development of the following studies were added to the review as well. Even though they only mention VR in the body of the paper and not in title, abstract, or keywords, the studies are summarized in Table 2.4 but will not be presented in detail.

2.4.4 Conclusion

The literature review set out to assess the current state of IS literature in the context of empirical VR studies. A total of 27 studies were identified, which have been analyzed according to various categories within the review. The majority of studies conducted experiments, thereby applying a student sample. With regard to the application domain, most of the studies stem from a shopping context, thus underlining not only VR's relevance for the retail sector, but also the topicality of this dissertation. While 10 studies referred to low immersive systems such as desktop environments, 17 studies applied or at least considered high immersive systems such as HMDs or CAVEs as their VR system under investigation. However, the majority of these studies (14) used HMDs, which are also more suitable for the wider consumer population in comparison to CAVE-based systems. Finally, the review considered whether studies have performed any kind of neurophysiological measurements especially against the background that in some of the recent HMDs eye tracking technology has already been integrated.

Overall, it remains interesting to continuously observe the further development of empirical VR studies within the IS discipline. Especially the development of the numbers of publications in the next few years (particularly after the remarkable peak of articles in 2019) could be directional for the entire IS research in this area.

Table 2.4: Summary of studies – additional studies

Authors (Year)	Method [Sample]	DO	Brief Description	Main Results	IM	VR Technology	Dependent Variables	Independent Variables	[Moderator/ Mediator]
Nah et al. (2011)	Ex (lab) [445]	VW	Influence of 2D vs. 3D virtual world environments on brand equity, behavioral intention, telepresence and enjoyment	Comparing 2D and 3D virtual environments reveals positive (mediated by telepresence and enjoyment) and negative effects (explained by distraction-conflict theory) on brand equity. Brand equity positively influences intention	l	desktop screen, mouse, keyboard, headset	behavioral intention	2D/3D	[NA/ telepresence, enjoyment, brand equity]
Jiang and Benbasat (2005)	Ex (lab) [80]	Sh	Influence of virtual control on perceived diagnosticity and flow	Both, visual and functional control increase flow and overall perceived diagnosticity. Visual control has an effect only in the absence of functional control	l	desktop screen, mouse, keyboard	diagnosticity, flow	control (visual, functional)	NA
Jiang and Benbasat (2007a)	Ex (lab) [176]	Sh	Influence of product presentation formats in terms of functional mechanisms (vividness, interactivity) on product purchase, website return intention	Interactivity of product presentations affect purchase and website return intention. Effect through diagnosticity, compatibility, enjoyment and attitude towards product/website	l	desktop screen, mouse, keyboard	intention to purchase, intention to return	vividness, interactivity (multiple static images, video with/ withour narration, VPE)	[NA/ diagnosticity, compatibility, shopping enjoyment, product attitude, website attitude]
Jiang and Benbasat (2007b)	Ex (lab) [176]	Sh	Influence of product presentation formats on product knowledge and perceived website diagnosticity	VPEs and videos lead to higher diagnosticity/ product knowledge (under moderate task complexity) than static pictures. Under high task complexity, all formats show equal results for product knowledge	l	desktop screen, mouse, keyboard	intention to return	product presentation formats (multiple static images, video with/ withour narration, VPE)	[task complexity/ actual product knowledge, diagnosticity, usefulness]

Note: IM=Immersion (h=high, l=low), VPE=Virtual Product Experience; Method: Ex=Experiment, DO=Domain: Sh=Shopping, VW=Virtual Worlds.

Part II

Acceptance of Virtual Reality Shopping Environments

Chapter 3

Shopping in Virtual Reality Stores: The Influence of Immersion on System Adoption [1]

Christian Peukert, Jella Pfeiffer, Martin Meißner, Thies Pfeiffer, Christof Weinhardt

> "VR technologies are fundamentally different from other information technologies and hence may require new conceptual models and understandings. As with any new information technology, caution must be exercised in assuming that understandings developed around earlier technologies will apply."
>
> Walsh and Pawlowski (2002, p. 305)

3.1 Introduction

Virtual Reality (VR) is a major trend during the last few years and is considered to influence the manner in which companies approach their customers (Berg and Vance, 2017; Grewal et al., 2017; Zahedi et al., 2016). Although

---

[1] This chapter comprises the authors accepted manuscript of an article published as the version of record in Journal of Management Information Systems © 2019 Informa UK Limited, trading as Taylor & Francis Group. Reprinted with permission. `https://www.tandfonline.com/doi/full/10.1080/07421222.2019.1628889`. Full reference: Peukert C., Pfeiffer J., Meißner M., Pfeiffer T., Weinhardt C. (2019). "Shopping in Virtual Reality Stores: The Influence of Immersion on System Adoption". Journal of Management Information Systems. 36:3, 755-788. `https://doi.org/10.1080/07421222.2019.1628889`. *Note*: The supplemental material of the authors accepted manuscript and further unpublished material can be found in Appendix C. The appendix is also based on joint work by the authors. Tables, figures, and appendices were renamed, reformatted, and newly referenced to fit the structure of the thesis. Chapter and section numbering and respective cross-references were modified. Formatting and reference style was adapted and references were updated. Opening quotation was not part of the article.

VR's first steps can be dated back to the 1960s (Sutherland, 1965), the wider consumer population's awareness level has only recently risen to today's high level as a consequence of falling prices and the advancement of VR system quality. Despite the stated importance, little is known about users' adoption behavior regarding VR applications, potentially because many VR applications are still in their nascent stage of development. One such example of a VR application is VR shopping environments. In these environments, customers who own head-mounted displays (HMDs) – such as HTC Vive or Oculus Rift – can dive into a complete, fully immersive 3D environment, move around naturally (i.e., by moving their bodies) in the stores and use navigation devices to interact with products by grabbing them and viewing them from different angles. The customers can (potentially) even communicate with sales persons or friends who appear as avatars. The VR environment can generate a variety of potential advantages, particularly for the retail business. Similar to e-commerce websites, VR stores are not constrained by opening hours and are therefore accessible 24/7 from any place with Internet access. Beyond this, VR applications incorporate multiple sensorial channels (Berg and Vance, 2017) that may offer a more interesting consumer experience through imagination and contribute to enhancing consumers' abilities to evaluate products (Cowan and Ketron, 2019). In fact, Grewal et al. (2017) recently emphasized that VR is going to substantially change consumers' shopping expectations.

The retail industry appears to see significant potential in VR. Regardless of whether it is China's e-commerce giant Alibaba (Buy+), the U.S. department store Macy's (Macy's VR), the Swedish furniture manufacturer IKEA (IKEA VR), or Europe's largest retailer for consumer electronics (Virtual SATURN), they all have – as a minimum – launched prototypes for virtual shopping environments, thereby testing opportunities of generating additional value for customers in VR. Nevertheless, as with any novel technology, like e-commerce 15 years ago (e.g., Gefen et al., 2003; Gefen and Straub, 2000), the main question is whether the customers will accept the technology and eventually use it on a regular basis. Literature that can serve as a starting point for answering this question investigated how virtual product experience influences perceived product diagnosticity or purchase intention (Jiang and Benbasat, 2005; Yi et al., 2015), it assessed whether VR enhances consumer learning about products (Suh and Lee, 2005), and it examined shopping behavior within 3D virtual worlds, which were applied as shopping environments (Jin and Bolebruch, 2009; Jin, 2009). Although the studies address aspects, which are also relevant for current and future VR shopping environments, the current technology is capable of delivering far more than what was recently understood as VR.

The main characteristic of VR technology is the degree of immersion, which such a system can potentially deliver (Suh and Lee, 2005). Immersion describes to what extent technological features of the VR environment "are capable of delivering an inclusive, extensive, surrounding and vivid illusion of reality to the senses of a human participant" (Slater and Wilbur, 1997, pp. 604/605). With the recent advance in consumer VR technology, the immersive experience is considerably more pronounced, because it can create real-world experiences (Bowman and McMahan, 2007). The degree of immersion of current technologies, such as HMDs, does indeed go far beyond the above mentioned studies, which used ordinary desktop PCs to display products in virtual worlds, such as Second Life, or employed virtual tours, or videos of products. Given that the VR technology has rapidly evolved, past studies give us almost no information about how higher degrees of immersion affect the acceptance of virtual shopping environments. To the best of our knowledge, research has so far not investigated and tried to explain the adoption of highly immersive shopping environments.

Following research in the field of e-commerce (Childers et al., 2001; Koufaris, 2002), we consider a *utilitarian* and a *hedonic* path to explain how immersion influences adoption. The e-commerce literature has identified the ability to view products from various angles and distances, and the possibility to see a simulation of the products' functionality by clicking on images and videos, as factors that positively influence the perceived ability to judge a product (*perceived diagnosticity*) (Jiang and Benbasat, 2005). Based on these findings, we argue that immersion will positively influence perceived diagnosticity and, in turn, the user's acceptance of VR shopping environments through a utilitarian path. Furthermore, building on other research (Schultze and Orlikowski, 2010; Slater and Wilbur, 1997), we argue that immersion should positively influence *perceived telepresence*, which is defined as the perception of being present in an unreal environment and, in turn, acceptance through a hedonic path (Koufaris, 2002; Nah et al., 2011; Sylaiou et al., 2010).

In order to test our research model, we conduct an experiment in which participants are randomly assigned to either shop in a highly immersive VR shopping environment by using a HMD, or to shop in a low immersive environment by using a desktop computer. Both shopping environments show the exact same supermarket shelf created with (almost) the same software to control for factors other than immersion.

We find that the utilitarian and hedonic path work in opposite directions and, in sum, cancel each other out. In contrast to our hypothesis, we find a negative effect of immersion along the utilitarian path. We are able to explain this result by taking the participant's reported readability of the product information into account. Although we used the best equipment available when we conducted the study, readability was relatively low in the VR shopping environment, due to technical reasons. In fact, when we control for readability, we find that immersion has a positive effect on the consumer's intention to adopt the shopping environment.

Several theoretical and practical contributions result from our paper: First, we specify the term immersion, separate it from telepresence, and discuss how immersion can be experimentally manipulated. Second, we propose and validate a research model for the context of immersive VR shopping environments, which combines and extends existing findings from e-commerce literature with the concept of immersion. In contrast to previous research findings (Van der Heijden, 2004; Childers et al., 2001; Jiang and Benbasat, 2007a; Koufaris, 2002), the utilitarian and hedonic paths cancel each other out when testing the framework in an immersive VR context. Third, the empirical results show that the negative utilitarian path in the model can be explained with a current technological restriction, which is the low readability of detailed information on product packages. Fourth, from a practitioner's perspective, we identify key design factors that increase the user's adoption of VR environments. We particularly find that designers need to pay special attention to the current state of the technology. In our context, we find that the readability of content in VR can substantially affect the outcome and usability of VR environments. Other characteristics of VR technology, such as the different possibilities to interact with the environment, restrictions with regard to real-time simulations of items' characteristics, or possible user sickness, can also be factors that need to be taken into account, not only for studying the effects of VR on user behavior and adoption, but also for designing the systems accordingly.

3.2 Theoretical Background

3.2.1 Virtual Reality, Immersion, and Telepresence

In contrast to the prior understanding of the term VR in some articles within the IS field (e.g., 3D product presentations or environments shown on a desktop screen (Lee and Chung, 2008; Suh and Lee, 2005)), current VR is mostly associated with a simulated environment, which a user experiences by using a HMD or a Cave Automatic Environment (CAVE). Berg and Vance (2017, p. 1) state that virtual reality is an immersive computing technology, which incorporates a "set of technologies that enable people to immersively experience a world beyond reality." Although this corresponds with the initial definitions of VR mainly focusing on the applied hardware (for an overview, see Steuer (1992)), it also draws attention to the resulting subjective impression that VR is "a real or simulated environment in which a perceiver experiences telepresence" (Steuer, 1992, pp. 76/77). Telepresence is defined as "a sense of presence in a mediated environment" (Klein, 2003, p. 42). Besides the word *telepresence* (Nah et al., 2011; Suh and Lee, 2005), others describe this phenomenon as *presence* (Witmer and Singer, 1998), *spatial presence* (Schubert et al., 2001) or *VR presence* (Sylaiou et al., 2010). It is a common argument that immersion (technological) is an essential precondition for experiencing telepresence (perception) (Cummings and Bailenson, 2016; Schubert et al., 2001; Schultze and Orlikowski, 2010; Sharda et al., 2004), thereby pointing out that telepresence "is a human response to immersion" (Schultze and Orlikowski, 2010, p. 813). In our understanding – which is grounded in the definition of immersion by Slater and Wilbur (1997) but also follows many other researchers (Cummings and Bailenson, 2016; Schultze and Orlikowski, 2010; Sharda et al., 2004; Slater, 1999) – immersion is not a subjective feeling, but an objective measure throughout. Therefore, the term *immersion* should not be used synonymously to *presence*.

The most prominent feature that objectively describes VR systems, is thus their degree of immersion (Suh and Lee, 2005), which covers the degree of isolation from reality (inclusive), the number and particularly the magnitude of different sensory channels that are stimulated (extensive), the presentation format in terms of the field-of-view delivered by the medium (surrounding), as well as the extent to which a system is capable of creating naturalistic environments from a representational point of view (vividness) (Slater and Wilbur, 1997). In addition to these concepts, Steuer (1992) outlines the concept of interactivity as predetermined by the system's features (immersion) and he defines it as the degree "to which users of a medium can influence the form or content of the mediated environment" (Steuer, 1992, p. 80) which can, for example, again be subdivided into factors, which describe the possible interaction space (range) or whether a system naturalistically responds to input signals (mapping). Such technical, recently emerged features that belong to immersion are high-quality graphic cards, which allow the creation of realistic visual stimuli at ultra-low latencies, and advanced human-computer interaction methods, which allow gestural input and room-scale full-body interaction.

Within their study, Suh and Lee (2005) use the degree of immersion to classify systems in "non-immersive" and "immersive" VR. According to their classification, VR systems, which use HMDs, are considered as immersive VR, and systems, which use desktop screens, are considered to be non-immersive. Since we argue that even computer screens can deliver a sense of telepresence (Kim and Biocca, 1997; Klein, 2003; Steuer, 1992), we classify desktop applications as low immersive rather than non-immersive, thereby suggesting a distinction between high and low immersive VR. Generally, the vision of high immersive VR can be achieved with a HMD. High immersive VR delivers a 360° field of view, which exactly reconstructs real-life viewing habits. The vision's distinct media richness increases the environment's vividness, compared to an ordinary display on a desktop screen (low immersion). In high immersive VR, particularly the perceived size of objects is similar to reality. Furthermore, in high immersive VR, the interactivity with the environment is controlled through manual actions – with or without the help of controllers. Head and hand positions are tracked in real time, whereby the body position is replicated on a one-to-one basis and manual actions, such as grasping, are directly interpreted. In contrast to a low immersion setting, in which all interactions are operated via the computer mouse or keyboard.

3.2.2 Shopping in Virtual Reality Environments

Generally, information systems are often divided into utilitarian and hedonic systems (Van der Heijden, 2004). Van der Heijden (2004, pp. 696/695) describes that the objective of a utilitarian system is "to increase user's task performance while encouraging efficiency," whereas the objectives of hedonic systems are to "provide self-fulfilling rather than instrumental value to the user, are strongly connected to home and leisure activities, focus on the fun-aspect of using information systems, and encourage prolonged rather than productive use." Online retail shopping goals can similarly be understood as being hedonic and utilitarian at the same time (Childers et al., 2001; Chiu et al., 2014). Following the idea of Childers et al. (2001) and the empirical results presented by Koufaris (2002), we argue that VR applied in a shopping context can be also viewed from a utilitarian and a hedonic perspective.

3.2.3 Utilitarian Perspective of VR shopping

Perceived product diagnosticity, which is very important for the utilitarian perspective, describes "the extent to which a consumer believes the shopping experience is helpful to evaluate a product" (Jiang and Benbasat, 2005, p. 111). Indeed, e-commerce has oftentimes been criticized for the less pronounced possibilities to evaluate products, for example, feeling, touching, and trying out products, compared to conventional in-store shopping (Jiang and Benbasat, 2005; Pavlou and Fygenson, 2006; Suh et al., 2011). Prior studies about e-commerce have therefore tried to address this issue by improving the product representation format to directly affect the perceived product diagnosticity (Jiang and Benbasat, 2005; Jiang and Benbasat, 2007a; Jiang and Benbasat, 2007b). The product representation format was manipulated by allowing a simulation of certain product functions by clicking on virtual product buttons (interactivity) or showing videos of products (vividness). In addition, the concept of perceived product diagnosticity has proven to be an important determinant of consumer behavior in further contexts, such as the evaluation of recommendation agents (Xu et al., 2014) or processing of software product trials (Kempf and Smith, 1998). Originally, the concept perceived diagnosticity is grounded in the accessibility-diagnosticity model (Feldman and Lynch, 1988). In short, the model describes that information is only used as basis for an evaluation of a product, for example, if the information is accessible and perceived as a better source for evaluating the product than all other alternative inputs (Feldman and Lynch, 1988).

Product diagnosticity is important for the utilitarian perspective, because the evaluation of the product is one of the main tasks, which users want to perform effectively and efficiently when they go shopping (Alba et al., 1997; Burke, 2002). These performance aspects translate directly to the construct of *perceived usefulness*, which is undisputedly the best-known construct concerning the evaluation of an IT system's utilitarian characteristic (Wu and Lu, 2013). *Perceived usefulness* was initially defined as "the degree to which a person believes that using a particular system would enhance his or her job performance" (Davis, 1989, p. 320). When focusing on VR, the construct covers the perceived usefulness of the entire shopping environment, including aspects such as whether the environment increases the productivity or effectiveness of shopping.

In sum, recent literature in the field of e-commerce focused on product diagnosticity as an important factor of information systems, which influences the utilitarian perspective. Prior research was restricted to manipulating single dimensions of immersion, which were implemented on an ordinary desktop

PC. It therefore remains an open question whether similar effects can be found in a high immersive VR shopping environment.

3.2.4 Hedonic Perspective of VR shopping

The counterpart to what is perceived usefulness in the utilitarian perspective, is the affective construct of *perceived enjoyment* in the hedonic perspective (Wu and Lu, 2013). Perceived enjoyment is widely applied for explaining the affective response to system use and 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 is one of the major goals that high immersive systems try to induce for example in fields like gaming, yet empirically evidence is still conflictive (Brown and Cairns, 2004; Jennett et al., 2008). When it comes to the field of shopping and retail, we found several studies that found a positive effect induced by perceived enjoyment. Lee and Chung (2008), for instance, compare two types of desktop-based online shopping experiences: one with a product presentation, which is characterized by images and text, and another one, which is characterized by illustrating a virtual shopping mall on the desktop that enables the user to explore 3D product presentations by moving through the mall. The authors find that shopping in the desktop VR shopping mall leads to a significant improvement regarding the perceived enjoyment and perceived quality assurance, which, as a consequence, increase customer satisfaction. Interestingly, the perceived convenience is not significantly improved. Similarly, the study by Jin (2009) empirically validates the shopping experience in a retail store inside the 3D virtual world of Second Life. The author investigates the effect of modality richness on the attitude towards the product, purchase intention, and enjoyment. She finds that an audio modality, compared to a text modality, leads to higher ratings on all three investigated constructs for respondents who had low product involvement, but not for respondents who had high product involvement. Jiang and Benbasat (2005) and Jiang and Benbasat (2007a) studied flow, which also incorporates cognitive enjoyment as a dimension, and found a positive effect for vividness (Jiang and Benbasat, 2005), as well as vividness and interaction (Jiang and Benbasat, 2007a). All four studies conducted their experiments in shopping environments shown on a desktop and, thus, had low immersion. The applied experimental setup can also be a reason why the main characteristic of VR – the ability to induce a feeling of telepresence – has not been considered as an important mediator.

Other studies outside the shopping context found a significant relationship between telepresence and enjoyment, for example, in the context of museums (Sylaiou et al., 2010) and the brand equity of a hospital (Nah et al., 2011). In the context of purchasing virtual goods in Second Life, Animesh et al. (2011) found – in a survey – that telepresence has an effect on flow, which – as indicated above – partially overlaps with enjoyment. As a result, we identified perceived telepresence and perceived enjoyment as relevant dimensions for characterizing the hedonic perspective of shopping in a VR environment.

3.3 Research Model & Hypotheses Development

Figure 3.1 illustrates our research model, which we describe in detail in the following paragraphs. The research model divides into two distinct paths, representing the utilitarian and hedonic dimension of shopping behavior (Childers et al., 2001). We particularly presume that a higher degree of immersion positively influences both paths and that the utilitarian path and hedonic path, in turn, positively impact on the intention to reuse a shopping environment.

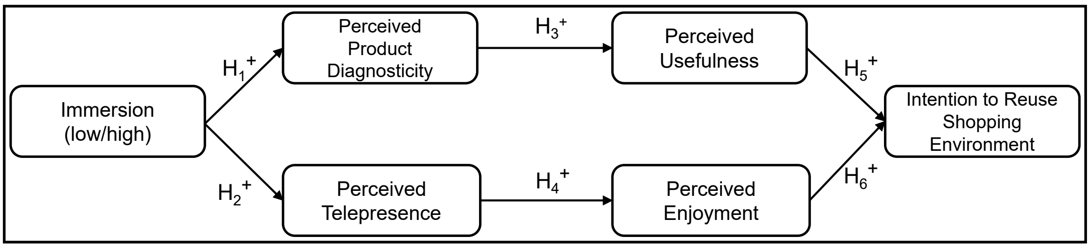


FIGURE 3.1: Research model VR shopping environment

3.3.1 The Effect of Immersion on Perceived Product Diagnosticity and Perceived Telepresence (H1 and H2)

When shopping online, customers must primarily draw on the information provided by the respective shops, because the fact of the matter is that they are not able to touch and feel the products, which can lead to a more difficult assessment of product quality compared to in-store shopping (Suh et al., 2011), or even feelings of uncertainty (Pavlou et al., 2007). According to Pavlou et al. (2007), the perceived product diagnosticity can be created through signals. One such signal is the product's representation format, which can significantly influence a consumer's perception of a displayed product, and simultaneously also the perceived product diagnosticity, because it helps consumers to understand the product features and, thus, to better judge product information and make decisions. For example, in an e-commerce setting, Jiang and Benbasat (2005) investigate effects of *visual* (varying viewing perspectives) and *functional* (experiencing product features) control, which cover aspects related to the vividness and interactivity dimensions of immersion. They show that, compared to a pallid product presentation, which uses pictures, functional control has a positive influence on perceived diagnosticity (Jiang and Benbasat, 2005). They also found that functional control had a stronger influence than visual control, possibly because the high visual control group did not change the representation format considerably: the product could be considered via QuickTime from all sides, compared to the display of a pallid picture. In another set of studies, they also include video product presentation formats in the comparison and again show that video presentations significantly increase the perceived diagnosticity, compared to a pallid picture presentation (Jiang and Benbasat, 2007b; Jiang and Benbasat, 2007a). We expect that the difference between viewing products from various angles and distances in low and high immersive environments will be much more pronounced than the difference between pallid pictures and QuickTime illustrations or videos in the way that Jiang and Benbasat (2005), Jiang and Benbasat (2007a), and Jiang and Benbasat (2007b) implemented them in a desktop scenario. High immersive environments enable high-quality 360° views and it is also possible to turn the products naturally with hand movements, which enables the users to position the product very flexibly in front of their eyes. Moreover, the true-to-scale product representation facilitates a product evaluation, which is very close to the habits in reality. At the same time, the experience still differs from physical reality, because the user will not get haptic input – i.e., she cannot feel the surface, texture, or weight of the individual product. However, future research can use specific hardware installations to give haptic or olfactory input and generate an even more immersive experience (Mihelj et al., 2014). In sum: High immersion VR shopping environments are very similar to a physical store regarding the visual input and the interaction possibilities. Building on the similarity regarding the visual input and interaction possibilities, we therefore hypothesize:

Hypothesis 1: *The higher the degree of immersion of the shopping environment, the higher the perceived product diagnosticity.*

In addition to the effects on perceived product diagnosticity, the degree of immersion can influence a customer's affective response to a shopping environment. According to Sylaiou et al. (2010, p. 246) "the goal of an immersive simulation is the ability to mislead one's senses reinforcing illusion of being somewhere other than one's physical location," thereby emphasizing the causal relationship between immersion and the induced perception of telepresence. The dimensionality of the shown information (2D vs. 3D) is shown to influence the perceived *telepresence* (Nah et al., 2011). In a similar way, Klein (2003) confirms that media richness, as well as user control, can induce a sense of telepresence. Increasing the immersion of a system according to the dimensions of Slater and Wilbur (1997) and Steuer (1992), should boost the media richness, as well as the interactivity of the system, and therefore we expect an impact on the perceived telepresence. As stated above, participants can interact with the high immersive shopping environment in several ways and, for example, Animesh et al. (2011) show that interactivity has an influence on telepresence. We therefore hypothesize as follows:

Hypothesis 2: *The higher the degree of immersion of the shopping environment, the higher the perceived telepresence.*

3.3.2 The Effect of Perceived Product Diagnosticity on Perceived Usefulness (H3)

A system is perceived as useful when it helps to fulfill a requested task. Within a shopping context, this requested task can be to understand product characteristics in order to support decision making. For instance, Kempf and Smith (1998, p. 328) measured the *perceived diagnosticity of trial*, which was defined as "the degree to which the consumer believes the trial is useful in evaluating the brand's attributes," thereby showing the close connection between diagnosticity and usefulness. We particularly argue that one of the consumers' main goals is to achieve a high product understanding, due to the increased ability of thoroughly evaluating a product (Burke, 2002; Jiang and Benbasat, 2007b). Therefore, shopping environments, which increase this product understanding, should also increase the perceived usefulness (Jiang and Benbasat, 2007b). In a study comparing different product presentation formats, Jiang and Benbasat (2007b) showed that higher perceived website diagnosticity leads to a higher perceived usefulness of the website. Based on this, we state the following:

Hypothesis 3: *Perceived product diagnosticity has a positive influence on the perceived usefulness of the shopping environment.*

3.3.3 The Effect of Perceived Telepresence on Perceived Enjoyment (H4)

An increase in media richness – for example 2D vs. 3D virtual worlds (Nah et al., 2011), or static pictures vs. videos (Jiang and Benbasat, 2007a), or question-based vs. attribute-based product customization (Kamis et al., 2010) – leads to an emotional experience, which is characterized by perceived *enjoyment*. Within their study, Nah et al. (2011) particularly show that a higher sense of telepresence leads to higher perceived enjoyment. They also outline the importance of considering telepresence as a predecessor of the hedonic construct of enjoyment. These findings are in line with a statement by Lombard and Ditton (1997) that presence (i.e., telepresence) is a significant influencing factor of enjoyment. In addition, the correlation between telepresence and enjoyment was shown by Sylaiou et al. (2010) in the context of interacting with a virtual museum. We therefore state as follows:

Hypothesis 4: *Perceived telepresence has a positive influence on perceived enjoyment.*

3.3.4 The Effect of Perceived Usefulness and Perceived Enjoyment on Intention to Reuse the Shopping Environment (H5 and H6)

Since the highly immersive VR technology, which is applied in the context of shopping, is new, the users' intention to reuse a VR shopping environment is of enormous interest. We expect that the utilitarian, as well as the hedonic, path will significantly influence the intention to reuse the VR shopping environment. In the context of online consumer behavior, the complementary influence of both perspectives (hedonic and utilitarian) – similarly operationalized by perceived usefulness and enjoyment – on the intention to reuse, has been shown by Koufaris (2002) before. Following the technology acceptance model (Davis, 1989) and the empirical results presented by Jiang and Benbasat (2007a) and Koufaris (2002), perceived usefulness will, in turn, increase the intention to reuse the shopping environment. In online shopping contexts, a number of studies have shown the interplay of those beliefs on behavioral intention (Gefen et al., 2003; Jiang and Benbasat, 2007b; Pavlou and Fygenson, 2006). We therefore propose:

Hypothesis 5: *Perceived usefulness of the shopping environment has a positive influence on the intention to reuse the shopping environment.*

It is a common argument that something, which is perceived as enjoyable, is a good candidate to be reused in the future. In fact, Koufaris (2002) – whilst investigating online consumer behavior – found this interplay between enjoyment and the intention of returning to a web-store. Similarly, in the context of applications to customize products in online-shops, Kamis et al. (2010) found that shopping enjoyment has a significant effect on the intention to revisit an online-shop in future. Furthermore, effects of perceived enjoyment on the intention to return to or reuse a website, are found over the attitude towards shopping on a website (Jiang and Benbasat, 2007a) or the perceived decision quality (Xu et al., 2014). Moreover, Nah et al. (2011) found that enjoyment affects the intention to visit a virtually seen hospital in reality. For the purpose of determining the intention to reuse a VR shopping environment, we therefore hypothesize:

Hypothesis 6: *Perceived enjoyment has a positive influence on the intention to reuse the shopping environment.*

3.4 Method

3.4.1 Manipulation of Immersion

In order to test the research model, we conducted a laboratory experiment, which manipulated the degree of immersion of the shopping environment between subjects. The participants had to make several purchase decisions either in a highly immersive VR shopping environment whilst wearing a HMD (HTC Vive, 2017 edition), or in a low immersive shopping environment displayed on a full HD 24” desktop computer screen. Thus, in the high immersion group, the participants had a panoramic field of view, which was made possible through the HMD (surrounding), and complete visual isolation from physical reality (inclusive). In terms of the immersion-dimension *extensive*, both groups were similar mainly accompanying the visual sense. Nevertheless, we argue that the magnitude with which the visual sense is accommodated is different between the groups, with the HMD addressing it more strongly. With respect to *vividness*: Although the HTC Vive reportedly has a combined resolution of 2160 x 1200 pixels,[2] it is technically questionable to simply add up the resolution of both eyes. Due to the large field of view (100° horizontally), the HTC Vive achieves approximately 11 pixels per degree visual angle.[3] Whereas the human fovea can presumably work with 60 pixels per degree and beyond (Elliot et al., 1995). The 24" full HD computer screen (1920 x 1080 pixels), which was used for the study, presents approximately 40 pixels per degree at the typical distance of about 60cm. Yet, the field of view of the HMD is much larger and thus a larger area of the visual field is stimulated by the scenario. It is hence difficult to objectively compare it to the low immersion environment. In both setups we maintained the highest possible framerate, which is 90 Hz for the HMD and 60 Hz for the desktop. The computer systems driving the two setups were designed to match these requirements.[4] Nevertheless, taking other factors that influence vividness into account, for example the high immersion environment supporting stereoscopic vision, simulated physics when handling the products, or dynamically changing shadows compared to the static shadows in the low immersion environment, we can conclude that the vividness is more pronounced in the high immersion environment.

In order to increase the control over factors other than the intended manipulation of immersion, we use (almost) the same program code for displaying both shopping environments (implemented by using Unity 5.5.3f1). The participant therefore saw the exact same product information and product models in both environments, which are shown in Figure 3.2.[5]

Next, we describe how the dimension *interactivity* (Steuer, 1992) was operationalized. In both environments, the participants can take products from the shelf. In the highly immersive environment, the participants can move freely within the environment (by natural walking) and they can also interact with the environment by using the two associated HTC controllers (one for each hand). By clicking and holding the controller's trigger, the participants can grab products and then move and turn their hands just as in a natural environment (the products "stick" to the controller and turn according to the participants' hand movements). The participant can also pass products from the one hand to the other hand, or even drop, pick up, or throw products (physics simulation). We also inserted a 3D model of a shopping cart in the VR environment in which participants had to put the chosen products. By

---

[2] `https://vive.com/us/product/vive-virtual-reality-system/`

[3] `https://roadtovr.com/understanding-pixel-density-retinal-resolution-and-why-its-important-for-vr-and-ar-headsets/`

[4] Please see Table C.1 in Appendix C.1 for the system specifications and applied rendering parameters.

[5] In addition, we refer to a video showing both environments as well as to a video comparing the high immersion (VR) shopping environment to the physical reality. Please see `https://pub.uni-bielefeld.de/record/2934590`

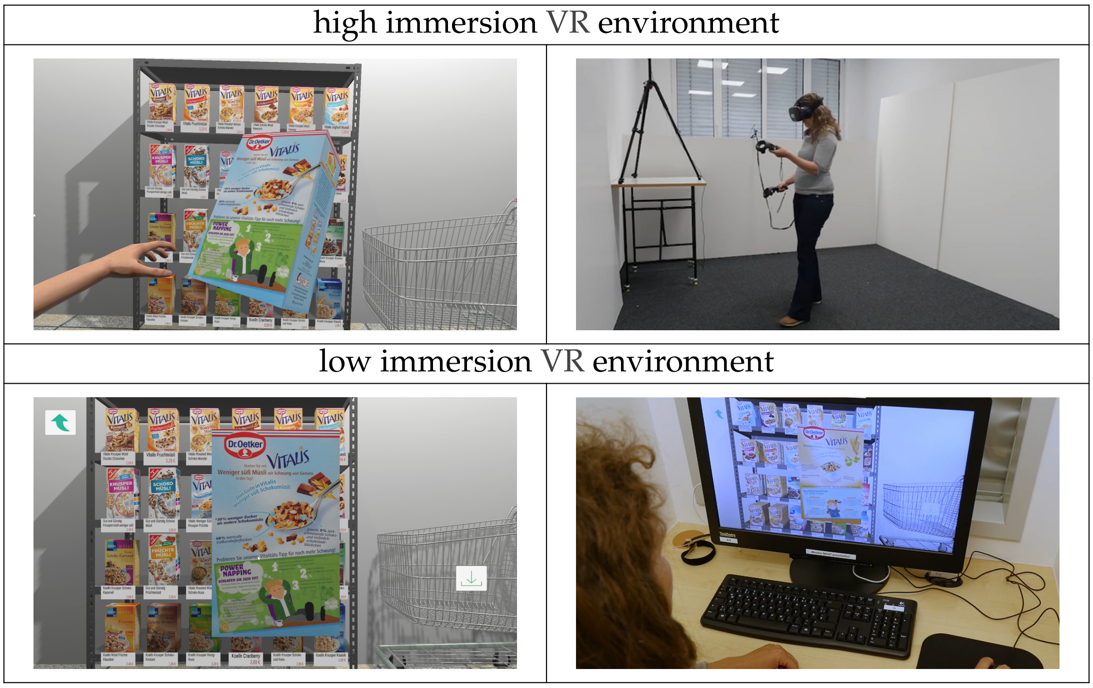


FIGURE 3.2: VR shopping environment and desktop shopping environment (top: high immersion VR; bottom: low immersion desktop environment; left: first-person perspective; right: third-person perspective).

designing the high immersive VR shopping environment, we followed the hardware and software guidelines of Slater and Usoh (1993). For instance, the factor formulated as "The self-representation of the participant, that is the participant's 'virtual body', should be similar in appearance to the participant's own body, respond correctly, and be seen to correlate with the movements of the participant" (Slater and Usoh, 1993, p. 222), was achieved by tracking the motion of the hands, as well as the head position, which was supported by the HTC Vive equipment. Through this, it was also possible to map the viewpoint exactly according to the real-world eye level (proprioceptive mapping). In the low immersive desktop environment, the participants interacted with the environment by using a mouse as input device. The participants could take a product from the shelf by clicking on it. The respective products popped up and could be rotated 360° by either clicking on it or moving the mouse, thereby enabling the participants to inspect the package from each side (including top and bottom). After having described the operationalization of all five dimensions individually, Table 3.1 demonstrates how the two environments differ along the dimensions of immersion presented by Slater and Wilbur (1997) as well as Steuer (1992).

As the table illustrates, we linked all the facets of the two environments to the associated dimension of immersion (Slater and Wilbur, 1997; Steuer, 1992) and, therefore, to the underlying theoretical construct *immersion*. If we now compare the two environments along all dimensions in a similar fashion as proposed by Slater (1999) (e.g., "Given two systems, if one has a larger field

Technological concepts (Slater and Wilbur, 1997; Steuer, 1992)	**High immersion group**	**Low immersion group**
Inclusive	physical reality visually shut out	physical reality visually exists apart of the screen
Extensive	visual (higher magnitude)	visual
Surrounding	panoramic field of view (110° diagonally)	limited to external 24” screen (47.76° diagonally)
Vivid	1080 x 1200 pixels (per eye) stereopsis, dynamic shadows, simulated physics	1920 x 1080 pixels no stereopsis, static shadows, no simulated physics
Interactive	proprioceptive mapping, controller used as input device; head and controller tracking	static environment, mouse used as input device

TABLE 3.1: Manipulation categorized according to the concepts of immersion.

of view than the other, then the first is (in my definition) more immersive than the second" (Slater, 1999, p. 560)), we can conclude that we have successfully instantiated the underlying theoretical construct immersion (high/low) through our two environments with which we can confirm instantiation validity (Lukyanenko et al., 2015).

3.4.2 Task and Procedure

Overall, the experimental procedure was the same for all participants. After arriving at the laboratory, they filled out a consent form, answered a short pre-questionnaire concerning their product involvement, and received instructions about the procedure, payment, and task. Afterwards, they participated in a training task to familiarize themselves with the task and especially with the shopping environment. The training task (same task as in the experiment, but with a different product category) ended when the participants felt confident about interacting in the respective environment. Then the actual experiment started. After completion of the experiment, the participants filled out a questionnaire.

We selected muesli as product category, because it is a low involvement and habitually bought product for which consumers’ relatively simple decision-making processes can be realistically tested in an experiment. Moreover, it allows for a conservative test of the effects, since we expect the effect of immersion on the utilitarian and hedonic path to be more pronounced (positive) for high involvement products. Furthermore, the product packages were easy to model in 3D (a very similar package size for most types of muesli; simple and planar surfaces). For a detailed discussion of why we have chosen muesli as product category, we refer the reader to the section "Limitations, Contributions, and Future Research."

Each participant answered ten consecutive choice tasks. We decided for repetitive choices in the same product category because of two reasons. First, we wanted to make participants familiar with the shopping process as fast as possible. Second, we wanted to be able to measure the participants' preferences. Thus, the choice tasks are generated by using a choice-based conjoint (CBC) design (Sawtooth Software Inc., 2013). The CBC design enables measuring the utility value of each product and the price sensitivity of respondents. This analysis is interesting from a marketing perspective, but goes beyond the scope of this paper. We will nevertheless report some of the results in the Discussion section. Furthermore, the CBC-based optimal design of the choice tasks ensures similarity to decisions, which consumers face in the marketplace, and involves trade-offs between product and price. Each choice task consists of 24 products, which are drawn from a total set of 40 products, and the prices vary for the same product across different choice tasks. Thus, each choice task gives the respondent reasons to think about the question which of the mueslis fits the personal preferences best and the varying prices motivate them to make each decision anew. For the last two of the ten choice tasks, the sample was randomly divided into two parts: Approximately half of the participants answered the last two choice tasks in the same environment (VR or desktop environment) and the other half made their choice in front of real shelves in the laboratory. We will show later that this division does not affect our results. We did that, because we measured the participants' eye movements in the high immersion group in order to be able to compare user behavior in VR with user behavior in reality. Eye movements in VR can be measured unobtrusively, because our SMI eye tracker is integrated in the HMD and therefore it should not have an impact on the participants' answers to our dependent variables.

All the participants' choices were incentive-aligned to motivate our respondents to disclose their true preferences (in line with Ding et al. (2005)). Each participant received an initial endowment of €14. It was explained to respondents that we would randomly realize one of their choices at the end of the experiment and would discount the price of the selected product from the initial endowment. In return, they would receive the chosen product.

We also controlled for bottom-up effects of visual attention that could potentially influence the probability of looking for and choosing products off the shelf. For example, studies by Atalay et al. (2012) showed that products, which are in horizontally central positions on the shelf, receive more visual attention and, consequently, are chosen more often. Chandon et al. (2009) found that increasing the number and position of shelf facings increased the attention to product packages and the probability of buying the respective products. We therefore randomly filled the four central positions on the shelf with four of the products in each of the conjoint design's 168 shelf configurations. Afterwards, the products that were not assigned to one of the central positions were placed on the shelf such that the products belonging to the same brand were located next to each other. By arranging the products in this way, we tried to ensure that the shelves looked realistic, because products of the same brand will also be placed next to each other in a real store.

3.4.3 Operationalization of Dependent Variables

We operationalized all dependent variables in the research model in a questionnaire by using common scales from literature.[6] For an overview of the applied items, we refer to Table C.2 in Appendix C.2. In addition, we measured certain scales, which were used in related literature. In particular, these were ease of use (Davis, 1989), the flow dimensions of *time distortion* and *concentration* (Koufaris, 2002; Novak et al., 2000), customer satisfaction (Szymanski and Hise, 2000), as well as compatibility, interactivity, and vividness (Jiang and Benbasat, 2007a). We also controlled for product involvement (FCBI Scale (Ratchford, 1987; Vaughn, 1986)), innovativeness (Agarwal and Prasad, 1998), mental and physical effort (Hart and Staveland, 1988), simulator sickness (Kennedy et al., 1993), prior experience with VR technology, and demographics such as age and gender. Since pretests showed that small text printed on the product packages were difficult to read in VR, we controlled for readability with a single-item construct, which asked the participants to rate the readability on a 7-point Likert scale from "very bad" to "very good," with the following wording: "Could you read all information which you wanted to consider for the evaluation of the muesli properly during the experiment?"

3.5 Results

Due to the confirmatory research objective of our study and an adequate sample size, CB SEM was used for the analysis of the main model (Gefen et al., 2000; Gefen et al., 2011).[7] Following other work (Jiang and Benbasat, 2007b; Xu et al., 2014), we test the effects of the treatment manipulation on the two dependent variables perceived product diagnosticity and telepresence separately by conducting a MANOVA. Throughout the analysis, we followed a two-stage approach first confirming the reliability of the measurement model and thereafter analyzing the structural model including testing the hypotheses. Before we report these results, we summarize important descriptives concerning the sample and the dependent variables.

---

[6] Scales used in the research model: Perceived telepresence (TEL) (Kim and Biocca, 1997; Klein, 2003; Nah et al., 2011), perceived enjoyment (ENJ) (Ghani et al., 1991; Koufaris, 2002), perceived product diagnosticity (DIAG) (Jiang and Benbasat, 2007a), perceived usefulness (USE) (Davis and Venkatesh, 1996; Koufaris, 2002; Vrechopoulos et al., 2004), intention to reuse shopping environment (INT) (Venkatesh et al., 2017; Wang and Benbasat, 2009; Xu et al., 2014).

[7] Testing the model using Partial Least Squares SEM (PLS SEM) reveals qualitatively similar results.

3.5.1 Descriptive Results

The participants were recruited from a large German university using the organizing and recruiting software *hroot* (Bock et al., 2012) and, when invited, were not informed about the fact that it would be a VR study. Yet, they were informed that we were looking for participants who generally eat muesli. On average, the pure experimental time, i.e., from starting the first questionnaire until finishing the second questionnaire, was 27.62 (sd=7.69) minutes for the low immersion group and 38.42 (sd=7.76) minutes for the high immersion group. The data was gathered in a period of about 6 weeks. Please note that because of the effort of recording the high immersion group – where we could only have one participant at a point of time – it took us alone 5 weeks for collecting the data for this group. Initially, 296 participants took part. Due to technical issues during the experiment – problems with the software, but mostly because of technical problems with the eye-tracker – the number of participants in the VR group declined to 132 and in the desktop group to 128. Three participants from the desktop group had to be excluded; two had abnormally short response times in the second questionnaire (participant's response time < mean(response time) - 2*sd(response time)) and one failed to answer a control question. After data cleansing, the sample size was 257 in total. As mentioned in the methodology section, the two main groups were again divided into subgroups, one of which executed the last two choice tasks in front of a real shopping shelf. We tested each construct for differences in the answering behavior between these different subgroups and found no significant differences (see Table C.4 in Appendix C.3) when comparing them with statistical tests (Mann-Whitney U or Welch's two-sample t-test, respectively). Based on this, we decided to merge the two groups for further analysis.

The average age within the sample was 22.63 (sd=2.60) and among the participants were 34 percent women, which correspondents to the percentage of female students at the inviting university. An analysis of the VR group participants' prior experience with VR shows, that for more than half of the participants (68) our experiment was their first experience with VR (53 participants stated it was their second or third time, whereas 11 stated that they have experienced it more often). Table 3.2 summarizes the mean values and standard deviations for the dependent variables and indicates whether these differed significantly between the two groups.

	VR (N=132)			**Desktop (N=125)**				**ALL (N=257)**	
Construct	M	SD	normtest.p	M	SD	normtest.p	p	M	SD
Diagnosticity	4.08	1.31	.125	4.69	1.51	.001	.001	4.38	1.44
Telepresence	5.11	1.34	.000	3.51	1.47	.029	.000	4.33	1.61
Enjoyment	5.06	1.34	.000	4.44	1.29	.145	.000	4.76	1.35
Usefulness	4.27	1.23	.036	4.28	1.59	.007	.655	4.28	4.28
Intention	4.05	1.66	.002	3.91	1.72	.001	.495	3.98	3.98
Readability	3.95	1.56	.000	5.69	1.33	.000	.000	4.79	1.70
Note: M = mean; SD = standard deviation. mormtest.p based on Shapiro-Wilk test.									

TABLE 3.2: Summary of variables.

The results for the NASA TLX (Hart and Staveland, 1988) and the simulator sickness questionnaire (Kennedy et al., 1993) were mixed.[8] We find that the *cognitive* and *physical load* were perceived as significantly higher in the high immersion condition in comparison to the low immersion condition (p<.05 and p<.001), whereas the perceived required *effort* (considering both aspects, i.e., mental and physical work) to accomplish the desired level of performance did not differ significantly between the conditions (p=.05). These results are somewhat inconclusive. With respect to the simulator sickness questionnaire, we found significant differences for the dimension *dizziness* between the conditions (p<.05): 1.5% of the participants within the high immersion group reported moderate and 9.8% mild symptoms, whereas in the low immersion group 3.2% claimed to have experienced mild symptoms. Similarly, for the dimension *general discomfort* the reported values were significantly different (p<.001), whereby values that differed from "no symptoms" were assigned only for the VR environment (11.4% stated mild and 3.2% moderate symptoms). It thus seems that these two dimensions are generally more of a concern for the VR condition. For the dimension *fatigue*, significantly less symptoms were reported for the high immersion condition than for the low immersion condition (p<.01), thereby indicating a more positive assessment for the high immersion condition with respect to this dimension. Immersion did not significantly influence the perceived ease of use of the shopping environment (Mann-Whitney U test: W=8735, p=.390, r=-.05). In addition, the values of ease of use are rated quite high (a combined average score of 6.51 for both groups on a 7-point Likert Scale), indicating that the usage of both environments was clear, understandable, and easy to learn.

---

[8] Please note: Within this section, we focus on the most important findings. For the complete results, we refer to Table C.5 and C.6 in Appendix C.3. For an overview of the applied items, we refer to Table C.3 in Appendix C.2.

3.5.2 Measurement Model

To analyze the quality of the SEM-measurement model, we performed a confirmatory factor analysis (CFA) using LISREL 9.30. First, we assessed the assumption of multivariate normality checking each indicators skewness and kurtosis (univariate normality) as well as Mardia's normalized estimate of multivariate kurtosis (Mardia, 1970). For the measures of univariate normality, the values do not indicate a departure from normality according to the thresholds given by West et al. (1995), however, the index of multivariate kurtosis (51.202) and its critical ratio (15.295, i.e., Mardia's square) are indicative of multivariate nonnormality (Byrne, 2016). Therefore, as a precaution, we used robust maximum likelihood (RML)[9] as estimation method, since this method adjusts for non-normality in the data (Jöreskog et al., 2016). We assessed the model using five fit indices (recommended cutoff values in parentheses): comparative fit index (CFI $\geq$ .95), Tucker-Lewis Index (TLI $\geq$ .95), root mean square error of approximation (RMSEA $\leq$ .06), standardized root mean square residual (SRMR $\leq$ .08), and adjusted goodness of fit index (AGFI $\geq$ .90) (Gefen et al., 2000; Gefen et al., 2011; Hu and Bentler, 1999). The initial model showed acceptable fit for three indices[10]: Satorra-Bentler $\chi^2(125)=245.72$, p<.001, CFI=.95, RMSEA=.061, SRMR=.069, while two did not exceed the recommended threshold value: TLI=.93 and AGFI=.85. However, these values were satisfactorily improved in the process of measurement model specification as described below.

Next, we assessed the psychometric properties of the measurement scales. Composite reliability (CR) was well above the threshold value of .70 (Hair et al., 2016) for all constructs, thereby indicating internal consistency reliability. Only the CR value of perceived telepresence (.692) failed to exceed the threshold value. After removing the item TEL.4., the CR value for the construct rose above the threshold (.727). We then assessed the convergent validity of the measurement model. All measurement items loaded significantly on the respective latent variable (p<.001) and the standardized loadings were all above the cutoff value of .60 (Bagozzi and Yi, 1988; Chin et al., 1997) except for ENJ.2. (.462; p<.001) and TEL.3. (.584; p<.001). We therefore examined the effect of removing these items on CR and average variance extracted (AVE), as Hair et al., 2016 suggest to only remove items from a scale if item deletion leads to an increase in AVE or CR above the required cutoff value. Item deletion of both indicators, indeed, led to an increase of the AVE of telepresence (.477) and enjoyment (.488) above the suggested cutoff value of .50 (Bagozzi and Yi, 1988). We thus excluded ENJ.2. and TEL.4. from further analysis. Table 3.3 summarizes the results for the assessment of internal consistency reliability and convergent validity.

For assessing the discriminant validity, we conducted for each pair of constructs a scaled difference chi-square test (Bryant and Satorra, 2012; Bryant and

---

[9] Calculating the model with the standard ML estimation, leads to qualitatively similar results.

[10] Robust fit indices based on Satorra-Bentler's χ^2.

					Correlations				
	M	**SD**	**CR**	**AVE**	**DIAG**	**TEL**	**USE**	**ENJ**	**INT**
Diagnosticity	4.38	1.44	.873	.631	**0.79**				
Telepresence	4.33	1.61	.708	.556	-0.12	**0.75**			
Usefulness	4.28	1.41	.900	.694	0.37**	0.10	**0.83**		
Enjoyment	4.76	1.35	.806	.581	0.10	0.51**	0.22**	**0.76**	
Intention to reuse	3.98	1.69	.952	.869	0.22**	0.16*	0.46**	0.28**	**0.93**

Note: *p<.05 and **p<.01 (two-tailed test). CR = composite reliability; AVE = average variance extracted. Diagonal values are square root of AVE.

TABLE 3.3: Properties of measurement scales.

Satorra, 2013) comparing obtained values from a constrained CFA model in which the correlation between a pair of constructs were set to unity (fixed) to a CFA model without constraints in terms of correlation (free) (Anderson and Gerbing, 1988; Bagozzi and Yi, 1988). All test results revealed a significantly lower chi-square value for the unconstrained (free) model indicating that the pairs of constructs are not perfectly correlated which confirms discriminant validity (Anderson and Gerbing, 1988; Bagozzi and Yi, 1988). Finally, the measurement model which meets the required internal consistency reliability, convergent validity and discriminant validity showed excellent model fit (Satorra-Bentler $\chi^2(80)=109.76$, p=.015, CFI=.99, TLI=.98, RMSEA=.038, SRMR=.044, AGFI=.91).

3.5.3 Hypotheses Testing: Effect of Immersion on Perceived Product Diagnosticity and Perceived Enjoyment

We conducted a multivariate analysis of variance (MANOVA) to test the effect of our experimentally manipulated variable, immersion (high/low), on perceived product diagnosticity and perceived telepresence. All MANOVA test statistics (Pillai's trace, Wilks' lambda, Hotelling's trace, Roy's largest root) revealed that the treatments differ significantly with respect to the two dependent variables (p<.001) (see Table C.7 in Appendix C.3). We therefore conducted two linear regressions separately on each dependent variable (Field et al., 2012).

We surprisingly find a negative effect along the utilitarian path (Table 3.4). Therefore, H_1 is not supported. We find that the higher the immersion, the lower is the perceived product diagnosticity.

						95% CI for B [a,b]	
Model	Unstd. Coeff. B	Std. Coeff. Beta	Bias [a]	Std. Error [a]	Sign. (2-tailed) [a]	Lower Bound	Upper Bound
Constant	4.693		-.001	.138	.000	4.427	4.951
High (vs. low) immersion	-.618	-.214	-.001	.177	.000	-.980	-.262

Note: a. due to non-normally distributed errors, results are based on 5000 bootstrap samples; b. Bias Corrected and accelerated (BCa) bootstrapping Confidence Intervals (CI). R^2=.046; adj. R^2=.042. Reestimating the model without applying bootstrap procedure reveals similar results.

TABLE 3.4: Linear regression model for perceived product diagnosticity.

As hypothesized, a higher degree of immersion has a positive effect on perceived telepresence (H_2), thereby revealing that the higher immersion group leads to higher perceived telepresence than the low immersion group (see Table 3.5).

						95% CI for B [a,b]	
Model	Unstd. Coeff. B	Std. Coeff. Beta	Bias [a]	Std. Error [a]	Sign. (2-tailed) [a]	Lower Bound	Upper Bound
Constant	3.508		-.002	.134	.000	3.250	3.765
High (vs. low) immersion	1.602	.497	-.003	.180	.000	1.240	1.962

Note: a. due to non-normally distributed errors, results are based on 5000 bootstrap samples; b. Bias Corrected and accelerated (BCa) bootstrapping Confidence Intervals (CI) R^2=.247; adj. R^2=.244. Reestimating the model without applying bootstrap procedure reveals similar results.

TABLE 3.5: Linear regression model for perceived telepresence.

3.5.4 Hypotheses Testing: Effect of the Utilitarian and Hedonic Path on the Intention to Reuse the Shopping Environment

We then proceeded with assessing the SEM-structural model. We again used LISREL 9.30 to test the proposed model and applied RML as estimation method. First, we checked the overall fit of the model and found the proposed model to meet all required fit indices (Satorra-Bentler $\chi^2(85)=123.10$, p=.004, CFI=.98, TLI=.98, RMSEA=.042, SRMR=.079, AGFI=.90) indicating that the model fits the data well. Second, we continued to test the remaining hypotheses. Figure 3.3 shows the results for the structural model.

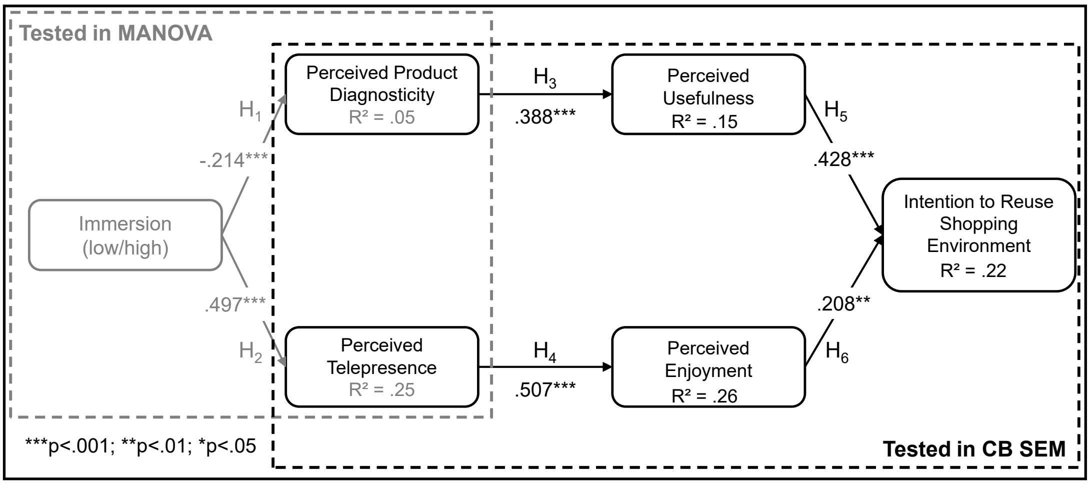


FIGURE 3.3: Results for the structural model. *Note*: R^2 values for perceived product diagnosticity and perceived telepresence and the standardized path coefficients from immersion on the latter two (all printed in grey) come from the MANOVA and the regression models.

All relationships in the structural model are significant. In line with H_4, higher perceived telepresence positively influences the perceived enjoyment, suggesting that a higher degree of telepresence induces a higher level of enjoyment. Ultimately, H_6 is supported, signaling that higher enjoyment positively influences the intention to reuse the shopping environment. In contrast to the induced positive effect of immersion along the hedonic path, we surprisingly found that the higher the immersion, the lower is the perceived product diagnosticity. However, the remaining hypotheses (H_3 and H_5) of the utilitarian path can be confirmed, thereby suggesting that a higher degree of perceived product diagnosticity leads to a higher level of perceived usefulness, which, in turn, impacts finally, significantly, and positively the behavioral intention. To summarize, the two main paths (hedonic and utilitarian) point in opposite directions. Whereas the hedonic path is positive, the utilitarian path is negative, due to the significant negative relationship between immersion and perceived product diagnosticity.

3.5.5 Further Analysis of the Utilitarian Path

In order to account for the unexpected negative effect of high immersion on perceived product diagnosticity, we conducted further analyses. In search of potential explanations for this phenomenon, we tested the influence of the technological constraint *readability*. Given the technical details about the visual fields of the HMD and the desktop screen used in our study, we expected the low immersive environment to have higher readability than the high immersive environment. This was confirmed with a Mann-Whitney U test (W=13119, p<.001, r=-.52; mean(low immersion)=5.69, sd(low immersion)=1.33; mean(high immersion)=3.95, sd(high immersion)=1.56). This might explain the negative effect of immersion on product diagnosticity. Indeed, the inclusion of readability as mediator between immersion and perceived product diagnosticity leads to an indirect only (full) mediation (Zhao et al., 2010). Following the approach by Hayes (2009), we applied bootstrapping (bias-corrected BC (Hayes and Scharkow, 2013)) for testing the mediation model. The direct effect of immersion on perceived product diagnosticity is not significant (CI [-.747, .018]) when we insert readability in the model as mediator, whereas the indirect effect is significant (CI [-.492, -.051]; see Table C.8 in Appendix C.3 for further results). Thus, the low readability in the high immersion group explains the negative effect of high immersion on perceived product diagnosticity. Please note that the direct effect of immersion on perceived product diagnosticity has a negative coefficient, which contradicts our H_1 (see Table C.8 in Appendix C.3). Since this effect is not significant, we do not want to over-interpret this result. Yet, a possible reason might be that the users in our low immersion group experienced rather high product diagnosticity compared to what they are accustomed to at e-commerce stores. In fact, they were able to see the product in a 360° field of view by moving the computer mouse. This feature is not yet implemented in all e-commerce stores and thus might have positively influenced the users' product diagnosticity judgments in the low immersion condition.

As an additional analysis, we were interested whether immersion has a direct effect on our main dependent variable, namely the intention to reuse the shopping environment. We therefore computed an ordinary least square linear regression model with and without readability as control variable (bootstrapped with 5000 samples). It reveals that, when controlling for readability, high (vs. low) immersion has a positive influence on the intention to reuse the shopping environment ($p<.05$), whereas there is no effect if we do not control for readability ($p=.523$). Concerning the VR environment, the estimated coefficient for the intention to reuse the shopping environment is 0.50 higher on the 7-point Likert scale compared to the desktop environment with low immersion when we control for readability ($p<.01$ for readability). Please refer to Table C.9 in Appendix C.3 for details of the analysis. In sum, this analysis shows that as soon as readability problems are solved in the VR environment, immersion is supposed to positively affect the intention to reuse the shopping environment.

3.6 Discussion

We conducted an experiment to analyze how the immersion of an IT artifact – a shopping environment – affects the users' intention to reuse it in the future. Our results show that immersion influences the user's intention along two paths, which ultimately cancel each other out. The degree of immersion increases users' enjoyment, because they perceive higher telepresence. Thus, they have more fun while shopping in this environment, because they escape reality and feel as if they are actually present in the shopping environment. Immersion therefore has a positive impact on user experience (Hassenzahl and Tractinsky, 2006). From the literature, we know that experience has a positive influence on other important factors, such as repatronage intentions (Hart et al., 2007), loyalty (Eighmey and McCord, 1998), or the time spent in a store, and the intention to buy more and other items (Swinyard, 1993). In sum, immersion can therefore not only positively influence the user's intention to reuse the IT artifact, but most probably it can also make other important benefits available to the IT system provider. Although an analysis of these other benefits is beyond the scope of this work, we can at least provide certain insights about the participants' preferences, which we were able to measure, due to the conjoint-analytic design of our choice task experiment. We tested how immersion affects *price sensitivity*, thereby describing the extent to which the customer focuses on the price when making the purchase decision, instead of attaching importance to other product characteristics. Participants in the high immersion group (mean=.3162, sd=.0922) were significantly less price-sensitive than participants in the low immersion group (mean=.3899, sd=.1017; W=11737, p<.001, r=-.37). Since our experiment was fully incentivized in the sense that the participants had to actually buy one of the chosen products, this result most probably has high external validity. It has major implications for retailers: Consumers might actually spend more money in a highly immersive shopping environment, because they are less price-sensitive.

To our surprise, we found that immersion has a negative effect on the users' perceived product diagnosticity and, thus, along the utilitarian path. We were able to explain this result with reference to a technical limitation of the current VR technology: Not all the participants could properly read the detailed product information, which was printed on the packaging. This technical limitation was unavoidable, because the HMD (HTC Vive), which we used in our study, had the highest resolution that was available for consumer devices when we conducted the study. At the time, we were aware that the current state of technology could potentially limit the generalizability to future IT artifacts, due to the results' dependence on the current technology. We therefore decided to conduct the experiment with a few precautionary measures: In order to address the problem as best as possible, we included a visual test in the experiment's preparation phase during which the participants had to read a short text aloud. Then, they were asked to report how good the readability was. If necessary, the settings were checked and adjusted again. When, within the experiment, a package was taken off the shelf, it was invisibly rescaled to a factor of 1.5 in order to increase the readability of information written in small letters. Still, these measures apparently did not entirely resolve the technical issues. In future research, however, the problem might vanish, since technology companies are already working at a fast pace on high-resolution HMDs that have resolutions of 4K or more.

Given that our experiment was the first VR experience for the majority of the participants, we found a relatively small percentage of participants who report negative experiences, such as dizziness or general discomfort. According to the participants, the high immersive environment creates less fatigue than the low immersive environment. In addition, the high ratings for ease of use also underline the quality of our application and the easiness to learn interacting with it, although it was for most of the participants their first time experiencing a VR application. Moreover, we also measured frustration, as well as perceived enjoyment, and the empirical results suggest that our participants had a good VR experience. In sum: While the utility of the VR environment has partially been diminished by technological restrictions, a multitude of other factors indicate a good usage experience.

3.7 Limitations, Contributions, and Future Research

We identified that the lower readability in the high immersion VR environment explained the negative influence of immersion on the utilitarian path. The importance of this technical limitation in our research model is interesting and directly transferable to all other packages on which consumers like to read detailed product information (e.g., frozen pizza, food processors or furniture (size, material, etc.)). At the same time, future research is required, because similar issues for other products and settings are likely. An example of insufficiently advanced algorithms that lead to limitations of the current technology would be cloth simulation, which is presently excellent for non-real time computer generated graphics (movies), but not yet ready for real-time interactive virtual reality multi-layer cloth simulations. Therefore, virtual tryouts of clothing that use a personalized avatar are still bound to technical limitations and the usefulness of high immersive environments might be affected by this technical constraint. Personalized clothing combined with virtual tryouts could be one of the most important advantages of mixed reality, since it is large scale, highly competitive, highly individual, and highly risky if the customer is not happy with the product delivered. We, thus, argue that it is important to conduct further empirical studies to test how these new developments of VR technology affect users' adoption behavior and to provide continuous advice to the system designers of VR applications.

We combined the theory about hedonic and utilitarian motives of online shopping (Childers et al., 2001) with the concept of immersion, which is especially relevant for the new context of VR shopping environments. To do justice to the influence of immersion, the paths were extended to include perceived diagnosticity (utilitarian) and perceived telepresence (hedonic). We also contribute to theory by explaining the negative utilitarian path via a new mediator "readability." Yet, we only found an R^2 value of 0.22 for the intention to reuse the shopping environment. Our study focused on cleanly manipulating immersion and studying its effect with an emphasis on a strong theory-driven simple model. We leave it to future research to identify other factors, such as trust in technology or the user's propensity to be an early adopter, that might influence the user's intention to use VR shopping environments.

In future studies, one might further disentangle the single dimensions of immersion and study which of them, or which combinations of them, have the largest effect on utilitarian as well as hedonic variables and, thus, in turn, influence the adoption intention. The meta-analysis of Cummings and Bailenson (2016) provides initial insights about the relationship between immersion and telepresence. The authors investigated how different facets of immersion affect spatial presence (i.e., telepresence) and found that when only a single dimension of immersion was manipulated, the strength of the effect on telepresence varied substantially. While manipulations of the field of view (surrounding) or of the stereoscopic vision (vividness) produced medium-sized effects and the tracking level (interactivity) had a large effect, image quality and resolution (also part of vividness) had significantly smaller effects. In line with these previous findings, we speculate that, in our study, telepresence was mainly influenced by differences in the field of view (110° vs. 47,76° diagonally; surrounding) and also by inclusiveness (a dimension not explicitly analyzed by Cummings and Bailenson (2016), because being completely isolated from physical reality compared to experiencing an environment on a quite narrow field of view while seeing an experimental cabin apart from the screen, should strongly help users forget about their immediate physical location. Furthermore, we expect the tracking level (head and controller tracking, as well as proprioceptive mapping vs. none; interactivity) to have a major impact on telepresence, because being able to grab and turn products with a controller while moving in front of a supermarket shelf and, in particular, seeing the environment responding to the movements, should feel much more natural compared to interacting with a mouse and keyboard.

In contrast, the relationship between immersion and product diagnosticity is largely unexplored. The studies that come closest are the ones by Jiang and Benbasat (2005), Jiang and Benbasat (2007a), and Jiang and Benbasat (2007b). In their empirical studies, the authors show that different product presentation formats that can best be described as vividness and interactivity positively influence product diagnosticity (they mostly compared product presentations in terms of palid pictures to video presentations). We argue that the differences between the environments in our study are even more pronounced. For our high immersion environment, we believe that the increased interactivity leads to a product evaluation close to the habits in reality (assessing products close to real-scale from different angles and distances). This is reinforced by the dimension of vividness, which specifically represents the naturalness of the environment (e.g., stereopsis, dynamic shadows, simulated physics) or the panoramic field of view (surrounding). All in all, we assume that the similarity to physical reality leads to the perception that one can evaluate the product appropriately. However, within the mediation analysis, we show that the technical constraint readability (i.e., resolution) had a substantial effect on perceived diagnosticity. We, therefore, argue that, unlike for telepresence, in our setting, the resolution and, thus, the quality of stimuli (specific facets of vividness) plays a prominent role that dominates the assessment of diagnosticity. All in all, we speculate that the dimensions of immersion have different effects on diagnosticity, as well as telepresence, and that, depending on the designer's goal, specific technical factors have to be implemented accordingly. More research needs to be conducted in the future to verify these speculations.

Yet, we decided to test the effect of immersion by simultaneously manipulating several subdimensions of immersion, because, first, we wanted to understand the big picture before focussing on the small *facets*. This is a common approach for a research study that investigates technology, which has not been used in many other studies in this context before, because by making strong manipulations, we can expect a larger effect size. Second, we wanted to test the two environments (i.e., VR and Desktop) the way they are currently offered on the market and primarily used. Thereby, a desktop environment, for instance, is mostly equipped with a full HD screen, as well as a mouse and keyboard as input devices, whereas state-of-the-art VR technology supports stereoscopic vision, room-scale tracking, and proprioceptive mapping. Consequently, by using one of the best VR glasses available on the consumer market, we ensured the currentness and practical relevance of our study.

We chose muesli as a product category, since testing this low involvement product, which is bought habitually, allows for a more conservative test of our model: In line with the behavioral decision-making literature (Moorthy et al., 1997; Park et al., 1989), we expect consumers to intensify their search and undertake cognitively demanding search processes for high involvement products, such as tents, clothes, furniture, or cars. For high involvement and non-habitual buying decisions, consumers can potentially benefit from the possibilities to interact with the products in the high immersive environment, because they can evaluate the products from all angles in real scale, look inside the product, or try different functionalities. They could, therefore, better judge various characteristics of the respective products. In addition, we expect that consumers will also enjoy these evaluation possibilities even more in high immersive environments.

Another reason for choosing muesli as a product for our empirical study is that the external validity of the data should be relatively high for muesli. It can be expected that, for high involvement products, consumers would gather information over several weeks, starting with need recognition and continuing with extensive pre-purchase information search activities (Grewal et al., 2016). The resulting more complex decision-making processes would therefore be less adequate to be realistically studied in our experiment. A laboratory setting may arguably intensify the participants' search compared to when they make decisions in regular supermarkets but, in our experiment, we find that decisions were made much faster as soon as the participants were used to making decisions. Compared to the first task, the respondents needed, on average, only about 61% of the time when making decisions in the last of the conjoint tasks. We therefore have at least some evidence that the respondents became accustomed to making decisions and applied decision heuristics (as they do in the marketplace for habitual decisions to save time and effort (Wood and Neal, 2009)). Examining such rather short decision processes is, therefore, also very suitable for an experimental study with time-limited sessions. Thus, since the purchasing context is realistic for muesli and no expert knowledge is required to make these typical consumer decisions in our experiment, we have some indication that consumers behaved like they would do in the marketplace. Muesli as a product also has the advantage that all respondents had consumed the product in recent years, had, thus, prior experience with the product, and knew, to some extent, which attributes were relevant for them when making decisions. Furthermore, we were able to fully incentive-align the choices such that the respondents received one of the products they had chosen immediately after the experiment ended. Despite all these arguments for mueslis, the investigation of high involvement products in further empirical studies is a promising and challenging task for future research.

Our study is also limited in that we showed only one shelf to the participants without creating an entire store environment. Still, we decided in favor of the simpler design to more easily control situational factors, such as the width of the aisles or the distances to reach certain products. How immersion affects both paths, is probably more pronounced when users can actually experience an entire VR store, because VR technology can improve self-orientation and, therefore, affects factors, such as *navigation* (Vince, 1998). We hence concur that expanding our research to an entire VR store, as recently implemented in a study by Schnack et al. (2019), would be interesting. Furthermore, the degree of immersion by itself in a complete VR store is probably much higher than in front of a single VR shelf, which can create an even higher variance between the two immersion groups in an experiment and, thus, lead to the model having an even larger explanatory power. Thus, although our results might not be generalizable with respect to these other products and VR environments, we believe that the immersion's positive impact is rather underestimated in our study. This underlines the large potential that we see for the adoption of VR artifacts. In addition, faithful rendering, shading, and lighting are factors that strongly influence the realism and the degree of immersion experienced by the user. We did our best to make our VR environment highly immersive, but acknowledge that there is still room for further improvement, such as using more advanced lighting or shading. Furthermore, researchers can also include other multimodal factors, such as ambient sound and olfactory stimulations, to further increase the degree of immersion.

A further limitation of our experiment is that the consumer VR market is still in its infancy, which also means that most of the participants in our study had no prior VR experience. The novelty of the VR environment could, for example, have had a positive effect on the participants' enjoyment (Brade et al., 2017). Furthermore, they had to learn how to interact in VR and this could have been an interesting experience and might have affected the results. However, the above mentioned limitation, namely not showing a complete retail store, could have kept the novelty factor quite low, because the complete potential of VR technology was not implemented. In the same vein, VR offers much more than mirroring reality one-to-one. In our study, the VR shopping environment was meant to replicate reality, because this was experimentally the cleanest way to manipulate immersion (without confounding the shopping environment with new features, which are only possible in VR). In future VR applications, however, users could potentially beam themselves up into space, could go shopping with avatars of their real friends, could be assisted by intelligent and interactive user assistance systems that are highly personalized (Meißner et al., 2019; Pfeiffer et al., 2017), could add interesting gamification elements, or the retail store itself could automatically adapt to the user's preferences (Meißner et al., 2019). Moreover, new possibilities of interacting with products in VR and AR settings may increase feelings of product ownership (Xu et al., 2018) over a product and, thus, potentially be used by marketers in VR shopping contexts. In essence, a replication of reality is not the correct approach to really test the adoption behavior of future VR technology. Our study is therefore limited by the fact that it focuses on a sound manipulation of the concept immersion, but does not test the possible effects of future VR technology. Nonetheless, a comparison of consumer behavior in virtual reality and physical reality in future studies is interesting, since it enables assessing the similarity of behavior in both environments (Siegrist et al., 2019).

3.8 Conclusion

In this article, we report results from an experiment which succeeds in systematically manipulating immersion, thereby analyzing its effects on the users' adoption. We find that immersion influences the user's intention to reuse the shopping environment along two paths (a hedonic and a utilitarian path), which ultimately cancel each other out. Immersion has a positive effect on the hedonic path, whereas the effect on the utilitarian path is negative. We show that the low resolution of the HMD explains this negative effect. This result provides some evidence for the notion that when even more advanced VR technology is available, immersion will also positively affect the utilitarian path. Although the perceived resolution of VR displays is at present not as good as the perceived resolution of computer screens (in terms of pixels per visual angle), it is immensely important to deal with the technology from an early stage, since it has the potential to dramatically change the interaction with computer systems. This change will not only affect the individual consumer, but also entire industry sectors, which will need to weigh up this technology's potential benefits or threats.

Acknowledgements: The authors thank the Nuremberg Institute for Market Decisions (formerly GfK Verein), founder and anchor shareholder of GfK SE, for funding this research.

Chapter 4

The Influence of Experience Versus Imagination on System Adoption [1]

Christian Peukert, Jella Pfeiffer, Martin Meißner, Thies Pfeiffer, Christof Weinhardt

> "The only source of knowledge is experience."
>
> Albert Einstein

4.1 Introduction

With Virtual Reality (VR) entering the mass markets, companies are becoming increasingly interested in using this new technology in shopping applications. SATURN, for example, which is Europe's largest retailer for consumer electronics, recently launched the Virtual SATURN shopping environment. Other VR shopping applications were started by the Chinese e-commerce company Alibaba, the US department store Macy's and the Swedish company IKEA. These multi-national retailers are thus experimenting with VR shopping applications, potentially because they see the technology as an opportunity to create competitive advantages (Inman and Nikolova, 2017). An obvious reason for using VR is to increase the number of different ways in which consumers can shop, extending the typical range from brick-and-mortar stores to e- and m-commerce further to VR shopping. The new VR stores are attractive for companies and customers as they are accessible 24/7 from any place with internet access. With the steady advance in and diffusion of VR technology, VR shopping environments could also soon be used by

---

[1] This chapter comprises an article that was published in the following outlet under the following title: Peukert C., Pfeiffer J., Meißner M., Pfeiffer T., Weinhardt C. (2019). "Acceptance of Imagined Versus Experienced Virtual Reality Shopping Environments: Insights from Two Experiments". In Proceedings of the 27th European Conference on Information Systems (ECIS), Stockholm & Uppsala, Sweden. ISBN 978-1-7336325-0-8 Research Papers. `https://doi.org/10.1007/978-3-030-28144-1_8`. *Note*: Tables and figures were renamed, reformatted, and newly referenced to fit the structure of the thesis. Chapter and section numbering and respective cross-references were modified. Formatting and reference style was adapted and references were updated. Opening quotation was not part of the article.

companies to provide consumers with a livelier online shopping experience. Up to this point, however, it remains an open research question, whether VR shopping environments will – once launched – be adopted by end-consumers.

Researchers from the fields of Information Systems IS (Suh and Lee, 2005; Steffen et al., 2017), Marketing (Pantano and Servidio, 2012; Grewal et al., 2017) and Innovation Management (Füller and Matzler, 2007; Berg and Vance, 2017) are beginning to realize the potential of VR, but only very few publications have conducted empirical tests of immersive and interactive VR shopping environments (Van Herpen et al., 2016; Meißner et al., 2019). Thus, we see the necessity to evaluate VR shopping similar to e-commerce 15 years ago (e.g., Gefen and Straub (2000) and Gefen et al. (2003)) as one of the key practical questions is whether customers will accept and use VR for shopping.

Research lacks empirical studies that investigate VR shopping from a user acceptance perspective. In the last decade, IS research has studied user acceptance of VR applications, primarily in non-immersive virtual worlds such as Second Life or in form of virtual product presentation formats (Jiang and Benbasat, 2005; Nah et al., 2011). The recent advance of VR technology, however, has substantially changed the degree of immersion generated by the system leading to VR environments, which can create an "illusion of reality to the senses of a human participant" (Slater and Wilbur, 1997, p. 605) and which can create real-world experiences (Bowman and McMahan, 2007). These changes were anticipated by the aforementioned authors, but are just becoming reality with the steady advance of VR technology. Because the degree of immersion is substantially higher in today's VR systems, research needs to (re-) examine user acceptance in high immersive VR shopping environments. However, the evaluation of new VR shopping environments is potentially challenging, because it requires bringing larger samples of respondents into VR. Therefore, the question arises whether respondents need to truly experience the VR environments to be able to evaluate them or whether they would also be able to do the same evaluation when just imagining to be in the respective environment based on a video. The latter could save high costs and effort from the experimenters' point of view, since today's VR studies are mainly conducted on a one-to-one basis. We therefore focus on the following research question:

RQ: *Does the acceptance evaluation of VR shopping environments depend on whether users have imagined (based on a video) versus experienced being in the VR environment?*

To answer this research question, we conducted two experiments comparing judgements from respondents who have either experienced a shopping environment wearing a head-mounted display (HMD) or had to imagine how the VR experience would be just based on watching a video introducing the VR environment. The contribution of our research paper thus is twofold. First, with respect to VR shopping systems, we determine how much potential customers see in VR shopping applications, especially how easy they think the environment is to use. We will also be able to evaluate the utilitarian and hedonic values of VR shopping. As we will test two very different shopping environments in Study 1 and 2, we will also see whether the respective evaluation holds across different VR implementations. By investigating our research question in two environments: a very basic one in Study 1 that is rather easy to imagine and a more complex and advanced environment in Study 2, we are furthermore able to specify whether an "imagined" scenario is applicable for simple but not for more complex to imagine scenarios. Second, our paper makes a methodological contribution, as we will be able to conclude whether experiencing the VR shopping environment is essential for users to be able to evaluate the respective technology. If we find that the intention to adopt to a large extent depends on user's prior experience, we must put adoption research that is solely based on an "imagined" experience with a system into question.

4.2 Theoretical Background

4.2.1 Immersive Virtual Reality Environments

VR can be defined as a simulated environment in which the user is perceptually surrounded (Loomis et al., 1999). The vision of a VR application can be realized by a Cave Automatic Environment (CAVE) or a HMD. HMDs available in 2018 have a view of about 110° diagonally and small but perceivable pixels. Together with the HMD, a head tracker and a fast computer are used that generate the visual field based on the position and orientation of the user. An immersive VR systems is "capable of delivering an inclusive, extensive, surrounding and vivid illusion of reality to the senses of a human participant" (Slater and Wilbur, 1997, pp. 604/605). Whereas the term *inclusiveness* indicates to what extent the VR system isolates a person from reality, the term *extensiveness* describes how and in what range the different sensory modalities are accommodated (Slater and Wilbur, 1997). If, for example, users can touch objects in VR by using controllers, the sense of touch accompanies the visual input. Similarly, smell or taste can make the VR experience more extensive. If the VR offers a panoramic field of vision, it is *surrounding*. Finally, *vividness* captures the "resolution, fidelity, and variety of energy simulated within a particular modality" (Slater and Wilbur, 1997, p. 605). A high richness of the shown information content or high resolution and quality of the display (e.g. number of pixels) contribute to increasing vividness. While telepresence – a term coined by Steuer (1992) – describes the feeling of "being in the virtual environment" (Slater and Wilbur, 1997, p. 605), the degree of immersion describes to what extent the perception of the virtual environment is similar to perception of reality (Suh and Lee, 2005) and is therefore predetermined by the applied technology. Telepresence thus "is a human response to immersion" (Schultze and Orlikowski, 2010, p. 813). Making VR environments more immersive is thus one of the main goals for further technological development (Blascovich et al., 2002).

4.2.2 The Potential Effect of Pre- and Post-Experience on the Evaluation of Technology Acceptance

Several empirical papers have already asked the question to what extent the acceptance of a technology might depend on the user's experience with it. Venkatesh and Davis (2000) hypothesized two moderating effects of user experience. The authors showed that the influence of subjective norms on perceived usefulness and intention to use the technology decreased with increasing experience. An explanation for this finding is that users who have more experience using a technology will be less dependent on the opinions of others and will to a larger extent base the evaluation of the technology on their own experience. In the context of the UTAUT model, Workman (2014) argued that previous positive or negative experiences with the technology are going to lead to positive and negative future expectations regarding the use of the technology. Having had positive experiences, users are expected to have a higher assessment of the technology and should more likely recommend the technology to others (Laforet and Li, 2005). Workman (2014) found a positive direct effect of user experience on intention to use for two technologies, social media and smart applications. Depending on the technology investigated, the author also found different positive interaction effects with key variables of the UTAUT model. More recently, Maruping et al. (2017) included experience into the UTAUT model and found that experience worked as a moderator for some of the predictors of the behavioral intention.

The results of the empirical studies investigating the UTAUT model, however, are less conclusive for the VR shopping context, as subjective norms, for example, have not yet been developed because of the newness of the technology. At this early stage, we consider it to be almost impossible to test experience in a similar way as it was done by Venkatesh and Davis (2000), Maruping et al. (2017) or Workman (2014). Instead we follow Bhattacherjee (2001), who suggested to use empirical designs that test for differences in pre- and post-experience of user acceptance. Although our experiments are not longitudinal in the sense that it compares the level of acceptance in a within-subjects design across several months, it still allows us to at least compare pre- and post-experience evaluation of key acceptance constructs in a between-subjects experiment in terms of "imagined" based on a video versus "experienced."

In line with this previous research, we expect that whether a user has experienced the VR environment before or not will affect key constructs related to user acceptance. We further think that this effect is pronounced for VR technology and deserves particular attention, because VR technology is said to be a fundamental different and new technology (Walsh and Pawlowski, 2002), as it is highly interactive and affects several senses to a degree that lets users fully immerse in an environment. The sensory experience makes VR technology different from other ISs like smartphones or social networks. It is therefore likely that users can hardly anticipate interacting with and experiencing such a system that is supposed to affect them through different modalities (gestures, movements, visually, sometimes even haptic, etc. (Mihelj et al., 2014). Based on our experience with lab studies using VR, we can indeed say that first-time users of VR are oftentimes quite excited when taking their first steps in an immersive and interactive VR environment. These prior observations suggest that the intention to use VR shopping will change when users experience VR shopping using a HMD compared to a situation in which they are asked to imagine what the VR experience would be like.

4.2.3 Variables of Interest

Technology adoption research is a core research field within the IS discipline (Benbasat and Barki, 2007; Venkatesh et al., 2007). Numerous studies were conducted and several technology acceptance models (TAM) were developed to predict behavioral outcomes such as the intention to use an IS (Davis et al., 1989; Venkatesh et al., 2003; Venkatesh et al., 2012). The initial model by Davis et al. (1989) was continually adapted to reflect the respective research context as accurately as possible. In most models, however, the main predictors remain *perceived usefulness* of the system, *perceived ease of use* of the system and the *intention to use* the system in the future. Whereby perceived usefulness is defined as "the degree to which a person believes that using a particular system would enhance his or her job performance" and perceived ease of use as "the degree to which a person believes that using a particular system would be free of effort" (Davis, 1989, p. 320). Despite the continuous criticism towards the TAM model (Benbasat and Barki, 2007), we argue that the variables provide a solid basis for initial research in the field of user acceptance of VR shopping environments.

In addition to the three well-known constructs from the original TAM (Davis, 1989), which primarily aims at explaining utilitarian adoption motives, Van der Heijden (2004) emphasized the importance of considering a hedonic perspective within IS adoption theories especially for pleasure-oriented ISs. Within an online shopping context, the importance of including both utilitarian and hedonistic motives in predicting behavioral intention has already been shown (Childers et al., 2001; Koufaris, 2002). Thus, we argue that also for VR shopping environments hedonic motivations need to be considered as determinants of technology acceptance. The most widely applied construct for measuring the affective response to a system is *perceived enjoyment*, which can be seen as the hedonic counterpart to the utilitarian construct *perceived usefulness* (Wu and Lu, 2013). Isolated from all utilitarian motives, Venkatesh (2000, p. 351) refers to perceived enjoyment 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." One of the key characteristics of VR systems is the ability to induce a feeling of telepresence. Telepresence refers to the "extent to which one feels present in the mediated environment, rather than in the immediate physical environment" (Steuer, 1992, p. 76). Telepresence is therefore the system-generated ability to cross-fade physical reality. The interplay between telepresence and perceived enjoyment was shown in contexts such as virtual museums (Sylaiou et al., 2010) or virtual worlds that were used to enhance brand equity (Nah et al., 2011). Because of the connection of the constructs, we argue that both constructs represent hedonic motivations and should be considered when studying user acceptance of VR shopping environments.

4.3 Study 1 – Basic VR Shopping Environment

Since the VR technology has not yet found its way into many living rooms and, so far, only a very few VR shopping applications are available, the question is whether consumers can judge the acceptance of a VR application without having experienced it. To address this research question, the first study focuses on a basic virtual shopping environment that is rather simple to imagine for potential users. We compare data from two treatments (between subjects). In the first treatment, participants took part in a laboratory study in a basic VR shopping environment (see Peukert et al. (2019b)). In the second treatment, the participants completed an online study. Participants from the laboratory treatment experienced a basic VR shopping environment wearing a HMD (HTC Vive) and using hand-held controllers to interact with the environment (one for each hand) in the KD^{2}Lab of the Karlsruhe Institute of Technology. In the following, we therefore refer to this group as **VR1Experienced**. Participants from the online questionnaire treatment received an introduction to the shopping environment using a 2D video. We thus call this experimental group **VR1Video**. Participants were then asked to *imagine* – based on the video – how their shopping experience in the virtual shopping environment would be like and to answer the final questionnaire against this background.

The considered (basic) VR shopping environment was designed to replicate reality and consisted of a single supermarket shelf that was filled with 24 different products (3D models of muesli packages) and placed in an ordinary room. Thus, the environment only showed one single shelf and not complete supermarket aisles or even an entire supermarket. Moreover, there was a shopping cart next to the shelf in which the participants had to put their chosen products. The environment allowed participants to take products from the shelf to have a closer look on each side of the package. The interactions in VR are close to interactions in the physical world: when a product is selected it sticks to the controller and can be moved, turned, and swapped to the other hand as in reality. Participants were also able to take two products at the same time (one with each controller) or even throw products on the floor. The virtual environment enabled a real-scale stereoscopic vision. Furthermore, participants could move freely within the environment by body movements – which is possible due to room-scale tracking, but limited to the available physical space. We decided to use muesli as product category for the study, as they can be easily modelled in 3D and our participants were used to this product and could easily relate to it.

4.3.1 Operationalization of Dependent Variables

We operationalized all dependent variables of interest adapting common scales from literature and using a 7-point Likert scale ranging from 1: "I totally disagree" to 7: "I totally agree." Table 4.1 provides an overview on the applied items and the respective sources. For the VR1Video treatment, we added the words "I think" to the beginning of all items and set the tense to "conditional simple" in order to express the imagination aspect (except for intention to use, as this scale already fitted to the context). We rephrased for example the item "I found my shopping experience interesting" to "I think I would find this shopping experience interesting." Within the online questionnaire, we additionally added "virtual" in front of "shopping environment" whenever it appeared to make sure that participants refer to the virtual shopping environment, e.g., "the shopping environment is easy to use" was rephrased to "I think the virtual shopping environment would be easy to use."

4.3.2 Task, Procedure, and Participants

Within the VR1Experienced treatment, participants were asked to make several decisions in front of a virtual shelf (experimental design based on a choice-based conjoint analysis (Sawtooth Software Inc., 2013) to simulate a real shopping situation. The task was to choose the muesli package which they would most likely buy in reality out of the displayed product sample. To increase the participants' motivation to behave as they were really doing their shopping, the experiment was incentive-aligned (Ding et al., 2005), i.e., participants received an initial endowment of 14€ from which the price of one of their decisions was debited, but in return they received the respective product (average price of the offered mueslis was 2.69€). The laboratory treatment lasted on average 38.42 min (SD=7.76 min).

In the VR1Video treatment, participants conducted the study only in front of their desktop computers. Thus, instead of experiencing VR, they saw a video of 43s showing the same environment and the supported interactions that the participants in the VR1Experienced treatment experienced. The video was taken from a first-person perspective and they were instructed that they would normally use a HMD and controllers to experience the shopping environment. They were asked to imagine based on the video that they would do their shopping within the introduced environment and to answer the questionnaire against this background. Participation was incentivized by the possibility to take part in a lottery in which the payoff was on average 3.85€ per participant (survey duration: mean=15.11 min; SD =4.55 min).

We recruited our participants from a subject pool of a large German university using the organizing and recruiting software *hroot* (Bock et al., 2012). For the VR1Experienced treatment, in total, datasets for 132 participants are available for which the sessions have run technically impeccable. Whereas for the VR1Video treatment, 65 participants completed the survey. During the data cleansing process, the number of participants for the analysis decreased to 62 (one person failed to correctly answer a control question, another indicated

Constructs	Items (adapted)		Outer Loading	
			Study 1	Study 2
Telepresence (Kim and Biocca, 1997; Nah et al., 2011; Klein, 2003)	TEL.1	I forgot about my immediate surroundings when I was doing the shopping.	.856	.858
	TEL.2	When the shopping task ended, I felt like I came back to the "real world" after a journey.	.810	.804
	TEL.3	During the shopping tasks, I forgot that I was in the middle of an experiment.	.700	.648
	TEL.4	The shopping environment displayed on the screen (in the virtual reality) seemed to be "somewhere I visited" rather than "something I saw."	.462	.474
Enjoyment (Ghani et al., 1991; Koufaris, 2002)	ENJ.1	I found my shopping experience interesting.	.839	.846
	ENJ.2	I found my shopping experience enjoyable.	.788	.837
	ENJ.3	I found my shopping experience exciting.	.739	.758
	ENJ.4	I found my shopping experience fun.	.917	.918
Ease of use (Davis, 1989; Vrechopoulos et al., 2004)	EOU.1	The shopping environment is easy to use.	.887	.875
	EOU.2	It is easy to become skillful at using the shopping environment.	.827	.909
	EOU.3	Learning to operate the shopping environment is easy.	.805	.901
	EOU.4	Interactions with the shopping environment are clear and understandable.	.879	.837
Usefulness (Davis and Venkatesh, 1996; Koufaris, 2002; Vrechopoulos et al., 2004)	USE.1	The shopping environment is useful for doing the shopping.	.810	.777
	USE.2	The shopping environment improves my shopping performance.	.881	.874
	USE.3	The shopping environment enhances my effectiveness when doing the shopping.	.836	.869
	USE.4	The shopping environment increases my shopping productivity.	.822	.872
Intention to use shopping environment (Wang and Benbasat, 2009; Xu et al., 2014; Venkatesh et al., 2017)	INT.1	Assuming I have access to the shopping environment, I intend to use it next time I am doing my shopping.	.965	.973
	INT.2	Assuming I have access to the shopping environment, I predict I would use it next time I am doing my shopping.	.933	.948
	INT.3	Assuming I have access to the shopping environment, I plan to use it next time I am doing my shopping.	.949	.973

TABLE 4.1: Scales Used in Study 1 for the VR1Experienced Treatment.

having problems with playing the video, and a third person was excluded because the person watched the video for 15 s only). Altogether, this leads to a sample of 194 participants with an average age of 22.5 years (SD=3.29) and among the participants 37.6% were female.

4.3.3 Results

First, we were interested in the pure effect of the treatment variable on the dependent variables independent of any theoretically underlying relationship between the dependent variables. By doing so, we can observe how the isolated evaluations of variables differ between treatments, which helps us to answer the research question of whether subjects really need to experience a VR environment to be able to judge it properly. We therefore examined the reliability of our scales using Cronbach's alpha. All values were greater than the commonly applied threshold of 0.7 (see Table 4.2), confirming the internal consistency reliability of the applied scales (Hair et al., 2016). We then merged the scores of the construct's individual items by calculating the mean value. Depending on whether the distribution assumptions for parametric tests were met, we applied the Welch Two Sample T-test or the Mann-Whitney U Test in order to compare the means between the treatments. Table 4.2 reports the results:

	VR1Experienced (N=132)			VR1Video (N=62)				ALL (N=194)					
Const.	**M (Mdn)**	**SD**	**SW-Test**	**M (Mdn)**	**SD**	**SW-Test**	**p**	**M (Mdn)**	**SD**	α	**CR**	**AVE**	**HTMT**
TEL	4.24 (4.25)	1.14	.138	3.77 (4.00)	1.46	.132	**.028^{*a}**	4.09 (4.00)	1.27	.716	.807	.523	yes
ENJ	5.08 (5.25)	1.22	<.001**	4.15 (4.00)	1.55	.045*	**<.001^{***b}**	4.78 (5.00)	1.40	.842	.893	.678	yes
USE	4.27 (4.50)	1.23	.036*	4.23 (4.25)	1.47	.358	**.962^{b}**	4.26 (4.50)	1.31	.859	.904	.702	yes
EOU	6.48 (6.75)	0.69	<.001**	5.61 (5.75)	1.01	.013*	**<.001^{***b}**	6.20 (6.50)	0.90	.875	.912	.722	yes
INT	4.05 (4.00)	1.66	.002**	3.88 (4.33)	1.85	.001**	**.618^{b}**	3.99 (4.00)	1.72	.945	.964	.900	yes
* *p*<.05; ** *p*<.01; *** *p*<.001													

TABLE 4.2: Summary variables of interest and test for group differences (SW = Shapiro-Wilk, p-value based on appropriate test a. Welch Two Sample T-test, b. Mann-Whitney U Test; calculating the tests using t-tests only, leads to qualitatively similar results; α= Cronbach's alpha, CR = Composite reliability, AVE = Average variance extracted, HTMT = Heterotrait-Monotrait Ratio: 1 is not included in confidence interval).

The results of the comparison of means for the two variables perceived telepresence (t(97.55)=2.24, p<.05, with an effect size of r=.22 (Rosnow and Rosenthal, 2005)) and perceived enjoyment (W=5580, p<.001, r=-.29), reveal significant differences for the treatments in the evaluation of the variables. The values for both show significantly higher values for the VR1Experienced treatment, indicating that participants underestimate the VR system's ability to induce a feeling of telepresence and that the perceived enjoyment which is created through using the VR environment is higher than expected. On the contrary, the results for perceived usefulness do not differ significantly between the treatments (W=4110, p=0.962, r=-.003). Accordingly, participants can well estimate the perceived usefulness without having the need to experience it. Similarly, the results for the behavioral outcome intention to use are not significant (W=4274, p=0.618, r=-.04). Here, as well, values for the intention to use from the VR1Experienced group coincide with the VR1Video group evaluation. For the remaining TAM variable perceived ease of use, the differences are, again, significant (W=6248, p<.001, r=-.43).

Second, since most of the variables originate from technology acceptance research, we are also interested in the effect of the individual variables on the ultimate TAM outcome variable intention to use. We therefore investigate a simple structural equation model (SEM) with two layers: From the treatment variable paths are modelled to telepresence, enjoyment, usefulness and ease of use (first layer), and from the latter variables a path to intention to use is modelled (second layer). Due to the exploratory research objective of our analysis, PLS SEM is used for the data analysis (Gefen et al., 2011). We first analyzed the quality of the measurement model. Cronbach's alpha (as stated above) as well as the composite reliability are above the threshold value of 0.7 (Hair et al., 2016) for all constructs, thereby confirming internal consistency reliability. Then, we evaluated the convergent validity by examining each indicator's outer loading and a construct's average variance extracted (AVE) (see Table 4.1 and Table 4.2). For the latter, the values for all the constructs were above the proposed threshold of 0.5 (Hair et al., 2011). However, with respect to the outer loadings, the indicator TEL.4 (0.462) had to be considered in more detail: Following Hair et al. (2016), indicators with an outer loading between 0.4 and 0.7 shall only be removed from the scale when item deletion increases the AVE or internal consistency reliability above the threshold. Since we have already met the respective threshold values, we decided to retain TEL.4 in the model. For assessing the discriminant validity, we draw upon the Fornell-Larcker criterion (Fornell and Larcker, 1981), the consideration of the cross loadings, as well as the Heterotrait-Monotrait Ratio (HTMT, see Table 4.2). All three tests confirm the discriminant validity of the measurement model.

Having confirmed the reliability of the measurement model, we then evaluated the results of the structural model. First, we checked the structural model for collinearity issues by analyzing the Inner VIF values among predicting constructs. We can confirm that all the values for predicting constructs are well below the commonly used threshold of 5 (Hair et al., 2011). Second, we proceeded with assessing the structural model. Figure 4.1 shows the results for the PLS structural model. The significance values for the path coefficients were obtained by means of bootstrapping (5000 samples, two tailed, bias-corrected and accelerated (BCa) without sign change).

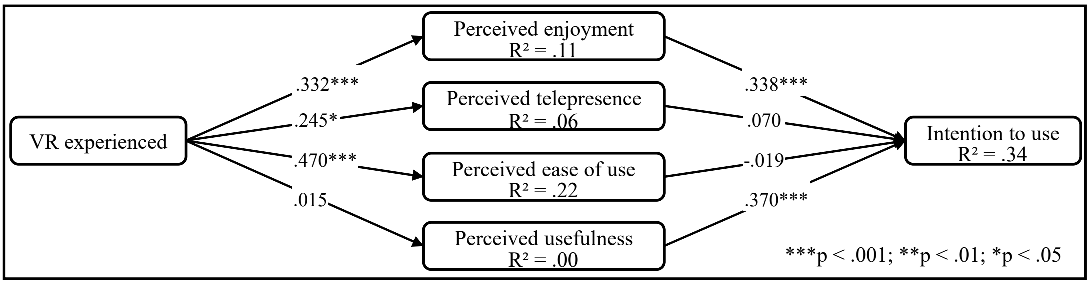


FIGURE 4.1: SEM basic VR shopping environment.

In the following, we primarily focus on the second layer of the SEM to answer the question of which variables have an influence on the intention to use. We find significant paths for perceived enjoyment and perceived usefulness (both significant at a .001 level), whereas the paths leading from telepresence and ease of use to intention are not significant. The independent variables explain 34 percent (adj. R^2 = .32) of the variance in intention to use, with perceived enjoyment (f^2 = .142; small effect) and perceived usefulness (f^2 = .190; medium effect) being the predictors with highest contribution ($f^2_{(TEL \rightarrow INT)}$ = .007; $f^2_{(EOU \rightarrow INT)}$ = .001).[2] Based on the results we conclude that the hedonic variable enjoyment as well as the utilitarian variable usefulness have the strongest influence on intention.

4.3.4 Discussion

According to the results, participants significantly underestimate the hedonic properties of the basic VR shopping environment (namely enjoyment and telepresence) purely in imagination, whereas the utilitarian outcome perceived usefulness and the behavioral outcome intention to use are surprisingly equally perceived. The findings for perceived telepresence show that participants cannot reliably envision the extent of the key characteristic of VR – inducing a feeling of telepresence – without having experienced the respective application. Research has already shown the linkage between the variables covering our hedonic perspective (Sylaiou et al., 2010; Nah et al., 2011). Interestingly, the significantly higher values for ease of use provide the insight that the basic VR shopping environment was perceived as being easier to use when experienced than when imagined (the average values are anyhow rather high for measurements on a 7-point Likert scale). This finding could be explained by the closeness of the supported interactions in the virtual shopping environment to the known habits in reality. The assessment of the perceived usefulness and intention was congruent, which may have been

---

[2] Adj. R^2: ENJ (.106), TEL (.055), EOU (.217), USE (-.005); f^2 VR Exp. on: ENJ (.124), TEL (.064), EOU (.284), USE (.000).

caused by the simplicity of the design of the basic shopping environment. When considering the relationships from the individual variables to intention to use, we find significant paths for enjoyment (hedonic) and usefulness (utilitarian). These findings are consistent with literature (Van der Heijden, 2004; Koufaris, 2002), in which utilitarian and hedonic variables equally predict the intention to use.

Within Study 1, we investigated consumer behavior in a highly controlled task that should be easy to be imagined with only a single shelf representing the shopping environment. Moreover, we choose muesli – mainly to reduce implementation effort – as product under consideration which can be classified as low-involvement product for which, for example, the real-scale product presentation only offers a small added value. This study thus serves as a starting point and establishes a lower bound for our investigated effect. We hence can conclude that for a basic and rather easy to imagine environment, participants are able to anticipate utilitarian effects of the system but not effects on hedonic values. We therefore now shed more light on our research question by analyzing a more advanced VR environment next.

4.4 Study 2 – Advanced VR Shopping Environment

The possibilities for designing virtual shopping environments are almost unlimited. Hence, VR shopping environments have by no means to be a one-to-one replication of reality. Whereas the Swedish furniture manufacturer IKEA sticks to modelling a realistic kitchen within their VR application – which seems to be reasonable for their context, SATURN let customers choose between two different VR environments to shop for consumer electronics: either in a penthouse-loft or in space on the planet Saturn. These VR shopping environments represent an entire world, in contrast to the plain environment which was applied in Study 1, and thus a much more pronounced experience. Similar to Study 1, we compare data from a treatment, in which participants take part in a laboratory study experiencing the advanced VR environment (**VR2Experienced**), with data from another treatment, in which participants participated in an online study watching a video that introduces the advanced shopping environment (**VR2Video**).

In the Virtual SATURN environment irrespective of the selected shopping environment, several consumer electronic products are displayed. As soon as participants take a closer look at a product, additional information about the product pops up. Moreover, further products can be considered in a virtual product catalog and put into the environment to view them in real-scale stereoscopic vision. The product catalog allows for browsing different product categories reaching from digital cameras over large kitchen appliances to drones. Generally, several functionalities are offered such as bookmarking products, requesting remote product advice by an employee, or gimmicks like a tape measure to determine the size of a product, a pen to draw within the environment, or a photo feature. Due to the size of the shopping environment, a feature is implemented to teleport oneself from one point to another, which can be used instead moving by body movements. The latter is possible due to room-scale tracking, but only in the restricted area of the available physical space. The general handling of products is – similar to Study 1 – close to interactions in reality (grabbing, turning, and throwing products is supported). Finally, products can be purchased via a direct link to the online shop. As outlined, the described shopping environment is relatively comprehensive and offers various possibilities, but, in turn, the question arises whether consumers can judge the acceptance of this advanced VR environment without having experienced it. We considered the penthouse-loft as experimental scene for Study 2, to limit the participants to only one environment to control for this factor. The penthouse-loft can be described as a huge fully furnished living room (including all kinds of electronic devices) with a connected open kitchen. To sum up, the main differences to the environment applied in Study 1 are that the shopping environment is comprehensive (in size and content), multiple product categories are presented, and that additional features are offered (i.e., features that do not exist in physical reality).

4.4.1 Task, Procedure, and Participants

Within the VR2Experienced treatment, we asked the participants to visit SATURN's penthouse-loft. We did not specify a specific task to let the participants experience the environment and the various functionalities on their own. However, they were asked to put one product that they liked into their shopping basket whenever they wanted to leave the shopping environment. The procedure for the VR2Video treatment was similar to Study 1. Hence, instead of experiencing the advanced shopping environment, participants saw an introduction video of 4:39 min taken from a first-person perspective that introduced the environment and the supported possibilities of interaction (as described above; VR2Experienced participants saw the same video as part of the instructions). Afterwards, participants were asked to imagine that they would do their shopping within the introduced shopping environment and to answer the questionnaire against this background. For the operationalization of the variables of interest, we applied the same scales as in Study 1 for both treatments respectively (Table 4.1). The recruiting process was similar to Study 1. Initially, 46 participants took part in the VR2Experienced treatment. Due to technological problems during the experiment, we excluded five participants from further analysis as the technological problems influenced their experience in the virtual shopping environment. In addition, we excluded two participants because of very limited German language skills resulting in a sample of 39 participants for further analysis. On average, a session lasted 38.16 minutes (SD=6.63) and participants received 10€ for taking part in the laboratory study. In total, 51 participants completed the online questionnaire for the VR2Video treatment of which, however, one person failed to correctly answer a control question and three additional only watched less than half of the video. After removing two other participants who in turn stated to have problems playing the video, the sample size for analysis is 45. Participation was incentivized by the possibility to take part in a lottery in which the payoff was on average 3.33€ per participant (survey duration: mean=20.64 min; SD =2.61 min). The average age of participants in both sub-samples is 23.74 years (SD=5.83) and 25% of the participants are female.

4.4.2 Results

First, we examined the reliability of our scales using Cronbach's alpha. All values were greater than the commonly applied threshold of .7 (Hair et al., 2016) except the value of perceived telepresence (see Table 4.3). We then tested whether removing individual items leads to a decisive improvement in the alpha value, however, this was not the case. As Cronbach's alpha tends to underestimate the internal consistency of the scale (Hair et al., 2016), we argue that we can apply the scale for the analysis as the value is only slightly below the threshold. Furthermore, the results are robust of whether we build the telepresence scale on three (dropping TEL.4 leads to an alpha of .683) or four items (W=1411.5, p<.001, r=-.55). Second, we continued the analysis in line with the approach of Study 1 (see Table 4.3).

The results of the comparison of means between treatments for perceived telepresence (t(82.0)=4.51, p<.001, r=.45) as well as perceived enjoyment (W=1557.5, p<.001, r=-.72) show significant differences. For both variables representing the hedonic perspective, the mean values are significantly higher in the VR2Experienced treatment from which the conclusion can be drawn that the hedonic capabilities of the system cannot be predicted without having experienced it. However, the results for the TAM variables perceived ease of use (W=1066, p<.1, r=-.18) and intention to use (W=1069.5, p<.1, r=-.19) do not reveal significant differences. Finally, the evaluation of the VR2Video group for the construct perceived usefulness is significantly lower than participants' evaluation in the VR2Experienced group (t(79.21)=2.16, p<.05, r=.24). Accordingly, participants state that the usefulness of the advanced shopping environment is higher when experienced than imagined based on a video.

	VR2Experienced (N=39)			**VR2Video (N=45)**				**ALL (N=84)**					
Const.	**M (Mdn)**	**SD**	**SW-Test**	**M (Mdn)**	**SD**	**SW-Test**	**p**	**M (Mdn)**	**SD**	α	**CR**	**AVE**	**HTMT**
TEL	5.03 (5.00)	0.98	.327	3.99 (4.00)	1.13	.638	$\mathbf{<.001^{***a}}$	4.48 (4.50)	1.18	.680	.797	.507	yes
ENJ	6.11 (6.25)	0.74	.011*	4.37 (4.75)	1.36	.032*	$\mathbf{<.001^{***b}}$	5.18 (5.50)	1.41	.862	.906	.708	yes
USE	4.10 (4.00)	1.26	.800	3.51 (3.50)	1.21	.360	$\mathbf{.034^{*a}}$	3.78 (3.75)	1.26	.871	.911	.721	yes
EOU	5.55 (5.75)	1.04	.071	5.04 (5.25)	1.30	.043*	$\mathbf{.090^{b}}$	5.28 (5.50)	1.21	.904	.933	.776	yes
INT	4.44 (5.00)	1.69	.054	3.67 (3.33)	1.90	.001**	$\mathbf{.084^{b}}$	4.02 (4.50)	1.83	.962	.976	.930	yes
* $p<.05$; ** $p<.01$; *** $p<.001$													

TABLE 4.3: Summary variables of interest and test for group differences (SW = Shapiro-Wilk, p-value based on appropriate test a. Welch Two Sample T-test, b. Mann-Whitney U Test; calculating the tests using t-tests only, leads to qualitatively similar results; α= Cronbach's alpha, CR = Composite reliability, AVE = Average variance extracted, HTMT = Heterotrait-Monotrait Ratio: 1 is not included in confidence interval).

Second – similar to Study 1 – we are interested in the effect of the variables on the intention to use and therefore follow the same approach as in Study 1 for the more advanced environment. We test the same SEM and proceed similarly to Study 1 with the evaluation of the measurement and structural model. As mentioned above, the Cronbach's alpha of perceived telepresence was slightly below the recommended 0.7 threshold. However, the composite reliability for telepresence indicated a sufficient value (0.797). In addition, the tests for convergent and discriminant validity were satisfactory, confirming the reliability of the measurement model (see Table 4.1 and Table 4.3). Only the outer loadings of TEL.3 (0.648) and TEL.4 (0.474) fell within the interval between 0.4 and 0.7 (see Table 4.1). Following the same argumentation as in Section 4.3.3, we decided to retain the items in the model. After having confirmed the reliability of the measurement model, we ruled out the possibility to suffer from collinearity issues (all the values for predicting constructs are well below 5) and proceeded with the analysis of the structural model. Figure 4.2 shows the results for the PLS structural model.

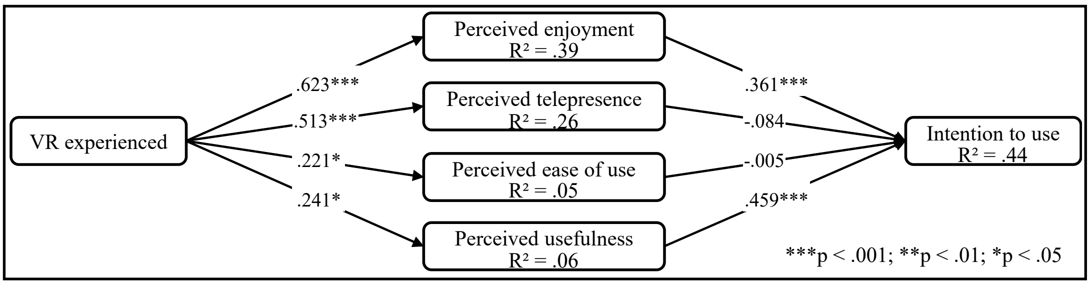


FIGURE 4.2: SEM advanced VR shopping environment.

Similar to Study 1, we solely focus on the second layer of the SEM since this is the subject of investigation. The two paths leading from enjoyment and usefulness to intention to use turn out to be significant (both positive and significant at a .001 level), whereas the remaining paths were not. The four predicting variables jointly explain 44 percent of the variance in intention to use (adj. R^2 = .416). However, perceived enjoyment (f^2 = .134; small effect) and perceived usefulness (f^2 = .288; medium effect) are the main contributors ($f^2_{(TEL \rightarrow INT)}$ = .009; $f^2_{(EOU \rightarrow INT)}$ = .000).[3] Based on the results, the hedonic variable enjoyment as well as the utilitarian variable usefulness turn out to have the highest impact on intention.

4.4.3 Discussion

We can overall summarize that within Study 2 the most part of the variables of interest have been (significantly) underestimated in the VR2Video treatment emphasizing the need to experience this advanced VR shopping environment. In particular, the effect of perceived enjoyment is very large with an effect size of r=-.72 followed by the effect of perceived telepresence (r=.45). All

---

[3] Adj. R^2: ENJ (.380), TEL (.254), EOU (.037), USE (.047); f^2 VR Exp. on: ENJ (.633), TEL (.356), EOU (.051), USE (.062).

three TAM variables show small effect sizes. Although perceived ease of use and intention to use are not significant at a .05 level, we find a trend that participants who experienced VR had higher overall ratings on these two constructs.

When comparing the individual results of Study 2 with those of the first study, it is noticeable that in both cases the hedonic variables were significantly lower rated in the VR1/2Video than in the respective VR1/2Experienced treatment. Thus, it seems to be a general problem that hedonic aspects are underestimated when only imagined based on a video, irrespective of whether the environment is basic or advanced. In contrast, for both studies the effects between groups on the intention to use are not significant, whereas for perceived usefulness and ease of use the results are inconsistent when comparing both studies – either significant for one study or the other (perceived usefulness significant in Study 2 only; perceived ease of use significant in Study 1 only). The results for the examination of variables influencing the intention to use are similar for the two studies: In both studies the hedonic variable perceived enjoyment and perceived usefulness are the variables that have a significant influence on the intention to use which fosters theories of two-sided motivations, i.e. hedonic and utilitarian, in the area of online retail consumer behavior (Childers et al., 2001; Koufaris, 2002).

In order to further understand the influence of the shopping environment's design on the shopping experience, the next section will only compare results between the two experience groups (VR1/2Experienced) from Study 1 and 2: We find that the more advanced shopping environment (M=6.11, SD=0.74) indeed leads to significantly higher perceived telepresence compared to the basic shopping environment (M=5.08, SD=1.22), t(71.32)=-4.24, p<.001, r=-45. Similarly, the comparison reveals significant differences with respect to perceived enjoyment (advanced: M=6.11, SD=0.74; basic: M=5.08, SD=1.22), W=1223.5, p<.001, r=-.38. Interestingly, the perceived usefulness was rated as equally high (advanced: M=4.10, SD=1.26; basic: M=4.27, SD=1.23), W=2704.5, p=.632, r=-.04. As expected, the perceived ease of use was higher in the simpler environment of the first study (W= 4011, p<.001, r=-0.42). In sum, there is no difference with respect to the intention to use between the simpler and the more advanced environment (W=2208.5, p=.178, r=-.10).

4.5 Limitations and Future Research

Within this paper, we reported results for two experiments trying to shed light on the acceptance of VR shopping environments from different perspectives – namely experience and imagination (based on a video). The analyses reported within this paper focused on investigating effects on several variables of interest and are of a more explorative nature. Although we have examined which variables have the largest impact on the intention to use, it remains a point for future research to theorize about and test further relationships between the variables. Overall, the paper has primarily been driven by the idea to investigate ways to reduce the effort and expenses that result from conducting VR lab experiments. As a result, we compared an online study showing a video (lower effort and expenses) to a real VR experience in the lab and wanted to learn whether similar results can be obtained. We are aware of the fact that the experimental design is not entirely clean in a classical sense (i.e. everything is kept constant except the manipulation) since the experiment duration and the incentive structure were not identical. Now that we have gained initial insights, the next step is to conduct another set of studies that follows a clean experimental design in order to validate the results.

Our research is also limited to studying the initial use based on the technology acceptance model. However, investigating continued use or "continuance" (Bhattacherjee, 2001) seems impossible at this point as these VR applications were launched very recently. Understanding the continued use of VR shopping environments, however, is an essential next step for future research, as the long-term survival of VR as a retail channel will be depending on customers' demand to use it. Adopters of VR shopping are supposed to decide at a later point in time whether they will continue or discontinue to use VR shopping. Future research can, for example, measure users' expectations with respect to the initial use of VR shopping as well as assess the degree to what expectations are met and change after the initial use of the system. The expectation-confirmation model (Bhattacherjee, 2001) is an excellent starting point that can guide this investigation.

As the VR shopping market is in the very early stages, the time is right to also start research projects tracking the change of beliefs and attitudes (Bhattacherjee and Premkumar, 2004) towards VR shopping over time. For retailers planning to offer VR shopping, it is essential to understand the factors that drive the changes of beliefs and attitudes as it will help them to build realistic user expectations that can be met. The Virtual SATURN environment is a good example demonstrating that companies will be able to extend user experience beyond the capabilities of physical stores or e-commerce (Shankar et al., 2011). Not only might certain groups of customers find this new way of shopping more appealing, it might also enable customers to make decisions that better satisfy their needs if they are able to compare products in new ways. More generally, companies can use VR environments as test settings to evaluate new sensory cues (Berg and Vance, 2017), such as changes in the lighting, colors or music of the store without implementing such changes in their physical stores. Adapting the shopping environment to individual needs might thus be a way to further increase user acceptance and to foster the continued use.

4.6 Conclusion

We conducted two experimental studies in the context of VR shopping environments. The most important finding of the studies is that experiencing VR shopping versus only imagining the VR experience had a substantial impact on the evaluation of the VR shopping experience. In a basic shopping environment, perceived telepresence, enjoyment and ease of use were rated to be significantly more positive than when experienced. In a more complex environment, perceived telepresence, enjoyment and usefulness were rated to be significantly more positive than when experienced. Thus, besides telepresence, the hedonic aspects of shopping are evaluated to be significantly better when participants have experienced the shopping environment than when they had to imagine it based on a video. Our empirical results are therefore important for retailers who plan to build and develop VR shopping applications and suggest that the enjoyment of the shopping experience is an essential factor for building successful VR shopping environments. Thus, our paper makes two main contributions: First, our results show that experiencing the VR shopping environment is essential for users to be able to evaluate the respective technology. Our empirical findings thus put adoption research into question that investigates ISs based on "imagined" experiences. Second, across two very different shopping environments, participants evaluated the utilitarian and particularly the hedonic dimensions of VR shopping very positive which suggests that investments in building VR shopping environments could be profitable for retailers and customers.

***Acknowledgements*:** The authors thank the Nuremberg Institute for Market Decisions (formerly GfK Verein), founder and anchor shareholder of GfK SE, for funding this research.

Part III

Towards Designing VR Shopping Environments

Chapter 5

Enriching VR Shopping Environments with Interactive Decision Aids [1]

Christian Peukert, Fabian Brossok, Jella Pfeiffer, Martin Meißner, Christof Weinhardt

> "Such capabilities are particularly valuable given that online stores cannot offer physical contact with products, do not allow face-to-face interaction with a salesperson, and may offer a very large number of alternatives because of their virtually infinite 'shelfspace,' i.e., the lack of physical constraints with respect to product display."
>
> Häubl and Trifts (2000, p. 6)

5.1 Introduction

The fundamentals of Virtual Reality (VR) technology can be traced back to the 1960s (Sutherland, 1965). However, only in recent years, the interest in the technology has increased rapidly with the introduction of affordable head-mounted displays (HMDs) to the mass consumer market. VR "provides a unique way to interact with the ever-growing digital landscape" (Berg and

---

[1] This chapter comprises an article that was published in the following outlet under the following title: Peukert C., Brossok F., Pfeiffer J., Meißner M., Weinhardt C. (2018). "Towards Designing Virtual Reality Shopping Environments". Presented at and in Conference Booklet of the 13th International Conference on Design Science Research in Information Systems and Technology (DESRIST), Chennai, India. *Note*: Unpublished supplemental material of the article can be found in Appendix D. The appendix is also based on joint work by the authors. Tables and figures were renamed, reformatted, and newly referenced to fit the structure of the thesis. Chapter and section numbering and respective cross-references were modified. Formatting and reference style was adapted and references were updated. Opening quotation was not part of the article.

Vance, 2017, p. 1) so that these technologies "enable people to immersively experience a world beyond reality" (Berg and Vance, 2017, p. 1) and thus enhances human computer interaction (HCI) to a level that has not been seen before. Although the gaming industry has been the most prominent application domain of VR technology, many other industries try to design applications to weigh up its potential in their respective context. Among them, the retail industry believes in its potential (Grewal et al., 2017): Key players have launched prototypes such as Buy+ (Alibaba), virtual SATURN (MediaOnline) or IKEA VR (IKEA).

VR shopping environments tend to combine benefits of both e-commerce and shopping in physical stores and even go beyond: Shops are opened around the clock, the product range is not limited by physical space, layouts of VR shopping environments and shelves could be continuously personalized to the shopper's needs and friends could easily join the shopping experience from remote in form of avatars.

Today, one of the main challenges most e-commerce websites are facing is to provide customers the right amount of information to cope well with the enormous product range (Wang and Benbasat, 2009). Offering different decision support is therefore a common functionality to help customers to make high quality decisions (Kasper, 1996). The main focus has been laid on interactive decision aids (IDAs) such as filter functions or sorting mechanisms (Groissberger and Riedl, 2017; Pfeiffer et al., 2009). While the application of IDAs in an e-commerce context has been under investigation for a long time (Häubl and Trifts, 2000), similar research is missing in the area of VR shopping environments. Moreover, the design of VR shopping environments is a new field for research and it remains an open question whether results from research on the design of e-commerce stores can be directly transferred to the design of VR shopping environments. Our paper therefore focuses on the following research question:

RQ: *Which IDAs and VR specific features will customers use in VR shopping environments?*

In order to address this research question, we initialized a research project following the design science research (DSR) approach (Hevner et al., 2004). Following the guidelines by Hevner et al. (2004), we see the entire VR shopping environment as our design artifact of interest. As a starting point, we investigate common IDAs known from e-commerce websites as well as VR specific features and are therefore able to design first low-fidelity prototypes in form of mockups based on well-known theory. We use an online survey (based on Paired Comparison-based Preference Measurement (PCPM) (Scholz et al., 2010)) showing these mockups on desktop screens for two specific product categories, mueslis and outdoor tents (between-subjects), to assess users' requirements. Mueslis represent a low-involvement, fast-moving consumer good (FMCG), whereas outdoor tents are a high-involvement product with a special need to see the built up product. Based on the findings, we will formulate meta-requirements in future.

We therefore contribute to theory by creating initial design knowledge in the area of VR shopping. For practitioners, we give first insights on what to consider when creating VR shopping environments with respect to the offered products.

5.2 Theoretical Background

5.2.1 Virtual Reality

Within this short paper, we build upon Steuer's definition that VR is "a real or simulated environment in which a perceiver experiences telepresence" (Steuer, 1992, pp. 76/77), whereby the term telepresence is defined as "a sense of presence in a mediated environment" (Klein, 2003, p. 42). For creating the feeling of telepresence, design guidelines exist for soft- and hardware components (Steuer, 1992; Slater and Usoh, 1993). In more detail, Steuer argues that telepresence can be achieved by designing the system to be *vivid* and *interactive*, whereas the former describes the representational richness, i.e., how information is presented to the senses, of a medium (Steuer, 1992). Further he argues that vividness is subdivided into breadth, i.e., number of accommodated senses, and depth, referring "to the resolution within each of these perceptual channels" (Steuer, 1992, p. 81). Transferring these guidelines to the context of VR shopping environments in which the main interaction takes place between the user and the products, we argue that it might be an important VR specific feature to allow customers inspecting products in a similar way as in reality. In particular, VR technology can provide product presentations in real scale (SCAL) and 3D (dimensionality: DIM). Moreover, the depth of vividness can be easily increased by displaying additional product information in the users' field of view (INFO). For example, in MediaSaturn's shopping environment, these three VR specific features are implemented: Products are presented in real size and 3D, and additional information pops up in a window when customers are located close to the products. We therefore include these three potentially interesting features in our study (see Table 5.1 marked in grey):

Attribute	Abbr.	Description
Filter	FIL	Filters products by thresholds for attribute values defined by the user. (Groissberger and Riedl, 2017)
Sort	SOR	Sorts the products in an order according to defined attributes by the user. (Groissberger and Riedl, 2017)
Compare	COMP	Compares attributes of products in a comparison matrix.
Remove	REM	Removes products selected by the user.
Mark	MARK	Marks products selected by the user.
Recommendations	RECO	Describes the basis on which the data for recommendations is collected.
Product information	INFO	Displays product information on an additional screen in the users' field of view.
Product presentation	DIM	Represents products in different dimensions and levels of detail.
Scale of product	SCAL	Represents the product in different scales with respect to reality.

TABLE 5.1: Identified IDAs and VR specific features (marked in grey).

5.2.2 Interactive Decision Aids (IDAs)

For e-commerce websites a vast body of literature considers the effect of IDAs as design artifacts on customer behavior (Groissberger and Riedl, 2017). IDAs "help consumers in making informed purchase decisions amidst the vast availability of online product offerings" (Wang and Benbasat, 2009, p. 295). For example, recommendation agents focus on learning preferences and ultimately recommending products, whereas interactive information management tools (IIMT) concentrate on fulfilling search and comparison tasks. The aim of IDAs is to outsource "resource-intensive, but standardizable, information processing tasks" (Häubl and Trifts, 2000, p. 6) to the computer. Pfeiffer (2010) and Groissberger and Riedl (2017) analyzed the application of IDAs in online shops and found that most commonly filter (FIL), sorting (SOR) and comparison (COMP) mechanisms are implemented (frequency of application in descending order). Based on their overview, we identified the IDAs described in Table 5.1 as potentially useful for our study of VR shopping environments in addition to the prior identified VR specific features.

We thus ground our DSR on several different sources as proposed by Hevner (2007), i.e., e-commerce applications, research on e-commerce IDAs, as well as VR literature and prototypes of VR shopping environments. The approach, which is described in the following, can be categorized as "Exaptation" according to the DSR Knowledge Contribution Framework by Gregor and Hevner (2013) since we apply known IDAs from e-commerce to the novel field of VR shopping environments. Table 5.2 provides an overview of applied IDAs and VR features across different sources:

		Attribute								
		FIL	SOR	COMP	REM	MARK	RECO	INFO	DIM	SCAL
Source	Pfeiffer (2010) and Groissberger and Riedl (2017)	X	X	X	X	X	X			
	Amazon.com (e-commerce)	X	X	X			X			
	Steuer (1992)							X	X	X
	Virtual SATURN (VR application)					X		X	X	X
	This work (VR)	X	X	X	X	X	X	X	X	X

TABLE 5.2: Overview of applied IDAs and VR specific features.

5.3 Research Methodology

Our DSR project aims at designing a VR shopping environment that supports customers in doing their shopping and follows the structure proposed by Kuechler and Vaishnavi (2008). Within this short paper, we focus on the first activity (Awareness of Problem) of our first design cycle. So far, literature has not discussed the specific requirements for this new environment. Therefore, we scanned the VR literature, existing e-commerce websites as well as VR applications in the retail sector to determine a set of design features that need to be evaluated. We then used a preference measurement method from marketing research, the PCPM approach, to determine the potential users' preferences regarding the respective design features within an online survey that was performed on a regular desktop screen. PCPM is based on the Analytic Hierarchy Process (AHP) and has been adapted to marketing research requirements. In particular, PCPM is well suited for measuring the preferences of products and services that have many different features (Scholz et al., 2010). The latter is a key advantage over other preference measurement approaches such as conjoint-analytic preference measurement that is more frequently used, but quite limited with respect to the number of features that can be included in the measurement.

5.4 Designing Decision Aids for VR Shopping Environments

5.4.1 Design of the Online Survey for Measuring Users' Requirements

PCPM uses pairwise comparisons to calculate the utilities of features on the individual (i.e., respondent) level. In our empirical study, we used a three-layer hierarchy consisting of 9 attributes and 30 attribute levels (see Table 5.3). Following Scholz et al. (2010) and Meißner and Decker (2009), we used a bottom-up evaluation of the hierarchy. Thus, the participants first compared the attribute levels before comparing the attributes. In total, the design led to 56 pairwise comparisons for each participant (38 for the attribute levels and 18 for the attributes).

As proposed by Scholz et al. (2010), a two-cycle design was used to reduce the number of comparisons needed on the attribute level. To ensure that participants understood the functionality of the IDAs, all attribute levels were illustrated using mockups and a caption additionally explained the function in written form on the screen (e.g., see Figure 5.1) before they were evaluated. The attributes were explained using abstract representations.

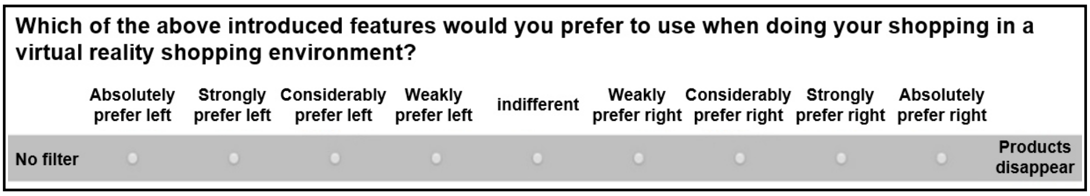
No filter | **Products disappear** | **Products are greyed out** | **Products are highlighted**

FIGURE 5.1: Example mockups of attribute levels for the attribute filter (FIL).

Within each pairwise comparison, participants were asked to state on a 9-point scale which of the two surveyed attributes/attribute levels they prefer more (Figure 5.2 exemplarily shows the scale for the evaluation of two attribute levels).

Attribute	**Attribute Level 0**	**Attribute Level 1**	**Attribute Level 2**	**Attribute Level 3**
FIL	No filter	Products are greyed out	Products disappear	Products are highlighted
SOR	No sorting	Sorting by a criterion without explicit display	Sorting by a criterion with explicit display	
COMP	No comparison matrix	Comparison matrix with two products	Comparison matrix with four or more products	
REM	No remove	Remove products		
MARK	No mark	Mark products		
RECO	No recommendations	Based on purchase history	Based on interaction data	Based on Eye tracking data
INFO	No product information	Selected product information	Detailed product information	Additional product information
DIM	2D-frontal image	2D image of all perspectives	3D product presentation	3D and additional images of product
SCAL	None-scale representation	None-scale representation; but indication of real size	Real-scale representation; without additional indication of real size	Real-scale representation; additional indication of real size

TABLE 5.3: Attributes and associated attribute levels.



Which of the above introduced features would you prefer to use when doing your shopping in a virtual reality shopping environment?

	Absolutely prefer left	Strongly prefer left	Considerably prefer left	Weakly prefer left	indifferent	Weakly prefer right	Considerably prefer right	Strongly prefer right	Absolutely prefer right	
No filter	○	○	○	○	○	○	○	○	○	Products disappear

FIGURE 5.2: 9-point scale for pairwise comparisons; exemplarily for two attribute levels of FIL.

Before the PCPM part of the survey started, participants were familiarized with making pairwise comparisons using PCPM and a video showed the VR environment in which the aids would be implemented in the future. Participants were asked to imagine that they were trying to find products that fit their personal preferences best.

5.4.2 Preliminary Results

In total, we recruited 500 participants (250 for each product category) from a subject pool of a large German university using the organizing and recruiting software hroot (Bock et al., 2012), from which 101 fully completed the questionnaire. Participants on average received 4€ for participation. Due to inconsistencies in the PCPM answering behavior (Mean Consistency Ratio > 0.5 for attribute level evaluation) or an abnormally short response time (t < 11 minutes) we excluded 10 participants from further analysis. Table 5.4 depicts the results for the attribute utilities (importances) and descriptive statistics:

	Muesli [n = 47] (Rank)	Tents [n = 44] (Rank)	Mann-Whitney-U Test p-Values
FIL	0.183 (2)	0.175 (1)	0.603
SOR	0.159 (3)	0.136 (3)	0.355
COMP	0.183 (1)	0.156 (2)	0.246
REM	0.118 (5)	0.074 (9)	0.146
MARK	0.055 (7)	0.090 (6)	0.051
RECO	0.075 (6)	0.086 (7)	0.079
INFO	0.130 (4)	0.105 (4)	0.226
DIM	0.043 (9)	0.076 (8)	**0.006
SCAL	0.053 (8)	0.103 (5)	*0.033
Avg. age	23.1 years	23.8 years	
Avg. CR	0.219	0.210	
Avg. RT	27.6 min (Mdn. = 21)	25.6 min (Mdn. = 19)	
Gender	f = 46.8%; m = 51.1%; else = 2.1%	f = 47.7%; m = 52.3%	

TABLE 5.4: Preliminary results for attribute utilities (*p < 0.05, **p < 0.01) and descriptive statistics. Abbreviations: Consistency Ration (CR), Response Time (RT).

The results for both product categories reveal that FIL, SORT and COMP are the most preferred IDAs. These results match the results of the analysis by Groissberger and Riedl (2017) and Pfeiffer (2010) for e-commerce stores outlining that these are the most often provided IDAs. It shows that familiarity with IDAs is a major criterion for users and that users might also want to stick to their already well-trained behavioral patterns in very different application environments. This might, however, change tremendously once users get familiar with virtual environments and adapt their interaction and information acquisition behavior to the new opportunities these environments offer.

Interestingly, we find only significant differences between both product categories with respect to the VR specific features DIM and SCALE. For outdoor tents these VR specific features are significantly more important. This can be easily explained by the fact that the size of muesli packages is a rather irrelevant decision criterion. Yet, when ranking the attributes according to their utility (attribute importance), we find a high correlation (Spearman correlation coefficient of 0.75) for the orders of both categories. This is quite surprising and a promising result as mueslis and tents differ on several dimensions such as product involvement, price range, or purchasing frequency. Thus, we can summarize that, first, it seems that VR shopping environments can offer similar functionalities for different product categories. And, second, in particular SCAL is a very important functionality for categories for which size matters and differs largely across products as is the case of tents.

5.5 Conclusion, Future Research and Limitations

Within this short paper, we reported first results of a survey investigating customer preferences with respect to potential IDAs and VR specific features in a VR shopping environment. Following the DSR approach by Kuechler and Vaishnavi (2008), we will derive meta-requirements and formulate design principles based on the final results (Suggestion) in a next step. As an example, a potential design principle could be to provide the virtual reality shopping environment with VR specific features illustrating the real scale (SCAL) of the product to convey a good assessment of the appearance in reality for products for which product size is an important decision criterion. Then, we will implement the most preferred functions into our existing shopping environment[2] (Development) and evaluate the impact of the implemented features on variables such as usability and user experience (Evaluation). We want to find out whether the implementation of the artifacts improves the intention to use VR shopping environments. We will conclude the first design cycle with the analysis of experimental data (Conclusion) and start the second design cycle with reflecting the findings of the first.

Our study design is limited to the fact that it does not allow us to detect interaction effects between IDAs or features. We argue that our design is sufficient

---

[2] We refer to a video showing the present state of the VR shopping environment: https://youtu.be/e1kJbQEBX7o

because surveying multiple functionalities and features at the same time (as possible when using a conjoint-analytic preference measurement approach) would enormously increase participants' cognitive load, particularly when participants have to imagine how combinations of IDAs work within this novel technology. For similar reasons, we decided to only survey IDAs which are familiar to the participants, or features that are easy to imagine, i.e., we did not address the full potential of new features that VR could offer. This was also motivated by another limitation of our study: The mock-ups were shown on regular desktop screens and not in a virtual environment because of practical limitations. Showing participants the mock-ups in the virtual reality would have required to invite them to our laboratory one-by-one or at least in small groups because we do not have many head-mounted-displays available. This would have resulted in a small sample size and would not allow to properly quantify the results and compute inferential statistics on the data. Therefore, a next step is to pick the most popular IDAs and features and let them rate in the virtual environment in a qualitative study. This would also allow for discussing design principles in more detail with the future users.

In addition, not only extending the survey to further product categories, but also considering different shopping goals or search phases can be an interesting future research stream. For example, it can be investigated whether customers prefer other IDAs when acting in a different search situation (e.g., goal-directed versus exploratory search (Venkatesh et al., 2017)) or in a different search phase (i.e., screening or in-depth comparison phase (Groissberger and Riedl, 2017)) or even if customers are looking for themselves or on behalf of another person (agent-task). Our paper has strong managerial/practical implications, as we identify IDAs and VR specific features as well as the respective design of the IDA or feature that designers should consider to increase the customer's adoption of VR environments.

Chapter 6

Developing Context-Aware User Assistance Systems Based on Eye Tracking Data Analysis [1]

Christian Peukert, Jessica Lechner, Jella Pfeiffer, Christof Weinhardt

> "[T]he real power of VR is not necessarily to produce a faithful reproduction of 'reality' but rather that it offers the possibility to step outside of the normal bounds of reality and realize goals in a totally new and unexpected way."
>
> Slater and Sanchez-Vives (2016, pp. 1–2)

6.1 Introduction

Eye tracking (ET) technology has recently enjoyed an upswing in attention. Not only the acquisitions of technology giants in the field of ET technology (e.g., Apple bought SMI or Oculus acquired The Eye Tribe) have contributed to this, but also the introduction of new products that are already equipped with ET technology (HTC Vive Pro Eye, Microsoft's HoloLens 2). The symbiosis of ET and virtual reality (VR) technology is obvious: Real-time gaze detection allows to only render the currently looked at regions in highest

---

[1] This chapter comprises an article that was published in the following outlet under the following title: Peukert C., Lechner J., Pfeiffer J., Weinhardt C. (2020). "Intelligent Invocation: Towards Designing Context-Aware User Assistance Systems Based on Real-Time Eye Tracking Data Analysis". In: Davis F., Riedl R., vom Brocke J., Léger PM., Randolph A., Fischer T. (eds) Information Systems and Neuroscience. Lecture Notes in Information Systems and Organisation, vol 32. Springer, Cham. Published [2020] [Springer Nature Switzerland AG] © All rights reserved. Reprinted with permission. `https://doi.org/10.1007/978-3-030-28144-1_8`. *Note*: Tables and figures were renamed, reformatted, and newly referenced to fit the structure of the thesis. Chapter and section numbering and respective cross-references were modified. Formatting and reference style was adapted and references were updated. Opening quotation was not part of the article.

quality (foveated rendering) (Patney et al., 2016), which in turn saves computational resources. Furthermore, advanced interactions can be offered by system designers (gaze selection), and avatars can be modeled more naturally by transferring the real eye movements to the virtual representation. We thus more and more experience a shift from ET, that solely serves as a post hoc diagnosis tool, to real-time ET data processing and usage due to the possibility to unobtrusively observe gaze behavior in VR (Meißner et al., 2019).

In literature more than 20 years ago, researchers have tried to detect different phases in customers' decision making based on ET data (Russo and Leclerc, 1994) measured in real-life contexts and in recent years this idea was further pursued (Gidlöf et al., 2013; Glaholt and Reingold, 2011; Pfeiffer et al., 2014). The knowledge in which decision phase a user is currently in could be of great interest for system designers who could use this information for the intelligent invocation of assistance systems (Friemel et al., 2018). In particular, a high potential is stated to so-called advanced user assistance systems (UAS) which promise to be context-aware and adaptive (Maedche et al., 2016). Depending on the decision phase (context-awareness), an assistance system might proactively offer suitable decision aids to the user (adaptive), e.g., a comparison matrix as soon as someone starts comparing products with each other (evaluation phase), or a filter function, that helps to eliminate products, which reduces the overall complexity right from the start (orientation phase). Such a system would, therefore, take over the selection of the aid, i.e., *how*, and the time of use, i.e., *when* they shall be supported, adaptively for a user.

Within this article, we, therefore, aim to detect phases in consumers' decision-making, which can potentially be used by advanced UAS to support consumers during their shopping in regular stores. In this context, we assume that image processing and object recognition can be performed in real time for practical applications. This article is closely related to the field of NeuroIS, since the information systems (IS) research problem, i.e., the identification of the right moment in time to assist consumers in their decision-making process (intelligent invocation), is solved using the neuro-physiological tool of ET (Vom Brocke and Liang, 2014).

6.2 Context-Aware Assistance Systems Meet Eye Tracking Phase Detection

In order to build a UAS with intelligent invocation based on ET, it must first be ensured that a phase detection can be performed in real time. Therefore, we start to examine existing approaches for their suitability for real-time phase detection.

Today, UAS are almost ubiquitous in e-commerce settings trying to increase a user's task performance by addressing the known problems of an enormous product range and information overload (Wang and Benbasat, 2005; Xiao and Benbasat, 2007). A UAS can have many facets: e.g., recommendation agents

(Xiao and Benbasat, 2007), interactive decision aids (Groissberger and Riedl, 2017), or chatbots. According to Maedche et al. (2016), UAS can be further specified along the dimensions *intelligence* and *interactivity*, defining a system that at least employs features of one dimension as an advanced UAS rather than a basic one. Advanced UAS primarily differentiate themselves by the fact that they are context-aware and adaptive. Especially context-awareness can be related to the intelligent time of automatic invocation. Whereas in the area of notifications much research has already been done focusing on the best time of invocation (e.g., Bailey and Konstan, 2006), empirical studies on intelligent invocation in the context of UAS are relatively scarce (Friemel et al., 2018). However, user assistance is by no means limited to an e-commerce context and assistance systems for regular stores are also in the focus of studies (e.g., mobile auto-ID technology (Venkatesh et al., 2017)).

Most commonly, studies that support a phase theory build upon at least two distinct phases, namely an *orientation* and an *evaluation* phase (Glaholt and Reingold, 2011). The orientation phase is thereby characterized by acquiring an initial overview of available products, whereas the evaluation phase primarily consists of paired comparisons between products. Besides, several studies argue that a subsequent *verification* phase can take place, in which the product choice is verified again (Gidlöf et al., 2013; Russo and Leclerc, 1994). In related literature, different approaches are proposed on how a phase detection based on ET data might be operationalized (Gidlöf et al., 2013; Russo and Leclerc, 1994; Reutskaja et al., 2011). Within this work-in-progress article, we will examine the approaches by Russo and Leclerc (1994) (R&L) and Gidlöf et al. (2013) (G) more closely, who both build upon three phases (orientation, evaluation, verification).

According to Russo and Leclerc (1994), an initial orientation phase consists of consecutive dwells on products up to the first re-dwell (the latter already counts to the second phase). As an indicator for the beginning of the third phase, a verbal announcement made by the participant is used from which the last re-dwell (going backward in time) is determined, which, in turn, defines the end of the second phase (Russo and Leclerc, 1994). In contrast, Gidlöf et al. (2013) solely rely on *dwells on the chosen product* to determine the different phases: The orientation phase includes all dwells up to the *first* dwell on the chosen product, which, however, already counts to the second phase (Gidlöf et al., 2013). The second phase, in turn, ends with the *last* dwell on the selected product (counting to the second phase), meaning that the last phase only consists of dwells not directed to the chosen product.

Even though the strict phase distinction is partly criticized, we consider it a good starting point to investigate points in time for an intelligent invocation. However, since both prior described approaches either require knowledge about the outcome of the decision process (product choice) or can only be determined through post-hoc analysis (last re-dwell before an announcement), we conclude that they are not applicable for real-time phase detection. We, therefore, propose an approach to detect the previously mentioned phases in real time and in the following reference to it as *On-the-fly-detection* (OFD).

Similar to the approach by Russo and Leclerc (1994), we argue that a re-dwell can be used as an indicator for the start of the evaluation phase since the evaluation phase is characterized by paired product comparisons between alternatives (Russo and Leclerc, 1994; Orquin and Loose, 2013). However, to address the criticism expressed by Gidlöf et al. (2013) that a re-dwell on any product can also occur by chance, we define the delineation rule more strictly and demand an X-Y-X sequence of transitions, i.e., a direct pair-wise comparison, as begin of the evaluation phase (re-dwell belongs to the second phase). For the distinction between the evaluation and verification phase, we preliminarily suggest using the time at which any product is first placed in the shopping cart. This point in time is meaningful because then a person has made an initial decision (evaluation phase is certainly finished) but still has the chance (if they want) to verify their choice. Of course, it may be possible that verification starts slightly in advance, but we have also decided to use this event because of the possible real-time detection (assuming that image processing and object recognition can be performed in real time in the future).

In order to test the three approaches with our existing data set, we needed to adapt the approaches slightly. In our experiment, participants did not announce their choice verbally, which is why the (R&L) approach cannot be tested one-to-one. Following Gidlöf et al. (2013) – who encountered the same problem within their study – we will also use the last dwell on the chosen product as a decision rule for the (R&L) approach. Unlike Gidlöf et al. (2013), we consider the last dwell on the chosen product as part of the verification phase, as a result of the experimental setup, because when placing a product in the shopping cart, a glance at the product happens nearly automatically. Furthermore, a dwell including the way to and the process of putting the product into the shopping cart is conceptually no longer an evaluation. Within the new OFD approach, a special case can occur that the event *product enters the shopping cart* takes place precisely during a dwell. In order to do justice to this we distinguish in OFD(A), the dwell will be counted to phase two or OFD(B), the dwell belongs to phase three. This subdivision is only essential for the following analysis, but not for an intelligent invocation, as the invocation would exclusively depend on the event. Fig. 6.1 illustrates the operationalization of the approaches:

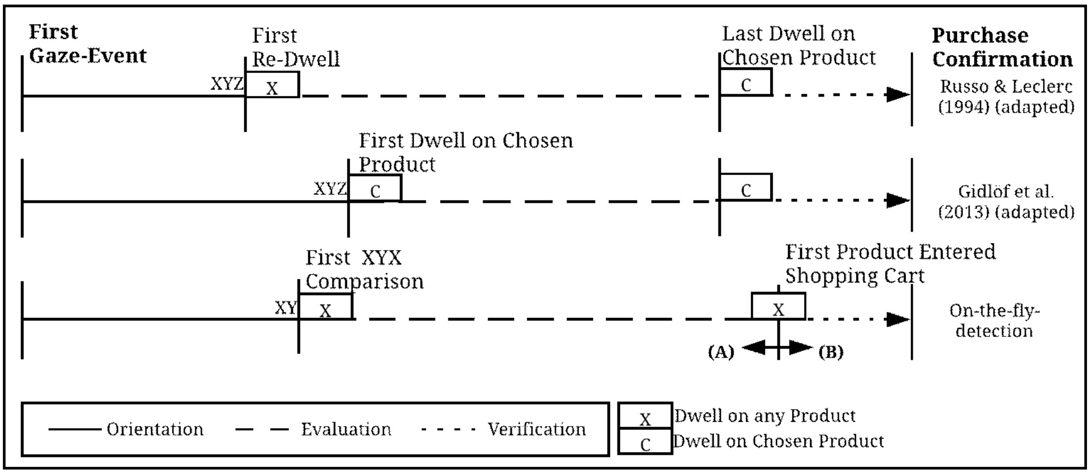


FIGURE 6.1: Comparison of phase definitions

6.3 Experimental Design & Procedure

The dataset (n=129) originates from an experiment in which students performed several consecutive choice tasks in front of a virtual supermarket shelf (Peukert et al., 2019b). The experimental design followed a choice-based conjoint analysis (CBC) (Sawtooth Software Inc., 2013), and the specific task was to always pick the product (muesli package) out of a set of 24 products which they would most likely buy in reality. The interaction possibilities were close to reality: participants could take products from the shelf, view them from all sides and in the end they had to put the chosen product in a virtual shopping cart. Similar to many e-commerce websites, a screen then appeared on which they had to confirm the purchase finally. In each task, the displayed products, as well as the prices, changed according to the CBC design (in total we had six price levels and 40 different products). For a description in more detail, we refer to Peukert et al. (2019b).

To record participants' eye movements, we used an HTC Vive head-mounted display with an integrated SMI eye tracker (250 Hz). We applied a velocity-based algorithm (consecutive eye movements with a velocity below (above) 50°/s were determined to be a fixation (saccade)) for fixation determination. We only considered data of the participant's dominant eye and only included fixations with a minimum fixation duration of 100 ms (Holmqvist et al., 2011). Fixations were automatically annotated to predefined areas of interest (AOIs). For this article, the product package as a whole, as well as the related price tag, were regarded as one interrelated AOI. As a next step, we aggregated consecutive fixations on the same AOI to dwells.

6.4 Preliminary Results

For the preliminary data analysis, we only consider the average values across all tasks irrespective of the order and only refer to the most interesting results.

In order to be able to evaluate the applicability of the approaches for real-time detection of the decision phases, it is initially important to determine whether it is generally possible to reliably detect the different phases based on the approaches. Table 6.1 provides an overview of the presence of the phases for the four tested approaches:

TABLE 6.1: Overview presence of phases (based on a total of 903 choices)

	Orientation	Evaluation	Verification
R&L: Russo and Leclerc (1994)	900	898	899
G: Gidlöf et al. (2013)	869	890	902
OFD(A): On-the-fly-detection (A)	878	878	149
OFD(B): On-the-fly-detection (B)	878	874	753

Overall, the table shows that in almost all cases the approaches detect an orientation and evaluation phase. In the approach by Gidlöf et al. (2013) ((G) approach) it could have happened that by chance the first dwell was already directed to the chosen product (1/24 chance) which means that the first phase is skipped. The OFD approach detected the XYX transition in 97 percent of total choices, which underlines the general applicability. For further analysis, we decided to exclude all decisions for which the XYX transition could not be detected, i.e., 25 decisions (similarly, we excluded three decisions for the (R&L) approach in which no re-dwell has taken place). Concerning the detection of the verification phase, the result of OFD(A) is especially noticeable, since only in 16.5 percent of the cases a verification phase is detected. Accordingly, following the same argumentation as for shifting the last dwell to the verification phase in the (R&L) and (G) approach, OFD(B) shall better be applied in the future.

Further, we were interested in key indicators for the phases (Table 6.2) to investigate to what extent they differ between the phases as well as between the approaches. With regard to phase durations, in all approaches, the evaluation stage dominates the decision-making process (similar to Russo and Leclerc (1994)). The orientation phase of (R&L) is the shortest followed by OFD and (G), whereby OFD's mean orientation phase duration (7.5s) could be sufficiently long for designing a meaningful intelligent invocation at the begin of the evaluation phase. Consistent with the literature (Gidlöf et al., 2013; Russo and Leclerc, 1994; Gloeckner and Herbold, 2011), we find shorter dwells within the orientation phase compared to the evaluation phase, which supports the theory of an initial scanning of products. For the verification phase, we find extremely long dwell durations, which can be most probably traced back to the experimental design (participants had to grab the product, turn away from the shelf and finally place it in the cart). Regarding the number of different fixated products per phase, it can be seen that the number is the highest in the evaluation phase, followed by the orientation phase, whereby the proportion of different products fixated in relation to the phase duration is much higher during orientation. Many participants only fixated one product (the chosen product) during the verification phase (note that the OFD(A) value is only based on 149 decisions, in which primarily participants are included who have fixated several other products).

TABLE 6.2: Measures differentiated by phase; values represent the mean (standard deviation)

	Orientation Phase			Evaluation Phase				Verification Phase			
	R&L	G	OFD(A)/(B)	R&L	G	OFD(A)	OFD(B)	R&L	G	OFD(A)	OFD(B)
Avg. phase duration [s]	4.11 (2.83)	10.00 (13.61)	7.50 (7.16)	46.82 (34.27)	40.91 (31.53)	46.79 (33.82)		5.66 (4.03)	5.68 (4.02)	3.35 (4.33)	
Avg. dwell duration [s]	0.42 (0.13)	0.51 (0.16)	0.47 (0.13)	0.69 (0.20)	0.70 (0.20)	0.75 (0.20)	0.71 (0.20)	2.10 (1.33)	2.11 (1.33)	0.57 (0.42)	2.14 (1.44)
Number of different products fixated	6.44 (3.34)	9.48 (6.15)	8.77 (5.40)	19.71 (4.73)	17.74 (5.91)	18.76 (5.56)	18.82 (5.47)	1.36 (1.62)	1.36 (1.62)	2.87 (4.26)	1.41 (2.10)

6.5 Limitations and Future Research

Within this work-in-progress paper, we preliminarily analyzed data retrieved from a preference measurement study in order to evaluate whether phases in decision making can be detected in VR shopping environments in real time. Since the primary objective of the underlying study was different, the experimental setting was not precisely tailored to the purpose of detecting phases. As mentioned in the prior section, the fact that consumers had to turn away from the shelf to confirm the purchase, could have influenced consumer behavior and thus the results. In future research, hence, a study shall be designed that focuses exclusively on phase detection. In addition to observing gaze behavior throughout a decision task, a further post-hoc analysis shall be conducted to test if the proposed phases are a reliable proxy for the consumers' actual executed decision process. Therefore, for instance, participants could retrospectively state in which decision phase they were currently in (e.g., retrospective think aloud based on a video recording (Guan et al., 2006)), or the decision making process could be coded by independent judges with respect to the decision phases (e.g., thematic coding).

Further, the analysis reported within this paper is preliminary and additional analyses need to be conducted to fully understand the phenomenon. This includes, for example, that at both – task- and respondent-level – it needs to be examined whether patterns can be identified, e.g., whether it is possible to determine clusters of participants that are similar to each other. Besides, so far, we have not assigned any relevance to the task sequence and have simply averaged across all tasks. Especially related to the verification phase it can be interesting for future research to consider people who have fixated more than one product during this phase, which might indicate that they did verify their selection to a greater extent. Furthermore, it should not be ignored that the standard deviation of most of the measures is quite high (e.g., the standard deviation of the average phase duration of the OFD approach is 7.16s) and therefore the meaningfulness of these indicators for the real-time phase detection needs to be investigated. Although the large variance between the time of invocation would underline the adaptivity of the UAS, it remains to be tested whether the point in time is considered useful by all users.

Given the assumption that such context-aware UAS are available in the near future, the key question then arises as to whether consumers accept these systems. From a technological perspective, an implementation in a VR shopping environment is already possible today, but users nonetheless have to be willing to share their gaze and interaction data to feed the UAS. Therefore, questions regarding privacy concerns need to be addressed in future research. In the same vein, it could be interesting to investigate to what extent explanations influence the acceptance of context-aware UAS (Gregor and Benbasat, 1999).

Finally, within this article, we followed the idea to use decision phases (Gidlöf et al., 2013; Russo and Leclerc, 1994) to trigger an intelligent invocation. However, further approaches shall be pursued in the future. For instance, other ET measures such as the saccade length or fixation duration could serve as additional indicators.

6.6 Conclusion

Within this article, we introduced the idea to design context-aware UAS based on the real-time analysis of ET data especially focusing on intelligent invocation. Based on the theory of decision phases in consumer decision-making, we propose an approach for on-the-fly-detection of decision phases which can potentially be used for intelligent invocations. In the future, such advanced UAS could help to reduce consumers' experienced cognitive load when doing their shopping by ensuring that the UAS steps in at the right time and also provides adequate support for the respective context. Such context-aware UAS could represent an entirely new shopping experience and thus be of great interest to practitioners. It remains to be seen whether such systems will gain acceptance in the future; nevertheless, it is important to start doing research in this area at an early stage.

Part IV

Finale

Chapter 7

Conclusion, Limitations & Future Research

> "People may one day be as familiar with VR systems as they are [with] the modern desktop workstation; however, we are not there yet."
>
> Berg and Vance (2017, p. 10)

7.1 Answers to the Research Questions

The dissertation has set out to investigate the emerging field of VR shopping environments based on four research questions. While RQ1 and RQ2 addressed perspectives of the acceptance of VR shopping environments, RQ3 and RQ4 shed light on design aspects in the context of user assistance features. The related research questions were motivated in Chapter 1 and will be answered on the basis of the findings of the previously presented studies in the following.

RQ1: *How does the degree of immersion in virtual shopping environments influence system adoption?*

The first RQ was addressed in the study presented in Chapter 3. To answer the question, a between-subjects experiment was conducted that manipulated the degree of immersion (high versus low immersion) by applying two treatments: Whereas participants of the high immersion treatment experienced the VR shopping environment by using a HMD and hand-held controllers, participants of the low immersion treatment faced the same environment by interacting with 3D product models in a desktop environment. The results show that immersion has a positive effect on a hedonic path through perceived telepresence, but a negative effect on a utilitarian path through perceived product diagnosticity, collectively having no influence on the users' intention to reuse the shopping environment in the future. The negative effect of immersion on perceived product diagnosticity was contrary to the hypothesized relationship, but can be explained via low readability of small prints on the product packages in the VR environment. Since this constitutes a limitation of today's VR technology, it is expected that as soon as the impediment is resolved by next-generation high-resolution HMDs, the full potential of VR can be unlocked.

RQ2: *Does the acceptance evaluation of VR shopping environments depend on whether users have imagined (based on a video) versus experienced being in the VR environment?*

Chapter 4 focused on the second RQ and presented results of two experimental studies of a rather exploratory nature. Each study consisted of a comparison between a real VR experience in the laboratory and a presentation of the VR experience based on a non-interactive online video (between-subjects). Afterward, the acceptance of the shopping environment was surveyed. The two experiments differed in that one used a basic and the other a more advanced shopping environment as the object of investigation. Overall, the results of both experiments suggest that a real VR experience is essential to evaluate the acceptance of VR shopping environments. In particular, participants systematically underestimated the variables perceived enjoyment and perceived telepresence when they only imagined being in the VR environment based on a video. Interestingly, the values for the intention to use the shopping environment did not show significant differences. Further, in accordance with literature (Van der Heijden, 2004; Koufaris, 2002), the results reveal that hedonic (i.e., perceived enjoyment) and utilitarian (i.e., perceived usefulness) variables positively affect the users' intention to use the shopping environment in the future. Finally, to build the bridge back to the initial motivation, from a practical point of view it can be concluded that a video presentation cannot replace an appointment with participants in the laboratory for a real VR experience at this stage.

RQ3: *Which of the established e-commerce IDAs and VR specific features do customers desire to use when shopping in VR shopping environments?*

The third RQ was approached in Chapter 5 using an online preference measurement study. The preference measurement comprised the assessment of the most popular IDAs known from e-commerce as well as VR specific features for two different product categories, namely mueslis and outdoor tents (between-subjects). For both product categories, the results indicate that comparison, filter, and sorting mechanisms are the most favored IDAs in the context of VR shopping environments. These findings are in line with e-commerce literature (e.g., Pfeiffer, 2010; Groissberger and Riedl, 2017) stating that these three IDAs are also the most applied decision aids on e-commerce websites. Therefore, the results suggest that participants' familiarity with the IDAs may have an influence on their evaluation, which, however, might change as soon as the wider consumer population gets accustomed to using VR applications. Concerning the VR specific features, the possibility to display additional product information was considered especially valuable (for both product categories ranked fourth out of nine places directly after the IDAs mentioned above). Overall, the assignment of utility values across the various assistance features indicated that users wanted to be supported employing similar features regardless of the product category. Yet, only for the two VR specific features addressing the product presentation (dimensionality and scale of presentation) significant differences were found between the attribute utilities for the product categories (higher for outdoor tents). In particular, a real-scale product presentation seems to be appropriate for product categories for which size represents an important decision criterion.

RQ4: *Can existing approaches to detect phases in consumer decision making based on eye tracking data be adapted to trigger an intelligent invocation of a UAS in VR?*

Chapter 6 presents a NeuroIS study that evaluates the applicability of existing decision phase detection approaches based on eye tracking data (in particular the approaches by Russo and Leclerc (1994) and Gidlöf et al. (2013)) against the backdrop of triggering an intelligent invocation of a UAS in VR in real time (RQ4). Both approaches are tested by analyzing eye tracking data from an experiment conducted in a high immersion VR shopping environment. Since the idea is to provide context-aware user assistance, one specific prerequisite is that the phase detection can be performed in real time. Yet, both approaches include knowledge about the purchased product in determining the decision phases, hence making them unsuitable for a real-time phase detection (simply for the reason that you do not know the purchased product in advance). Consequently, a new approach called *on-the-fly-detection* (OFD) is proposed, which is conceptualized in a way that it can be performed in real time. Similar to the approach of Russo and Leclerc (1994), the developed approach also relies on refixations on products to distinguish between the first two phases (literally, the orientation and evaluation phase). However, since the use of a single refixation at any product may lead to false triggers (as described by Gidlöf et al. (2013)), the proposed approach is stricter, requiring an X-Y-X fixation pattern for the phase transition. Nevertheless, it is reserved for future research to refine the approach (e.g., to determine threshold values regarding the fixation duration for the individual gaze events) and to test the application of such context-aware UAS with real users.

In conclusion, with the research questions just answered, this dissertation has followed the initial call of Walsh and Pawlowski (2002) according to which VR technology is in need of research from an IS perspective. Although this dissertation only provides an initial starting point, it may encourage other researchers to follow up on it.

7.2 Limitations & Future Research

Notwithstanding the dissertation's contributions, it has several limitations that need to be taken into account.[1] Following a discussion of the work's limitations, an outlook on future fields of research is given.

First, with reference to the opening quotation by Berg and Vance (2017), VR technology is still in its infancy waiting for the big breakthrough in the consumer industry market. This is accompanied by the fact that the participants in the prior described studies were not yet as familiar with the technology as, for instance, with desktop computers with which many of them grew up. This may – as the quotation indicates – change over time. Nevertheless, special precaution had to be taken in the experiments: In all VR experiments it was therefore ensured that 1) the participants learned and practiced the interactions with the environment step by step, 2) the interactions corresponded as closely as possible to interactions from reality, and 3) the participants were given as much time as they wanted to independently familiarize themselves with the VR environment before starting the experiment. Moreover, the nature of the tasks within the experiments was not playful. In total numbers, 92 participants out of all participants who took part in a VR session reported that is was their first VR experience, whereas for 66 participants it was their second or third experience and for 11 participants it was their fourth to sixth experience (two participants had more than six experiences). These numbers are in line with other recent VR studies also reporting that the majority of participants had no prior VR experience (Harms, 2019; Hartl and Berger, 2017). However, since it is precisely the research interest to investigate how people evaluate this novel technology, the limitation had to be tolerated and it must be noted that so-called *novelty effects* cannot be completely ruled out (Brade et al., 2017). In future research, therefore, long-term effects should also be investigated in order to validate whether the effects persist over longer time periods. As a starting point, IS continuance models could be pursued and adapted to the context, e.g., following the approach by Bhattacherjee and Premkumar (2004) and Bhattacherjee (2001).

Not only will people become more and more accustomed to VR experiences – assuming that the technology enjoys increasing popularity – but also VR technology will continue to evolve. Thus, problems that significantly influenced the user experience today might already be solved tomorrow. Yet, technological constraints represent limitations of recent studies. This dissertation also had to contend with technological constraints (readability issues as described in Chapter 3) that may soon probably no longer be worth mentioning. Nevertheless, it was important to show that such technological constraints are crucial influencing factors for evaluating the acceptance behavior. Although the readability issue was particularly relevant for the product category under investigation, similar restrictions may also apply for other product categories

---

[1] *Note*: The specific limitations of the individual studies have already been discussed within the respective chapters. This section is concerned with overarching limitations of the dissertation.

in the future. Whenever virtual representations do not manage to convey the feeling of a real representation to the senses, discrepancies may occur (e.g., as described by the uncanny valley (Mori et al., 2012; Dionisio et al., 2013; Seymour et al., 2018)). A well-known problem is, for instance, the lack of a presentation's haptic richness (Steffen et al., 2019; Slater et al., 2020). Even though haptic displays are already being experimented with to address this problem (Mihelj et al., 2014), time will pass until they are consumer-ready (Slater et al., 2020). However, visual displays may be enriched through next-generation high-resolution HMDs or new computing methodologies such as foveated rendering (Patney et al., 2016); as a result, eliminating the current readability issues. Accordingly, the latter mentioned limitations provide avenues for future research: A continuous evaluation of the acceptance of VR systems is necessary to understand how system changes affect user behavior from a theoretical perspective, but also to guide practitioners in developing new applications bearing the current state of technology in mind.

Further, the thesis is limited to the fact that all empirical investigations are based on participants recruited from a student sample of the Karlsruhe Institute of Technology (KIT). Even though "students are a promising customer group of VR glasses, because many of them are interested in new technologies and virtual media" (Hartl and Berger, 2017, p. 2423), the use of VR systems is not restricted to this demographic group of people. Indeed, the vast majority of studies examined within the literature review (see Chapter 2) employed student samples (17 out of 25 studies that indicated sample characteristics used a student sample at least for a subgroup of their studies). To ensure the generalizability of the results, studies with citizens covering a wider range of the overall population must therefore be carried out in the future. However, it might also be promising to specialize in specific population groups (instead of trying to reach everyone) that may take special advantage of VR technology. For instance, VR technology could help people with limited mobility to virtually experience things that would otherwise be difficult or impossible for them to do (e.g., Sussmann and Vanhegan (2000) propose the idea of virtual holidays).

After having concentrated on the bright side of VR, including how VR may help people, and how the quality of VR systems might continue to improve, it is crucial to also discuss the potential dark side of the upcoming development and to stress the importance of doing research in this area (Guzman et al., 2019; Slater et al., 2020). On the one hand, the increased system quality and personalization may come at a price. In order to further increase the degree of immersion of VR systems, the user must expect that additional personal data will be processed in real time (Slater et al., 2020). In this context, Bandara et al. (2019, p. 12) state that "[u]nlike the traditional e-commerce environment, the diversity and heterogeneity of data that is being shared is formidable," further emphasizing potential implications for consumers' privacy. For instance, although foveated rendering may improve the system performance (Patney et al., 2016), it also requires real-time processing of eye tracking data. In a similar vein, stand-alone HMDs can be used anywhere without having to be tethered to a computer, but, at the same time, several cameras and sensors usually capture the environment in detail to ensure tracking and avoid collisions. The list of such tradeoffs could be continued. However, it is important to draw attention towards expanding VR research to also consider such privacy-related aspects (Bandara et al., 2019; Guzman et al., 2019). A promising stream of research is to investigate how much personal data a user is willing to be processed in order to receive a more immersive experience (one might call it the *immersion-privacy tradeoff conflict*). On the other hand, as soon as computer-mediated experiences can be generated which are indistinguishable from reality (e.g., what Flavián et al. (2019) refer to as *pure mixed reality* or Slater et al. (2020) call *superrealism*), ethical questions will arise. For instance, Slater et al. (2020) raise the question as to what will happen if people prefer the virtual world over the real world. The effects of perceived realism that were desired, for instance, to treat phobias (Strickland et al., 1997; Balan et al., 2019), could now also have negative consequences as it may support the development of IT-triggered disorders (e.g., internet addiction) (Kloker, 2020). It will be important to start addressing these negative aspects at an early stage in order to intervene before it is too late. Preferably, independent research institutions that can shed light on such aspects from a neutral point of view are encouraged to do so.

Now, after having sketched out aspects of the dark side of the VR development, the focus shall be shifted back to the bright side. Even though this thesis focused specifically on the utilization of VR in the retail sector, the development of other immersive retail systems should also be investigated more closely in the future. Besides VR applications, companies have already launched AR applications (de Regt and Barnes, 2019; Grewal et al., 2017; Wedel et al., 2020). The applications thereby focus on presenting products in their real-life application context: For instance, this could include whether a piece of furniture fits into a niche (IKEA Place app), how a new toaster looks like on the kitchen counter (Amazon AR), or whether a pair of horn-rimmed glasses suits someone (misterspex.de). All of this can be comfortably tried out from home (see Wedel et al. (2020) for a list of further AR applications). The advantage of AR technology lies in its easy accessibility, because newer smartphones already integrate all hardware components necessary to run AR applications. In the future, it will be an interesting branch of research to investigate how the retail ecosystem will develop with immersive retail systems pushing into the market. Questions will arise as to how, when, and which technology should be used (Steffen et al., 2019), but also further questions regarding the design, i.e., whether immersive retail systems shall aim to replicate reality or whether they shall represent something completely new, can be addressed.

Finally, VR cannot only be seen from the perspective of the shopping environment of the future, but also as a purely experimental environment with the purpose of developing and testing smart assistance systems for shopping in regular stores (Meißner et al., 2019). On the one hand, features can be tested in VR that are not yet – but probably at some point in time – easy to implement in reality (e.g., real-time object recognition is realizable in VR with manageable effort, which might be a prerequisite for many AR-based assistance systems). On the other hand, "the high degree of telepresence should elicit behavior similar to that in physical reality" (Pfeiffer et al., 2020, p. 15), emphasizing that the data obtained in VR may be transferable to real store environments. As a result, using VR as experimental environment permits to achieve high ecological validity while maintaining a high level of experimental control (Meißner et al., 2019; Pfeiffer et al., 2020). This constitutes a promising combination for future research endeavors.

7.3 The End

The dissertation pursued the objective to investigate next-generation shopping applications particularly in the form of VR shopping environments. Following a literature review outlining the current state of empirical VR research in the IS field, the dissertation examined VR shopping environments from different perspectives. By means of four studies, questions regarding the adoption and the design of VR shopping environments were investigated. Overall, VR shopping is not expected to replace e-commerce platforms or traditional brick-and-mortar stores in the short run. Instead, for the time being, VR shopping will be complementary to rather than a substitute for existing retail channels. Nevertheless, especially for retailers pursuing an omni-channel strategy, it is important to immediately begin to examine how v-commerce can be integrated in their ecosystem (de Regt and Barnes, 2019). Similarly, Wedel et al. (2020, p. 15) state that VR "is likely to become an integral component of the marketing landscape" and attribute their optimistic assessment with respect to VR's potential to large companies' continuous investments in the mass-market suitability as well as ongoing innovations by start-ups. At this point in time, acceptance research provides sound indications of the future developments of VR applications, which is why it is crucial to continue the research presented within this work in the future.

I want to close this dissertation with the words of two VR pioneers and share their vision that technology – whatsoever it is – shall be developed always having in mind to change the world to a better place: Therefore, I hope that this work "will provoke readers to think as paradigm changers, and advance VR to realize different worlds that might have a positive impact on the lives of millions of people world-wide, and maybe even help a little in saving the planet" (Slater and Sanchez-Vives, 2016, p. 2). This might be a reduction of returns from online shopping due to the better a priori imagination of products (Hong and Pavlou, 2014; Yang and Xiong, 2019), or more natural and vivid virtual get-togethers of people – especially in times when physical closeness should be kept to a minimum.

Part V

Appendix

Appendix A

Supplementary Material Chapter 1

A.1 VR Applications – References

TABLE A.1: List of mentioned VR applications with reference

Source	Application (Company)	Link to application/ describing article	Date	Last accessed
Steam (2016)	**IKEA VR Experience (IKEA)**	`https://store.steampowered.com/app/447270/IKEA_VR_Experience/?l=german`	n.a.	07/17/20, 03:50pm
IKEA (2017)	**IKEA VR Pancake Kitchen (IKEA)**	`https://newsroom.inter.ikea.com/news/all/ikea-invites-people-to-make-virtual-pancakes---releases-a-virtual-reality-app-on-steam/s/a5702517-ee4d-4a2f-a9a8-7f311b43cd84`	05/30/17	07/17/20, 03:51pm
Demodern (n.d.)	**IKEA Virtual Reality Showroom (IKEA)**	`https://demodern.com/projects/ikea-vr-showroom`	n.a.	07/17/20, 03:52pm
Demodern (n.d.)	**IKEA Immerse App (IKEA)**	`https://demodern.com/projects/ikea-vr-immerse`	n.a.	07/17/20, 03:53pm
Macy's (n.d.)	**Macy's 3D room designer (Macy's)**	`https://www.macys.com/ce/virtual-room-designer/index`	n.a.	07/17/20, 03:54pm
MediaMarkt-Saturn (2017)	**Virtual SATURN (MediaMarkt-Saturn)**	`https://www.mediamarktsaturn.com/en/press/press-releases/%E2%80%9Cvirtual-saturn%E2%80%9D-saturn-launches-europe%E2%80%99s-first-virtual-reality-shopping-world`	11/20/17	07/17/20, 03:59pm
Wang, H.H. (2016)	**Buy+ (Alibaba)**	`https://www.forbes.com/sites/helenwang/2016/11/06/how-alibaba-will-use-the-worlds-biggest-shopping-day-to-transform-retail/#36a089756d4e`	11/06/16	07/17/20, 04:00pm
Mastercard (2017)	**Atelier Swarovski Virtual Showroom (Mastercard, Swarovski)**	`https://newsroom.mastercard.com/press-releases/mastercard-and-swarovski-launch-virtual-reality-shopping-experience/`	11/25/17	07/17/20, 04:01pm
eBay (2016)	**Virtual department store (eBay, Myer)**	`https://www.ebayinc.com/stories/press-room/au/worlds-first-virtual-reality-department-store/`	05/19/16	07/17/20, 04:02pm
eMarketer (2016)	**The North Face 360-degree videos (North Face)**	`https://www.emarketer.com/Article/North-Face-Uses-360-Degree-Video-Connect-Brand-with-Joy-Outdoors/1013482`	01/20/16	07/17/20, 04:04pm
Beer, J. (2016)	**A Walk in Their Shoes (Toms Shoes, AT&T)**	`https://www.fastcompany.com/3059526/why-toms-shoes-and-att-are-taking-a-virtual-reality-trip-to-colombia`	05/06/16	07/17/20, 04:12pm
Arthur, R. (2015)	**Virtual Reality Catwalk Experience (Tommy Hilfiger)**	`https://www.forbes.com/sites/rachelarthur/2015/10/25/hands-on-with-tommy-hilfigers-in-store-virtual-reality-catwalk-experience/#78f48ab53ee4`	10/25/15	07/17/20, 04:13pm

Source	Application (Company)	Link to application/ describing article	Date	Last accessed
Volvo (n.d.)	**Volvo Reality (Volvo)**	`https://www.volvocars.com/us/about/our-points-of-pride/google-cardboard`	n.a.	07/17/20, 04:14pm

Appendix B

Supplementary Material Chapter 2

B.1 Literature Review

TABLE B.1: Literature review – overview of considered journals

Outlet	Rank	Retrieved	Database	Search	Hits	Relevant
Information Systems Research	A+ *	02/2020	Informs	Title/Abstract/Keywords	1	**1**
Management Information Systems Quarterly	A+ *	02/2020	AIS Library	Title/Abstract/Keywords	2	**2**
Journal of Management Information Systems	A *	02/2020	Tandfonline	Title/Abstract/Keywords	3	**3**
Journal of the AIS	A *	02/2020	AIS Library	Title/Abstract/Keywords	2	0
Journal of Information Technology	A *	02/2020	Palgrave Macmillan	Title/Abstract/Keywords	2	0
Information Systems Journal	A *	02/2020	Wiley Online Library	Title/Abstract/Keywords	0	0
European Journal of Information Systems	A *	02/2020	Palgrave Macmillan	Title/Abstract/Keywords	0	0
Journal of Strategic Information Systems	A *	02/2020	ScienceDirect	Title/Abstract/Keywords	0	0
Mathematical Programming	A	04/2020	Link.springer	Title/Abstract/Keywords	0	0
INFORMS Journal on Computing	A	04/2020	Informs	Title/Abstract/Keywords	0	0
SIAM Journal on Computing	A	04/2020	SIAM	Title/Abstract/Keywords	0	0
ICIS Proceedings	A	04/2020	AIS Library	Title/Abstract	8	**3**
Journal of the ACM	B	04/2020	ACM digital library	Title/Abstract/Keywords	0	0
Decision Support Systems	B	04/2020	ScienceDirect	Title/Abstract/Keywords	0	0
Decision Sciences	B	04/2020	Wiley Online Library	Title/Abstract/Keywords	1	0
Computers and Operations Research	B	04/2020	ScienceDirect	Title/Abstract/Keywords	1	0
IEEE Transactions on Engineering Management	B	04/2020	IEEE Xplore	Title/Abstract/Keywords	1	0
Business & Information Systems Engineering	B	04/2020	AIS Library	Title/Abstract/Keywords	0	0
ACM Transactions on Information Systems	B	04/2020	ACM digital library	Title/Abstract/Keywords	4	0
International Journal of Electronic Commerce	B	04/2020	ACM digital library	Title/Abstract/Keywords	1	**1**
ACM Transactions on Management Information Systems	B	04/2020	ACM digital library	Title/Abstract/Keywords	2	0
ACM Computing Surveys	B	04/2020	ACM digital library	Title/Abstract/Keywords	10	0
Journal of Computational Finance	B	04/2020	Web of Science / Scopus	Title/Abstract/Keywords	0	0
Artificial Intelligence	B	04/2020	ScienceDirect	Title/Abstract/Keywords	2	0
Group Decision and Negotiation	B	04/2020	Link.springer	Title/Abstract/Keywords	0	0
ACM SIGMIS Database	B	04/2020	ACM digital library	Title/Abstract/Keywords	5	0
ECIS Proceedings	B	04/2020	AIS Library	Title/Abstract	10	**7**
IEEE Transactions on Software Engineering	B	04/2020	IEEE Xplore	Title/Abstract/Keywords	0	0
Data & Knowledge Engineering	B	04/2020	ScienceDirect	Title/Abstract/Keywords	0	0

Proceedings International Conference on Conceptual Modeling (ER)	B	04/2020	Link.springer	Title/Abstract/Keywords	1	0
Communications of the ACM	B	04/2020	ACM digital library	Title/Abstract/Keywords	52	0
Information & Management	B	04/2020	ScienceDirect	Title/Abstract/Keywords	3	**2**
Information Systems	B	04/2020	Wiley Online Library	Title/Abstract/Keywords	0	0
MIS Quarterly Executive	B	04/2020	AIS Library	Title/Abstract/Keywords	0	0
Journal of Decision Systems	B	04/2020	Tandfonline	Title/Abstract/Keywords	1	0
Information and Organization	B	04/2020	ScienceDirect	Title/Abstract/Keywords	1	0
Information Systems Frontiers	B	04/2020	ACM digital library	Title/Abstract/Keywords	5	0
Electronic Markets	B	04/2020	Link.springer	Title/Abstract/Keywords	1	0
ACM Transactions on Computer-Human Interaction	B	04/2020	ACM digital library	Title/Abstract/Keywords	33	**8**
All					152	**27**

Note: * marks all studies that are part of the *IS Senior Scholars' basket of eight*. Ranking based on "VHB-Jourqual 3: Business and Information Systems."

TABLE B.2: Relevant studies – supplementary information

Authors (Year)	Task	VR Environment	Sample	Incentive
Experiments				
Balan et al. (2019)	collect coins that are hidden on different floors of a building	(replication of reality) city (streets, cars, trees) and multi-floor building	acrophobic persons	NA
Harms (2019)	virtually brew coffee or copy a paper	room with coffee machine, cup/ copier, paper	students, shoppers	NA
Huotari et al. (2004)	information search tasks and recall task of diagrams	graphical IS in terms of a university student register	students	course credit
Kampling (2018)	postal worker process, sorting and billing of letters/ parcels	virtual post office including a counter, tables, chairs, computers	students	NA
Kim et al. (2015)	route replication task, recall of landmarks	maze with landmark objects	students	course credit/ no incentive
McGill et al. (2016)	watch media content (documentaries)	movie shown on a TV in a room, in a cinema, 360°movie, partner	students (couples)	NA
Peukert et al. (2019a)	experience vs. imagine to be in the shopping environment based on a video (S1: muesli shopping, S2: consumer electronics)	S1: basic shopping environment (shelf + shopping cart), S2: advanced shopping environment (VirtualSaturn environment)	students	S1: EUR14 + product lab, lottery online ,S2: EUR10 lab, lottery online
Peukert et al. (2019b)	Consecutive product (muesli) choice-tasks	shopping shelf, shopping cart	students	EUR14 + chosen product (incentive-aligned)
Pfeiffer et al. (2020)	choice-task (agent/ non agent own preferences)	shopping shelf and cart	S1: students, S2: shop clients	S1: EUR5 + product (incentive-aligned), S2: EUR10
Qiu and Benbasat (2005)	shop for a digital camera, memory card, photo printer	web-based application	students	10 + 10%*chancetowin*200 gift card (valued at half the price of chosen camera) (incentive-aligned)

Ruddle and Lessels (2009)	search task for targets	S1: room with virtual boxes in which targets are hidden, cylinders, furniture, computers; S2: all salient surrounding objects (e.g. door, cupboards, computers) were removed, grey walls added	NA	monetary
Ruddle et al. (2011)	search task for targets in large-scale virtual marketplace	S1: small in extent large-scale (9.75 x 6.75m) virtual marketplace; S2: large in extent large-scale (65 x 45m) virtual marketplace; targets were pictures of everyday objects, marketplace divided by grids of walls	NA	monetary
Slater et al. (1995)	picking task	rooms, an object, chairs, and a chasm	students	NA
Suh and Lee (2005)	Product examination on the website	Shopping website with 3D representations of products or with static interfaces, i.e., still product pictures	students	$10 gift card
Suh et al. (2011)	Shop for apparel and choose the most appropriate one	virtual store offering apparel, avatar (some based on body scan)	students	$20 and lottery $1000 laptop
Wang and Suh (2019)	boat task/ sledding task	virtual boat trip/ sledding down a mountain with the aim of avoiding obstacles	students	NA
Westland and Au (1997)	shopping for merchandise	three-dimensional re-creation of a store, merchandise items on the shelves	students	prequesite for course credit
Yang and Xiong (2019)	shop for clothes	S1: VFR with virtual model (personalization of model possible), S2: VFR with (full body scan personalized) avatar, S3: VFR with (personalized) avatar	S1/2: online shoppers, S3: female students	S3: Yuan30
Surveys				

Hartl and Berger (2017)	play game and watch 360°content	game: flying around surreal world and shoot obstacles	students	EUR5
Khalifa and Shen (2004)	NA	web-based application	virtual community (health focus) member	NA
Krasonikolakis et al. (2014)	NA	NA	VW user	partly paid in Linden Dollar
Lee et al. (2020)	experience the different stories about the mine	visiting a mine including dry room, lift ride, walk through the mine itself	museum visitors	NA
Steffen et al. (2019)	S1: interact with 360°video, S2: inform about VR/AR products, S3: interact with 360°video	S1: 360°videos (conference room/action movie), S2: no VR experience, S3: as in S1	S1: students, S2: amazon mechanical turk, S3: professionals	S2: $2
Sussmann and Vanhegan (2000)	NA	NA	VR researchers and citizens (tourists)	NA
Interviews				
Mütterlein and Hess (2017)	NA	NA	media practitioners	NA
Schwarze et al. (2019)	card sorting of facial expressions to related emotion	virtual room (table, windows, floor, walls, plants) and virtual emotions cards	autistic children (males)	NA
Yap and Bjoern-Andersen (1998)	test the VR system	illustration of processes, physically non-existent products, plants	employees	NA
Note: S=Study				

Appendix C

Supplementary Material Chapter 3

C.1 Technical Appendix

Specification	**High immersion (VR)**	**Low immersion (Desktop)**
Graphics	NVIDIA GeForce GTX 1080	Intel(R) HD Graphics 4600
Video Memory	8 GB GDDR5X	2 GB DDR3 (processor graphics)
System memory (RAM)	16 GB	8 GB
Processor model	Intel(R) Core(TM) i7-6700K	Intel(R) Core(TM) i7-4765T
CPU	4 GHz, 4 cores (8 logical)	2 GHz, 4 cores (8 logical)

TABLE C.1: Summary of system specifications and further information about the created shopping environments.

We used the Unity Version 5.5.3f1 with the following settings in both conditions: quality setting "Fantastic," four pixels light counts, full resolution texture quality, forced anisotropic textures, four times multi sampling, hard and soft shadows with high resolution, and close fit shadow projections with four shadow cascades. Lighting of interior and wagon was baked with 40 texels per unit and a padding of two texels. Ambient occlusion was not used, due to mainly dynamic (movable) objects. The products were dynamic and used real-time shadows. The texture size per package was 4096 x 4096. Since the geometries of the packages are rather simple (boxes), the performance of the real-time shadow computations was not an issue.

C.2 Measurement Scales

Constructs	Code	Items (adapted)	Loading
	Hedonic dimension		
Perceived telepresence (TEL) (Kim and Biocca, 1997; Nah et al., 2011; Klein, 2003)	TEL.1.	I forgot about my immediate surroundings when I was doing the shopping.	.604
	TEL.2.	When the shopping task ended, I felt like I came back to the "real world" after a journey.	.868
	TEL.3.	During the shopping tasks, I forgot that I was in the middle of an experiment. (dropped)	.614*
	TEL.4..	The shopping environment displayed on the screen (in the virtual reality) seemed to be "somewhere I visited" rather than "something I saw." (dropped)	.323*
Perceived enjoyment (ENJ) (Ghani et al., 1991; Koufaris, 2002)	ENJ.1.	I found my shopping experience interesting.	.825
	ENJ.2.	I found my shopping experience enjoyable. (dropped)	.462*
	ENJ.3.	I found my shopping experience exciting.	.740
	ENJ.4.	I found my shopping experience fun.	.717
	Utilitarian dimension		
Perceived product diagnosticity (DIAG) (Jiang and Benbasat, 2007a)	DIAG.1.	The shopping environment was helpful for me to evaluate the mueslis.	.790
	DIAG.2.	The shopping environment was helpful for me to understand the characteristics of the mueslis.	.817
	DIAG.3.	The shopping environment was helpful in familiarizing me with the mueslis.	.777
Perceived usefulness (USE) (Davis and Venkatesh, 1996; Koufaris, 2002; Vrechopoulos et al., 2004)	USE.1.	The shopping environment is useful for doing the shopping.	.751
	USE.2.	The shopping environment improves my shopping performance.	.850
	USE.3.	The shopping environment enhances my effectiveness when doing the shopping.	.863
	USE.4.	The shopping environment increases my shopping productivity.	.862
	Behavioral intention		
Intention to reuse shopping environment (INT) (Wang and Benbasat, 2009; Xu et al., 2014; Venkatesh et al., 2017)	INT.1.	Assuming I have access to the shopping environment, I intend to use it next time I am doing my shopping.	.968
	INT.2.	Assuming I have access to the shopping environment, I predict I would use it next time I am doing my shopping.	.876
	INT.3.	Assuming I have access to the shopping environment, I plan to use it next time I am doing my shopping.	.946
Note: All items used a 7-point Likert scale. *initial item loading for items which were removed in course of the analysis of the measurement model.			

TABLE C.2: Scales used in the research model and standardized item loadings.

<table>
<tr><th>Constructs</th><th>Code</th><th>Items (adapted)</th><th>Scale</th></tr>
<tr><td rowspan="4">Perceived ease of use (EOU) (Davis, 1989; Koufaris, 2002; Vrechopoulos et al., 2004)</td><td>EOU.1.</td><td>The shopping environment was easy to use.</td><td rowspan="4">7-point Likert scale</td></tr>
<tr><td>EOU.2.</td><td>It is easy to become skillful at using the shopping environment.</td></tr>
<tr><td>EOU.3.</td><td>Learning to operate the shopping environment is easy.</td></tr>
<tr><td>EOU.4.</td><td>Interactions with the shopping environment are clear and understandable.</td></tr>
<tr><td rowspan="6">NASA task load index (Hart and Staveland, 1988)</td><td>COGL.</td><td>How much mental and perceptual activity was required during the experiment (e.g., thinking, deciding, calculating, remembering, comparing, searching, etc.)? The cognitive load was … (low | high)</td><td rowspan="6">21-point Likert scale</td></tr>
<tr><td>PHYL.</td><td>How much physical activity was required during the experiment (e.g., grabbing, turning, moving, stretching, bending, coordinating, etc.)? The physical load was … (low | high)</td></tr>
<tr><td>TEMP.</td><td>How much time pressure did you feel due to the rate or pace at which the tasks or task elements occurred? The time pressure was … (low | high)</td></tr>
<tr><td>PERF.</td><td>How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)? My task performance was … (bad | good)</td></tr>
<tr><td>EFFO.</td><td>How hard did you have to work (mentally and physically) to accomplish your level of performance? The work required was ... (low | high)</td></tr>
<tr><td>FRUS.</td><td>How frustrated (e.g. insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent) did you feel during the experiment? My frustration level was … (low | high)</td></tr>
<tr><td rowspan="8">Simulator Sickness (SIM) (Kennedy et al., 1993)</td><td colspan="2">Question: Did you experience the following symptoms during the experiment?</td><td></td></tr>
<tr><td>SIM.1.</td><td>Nausea</td><td rowspan="7">4-point scale with the categories: 0 (none), 1 (slight), 2 (moderate), 3 (severe) symptoms</td></tr>
<tr><td>SIM.2.</td><td>Headache</td></tr>
<tr><td>SIM.3.</td><td>Eyestrain</td></tr>
<tr><td>SIM.4.</td><td>Dizziness</td></tr>
<tr><td>SIM.5.</td><td>Blurred vision</td></tr>
<tr><td>SIM.6.</td><td>Fatigue</td></tr>
<tr><td>SIM.7.</td><td>General discomfort</td></tr>
<tr><td colspan="4"><i>Note</i>: EOU: perceived ease of use of the system; COGL: cognitive load; PHYS: physical load; TEMP: temporal demand; PERF: performance; EFFO: effort; FRUS: frustration; SIM: simulator sickness.</td></tr>
</table>

TABLE C.3: Scales used for assessing task load, simulator sickness and ease of use.

C.3 Descriptive Statistics and Supplemental Analyses

	VR (N=132)							Desktop (N=125)						
	VR (N=63)			VR Real (N=69)			p	Desktop (N=63)			Desktop Real (N=62)			p
Construct	M	SD	norm.p	M	SD	norm.p		M	SD	norm.p	M	SD	norm.p	
DIAG	4.19	1.33	0.38	3.97	1.3	0.09	.340	4.6	1.55	0.03	4.78	1.49	0.05	.542
TEL	5.28	1.31	0.00	5.0	1.36	0.01	.120	3.58	1.43	0.11	3.44	1.51	0.04	.501
ENJ	5.02	1.39	0.25	5.1	1.31	0.01	.841	4.45	1.28	0.02	4.42	1.3	0.05	.795
USE	4.21	1.29	0.10	4.33	1.18	0.40	.593	4.21	1.56	0.13	4.35	1.62	0.07	.623
INT	3.91	1.56	0.25	4.18	1.75	0.01	.358	3.76	1.72	0.02	4.07	1.73	0.05	.290
Note: p-value based on either Mann-Whitney-U-Test or Welch Two Sample t-test. No significant difference could be found which is why we merged both subgroups for the analysis.														

TABLE C.4: Descriptive statistics and tests for the latent variables when split into the two subgroups.

	VR (N=132)			Desktop (N=125)				ALL (N=257)	
Construct	M	SD	normtest.p	M	SD	normtest.p	p	M	SD
Cognitive load	45.30	24.15	.000	38.52	22.89	.000	0.021	42.00	23.74
Physical load	30.34	21.15	.000	16.68	19.56	.000	0.000	23.70	21.47
Temporal demand	22.99	22.15	.000	20.40	21.12	.000	0.231	21.73	21.65
Performance	82.82	12.99	.000	82.32	14.05	.000	0.616	82.06	13.49
Effort	30.98	20.80	.000	26.24	20.32	.000	0.054	28.67	20.66
Frustration	21.86	23.36	.000	20.56	24.83	.000	0.294	21.23	24.05
Ease of use	6.48	0.690	.000	6.53	0.698	.000	0.390	6.51	0.69

TABLE C.5: Summary descriptive statistics for assessing the task load and perceived ease of use of the system.

	VR (N=132)					Desktop (N=125)					
Symptom	No symptoms (0)	Mild symptoms (1)	Moderate symptoms (2)	Severe symptoms (3)	Sum Score	No symptoms (0)	Mild symptoms (1)	Moderate symptoms (2)	Severe symptoms (3)	Sum Score	p-value
Nausea	127	4	1	0	6	124	1	0	0	1	.371
Headache	120	10	2	0	14	115	10	0	0	10	.622
Eyestrain	97	30	4	1	41	106	15	4	0	23	.068
Dizzy	117	13	2	0	17	121	4	0	0	4	.021
Blurred vision	19	64	42	7	169	113	12	0	0	12	.000
Fatigue	109	21	2	0	25	83	37	5	0	47	.009
General discomfort	115	15	2	0	19	125	0	0	0	0	.000

Note: p-value based on Fisher's Exact Test for count data.

TABLE C.6: Comparison Simulator Sickness questionnaire.

Pillai's Trace	$V = .281$	F(2,254) = 49.636	p <.001
Wilks' Lambda	$\Lambda = .719$	F(2,254) = 49.636	p <.001
Hotelling's Trace	$T = .391$	F(2,254) = 49.636	p <.001
Roy's Largest Root	$\Theta = .391$	F(2,254) = 49.636	p <.001

TABLE C.7: MANOVA test statistics.

						CI Bias-Corrected (BC)	
		Coefficient		Bias	Bootstrap Std. Error	**2.5%**	**97.5%**
Indirect effect	IMM→DIAG	a x b	-.263	-.003	.112	-.492	-.051
Direct effect	IMM→DIAG	c′	-.354	.001	.194	-.747	.018
Total Effect	IMM→DIAG	c	-.618	.004	.176	-.981	-.286

Note: Bootstrapping: 5000 subsamples, bias-corrected (BC) CIs. Due to non-normally distributed errors, we used a robust method (bootstrapping) to calculate the direct effect.

TABLE C.8: Results of mediation analysis with readability as mediator.

	Model 1		Model 2	
	Coeff. (Std. Error)^a	Sign. (2-tailed)^a	Coeff. (Std. Error)^a	Sign. (2-tailed)^a
Constant	3.915 (.151)	.000	2.713 (.426)	.000
High (vs. low) immersion	.136 (.209)	.523	.504 (.233)	.029
Readability	-	-	.211 (.072)	.005
R^2 (adj. R^2)	.002 (-.002)		.035 (.027)	

Note: a. due to non-normally distributed errors, results are based on 5000 bootstrap samples (Bias Corrected and accelerated (BCa) bootstrapping). Reestimating the model without applying bootstrap procedure reveals similar results.

TABLE C.9: Linear regression model of immersion on intention to reuse (Model 1) and controlling for readability (Model 2).

C.4 PLS SEM Analysis (unpublished)

In addition to the analysis of the research model using covariance-based structural equation modeling (CB SEM), an analysis using partial least squares structural equation modeling (PLS SEM) was performed to demonstrate the robustness of the results. In doing so, the two-stage approach by Hair et al. (2016) to analyze and interpret the research model was followed.

Measurement Model: Cronbach's alpha and the composite reliability are well above the threshold value of 0.70 and 0.70 respectively (Hair et al., 2016) for all constructs, thereby indicating internal consistency reliability. Only the Cronbach's alpha value of perceived telepresence (0.677) did not exceed the threshold value, whereas the threshold for the composite reliability was surpassed (0.753, see Table C.10).

Construct	DIAG	TEL	ENJ	USE	INT	Threshold
Cronbach's alpha	.836	.677	.774	.899	.951	>0.7
Composite reliability	.901	.753	.852	.929	.969	>0.7

TABLE C.10: Measurement model – internal consistency reliability (before removing TEL.4.)

After dropping the item TEL.4., the construct's Cronbach's alpha increased above the cutoff value (0.708). Table C.11 shows the final specific values for assessing the internal consistency reliability.

Construct	DIAG	TEL	ENJ	USE	INT	Threshold
Cronbach's alpha	.836	.708	.774	.899	.951	>0.7
Composite reliability	.901	.806	.852	.929	.969	>0.7

TABLE C.11: Measurement model evaluation – internal consistency reliability (after removing TEL.4.)

Then, the convergent validity was evaluated by examining each indicator's outer loading and a construct's AVE. For the latter, the values for all the constructs were well above the proposed threshold of 0.50 (Hair et al., 2011). Regarding the outer loadings, the two indicators ENJ.2. (0.532) and TEL.3. (0.519) had to be considered in more detail, since their values did not exceed the 0.70 threshold (Hair et al., 2016). Following Hair et al. (2016), it was analyzed – for both indicators – how indicator deletion impacted on internal consistency reliability. Since the internal consistency reliability of perceived telepresence suffered from the deletion of TEL.3., the decision was made to remove only ENJ.2. from the measurement model. This resulted in sufficient values for the internal consistency reliability and convergent validity (see Table C.12).

For assessing the discriminant validity, the Fornell-Larcker criterion (Fornell and Larcker, 1981), the cross loadings, as well as the Heterotrait-Monotrait

Construct	DIAG	TEL	ENJ	USE	INT	Threshold
Cronbach's alpha	.836	.708	.804	.899	.951	>0.7
Composite reliability	.901	.807	.884	.929	.969	>0.7
AVE	.752	.594	.717	.767	.911	>0.5

TABLE C.12: Measurement model evaluation – internal consistency reliability and convergent validity (after removing TEL.4. and ENJ.2.)

Ratio (HTMT) were considered. All three tests confirmed the discriminant validity of the measurement model (see Table C.14, Table C.15, and Table C.16). The evaluation of the measurement model is summarized in Table C.13.

		Convergent validity		Internal consitency reliability		Discriminant validity
		Outer loadings	AVE	Comp. reliability	Cronb. alpha	HTMT
Construct	Indicator	>.70	>.50	>.70	>.70	HTMT conf. Int. does not include 1
Perceived product diagnosticity	DIAG.1.	.855	.752	.901	.836	yes
	DIAG.2.	.869				
	DIAG.3.	.879				
Perceived telepresence	TEL.1.	.834	.594	.807	.708	yes
	TEL.2.	.901				
	TEL.3.	.522				
Perceived enjoyment	ENJ.1.	.877	.717	.884	.804	yes
	ENJ.3.	.851				
	ENJ.4.	.812				
Perceived usefulness	USE.1.	.845	.767	.929	.899	yes
	USE.2.	.892				
	USE.3.	.886				
	USE.4.	.878				
Intention to reuse	INT.1.	.968	.911	.969	.951	yes
	INT.2.	.934				
	INT.3.	.961				
Immersion	IMM.1.	1.000	1.000	1.000	1.000	yes

TABLE C.13: Measurement model evaluation following Hair et al. (2016)

Structural Model: After having confirmed the reliability of the measurement model, the results of the structural model were evaluated. Therefore, the structural model was checked for collinearity issues by assessing the Inner VIF values for all predicting constructs. All values for predicting constructs are well below the commonly applied cutoff value of 5 (Hair et al., 2016). Next, the structural model was evaluated. Figure C.1 presents the results

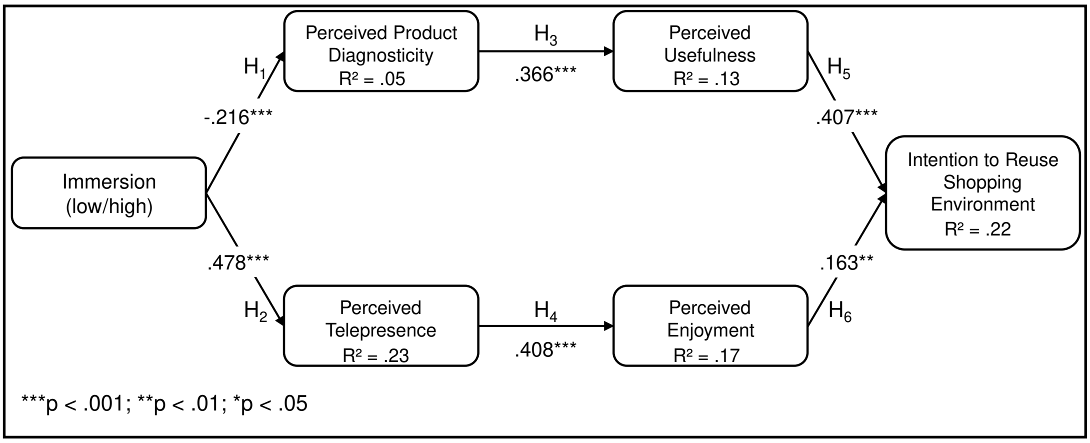


FIGURE C.1: Results of PLS SEM

of the PLS SEM structural model. Bootstrapping was applied to obtain the significance values for the path coefficients (configuration: 5000 samples, two tailed, BCa without sign change).

All relationships in the structural model are significant at a .001 level, except the relationship between perceived enjoyment and the dependent variable intention to reuse the shopping environment (significant at a .01 level). All in all, the results are qualitatively similar to the results obtained by testing the model using CB SEM (see Chapter 3).

Overall, the R^2 values are rather weak. Figure C.1 reflects all R^2 values (adj. R^2: Diagnosticity 0.04, Telepresence 0.226, Usefulness 0.130, Enjoyment 0.163, Intention 0.212). Concerning the effect size f^2, the effect of immersion on telepresence (.296), usefulness on intention (.204), telepresence on enjoyment (.200), and diagnosticity on usefulness (.154), can be classified as a medium effect according to Henseler et al. (2009), whereas the effect of immersion on diagnosticity (.049), as well as enjoyment on intention (.033), can be interpreted as small.

	IMM	**DIAG**	**TEL**	**ENJ**	**USE**	**INT**
IMM	**1.000**					
DIAG	-.216	**.867**				
TEL	.478	-.052	**.770**			
ENJ	.230	.075	.408	**.847**		
USE	-.008	.366	.111	.193	**.876**	
INT	.040	.193	.169	.241	.439	**.955**

TABLE C.14: Measurement model evaluation — Fornell-Larcker criterion

	IMM	INT	DIAG	ENJ	TEL	USE
ENJ.1.	0.167	0.24	0.09	**0.877**	0.354	0.129
ENJ.3.	0.265	0.153	0.088	**0.851**	0.408	0.176
ENJ.4.	0.141	0.226	0.000	**0.812**	0.26	0.192
INT.1.	0.037	**0.968**	0.186	0.247	0.176	0.42
INT.2.	0.046	**0.934**	0.157	0.204	0.175	0.411
INT.3.	0.032	**0.961**	0.208	0.238	0.135	0.425
PDIAG.1.	-0.155	0.147	**0.855**	0.03	-0.065	0.3
PDIAG.2.	-0.206	0.163	**0.869**	0.09	-0.086	0.281
PDIAG.3.	-0.2	0.188	**0.879**	0.073	0.004	0.362
PUSE.1.	-0.045	0.383	0.394	0.172	0.089	**0.845**
PUSE.2.	-0.051	0.428	0.316	0.132	0.079	**0.892**
PUSE.3.	0.042	0.348	0.287	0.199	0.133	**0.886**
PUSE.4.	0.04	0.368	0.267	0.177	0.091	**0.878**
TEL.1.	0.35	0.151	0.022	0.3	**0.834**	0.156
TEL.2.	0.508	0.125	-0.112	0.401	**0.901**	0.045
TEL.3.	-0.034	0.225	0.094	0.189	**0.522**	0.124
IMM.1.	1.000	0.04	-0.216	0.23	0.478	-0.008

TABLE C.15: Measurement model evaluation — cross loadings

	IMM	**DIAG**	**TEL**	**ENJ**	**USE**	**INT**
DIAG	.235					
TEL	.445	.125				
ENJ	.251	.103	.488			
USE	.054	.412	.170	.231		
INT	.041	.214	.257	.278	.054	

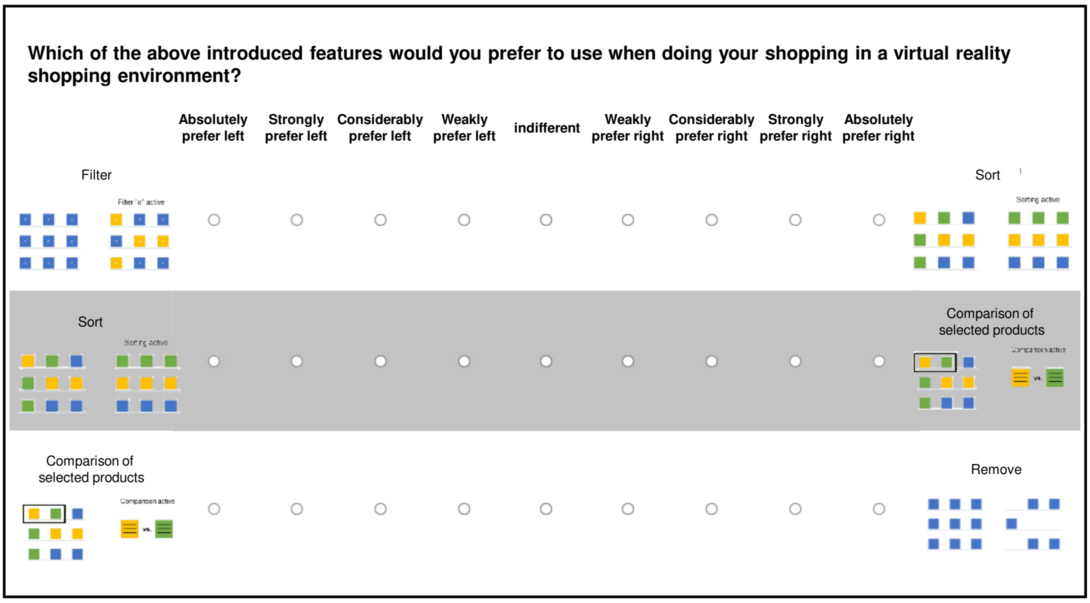
TABLE C.16: Measurement model evaluation — Heterotrait-Monotrait Ratio (HTMT); bootstrapping confirmed HTMT

Appendix D

Supplementary Material Chapter 5

D.1 Abstract Attribute Representation (unpublished)

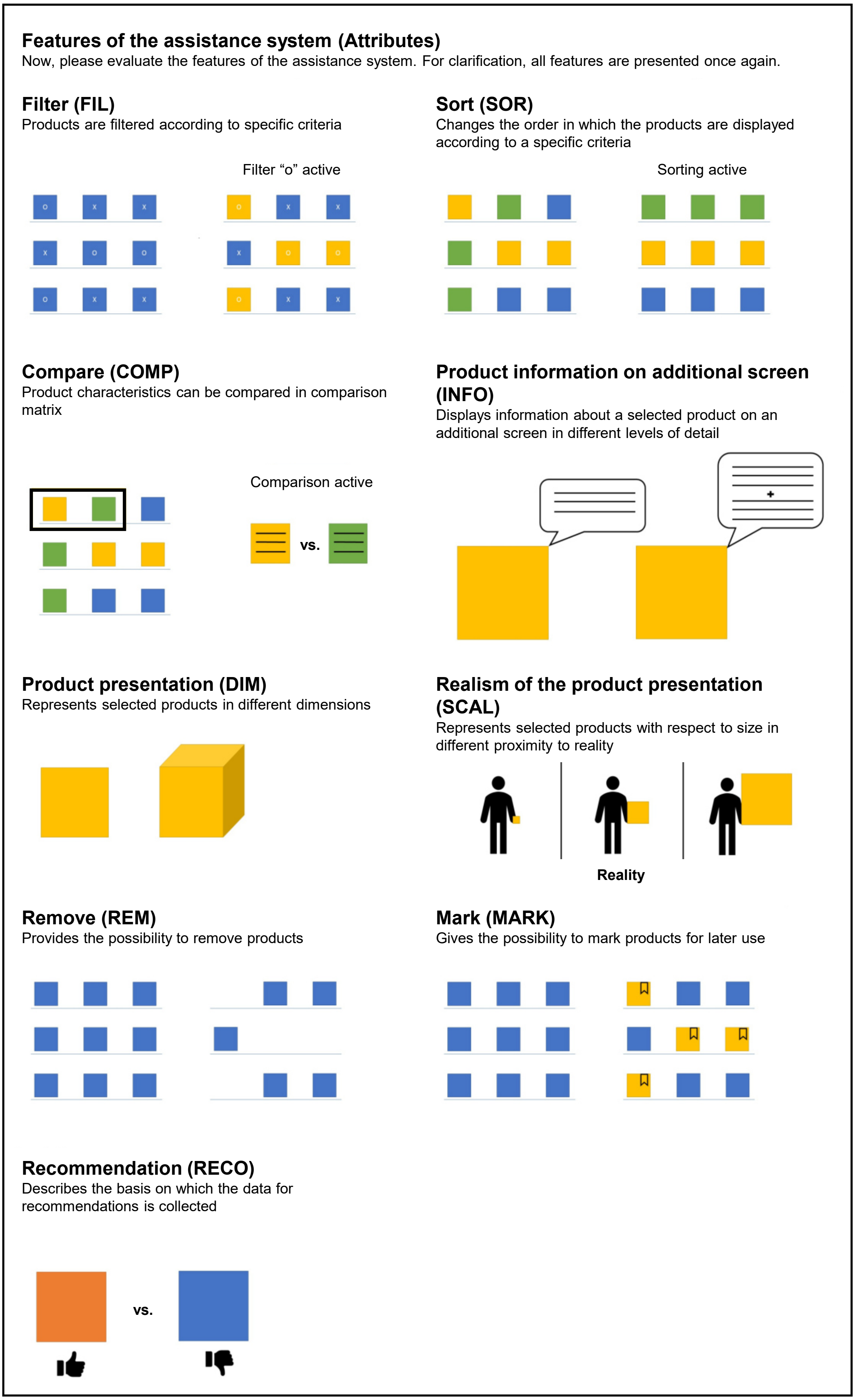
Exemplary illustration of how the survey of the attribute levels looked like in the experiment:



Which of the above introduced features would you prefer to use when doing your shopping in a virtual reality shopping environment?

	Absolutely prefer left	**Strongly prefer left**	**Considerably prefer left**	**Weakly prefer left**	**indifferent**	**Weakly prefer right**	**Considerably prefer right**	**Strongly prefer right**	**Absolutely prefer right**	
Filter	○	○	○	○	○	○	○	○	○	Sort
Sort	○	○	○	○	○	○	○	○	○	Comparison of selected products
Comparison of selected products	○	○	○	○	○	○	○	○	○	Remove

FIGURE D.1: 9-point scale for pairwise comparisons on attribute level – exemplary overview of how the pairwise comparisons looked like in the experiment



Features of the assistance system (Attributes)

Now, please evaluate the features of the assistance system. For clarification, all features are presented once again.

Filter (FIL)

Products are filtered according to specific criteria

Sort (SOR)

Changes the order in which the products are displayed according to a specific criteria

Compare (COMP)

Product characteristics can be compared in comparison matrix

Product information on additional screen (INFO)

Displays information about a selected product on an additional screen in different levels of detail

Product presentation (DIM)

Represents selected products in different dimensions

Realism of the product presentation (SCAL)

Represents selected products with respect to size in different proximity to reality

Remove (REM)

Provides the possibility to remove products

Mark (MARK)

Gives the possibility to mark products for later use

Recommendation (RECO)

Describes the basis on which the data for recommendations is collected

FIGURE D.2: Abstract attribute introduction – exemplary overview of how the attributes were introduced in the experiment

Bibliography

Agarwal, R. and J. Prasad (1998). "A conceptual and operational definition of personal innovativeness in the domain of information technology". In: *Information Systems Research* 9.2, pp. 204–215.

Alba, J., J. Lynch, B. Weitz, C. Janiszewski, R. Lutz, A. Sawyer, and S. Wood (1997). "Interactive home shopping: Consumer, retailer, and manufacturer incentives to participate in electronic marketplaces". In: *Journal of Marketing* 61.3, pp. 38–53.

Anderson, J. C. and D. W. Gerbing (1988). "Structural equation modeling in practice: A review and recommended two-step approach". In: *Psychological Bulletin* 103.3, pp. 411–423.

Animesh, A., A. Pinsonneault, S.-B. Yang, and W. Oh (2011). "An odyssey into virtual worlds: Exploring the impacts of technological and spatial environments on intention to purchase virtual products". In: *MIS Quarterly* 35.3, pp. 789–810.

Anthes, C., R. J. García-Hernández, M. Wiedemann, and D. Kranzlmüller (2016). "State of the art of virtual reality technology". In: *2016 IEEE Aerospace Conference*. Big Sky, USA, pp. 1–19.

Anthes, G. (2019). "Augmented reality gets real". In: *Communications of the ACM* 62.9, pp. 16–18.

Arthur, K. W., K. S. Booth, and C. Ware (1993). "Evaluating 3D task performance for fish tank virtual worlds". In: *ACM Transactions on Information Systems* 11.3, pp. 239–265.

Atalay, A. S., H. O. Bodur, and D. Rasolofoarison (2012). "Shining in the center: Central gaze cascade effect on product choice". In: *Journal of Consumer Research* 39.4, pp. 848–866.

Bagozzi, R. P. and Y. Yi (1988). "On the evaluation of structural equation models". In: *Journal of the Academy of Marketing Science* 16.1, pp. 74–94.

Bailey, B. P. and J. A. Konstan (2006). "On the need for attention-aware systems: Measuring effects of interruption on task performance, error rate, and affective state". In: *Computers in Human Behavior* 22.4, pp. 685–708.

Balan, O., G. Moise, A. Moldoveanu, F. Moldoveanu, and M. Leordeanu (2019). "Automatic adaptation of exposure intensity in VR acrophobia therapy, based on deep neural networks". In: *Proceedings of the 27th European Conference on Information Systems (ECIS)*. Stockholm & Uppsala, Sweden, pp. 1–14.

Bandara, R., M. Fernando, and S. Akter (2019). "Privacy concerns in E-commerce: A taxonomy and a future research agenda". In: *Electronic Markets*, pp. 1–19.

Basdogan, C., C. H. Ho, M. A. Srinivasan, and M. Slater (2000). "An experimental study on the role of touch in shared virtual environments". In: *ACM Transactions on Computer-Human Interaction* 7.4, pp. 443–460.

Benbasat, I. and H. Barki (2007). "Quo vadis, TAM?" In: *Journal of the Association for Information Systems* 8.4, pp. 211–218.

Berg, L. P. and J. M. Vance (2017). "Industry use of virtual reality in product design and manufacturing: A survey". In: *Virtual Reality* 21, pp. 1–17.

Bhattacherjee, A. (2001). "Understanding information systems continuance: An expectation-confirmation model". In: *MIS Quarterly* 25.3, pp. 351–370.

Bhattacherjee, A. and G. Premkumar (2004). "Understanding changes in belief and attitude toward information technology usage: A theoretical model and longitudinal test". In: *MIS Quarterly* 28.2, pp. 229–254.

Biocca, F., C. Owen, A. Tang, and C. Bohil (2007). "Attention issues in spatial information systems: Directing mobile users' visual attention using augmented reality". In: *Journal of Management Information Systems* 23.4, pp. 163–184.

Blascovich, J., J. Loomis, A. C. Beall, K. R. Swinth, C. L. Hoyt, and J. N. Bailenson (2002). "Immersive virtual environment technology as a methodological tool for social psychology". In: *Psychological Inquiry* 13.2, pp. 103–124.

Bock, O., A. Nicklisch, and I. Baetge (2012). "hroot: Hamburg registration and organisation online tool". In: *WiSo-HH Working Paper Series* 1, pp. 1–14.

Bowman, D. A. and R. P. McMahan (2007). "Virtual reality: How much immersion is enough?" In: *Computer* 40.7, pp. 36–43.

Brade, J., M. Lorenz, M. Busch, N. Hammer, M. Tscheligi, and P. Klimant (2017). "Being there again – presence in real and virtual environments and its relation to usability and user experience using a mobile navigation task". In: *International Journal of Human-Computer Studies* 101, pp. 76–87.

Briggs, R. O., J. F. J. Nunamaker, and R. H. J. Sprague (1997). "1001 Unanswered research questions in GSS". In: *Journal of Management Information Systems* 14.3, pp. 3–21.

Brocke, J. vom and T.-P. Liang (2014). "Guidelines for neuroscience studies in Information Systems research". In: *Journal of Management Information Systems* 30.4, pp. 211–233.

Brooks, F. P. (1999). "What's real about virtual reality?" In: *IEEE Computer Graphics and Applications* 19.6, pp. 16–27.

Brown, E. and P. Cairns (2004). "A grounded investigation of game immersion". In: *Proceedings of CHI'04 Extended Abstracts of the 2004 Conference on Human Factors and Computing Systems*. Vienna, Austria, pp. 1297–1300.

Bryant, F. B. and A. Satorra (2012). "Principles and practice of scaled difference chi-square testing". In: *Structural Equation Modeling* 19.3, pp. 372–398.

– (2013). *EXCEL macro file for conducting scaled difference chi-square tests via LISREL 8, LISREL 9, EQS, and Mplus*.

Burke, R. R. (2002). "Technology and the customer interface: What consumers want in the physical and virtual store". In: *Journal of the Academy of Marketing Science* 30.4, pp. 411–432.

Byrne, B. M. (2016). *Structural Equation Modeling with AMOS: Basic Concepts, Applications, and Programming*. 3rd ed. New York: Routledge.

Cavusoglu, H., A. R. Dennis, and J. Parsons (2019). "Special Issue: Immersive Systems". In: *Journal of Management Information Systems* 36.3, pp. 680–682.

Chandon, P., J. W. Hutchinson, E. T. Bradlow, and S. H. Young (2009). "Does in-store marketing work? Effects of the number and position of shelf facings on brand attention and evaluation at the point of purchase". In: *Journal of Marketing* 73.6, pp. 1–17.

Chaturvedi, A. R., D. R. Dolk, and P. L. Drnevich (2011). "Design principles for virtual worlds". In: *MIS Quarterly* 35.3, pp. 673–684.

Childers, T. L., C. L. Carr, J. Peck, and S. Carson (2001). "Hedonic and utilitarian motivations for online retail shopping behavior". In: *Journal of Retailing* 77.4, pp. 511–535.

Chin, W. W., A. Gopal, and W. D. Salisbury (1997). "Advancing the theory of adaptive structuration: The development of a scale to measure faithfulness of appropriation". In: *Information System Research* 8.4, pp. 342–367.

Chiu, C.-M., E. T. Wang, Y.-H. Fang, and H.-Y. Huang (2014). "Understanding customers' repeat purchase intentions in B2C e-commerce: The roles of utilitarian value, hedonic value and perceived risk". In: *Information Systems Journal* 24.1, pp. 85–114.

Cowan, K. and S. Ketron (2019). "A dual model of product involvement for effective virtual reality: The roles of imagination, co-creation, telepresence, and interactivity". In: *Journal of Business Research* 100, pp. 483–492.

Cruz-Neira, C., D. J. Sandin, T. A. DeFanti, R. V. Kenyon, and J. C. Hart (1992). "The cave: Audio visual experience automatic virtual environment". In: *Communications of the ACM* 35.6, pp. 64–72.

Cruz-Neira, C., D. J. Sandin, and T. A. DeFanti (1993). "Surround-screen projection-based virtual reality: The design and implementation of the CAVE". In: *Proceedings of the 20th Annual Conference on Computer Graphics and Interactive Techniques*. Anaheim, USA, pp. 135–142.

Cummings, J. J. and J. N. Bailenson (2016). "How immersive is enough? A meta-analysis of the effect of immersive technology on user presence". In: *Media Psychology* 19.2, pp. 272–309.

Davis, F. D. (1989). "Perceived usefulness, perceived ease of use, and user acceptance of information technology". In: *MIS Quarterly* 13.3, pp. 319–340.

Davis, F. D. and V. Venkatesh (1996). "A critical assessment of potential measurement biases in the technology acceptance model: Three experiments". In: *International Journal of Human-Computer Studies* 45.1, pp. 19–45.

Davis, F. D., R. P. Bagozzi, and P. R. Warshaw (1989). "User acceptance of computer technology: a comparison of two theoretical models". In: *Management Science* 35.8, pp. 982–1003.

Deering, M. F. (1995). "HoloSketch: A virtual reality sketching / animation tool". In: *ACM Transactions on Computer-Human Interaction* 2.3, pp. 220–238.

Ding, M., R. Grewal, and J. Liechty (2005). "Incentive-aligned conjoint analysis". In: *Journal of Marketing Research* 42.1, pp. 67–82.

Dionisio, J. D. N., W. G. Burns, and R. Gilbert (2013). "3D virtual worlds and the metaverse: Current status and future possibilities". In: *ACM Computing Surveys* 45.3, pp. 1–38.

Eighmey, J. and L. McCord (1998). "Adding value in the information age: Uses and gratifications of sites on the world wide web". In: *Journal of Business Research* 41.3, pp. 187–194.

Elliot, D. B., K. C. H. Yang, and D. Whitaker (1995). "Visual acuity changes throughout adulthood in normal, healthy eyes: Seeing beyond 6/6". In: *Optometry and Vision Science* 72.3, pp. 186–191.

Feldman, J. M. and J. G. Lynch (1988). "Self-generated validity and other effects of measurement on belief, attitude, intention, and behavior." In: *Journal of Applied Psychology* 73.3, pp. 421–435.

Fernandes, A. S. and S. K. Feiner (2016). "Combating VR sickness through subtle dynamic field-of-view modification". In: *2016 IEEE Symposium on 3D User Interfaces (3DUI)*. Greenville, USA, pp. 201–210.

Field, A., J. Miles, and Z. Field (2012). *Discovering Statistics Using R*. London: Sage Publications.

Fitzmaurice, G. W., S. Zhai, and M. H. Chignell (1993). "Virtual reality for palmtop computers". In: *ACM Transactions on Information Systems* 11.3, pp. 197–218.

Flavián, C., S. Ibáñez-Sánchez, and C. Orús (2019). "The impact of virtual, augmented and mixed reality technologies on the customer experience". In: *Journal of Business Research* 100, pp. 547–560.

Fornell, C. and D. F. Larcker (1981). "Structural equation models with unobservable variables and measurement error: Algebra and statistics". In: *Journal of Marketing Research* 18.3, pp. 382–388.

Franceschi, K., R. M. Lee, S. H. Zanakis, and D. Hinds (2009). "Engaging group e-learning in virtual worlds". In: *Journal of Management Information Systems* 26.1, pp. 73–100.

Frees, S., G. D. Kessler, and E. Kay (2007). "PRISM interaction for enhancing control in immersive virtual environments". In: *ACM Transactions on Computer-Human Interaction* 14.1, pp. 1–31.

Friemel, C., S. Morana, J. Pfeiffer, and A. Maedche (2018). "On the role of users' cognitive-affective states for user assistance invocation". In: *Information Systems and Neuroscience. Lecture Notes in Information Systems and Organisation, vol 25.* Ed. by F. Davis, R. Riedl, J. vom Brocke, P.-M. Léger, and A. Randolph. Vol. 25. Cham: Springer, pp. 37–46.

Füller, J. and K. Matzler (2007). "Virtual product experience and customer participation – a chance for customer-centred, really new products". In: *Technovation* 27.6-7, pp. 378–387.

Gefen, D. and D. W. Straub (2000). "The relative importance of perceived ease of use in IS adoption: A study of e-commerce adoption". In: *Journal of the Association for Information Systems* 1.1, pp. 1–28.

Gefen, D. and D. W. Straub (2004). "Consumer trust in B2C e-Commerce and the importance of social presence: Experiments in e-Products and e-Services". In: *Omega* 32, pp. 407–424.

Gefen, D., D. W. Straub, and M.-C. Boudreau (2000). "Structural equation modeling and regression: Guidelines for research practice". In: *Communications of the Association for Information Systems* 4, pp. 1–77.

Gefen, D., E. Karahanna, and D. W. Straub (2003). "Trust and TAM in online shopping: An integrated model". In: *MIS Quarterly* 27.1, pp. 51–90.

Gefen, D., E. E. Rigdon, and D. Straub (2011). "Editor's comments: An update and extension to SEM guidelines for administrative and social science research". In: *MIS Quarterly* 35.2, pp. iii–xiv.

Ghani, J. A., R. Supnick, and P. Rooney (1991). "The experience of flow in computer-mediated and in face-to-face groups". In: *Proceedings of the International Conference on Information Systems (ICIS)*. New York, USA, pp. 229–237.

Gidlöf, K., A. Wallin, R. Dewhurst, and K. Holmqvist (2013). "Using eye tracking to trace a cognitive process: Gaze behaviour during decision making in a natural environment". In: *Journal of Eye Movement Research* 6.1, pp. 1–14.

Glaholt, M. G. and E. M. Reingold (2011). "Eye movement monitoring as a process tracing methodology in decision making research". In: *Journal of Neuroscience, Psychology, and Economics* 4.2, pp. 125–146.

Gleasure, R. and J. Feller (2016). "A rift in the ground: Theorizing the evolution of anchor values in crowdfunding communities through the oculus rift case study". In: *Journal of the Association for Information Systems* 17.10, pp. 708–736.

Gloeckner, A. and A.-K. Herbold (2011). "An eye-tracking study on information processing in risky decisions: Evidence for compensatory strategies based on automatic processes". In: *Journal of Behavioral Decision Making* 24.1, pp. 71–98.

Gregor, S. and I. Benbasat (1999). "Explanations from intelligent systems: Theoretical foundations and implications for practice". In: *MIS Quarterly* 23.4, pp. 497–530.

Gregor, S. and A. R. Hevner (2013). "Positioning and presenting design science research for maximum impact". In: *MIS Quarterly* 37.2, pp. 337–355.

Grewal, D., Y. Bart, M. Spann, and P. P. Zubcsek (2016). "Mobile advertising: A framework and research agenda". In: *Journal of Interactive Marketing* 34, pp. 3–14.

Grewal, D., A. L. Roggeveen, and J. Nordfält (2017). "The future of retailing". In: *Journal of Retailing* 93.1, pp. 1–6.

Groissberger, T. and R. Riedl (2017). "Do online shops support customers' decision strategies by interactive information management tools? Results of an empirical analysis". In: *Electronic Commerce Research and Applications* 26, pp. 131–151.

Guan, Z., S. Lee, E. Cuddihy, and J. Ramey (2006). "The validity of the stimulated retrospective think-aloud method as measured by eye tracking". In: *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, CHI 2006*. Montréal, Canada, pp. 1253–1262.

Gutiérrez, M. A., F. Vexo, and D. Thalmann (2008). *Stepping into virtual reality*. Springer, London, pp. 1–214.

Guzman, J. A., K. Thilakarathna, and A. Seneviratne (2019). "Security and privacy approaches in mixed reality: A literature survey". In: *ACM Computing Surveys* 52.6, pp. 1–37.

Hair, J. F., C. M. Ringle, and M. Sarstedt (2011). "PLS-SEM: Indeed a silver bullet". In: *Journal of Marketing Theory and Practice* 19.2, pp. 139–152.

Hair, J. F., G. T. M. Hult, C. M. Ringle, and M. Sarstedt (2016). *A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM)*. Los Angeles: Sage Publications.

Harms, P. (2019). "Automated usability evaluation of virtual reality applications". In: *ACM Transactions on Computer-Human Interaction* 26.3, pp. 1–36.

Hart, C., A. M. Farrell, G. Stachow, G. Reed, and J. W. Cadogan (2007). "Enjoyment of the shopping experience: Impact on customers' repatronage intentions and gender influence". In: *The Service Industries Journal* 27.5, pp. 583–604.

Hart, S. G. and L. E. Staveland (1988). "Development of NASA-TLX (task load index): Results of empirical and theoretical research". In: *Advances in Psychology* 52, pp. 139–183.

Hartl, E. and B. Berger (2017). "Escaping reality: Examining the role of presence and escapism in user adoption of virtual reality glasses". In: *Proceedings of the 25th European Conference on Information Systems (ECIS)*. Guimarães, Portugal, pp. 2413–2428.

Hassenzahl, M. and N. Tractinsky (2006). "User experience - a research agenda". In: *Behaviour & Information Technology* 25.2, pp. 91–97.

Häubl, G. and V. Trifts (2000). "Consumer decision making in online shopping environments: The effects of interactive decision aids". In: *Marketing Science* 19.1, pp. 4–21.

Hayes, A. F. (2009). "Beyond Baron and Kenny: Statistical mediation analysis in the new millennium". In: *Communication Monographs* 76.4, pp. 408–420.

Hayes, A. F. and M. Scharkow (2013). "The relative trustworthiness of inferential tests of the indirect effect in statistical mediation analysis: Does method really matter?" In: *Psychological Science* 24.10, pp. 1918–1927.

Heijden, H. van der (2004). "User acceptance of hedonic information systems". In: *MIS Quarterly* 28.4, pp. 695–704.

Henseler, J., C. M. Ringle, and R. R. Sinkovics (2009). "The use of partial least squares path modeling in international marketing". In: *Advances in International Marketing* 20, pp. 277–319.

Herpen, E. van, E. van den Broek, H. C. van Trijp, and T. Yu (2016). "Can a virtual supermarket bring realism into the lab? Comparing shopping behavior using virtual and pictorial store representations to behavior in a physical store". In: *Appetite* 107.1, pp. 196–207.

Hevner, A. R. (2007). "A three cycle view of design science research". In: *Scandinavian Journal of Information Systems* 19.2, pp. 87–92.

Hevner, A. R., S. T. March, J. Park, and S. Ram (2004). "Design science in Information Systems research". In: *MIS Quarterly* 28.1, pp. 75–105.

Holmqvist, K., M. Nyström, R. Andersson, R. Dewhurst, H. Jarodzka, and J. van de Weijer (2011). *Eye Tracking: A Comprehensive Guide to Methods and Measures*. Oxford: Oxford University Press.

Hong, Y. and P. A. Pavlou (2014). "Product fit uncertainty in online markets: Nature, effects, and antecedents". In: *Information Systems Research* 25.2, pp. 328–344.

Hsieh, C.-C. (2002). "Smoothness in frame reduction". In: *Computers & Operations Research* 29, pp. 1807–1818.

Hu, L.-t. and P. M. Bentler (1999). "Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives". In: *Structural Equation Modeling* 6.1, pp. 1–55.

Huang, Z. and M. Benyoucef (2013). "From e-commerce to social commerce: A close look at design features". In: *Electronic Commerce Research and Applications* 12.4, pp. 246–259.

Huotari, J., K. Lyytinen, and M. Niemelä (2004). "Improving graphical information system model use with elision and connecting lines". In: *ACM Transactions on Computer-Human Interaction* 11.1, pp. 26–58.

Huttner, J.-P., Z. Qian, and S. Robra-Bissantz (2019). "A virtual memory palace and the user's awareness of the method of loci". In: *Proceedings of the 27th European Conference on Information Systems (ECIS)*. Stockholm & Uppsala, Sweden, pp. 1–14.

Inman, J. J. and H. Nikolova (2017). "Shopper-facing retail technology: A retailer adoption decision framework incorporating shopper attitudes and privacy concerns". In: *Journal of Retailing* 93.1, pp. 7–28.

Jennett, C., A. L. Cox, P. Cairns, S. Dhoparee, A. Epps, T. Tijs, and A. Walton (2008). "Measuring and defining the experience of immersion in games". In: *International Journal of Human-Computer Studies* 66.9, pp. 641–661.

Jiang, Z. and I. Benbasat (2005). "Virtual product experience: Effects of visual and functional control of products on perceived diagnosticity and flow in electronic shopping". In: *Journal of Management Information Systems* 21.3, pp. 111–147.

– (2007a). "Investigating the influence of the functional mechanisms of online product presentations". In: *Information Systems Research* 18.4, pp. 454–470.

– (2007b). "The effects of presentation formats and task complexity on online consumers' product understanding". In: *MIS Quarterly* 31.3, pp. 475–500.

Jin, S.-A. A. (2009). "The roles of modality richness and involvement in shopping behavior in 3D virtual stores". In: *Journal of Interactive Marketing* 23.3, pp. 234–246.

Jin, S.-A. A. and J. Bolebruch (2009). "Virtual commerce (v-commerce) in Second Life: The roles of physical presence and brand-self connection". In: *Journal of Virtual Worlds Research* 2.4, pp. 3–12.

Jöreskog, K. G., U. H. Olsson, and F. Y. Wallentin (2016). *Multivariate Analysis with LISREL*. Cham: Springer.

Kamis, A., T. Stern, and D. M. Ladik (2010). "A flow-based model of web site intentions when users customize products in business-to-consumer electronic commerce". In: *Information Systems Frontiers* 12.2, pp. 157–168.

Kampling, H. (2018). "Feeling presence in immersive virtual reality for individual learning". In: *Proceedings of the 39th International Conference on Information Systems (ICIS)*. San Francisco, USA, pp. 1–9.

Kasper, G. M. (1996). "A theory of decision support system design for user calibration". In: *Information Systems Research* 7.2, pp. 215–232.

Kempf, D. S. and R. E. Smith (1998). "Consumer processing of product trial and the influence of prior advertising: A structural modeling approach". In: *Journal of Marketing Research* 35.3, pp. 325–338.

Kennedy, R. S., N. E. Lane, K. S. Berbaum, and M. G. Lilienthal (1993). "Simulator sickness questionnaire: An enhanced method for quantifying simulator sickness". In: *The International Journal of Aviation Psychology* 3.3, pp. 203–220.

Kessler, G. D., L. F. Hodges, and N. Walker (1995). "Evaluation of the CyberGlove as a whole-hand input device". In: *ACM Transactions on Computer-Human Interaction* 2.4, pp. 263–283.

Khalifa, M. and N. Shen (2004). "System design effects on social presence and telepresence in virtual communities". In: *Proceedings of the 25th International Conference on Information Systems (ICIS)*. Washington, DC, USA, pp. 547–558.

Kim, J. S., D. Gračanin, T. Yang, and F. Quek (2015). "Action-transferred navigation technique design approach supporting human spatial learning". In: *ACM Transactions on Computer-Human Interaction* 22.6, pp. 1–42.

Kim, T. and F Biocca (1997). "Telepresence via television: Two dimensions of telepresence may have different connections to memory and persuasion". In: *Journal of Computer-Mediated Communication* 3.2.

Klein, L. R. (2003). "Creating virtual product experiences: The role of telepresence". In: *Journal of Interactive Marketing* 17.1, pp. 41–55.

Kloker, S. (2020). "Non-addictive Information Systems". In: *Information Systems Frontiers* 22.3, pp. 549–562.

Koufaris, M. (2002). "Applying the technology acceptance model and flow theory to online consumer behavior". In: *Information Systems Research* 13.2, pp. 205–223.

Krasonikolakis, I., A. Vrechopoulos, and A. Pouloudi (2014). "Store selection criteria and sales prediction in virtual worlds". In: *Information & Management* 51.6, pp. 641–652.

Kuechler, B. and V. Vaishnavi (2008). "Theory development in design science research: Anatomy of a research project". In: *Proceedings of the 3rd International Conference on Design Science Research in Information Systems and Technology (DESRIST)*. Atlanta, USA, pp. 1–15.

Laforet, S. and X. Li (2005). "Consumers' attitudes towards online and mobile banking in China". In: *International Journal of Bank Marketing* 23.5, pp. 362–380.

Lee, H., T. H. Jung, M. C. tom Dieck, and N. Chung (2020). "Experiencing immersive virtual reality in museums". In: *Information & Management* 57.5.

Lee, K. C. and N. Chung (2008). "Empirical analysis of consumer reaction to the virtual reality shopping mall". In: *Computers in Human Behavior* 24.1, pp. 88–104.

Lee, K. M. (2004). "Presence, explicated". In: *Communication Theory* 14.1, pp. 27–50.

Liu, Y. A., Z. J. Jiang, and H. C. Chan (2019). "Touching products virtually: Facilitating consumer mental imagery with gesture control and visual presentation". In: *Journal of Management Information Systems* 36.3, pp. 823–854.

Lombard, M. and T. Ditton (1997). "At the heart of it all: The concept of presence". In: *Journal of Computer-Mediated Communication* 3.2.

Loomis, J. M., J. J. Blascovich, and A. C. Beall (1999). "Immersive virtual environment technology as a basic research tool in psychology". In: *Behavior Research Methods, Instruments, & Computers* 31.4, pp. 557–564.

Lucas, H. C. and J. Baroudi (1994). "The role of information technology in organization design". In: *Journal of Management Information Systems* 10.4, pp. 9–23.

Lukyanenko, R., J. Evermann, and J. Parsons (2015). "Guidelines for establishing instantiation validity in IT artifacts: A survey of IS research". In: *Proceedings of the 10th International Conference on Design Science Research in Information Systems and Technology (DESRIST)*. Dublin, Ireland, pp. 430–438.

Luo, C., Y. Shen, and Y. A. Liu (2019). "Look and feel: The importance of sensory feedback in virtual product experience". In: *Proceedings of the 40th International Conference on Information Systems (ICIS)*. Munich, Germany, pp. 1–9.

Maedche, A., S. Morana, S. Schacht, D. Werth, and J. Krumeich (2016). "Advanced user assistance systems". In: *Business and Information Systems Engineering* 58.5, pp. 367–370.

Mardia, K. V. (1970). "Measures of multivariate skewness and kurtosis with applications". In: *Biometrika* 57.3, pp. 519–530.

Martínez-Navarro, J., E. Bigné, J. Guixeres, M. Alcañiz, and C. Torrecilla (2019). "The influence of virtual reality in e-commerce". In: *Journal of Business Research* 100, pp. 475–482.

Maruping, L. M., H. Bala, V. Venkatesh, and S. A. Brown (2017). "Going beyond intention: Integrating behavioral expectation into the unified theory of acceptance and use of technology". In: *Journal of the Association for Information Science and Technology* 68.3, pp. 623–637.

McGill, M., J. H. Williamson, and S. Brewster (2016). "Examining the role of smart TVs and VR HMDs in synchronous at-a-distance media consumption". In: *ACM Transactions on Computer-Human Interaction* 23.5, pp. 1–57.

Meißner, M. and R. Decker (2009). "An empirical comparison of CBC and AHP for measuring consumer preferences". In: *Proceedings of the 10th International Symposium on the Analytic Hierarchy Process*. Pittsburgh, USA, pp. 1–13.

Meißner, M., J. Pfeiffer, T. Pfeiffer, and H. Oppewal (2019). "Combining virtual reality and mobile eye tracking to provide a naturalistic experimental environment for shopper research". In: *Journal of Business Research* 100, pp. 445–458.

Mihelj, M., D. Novak, and S. Beguš (2014). *Virtual Reality Technology and Applications*. Vol. 68. Intelligent systems, control and automation: Science and engineering. Dordrecht: Springer.

Milgram, P. and F. Kishino (1994). "A taxonomy of mixed reality visual displays". In: *IEICE Transactions on Information and Systems* 77.12, pp. 1321–1329.

Milgram, P., H. Takemura, A. Utsumi, and F. Kishino (1995). "Augmented reality: A class of displays on the reality-virtuality continuum". In: *Proceedings of the SPIE 2351,Telemanipulator and Telepresence Technologies*. Boston, USA, pp. 282–292.

Moorthy, S., B. T. Ratchford, and D. Talukdar (1997). "Consumer information search revisited: Theory and empirical analysis". In: *Journal of Consumer Research* 23.4, pp. 263–277.

Morana, S., J. Pfeiffer, and M. T. P. Adam (2020). "User assistance for intelligent systems". In: *Business & Information Systems Engineering* 62.3, pp. 189–192.

Mori, M., K. F. MacDorman, and N. Kageki (2012). "The Uncanny Valley [From the Field]". In: *IEEE Robotics & Automation Magazine* 19.2, pp. 98–100.

Mütterlein, J. and T. Hess (2017). "Exploring the impacts of virtual reality on business models: The case of the media industry". In: *Proceedings of the 25th European Conference on Information Systems (ECIS)*. Guimarães, Portugal, pp. 3213–3222.

Nacenta, M. A., M. Hancock, C. Gutwin, and S. Carpendale (2016). "The effects of changing projection geometry on perception of 3D objects on and around tabletops". In: *ACM Transactions on Computer-Human Interaction* 23.2, pp. 1–54.

Nah, F. F.-H., B. Eschenbrenner, and D. DeWester (2011). "Enhancing brand equity through flow and telepresence: A comparison of 2D and 3D virtual worlds". In: *MIS Quarterly* 35.3, pp. 731–747.

Novak, T. P., D. L. Hoffman, Y.-F. Yung, T. P. Novak, and D. L. Hoffman (2000). "Measuring the customer experience in online environments: A structural modeling approach". In: *Marketing Science* 19.1, pp. 22–42.

Nunamaker, J. F., R. O. Briggs, D. D. Mittleman, D. R. Vogel, and P. A. Balthazard (1996). "Lessons from a dozen years of group support systems research: A discussion of lab and field findings". In: *Journal of Management Information Systems* 13.3, pp. 163–207.

Orquin, J. L. and S. M. Loose (2013). "Attention and choice: A review on eye movements in decision making". In: *Acta Psychologica* 144.1, pp. 190–206.

Pantano, E. and R. Servidio (2012). "Modeling innovative points of sales through virtual and immersive technologies". In: *Journal of Retailing and Consumer Services* 19.3, pp. 279–286.

Paré, G., M. C. Trudel, M. Jaana, and S. Kitsiou (2015). "Synthesizing information systems knowledge: A typology of literature reviews". In: *Information and Management* 52.2, pp. 183–199.

Park, C. W., E. S. Iyer, and D. C. Smith (1989). "The effects of situational factors on in-store grocery shopping behavior: The role of store environment and time available for shopping". In: *Journal of Consumer Research* 15.4, pp. 422–433.

Patney, A., M. Salvi, J. Kim, A. Kaplanyan, C. Wyman, N. Benty, D. Luebke, and A. Lefohn (2016). "Towards foveated rendering for gaze-tracked virtual reality". In: *ACM Transactions on Graphics* 35.6, pp. 1–12.

Pavlou, P. A. and M. Fygenson (2006). "Understanding and predicting electronic commerce adoption: An extension of the theory of planned behavior". In: *MIS Quarterly* 30.1, pp. 115–143.

Pavlou, P. A., H. Liang, and Y. Xue (2007). "Understanding and mitigating uncertainty in online exchange relationships: A principal-agent perspective". In: *MIS Quarterly* 31.1, pp. 105–136.

Peukert, C., J. Pfeiffer, M. Meissner, T. Pfeiffer, and C. Weinhardt (2019a). "Acceptance of imagined versus experienced virtual reality shopping environments: Insights from two experiments". In: *Proceedings of the 27th European Conference on Information Systems (ECIS)*. Stockholm & Uppsala, Sweden, pp. 1–16.

Peukert, C., J. Pfeiffer, M. Meißner, T. Pfeiffer, and C. Weinhardt (2019b). "Shopping in virtual reality stores: The influence of immersion on system adoption". In: *Journal of Management Information Systems* 36.3, pp. 755–788.

Peukert, C., J. Lechner, J. Pfeiffer, and C. Weinhardt (2020). "Intelligent invocation: Towards designing context-aware user assistance systems based on real-time eye tracking data analysis". In: *Information Systems and Neuroscience. NeuroIS 2019. Lecture Notes in Information Systems and Organisation, vol 32*. Ed. by F. Davis, R. Riedl, J. vom Brocke, P.-M. Léger, A. Randolph, and T. Fischer. Cham: Springer International Publishing, pp. 73–82.

Pfeiffer, J., M. Meißner, E. Brandstätter, R. Riedl, R. Decker, and F. Rothlauf (2014). "On the influence of context-based complexity on information search patterns: An individual perspective". In: *Journal of Neuroscience, Psychology, and Economics* 7.2, 103–124.

Pfeiffer, J. (2010). "Interaktive Entscheidungshilfen". In: *Vertriebsinformationssysteme*. Ed. by J. Becker, R. Knackstedt, O. Müller, and A. Winkelmann. Berlin, Heidelberg: Springer, pp. 105–123.

– (2012). *Interactive Decision Aids in E-Commerce*. 2012th ed. Contributions to Management Science. Heidelberg: Springer Berlin Heidelberg.

Pfeiffer, J., R. Riedl, and F. Rothlauf (2009). "On the relationship between interactive decision aids and decision strategies: A theoretical analysis". In: *Proceedings of the 9th Internationale Tagung Wirtschaftsinformatik (WI)*. Vienna, Austria, pp. 161 –170.

Pfeiffer, J., T. Pfeiffer, A. Greif-Winzrieth, M. Meißner, P. Renner, and C. Weinhardt (2017). "Adapting human-computer-interaction of attentive smart glasses to the trade-off conflict in purchase decisions: An experiment in a virtual supermarket". In: *Proceedings of the 11th International Conference on Augmented Cognition (AC)*. Vancouver, Canada, pp. 219–235.

Pfeiffer, J., T. Pfeiffer, M. Meißner, and E. Weiß (2020). "Eye-tracking-based classification of information search behavior using machine learning: Evidence from experiments in physical shops and virtual reality shopping environments". In: *Information Systems Research* (in press), pp. 1–17.

Pollefeys, M. and L. van Gool (2002). "From images to 3D models". In: *Communications of the ACM* 45.7, pp. 50–55.

Qiu, L. and I. Benbasat (2005). "An investigation into the effects of text-to-speech voice and 3D avatars on the perception of presence and flow of live help in electronic commerce". In: *ACM Transactions on Computer-Human Interaction* 12.4, pp. 329–355.

Ratchford, B. T. (1987). "New insights about the FCB grid". In: *Journal of Advertising Research* 27, pp. 24–38.

Regt, A. de and S. J. Barnes (2019). "V-Commerce in retail: Nature and potential impact". In: *Augmented Reality and Virtual Reality: The Power of AR and VR* *for Business*. Ed. by M. C. tom Dieck and T. Jung. Vol. 29. Cham: Springer International Publishing, pp. 17–25.

Reutskaja, E., R. Nagel, C. F. Camerer, and A. Rangel (2011). "Dynamics in consumer choice under time pressure: An eye-tracking study". In: *The American Economic Review* 101.2, pp. 900–926.

Rosnow, R. L. and R. Rosenthal (2005). *Beginning Behavioral Research: A Conceptual Primer*. 5th ed. Englewood Cliffs: Pearson/Prentice Hall.

Rowe, F. (2014). "What literature review is not: Diversity, boundaries and recommendations". In: *European Journal of Information Systems* 23.3, pp. 241–255.

Ruddle, R. A. and S. Lessels (2009). "The benefits of using a walking interface to navigate virtual environments". In: *ACM Transactions on Computer-Human Interaction* 16.1, pp. 1–18.

Ruddle, R. A., E. Volkova, and H. H. Bülthoff (2011). "Walking improves your cognitive map in environments that are large-scale and large in extent". In: *ACM Transactions on Computer-Human Interaction* 18.2, pp. 1–20.

Russo, J. E. and F. Leclerc (1994). "An eye-fixation analysis of choice processes for consumer nondurables". In: *Journal of Consumer Research* 21.2, pp. 274–290.

Sawtooth Software Inc. (2013). "The CBC system for choice-based conjoint analysis". In: *Sawtooth Software Technical Paper Series* 8, pp. 1–27.

Schmeil, A., M. J. Eppler, and S. de Freitas (2012). "A structured approach for designing collaboration experiences for virtual worlds". In: *Journal of the Association for Information Systems* 13.10, pp. 836–860.

Schnack, A., M. J. Wright, and J. L. Holdershaw (2019). "Immersive virtual reality technology in a three-dimensional virtual simulated store: Investigating telepresence and usability". In: *Food Research International* 117, pp. 40–49.

Scholz, S. W., M. Meißner, and R. Decker (2010). "Measuring consumer preferences for complex products: A compositional approach based on paired comparisons". In: *Journal of Marketing Research* 47.4, pp. 685–698.

Schubert, T., F. Friedmann, and H. Regenbrecht (2001). "The experience of presence: Factor analytic insights". In: *Presence* 10.3, pp. 266–281.

Schultze, U. (2010). "Embodiment and presence in virtual worlds: A review". In: *Journal of Information Technology* 25.4, pp. 434–449.

Schultze, U. and R. O. Mason (2012). "Studying cyborgs: Re-examining internet studies as human subjects research". In: *Journal of Information Technology* 27.4, pp. 301–312.

Schultze, U. and W. J. Orlikowski (2010). "Research commentary—virtual worlds: A performative perspective on globally distributed, immersive work". In: *Information Systems Research* 21.4, pp. 810–821.

Schwarze, A., H. Freude, and B. Niehaves (2019). "Advantages and propositions of learning emotion recognition in virtual reality for people with autism". In: *Proceedings of the 27th European Conference on Information Systems (ECIS)*. Stockholm & Uppsala, Sweden, pp. 1–15.

Seymour, M., K. Riemer, and J. Kay (2018). "Actors, avatars and agents: Potentials and implications of natural face technology for the creation of realistic visual presence". In: *Journal of the Association for Information Systems* 19.10, pp. 953–981.

Shankar, V., J. J. Inman, M. Mantrala, E. Kelley, and R. Rizley (2011). "Innovations in shopper marketing: Current insights and future research issues". In: *Journal of Retailing* 87.1, pp. 29–42.

Sharda, R., N. C. Romano Jr., J. A. Lucca, M. Weiser, G. Scheets, J.-M. Chung, and C. M. Sleezer (2004). "Foundation for the study of computer-supported collaborative learning requiring immersive presence". In: *Journal of Management Information Systems* 20.4, pp. 31–64.

Sheridan, T. B. (1992). "Musings on Telepresence and Virtual Presence". In: *Presence: Teleoperators and Virtual Environments* 1.1, pp. 120–126.

Sidenmark, L. and H. Gellersen (2019). "Eye, head and torso coordination during gaze shifts in virtual reality". In: *ACM Transactions on Computer-Human Interaction* 27.1, pp. 1–40.

Siegrist, M., C.-Y. Ung, M. Zank, M. Marinello, A. Kunz, C. Hartmann, and M. Menozzi (2019). "Consumers' food selection behaviors in three-dimensional (3D) virtual reality". In: *Food Research International* 117, pp. 50–59.

Skarbez, R., F. P. Brooks, and M. C. Whitton (2017). "A survey of presence and related concepts". In: *ACM Computing Surveys* 50.6, pp. 1–39.

Slater, M. (1999). "Measuring presence: A response to the Witmer and Singer Presence Questionnaire". In: *Presence* 8.5, pp. 560–565.

– (2003). "A note on presence terminology". In: *Presence connect* 3.3, pp. 1–5.

– (2009). "Place illusion and plausibility can lead to realistic behaviour in immersive virtual environments". In: *Philosophical Transactions of the Royal Society B: Biological Sciences* 364.1535, pp. 3549–3557.

Slater, M. and M. V. Sanchez-Vives (2016). "Enhancing our lives with immersive virtual reality". In: *Frontiers in Robotics and AI* 3.74, pp. 1–47.

Slater, M. and M. Usoh (1993). "Representations systems, perceptual position, and presence in immersive virtual environments". In: *Presence: Teleoperators and Virtual Environments* 2.3, pp. 221–233.

Slater, M. and S. Wilbur (1997). "A framework for immersive virtual environments (FIVE): Speculations on the role of presence in virtual environments". In: *Presence: Teleoperators and Virtual Environments* 6.6, pp. 603–616.

Slater, M., M. Usoh, and A. Steed (1995). "Taking steps: The influence of a walking technique on presence in virtual reality". In: *ACM Transactions on Computer-Human Interaction* 2.3, pp. 201–219.

Slater, M., C. Gonzalez-Liencres, P. Haggard, C. Vinkers, R. Gregory-Clarke, S. Jelley, Z. Watson, G. Breen, R. Schwarz, W. Steptoe, D. Szostak, S. Halan, D. Fox, and J. Silver (2020). "The ethics of realism in virtual and augmented reality". In: *Frontiers in Virtual Reality* 1, pp. 1–13.

Steffen, J., J. Gaskin, T. Meservy, and J. Jenkins (2017). "The missing framework for virtually assisted activities". In: *Proceedings of the 38th International Conference on Information Systems (ICIS)*. Seoul, South Korea, pp. 1–15.

Steffen, J. H., J. E. Gaskin, T. O. Meservy, J. L. Jenkins, and I. Wolman (2019). "Framework of affordances for virtual reality and augmented reality". In: *Journal of Management Information Systems* 36.3, pp. 683–729.

Steininger, D. M. (2019). "Linking information systems and entrepreneurship: A review and agenda for IT-associated and digital entrepreneurship research". In: *Information Systems Journal* 29.2, pp. 363–407.

Steuer, J. (1992). "Defining virtual reality: Dimensions determining telepresence". In: *Journal of Communication* 42.4, pp. 73 –93.

Strickland, D., L. Hodges, M. North, and S. Weghorst (1997). "Overcoming phobias by virtual exposure". In: *Communications of the ACM* 40.8, pp. 34–39.

Suh, K.-S. and Y. E. Lee (2005). "The effects of virtual reality on consumer learning: An empirical investigation". In: *MIS Quarterly* 29.4, pp. 673–697.

Suh, K.-S., H. Kim, and E. K. Suh (2011). "What if your avatar looks like you? Dual-congruity perspectives for avatar use". In: *MIS Quarterly* 35.3, pp. 711–729.

Sussmann, S. and H. Vanhegan (2000). "Virtual reality and the tourism product substitution or complement?" In: *Proceedings of the 8th European Conference on Information Systems (ECIS)*. Vienna, Austria, pp. 1–8.

Sutherland, I. E. (1965). "The ultimate display". In: *Proceedings of the 3rd International Federation of Information Processing Congress (IFIP)*. New York, USA, pp. 506–508.

Sutherland, I. E. (1968). "A head-mounted three dimensional display". In: *Proceedings of the AFIPS '68 Fall Joint Computer Conference, Part I*. San Francisco, USA, pp. 757–764.

Swinyard, W. R. (1993). "The effects of mood, involvement, and quality of store experience on shopping intentions". In: *Journal of Consumer Research* 20.2, pp. 271–280.

Sylaiou, S., K. Mania, A. Karoulis, and M. White (2010). "Exploring the relationship between presence and enjoyment in a virtual museum". In: *International Journal of Human-Computer Studies* 68.5, pp. 243–253.

Szymanski, D. M. and R. T. Hise (2000). "E-satisfaction: An initial examination". In: *Journal of Retailing* 76.3, pp. 309–322.

Tarafdar, P., A. Leung, W. T. Yue, and I. Bose (2019). "Impact of immersive interface design on consumer perceptions during online product presentation". In: *Proceedings of the 40th International Conference on Information Systems (ICIS)*. Munich, Germany, pp. 1–17.

Vaughn, R. (1986). "How advertising works: A planning model revisited". In: *Journal of Advertising Research* 27, pp. 57–66.

Venkatesh, V. (2000). "Determinants of perceived ease of use: Integrating control, intrinsic motivation, and emotion into the technology acceptance model". In: *Information Systems Research* 11.4, pp. 342–365.

Venkatesh, V. and F. D. Davis (2000). "A theoretical extension of the technology acceptance model: Four longitudinal field studies". In: *Management Science* 46.2, pp. 186–204.

Venkatesh, V., M. G. Morris, G. B. Davis, and F. D. Davis (2003). "User acceptance of information technology: Toward a unified view". In: *MIS Quarterly* 27.3, pp. 425–478.

Venkatesh, V., F. D. Davis, and M. G. Morris (2007). "Dead or alive? The development, trajectory and future of technology adoption research". In: *Journal of the Association for Information Systems* 8.4, pp. 267–286.

Venkatesh, V., J. Y. Thong, and X. Xu (2012). "Consumer acceptance and use of information technology: Extending the unified theory of acceptance and use of technology". In: *MIS Quarterly* 36.1, pp. 157–178.

Venkatesh, V., J. A. Aloysius, H. Hoehle, S. Burton, and S. M. Walton (2017). "Design and evaluation of auto-id enabled shopping assistance artifacts in customers' mobile phones: Two retail store laboratory experiments". In: *MIS Quarterly* 41.1, pp. 83–113.

Vince, J. (1998). "What is Virtual Reality?" In: *Essential Virtual Reality Fast: How to Understand the Techniques and Potential of Virtual Reality*. London: Springer, pp. 1–7.

Vinnikov, M., R. S. Allison, and S. Fernandes (2017). "Gaze-contingent auditory displays for improved spatial attention in virtual reality". In: *ACM Transactions on Computer-Human Interaction* 24.3, pp. 1–38.

Vrechopoulos, A. P., R. M. O'Keefe, G. I. Doukidis, and G. J. Siomkos (2004). "Virtual store layout: An experimental comparison in the context of grocery retail". In: *Journal of Retailing* 80.1, pp. 13–22.

Walsh, K. R. and S. D. Pawlowski (2002). "Virtual reality: A technology in need of IS research". In: *Communications of the Association for Information Systems* 8, pp. 297–313.

Wang, G. and A. Suh (2019). "User adaptation to cybersickness in virtual reality: A qualitative study". In: *Proceedings of the 27th European Conference on Information Systems (ECIS)*. Stockholm & Uppsala, Sweden, pp. 1–15.

Wang, W. and I. Benbasat (2005). "Trust in and adoption of online recommendation agents". In: *Journal of the Association for Information Systems* 6.3, pp. 72–101.

– (2008). "Attributions of trust in decision support technologies: A study of recommendation agents for e-commerce". In: *Journal of Management Information Systems* 24.4, pp. 249–273.

– (2009). "Interactive decision aids for consumer decision making in e-commerce: The influence of perceived strategy restrictiveness". In: *MIS Quarterly* 33.2, pp. 293–320.

Ware, C. and R. Balakrishnan (1994). "Reaching for objects in VR displays: Lag and frame rate". In: *ACM Transactions on Computer-Human Interaction* 1.4, pp. 331–356.

Ware, C. and K. Lowther (1997). "Selection using a one-eyed cursor in a fish tank VR environment". In: *ACM Transactions on Computer-Human Interaction* 4.4, pp. 309–322.

Ware, C. and J. Rose (1999). "Rotating virtual objects with real handles". In: *ACM Transactions on Computer-Human Interaction* 6.2, pp. 162–180.

Watson, B., N. Walker, L. F. Hodges, and A. Worden (1997). "Managing level of detail through peripheral degradation". In: *ACM Transactions on Computer-Human Interaction* 4.4, pp. 323–346.

Webster, J. and R. T. Watson (2002). "Analyszing the past to prepare for the future: Writing a literature review". In: *MIS Quarterly* 26.2, pp. xiii–xxiii.

Wedel, M., E. Bigné, and J. Zhang (2020). "Virtual and augmented reality: Advancing research in consumer marketing". In: *International Journal of Research in Marketing* (in press), pp. 1–23.

West, S. G., J. F. Finch, and P. J. Curran (1995). "Structural Equation Models with Nonnormal Variables: Problems and Remedies". In: *Structural Equation Modeling: Concepts, Issues, and Applications*. Ed. by R. H. Hoyle. Thousand Oaks: Sage Publications, pp. 57–75.

Westland, J. C. and G. Au (1997). "A comparison of shopping experiences across three competing digital retailing interfaces". In: *International Journal of Electronic Commerce* 2.2, pp. 57–69.

Witmer, B. G. and M. J. Singer (1998). "Measuring presence in virtual environments: A presence questionnaire". In: *Presence: Teleoperators and Virtual Environments* 7.3, pp. 225–240.

Witmer, B. G., C. J. Jerome, and M. J. Singer (2005). "The factor structure of the presence questionnaire". In: *Presence: Teleoperators and Virtual Environments* 14.3, pp. 298–312.

Wood, W. and D. T. Neal (2009). "The habitual consumer". In: *Journal of Consumer Psychology* 19.4, pp. 579–592.

Workman, M. (2014). "New media and the changing face of information technology use: The importance of task pursuit, social influence, and experience". In: *Computers in Human Behavior* 31, pp. 111–117.

Wu, J. and X. Lu (2013). "Effects of extrinsic and intrinsic motivators on using utilitarian, hedonic, and dual-purposed information systems: A meta-analysis". In: *Journal of the Association for Information Systems* 14.3, pp. 153–191.

Xiao, B. and I. Benbasat (2007). "E-commerce product recommendation agents: Use, characteristics, and impact". In: *MIS Quarterly* 31.1, pp. 137–209.

Xu, J. D., I. Benbasat, and R. T. Cenfetelli (2014). "The nature and consequences of trade-off transparency in the context of recommendation agents". In: *MIS Quarterly* 38.2, pp. 379–406.

Xu, P., D. Liu, and J. Lee (2018). "Mobile augmented reality, product sales, and consumer evaluations: Evidence from a natural experiment". In: *Proceedings of the 39th International Conference on Information Systems (ICIS)*. San Francisco, USA, pp. 1–9.

Yang, S. and G. Xiong (2019). "Try it on! Contingency effects of virtual fitting rooms". In: *Journal of Management Information Systems* 36.3, pp. 789–822.

Yang, S. B., J. H. Lim, W. Oh, A. Animesh, and A. Pinsonneault (2012). "Research note—Using real options to investigate the market value of virtual world businesses". In: *Information Systems Research* 23.3-part-2, pp. 1011–1029.

Yap, A. Y. and N. Bjoern-Andersen (1998). "Energizing the nexus of corporate knowledge: A portal toward the virtual organization". In: *Proceedings of the 19th International Conference on Information Systems (ICIS)*. Charlotte, USA, pp. 273–286.

Yi, C., Z. Jiang, and I. Benbasat (2015). "Enticing and engaging consumers via online product presentations: The effects of restricted interaction design". In: *Journal of Management Information Systems* 31.4, pp. 213–242.

Zahedi, F. M., N. Walia, and H. Jain (2016). "Augmented virtual doctor office: Theory-based design and assessment". In: *Journal of Management Information Systems* 33.3, pp. 776–808.

Zhang, Y., L. Liu, and S. Y. Ho (2020). "How do interruptions affect user contributions on social commerce?" In: *Information Systems Journal* 30.3, pp. 535–565.

Zhao, X., J. G. Lynch, and Q. Chen (2010). "Reconsidering Baron and Kenny: Myths and truths about mediation analysis". In: *Journal of Consumer Research* 37.2, pp. 197–206.

Zuckerberg, M. (2017). "Oculus Connect 4 | Day 1 Keynote [Video]". In: *YouTube (2017, October 12)*, last accessed 07/07/20, 5:20pm. URL: `https://www.youtube.com/watch?v=QAa1GjiLktc`.

Christian Peukert

Versicherung

gemäß § 13 Absatz 2 Ziffer 5 der Promotionsordnung des Karlsruher Instituts für Technologie (KIT) für die KIT-Fakultät für Wirtschaftswissenschaften

1. Einen erheblichen Verstoß gegen die Grundsätze guter wissenschaftlicher Praxis habe ich bislang nicht begangen.

2. Diesem Promotionsverfahren gingen keine anderen Promotionsverfahren voran und ich bin in keinen weiteren Promotionsverfahren Kandidat.

(3. Nicht zutreffend.)

4. Ein entgeltliches Vertragsverhältnis, das eine gewerbliche Promotionsberatung zum Gegenstand hat und zur Unselbstständigkeit zumindest einer Promotionsleistung führen kann, besteht bzw. bestand nicht.

5. Die „Regeln zur Sicherung guter wissenschaftlicher Praxis am Karlsruher Institut für Technologie (KIT)“ habe ich beachtet.

6. In die Dissertation wurden Vorveröffentlichungen und zur Veröffentlichung eingereichten Arbeiten einbezogen, bei denen ich im Rahmen einer Mitautorenschaft jeweils einen signifikanten Teil selbstständig erbracht habe. Eine Aufstellung mit den Angaben:

Autoren/Autorinnen:
Titel der Vorveröffentlichung:
Veröffentlicht in:

ist dieser Erklärung beigefügt. Die Aufstellung ist Bestandteil dieser Erklärung.

7. Die Dissertation oder Teile davon wurden nicht bei einer anderen Fakultät als Dissertation eingereicht.

8. Die Richtigkeit der vorstehenden Erklärungen bestätige ich.

Karlsruhe, den

____

Christian Peukert

Anlage: Aufstellung der Vorveröffentlichungen und zur Veröffentlichung eingereichten Arbeiten

Autoren/Autorinnen: Peukert, C., Pfeiffer, J., Meißner, M., Pfeiffer, T., Weinhardt, C.
Titel der Vorveröffentlichung: “Shopping in virtual reality stores: The influence of immersion on system adoption”
Veröffentlicht in: *Journal of Management Information Systems*, 36(3), 755-788, 2019.

Autoren/Autorinnen: Peukert, C., Pfeiffer, J., Meißner, M., Pfeiffer, T., Weinhardt, C.
Titel der Vorveröffentlichung: “Acceptance of imagined versus experienced virtual reality shopping environments: Insights from two experiments”
Veröffentlicht in: In *Proceedings of the 27th European Conference on Information Systems (ECIS)*, Stockholm & Uppsala, Sweden, 2019.

Autoren/Autorinnen: Peukert, C., Brossok, F., Pfeiffer, J., Meißner, M., Weinhardt, C.
Titel der Vorveröffentlichung: “Towards designing virtual reality shopping environments.”
Veröffentlicht in: In *Conference Booklet of the 13th International Conference on Design Science Research in Information Systems and Technology (DESRIST)*, Chennai, India, 2018.

Autoren/Autorinnen: Peukert, C., Lechner, J., Pfeiffer, J., Weinhardt, C.
Titel der Vorveröffentlichung: “Intelligent invocation: Towards designing context-aware user assistance systems based on real-time eye tracking data analysis.”
Veröffentlicht in: In Davis F., Riedl R., vom Brocke J., Léger PM., Randolph A., Fischer T. (eds) *Information Systems and Neuroscience (NeuroIS Retreat 2019)*, 32, 73-82, Springer, Cham, 2020.