International Journal of Human – Computer Studies 101 (2017) 76–87

Contents lists available at ScienceDirect

Int. J. Human–Computer Studies

journal homepage: www.elsevier.com/locate/ijhcs

Being there again – Presence in real and virtual environments and its relation to usability and user experience using a mobile navigation task

Jennifer Brade[a,1], Mario Lorenz[a,b,1,*], Marc Busch[c], Niels Hammer[d,e], Manfred Tscheligi[c], Philipp Klimant[a]

[a] Technische Universität Chemnitz, Professorship for Machine Tools and Forming Technology, Reichenhainer Straße 70, 09126 Chemnitz, Germany
[b] University Hospital Leipzig, Department of Orthopedics, Trauma and Plastic Surgery, Liebigstrasse 20, 04103 Leipzig, Germany
[c] Austrian Institute of Technology GmbH, Innovation Systems, Donau-City-Str., 1 1220 Vienna, Austria
[d] University of Otago, Department of Anatomy, Clinical Anatomy Group, 270 Great King Street, Dunedin 9054, New Zealand
[e] University of Leipzig, Department of Anatomy, Liebigstraße 13, 04103 Leipzig, Germany

A R T I C L E I N F O

Keywords:
Presence
User studies
Usability
User experience
Vitual reality
Mobile devices

A B S T R A C T

The possibility of using virtual environments instead of real field or laboratory environments is a promising research field. However, before virtual environments are able to replace the traditional environments the differences between the methods must be worked out. We take up on previous studies which compared different real and virtual environments concerning presence and usability and expand the research on the factor of user experience. We compared a virtual field environment (CAVE – Cave Automatic Virtual Environment) and a real field environment (city center of Chemnitz, Germany) in a between-subject-design concerning presence, and evaluate its impact on the usability and the user experience of a geocaching game. The data of 60 participants was analyzed and shows significantly higher ecological validity for the real field environment but higher values for engagement and negative effects in the virtual field environment. Concerning usability, significant differences were verified between the two environments. All presence factors correlated significantly with usability in the CAVE, but did not correlate in the real-field environment. Concerning user experience, the CAVE showed significantly higher hedonic quality values, whereas the real field environment had higher pragmatic quality values. In both conditions presence and user experience factors were partly correlated. Our results indicate that virtual environments can be an alternative to real environments for user experience studies, when a high presence is achieved.

1. Introduction

Technical inventions such as interactive maps are increasingly enriching our lives. These applications do not only show the places of interest, but they also track the user's position, provide the best local traffic route, reveal which restaurant is nearby and how other users rated it. However, comprehensive information is not satisfactory for the user. Two factors – usability and user experience (defined in Table 1) – are essential for interactive products and therefore for mobile navigation applications. Both factors determine the success of a product, because a good usability supports us when using applications and a good user experience leads to using an application with pleasure.

Typically, researchers conduct field or laboratory studies to get products or systems evaluated by users. Both of these settings exhibit different strengths and weaknesses: field studies are more ecologically valid but confounding variables can be less controlled, whereas laboratory studies are characterized by better experimental control, but are less realistic to participants. The use of virtual environments offers the possibility to combine the benefits of both environments (Loomis et al., 1999). Due to advances in the field of virtual reality (VR), a variety of systems are providing a lot of different options for human computer interaction studies. However when using such VR systems for these kinds of studies, they have to meet high requirements concerning realistic visualization and a plausible storytelling. Without a convincing presentation of the setting, the user will not have the feeling of being in the mediated environment and the benefits of the virtual setting compared to laboratory or field studies are nullified. This phenomenon is described by the term "presence", the participant's

* Corresponding author at: Technische Universität Chemnitz, Professorship for Machine Tools and Forming Technology, Reichenhainer Straße 70, 09126 Chemnitz, Germany.
E-mail addresses: jennifer.brade@mb.tu-chemnitz.de (J. Brade), mario.lorenz@mb.tu-chemnitz.de (M. Lorenz), marc.busch@ait.ac.at (M. Busch), nlshammer@googlemail.com (N. Hammer), manfred.tscheligi@ait.ac.at (M. Tscheligi), philipp.klimant@mb.tu-chemnitz.de (P. Klimant).

[1] Equal contributors.

http://dx.doi.org/10.1016/j.ijhcs.2017.01.004
Received 25 March 2016; Received in revised form 13 September 2016; Accepted 23 January 2017
Available online 26 January 2017
1071-5819/

Table 1
Definition of the factors usability, user experience and presence.

Factor	Definition
Usability	Usability describes the fitness of use of a product and summarizes pragmatic aspects of the product or system. Contrary to user experience, usability does not respect hedonic quality aspects.
User experience	User experience is characterized as "a person's perceptions and response that result from the use or anticipated use of a product, system or service" (Law et al., 2009). User experience includes the holistic assessment of the user because it extends common usability factors with aesthetics, joy-of-use and attractiveness (Rauschenberger et al., 2013).
Presence	Presence is described as the "sense of being in the virtual environment" and is seen as a cognitive state that results from information processing of stimuli in the environment from various senses (Slater and Wilbur, 1997).

feeling of "being there" (Barfield et al., 1995) (see Table 1).

Because of the advantages of virtual environments, it might be reasonable to use them instead of field or laboratory environments for product evaluation studies. However, we must first examine the influence of the environment on the perceived presence. Some studies research the concept of presence in different virtual environments (Gorini et al., 2011; Lorenz et al., 2015; Tang et al., 2004), whereas others compare virtual and real environments concerning perceived presence (Busch et al., 2014; Mania, 2001; Mania and Chalmers, 2004; Nisenfeld, 2003; Usoh et al., 2000). But only one study by Busch et al. (2014) directly addressed influences on presence and usability caused by different environments (virtual versus real laboratory). Unfortunately, this study lacks the comparison of virtual and real laboratory environments in terms of user experience, as well as the evaluation of a real field environment. As described in Table 1 it is insufficient to consider usability alone and it is also important to compare both kinds of environments with virtual environments to make meaningful statements. In addition, in this said study investigating usability, user experience was not considered. Only the fitness of use was assessed but not the acceptance.

Our study tries to approach the fundamental understanding of the relationships between presence, usability and user experience by examining them using a mobile navigation task in a virtual and a real field environment. Our results were in line with previous studies (Busch et al., 2014) and confirmed that a virtual field environment may be used as a substitute for a field environment even if the influences of presence have to be considered. The results showed a positive connection of a virtual field environment and hedonic qualities and confirmed the effect of usability on perceived presence. We offer guidance for usability and user experience researchers and practitioners for performing virtual user experience and usability product evaluations and discover important factors that have to be considered for the interpretation of the results.

The results presented in this paper are part of larger study and relevant for different scientific areas. The parts of the results that are important for an industrial/ergonomic viewpoint were cited in (Brade et al., 2016), where we concentrated on discussing the benefits virtual reality offers for the user. In (Brade et al., 2016) we show how traditional industrial approaches for product development can benefit from using virtual environments in industrial product development to increase productivity. Contrary to this, the results are interpreted from the psychological viewpoint in this paper.

2. Related work

2.1. Presence in real and virtual environments

Virtual reality provides the possibility to immerse someone into a computer-generated environment. To understand the differences between the technical aspects necessary to immerse someone, and a person's psychological involvement in a virtual scenario it is important that one understands the differences between the terms immersion and presence and how they are related. Slater and Wilbur (1997) define immersion as "a description of a technology, and describes 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". Whereas presence is described as in Table 1. The perceived presence is therefore influenced by the level of immersion in different virtual environments. Coelho et al. (2006) divides the concept of presence into media and inner presence; the experience of presence resulting from a set of parameters of a medium that enables the virtual environment, is known as media presence. This technological definition disregards the involvement of psychological components; therefore they are included in the definition of inner presence: which is the psychological experience of the virtual environment, including human perception, cognition and psychomotor capacities. For our study we relate to the concept of inner presence as we examine the psychological experience.

In order to measure presence, Schuemie et al. (2001) list several methods that can be divided into subjective (using questionnaires) and objective measures, with post-experiment questionnaires being the most common approach for assessment. One of the most validated questionnaires, the Independent Television Commission Sense of Presence Inventory (ITC-SOPI) by Lessister et al. (2001), has been used previously within the literature (Busch et al., 2014; Usoh et al., 2000; Nisenfeld, 2003; Tang et al., 2004; Gorini et al., 2011) and was shown to produce reliable results.

Several studies have researched the effects of presence in virtual environments: Gorini et al. (2011) compared the effects of using an external computer screen with a virtual environment that utilized a head-mounted display (HMD) when assessing presence in a virtual hospital task. Presence values were significantly higher for all items of the questionnaires ITC-SOPI and University London College Questionnaire (UCL) (Slater et al., 1994) in the immersive HMD condition. Comparatively, Tang et al. (2004) also utilized a HMD, but compared it with an augmented reality (AR) environment and showed significantly higher values for the presence factor *sense of physical space* for the AR environment. However, there were no significant differences concerning the other factors of the ITC-SOPI questionnaire.

The study of Usoh et al. (2000), which was extended by Nisenfeld (2003), also compares a HMD virtual environment with a real environment. The authors assessed presence by using the ITC-SOPI questionnaire and found significantly higher presence values for the real environment as well as a significantly increased, sense of physical space and ecological validity. Simultaneously, significantly higher values for the negative effects scale for the virtual environment were recorded. This study is very relevant for our work, but disregarded the examination of user-oriented factors between real and virtual environments. Another study that assessed presence and usability when comparing a laboratory environment with a specific type of virtual field environment, the five-sided Cave Automatic Virtual Environment (CAVE), is the work of Busch et al. (2014). The differences between the environments concerning usability (assessed with the System Usability Scale (SUS) by Brooke (1996)) and presence (measured with the ITC-SOPI questionnaire) showed significantly higher values for engagement and the negative effect scale for the virtual field environment. Similarly, significantly higher values for the ecological validity scale in the real laboratory environment were observed. The authors did not find significant differences concerning usability between the two conditions, but they found correlations between the presence factors and the usability for both environments. The sense of physical space was positively associated with usability in both environments. Furthermore, engagement and negative effects also correlated significantly in the virtual field environment, while ecological validity correlated significantly with usability in the real laboratory environment. These results are most relevant for our present work, because Busch et al. (2014) examined the connection of presence and usability in different environments for the first time. However, they only addressed the pragmatic quality of a product and left out the important factor of user experience.

2.2. User experience in virtual environments

All relevant aspects for the subjective assessment of a product are summarized by the term "user experience" (Hassenzahl and Tractinsky, 2006) (see Table 1). The assessment of user experience for interactive products in real field and laboratory studies has become very common. However, the evaluation of user experience in virtual environments has not yet been undertaken. Using virtual environments for user experience evaluations may lead to better/improved cost efficiency and simultaneously require less effort for the technical scenario setup than field or laboratory environments, but before these benefits eventuate, it is necessary to prove the ecological validity of evaluations in virtual environments. Until now, few studies have recognized the importance of investigating user experience in virtual environments: Sylaiou et al. (2010) conducted a mixed reality usability study with 29 participants to examine the relationship between presence and enjoyment. Comparing a museum visit in an AR environment with a real environment, the results showed a significant correlation between enjoyment and presence and a high level of presence was associated with satisfaction and gratification. These findings support a decision to choose a highly immersive virtual environment to reach a high presence to increase the positive feelings of the user during the task performance.

Albrecht et al. (2013) compared a mobile AR learning environment (mARble) with a real learning environment – a textbook. They conducted a study with ten students and measured learning success, usability, and pragmatic and hedonic quality. The assessment analysis showed that the AR supported learning group could acquire more knowledge and had significantly more positive ratings concerning hedonic quality when compared to the control group (no AR support); however, no significant differences for pragmatic quality were observed. Moreover, the results of this study should be interpreted with caution due to the small number of participants. Finally, a meta-analysis Patel and Nichols (2004) addressing presence, usability and enjoyment in different VR systems (including a CAVE, Powerwall, HMD and desktop systems) has shown that desktop systems are less enjoyable than HMDs and projective systems while the CAVE is deemed the most pleasurable system. The authors also found a significantly positive correlation between presence and enjoyment.

2.3. Usability in different environments

One part of user experience is the term usability (see Table 1). Comparative studies in laboratory, field and virtual environments show conflicting findings concerning usability. Kaikkonen et al. (2005) did not find significant differences between the number, or severity of these usability problems, or task performance time between laboratory and field environments. Similar results were presented by Busch et al. (2014) who compared a real laboratory environment with a virtual field environment in terms of usability and learnability. They used the SUS questionnaire and showed no significant differences between the environments. This is in line with Patel and Nichols (2004) who reported quite similar usability scores for different VR-systems. All of the aforementioned studies report no differences in usability between the environments; however, no comparisons are made to a real field environment.

In contrast, Duh and Chen (2006) detected significantly more usability problems and longer task performance times in the field environment compared to the laboratory environment. Additionally, participants in the field conditions showed more negative behavior. Sun and May (2013) also detected more negative behavior in the field setting, but no significant differences in the number of usability problems between the field and laboratory environments. In contrast to these a study on mobile systems comparing the laboratory and field by Kjeldskov et al. (2004) reported significantly more usability problems in the laboratory. Furthermore, they divided them into three categories: critical, serious and cosmetic problems. There were no significant differences in critical problems, but significant differences in serious and cosmetic problems between the conditions were evident.

The presented overview of studies shows inconsistent findings concerning the kind of environments, the evaluation techniques and the factors that were examined. Therefore, more research is necessary to give meaningful statements on the influence of different environments on presence and their relationship to usability and user experience.

3. Experimental method

3.1. Research questions and hypotheses

The discussed related studies clearly demonstrate the need to examine presence, usability and user experience in VR in comparison to a real field environment, as this has not been done before. We compared two kinds of field environments (real and virtual) and investigated whether significant effects on reported presence, usability and user experience were evident (H1). We used a mobile navigation application as the evaluation scenario. Table 2 gives a detailed overview of the used environment, technical setup and dependent variables.

In addition we wanted to investigate whether the reported presence has a significant influence on the reported user experience and usability (H2, H3). We therefore expected the following scenarios:

H1: The environment will significantly affect presence.

Based on previous work (Busch et al., 2014; Nisenfeld, 2003; Usoh et al., 2000), it is expected that the presence factors, sense of physical space, engagement, and ecological validity will be significantly higher in the real field environment, while negative effects will be significantly higher in the virtual field environment.

H2: The real field experiment will offer a higher usability rating than the virtual field environment.

Supported by previous studies that show a lower performance (de Kort et al., 2003) and more negative effects in a virtual environment (Busch et al., 2014; Toet and van Schaik, 2012), we expect that a real field environment will generate a higher usability. Based on earlier work (Busch et al., 2014), where some presence factors and the SUS were associated, we expect that there will be a positive association between presence factors and the SUS.

H3: The real field experiment will offer a higher user experience rating

Table 2
Overview of environments, setup and variables.

	Virtual	Real
Environment	Field environment	
Technical setup	Five-side CAVE	Real city
Dependent variables	Subjective presence of environment Usability and user experience of a mobile application	

than the virtual field environment.

As we expect differences in presence in the two environments and more negative effects in the virtual field environments, we expect different results in the user experience too. We hypothesize significant positive associations between presence factors and the user experience in both environments.

Finally, once these hypotheses have been verified, we aimed to identify the influencing factors on usability and user experience that occur in virtual field environments compared to real field environments. This shall allow others who are conducting usability and user experience studies in virtual field environments to assess the correctness of their findings. We want to increase the confidence in their found results by identifying the factors that may bias their findings and therefore helping them prevent false conclusions.

3.2. Setup and mechanics of the study

The hypotheses were tested in a between-subject study with the environment as the independent variable (Brade et al., 2016). Participants were randomly assigned to one of two groups where they had to complete specific tasks in either a real field environment or a virtual field environment. Eleven dependent variables were recorded: four presence factors (sense of physical space, engagement, ecological validity and negative effects), measured with the ITC-SOPI questionnaire, together with seven user experience factors (attractiveness, perspicuity, efficiency, dependability, stimulation and novelty) measured with the User Experience Questionnaire (UEQ) (Laugwitz et al., 2008), and usability measured with the SUS. We used the same questionnaires in both environments to ensure comparability, and to obtain baseline data for presence in reality, as some participants might get sick from looking at the mobile whilst walking, that would reflect in higher negative effect.

The study itself consisted of three parts (Brade et al., 2016): pre-assessment, main study and post-assessment. In the pre-assessment, we collected demographic variables (age, gender and education) as well as a self-assessment of the participant's own sense of orientation and spatial ability. The main study comprised a geocaching game with a smartphone application in the real or virtual city center of Chemnitz, Germany. All users had to solve the same seven tasks in the same order. Afterwards, we assessed the dependent variables in the post-assessment with post-test questionnaires, where the participants were asked to only rate the used geocaching application and not the system as a whole. All participants received financial compensation (5 €) or course credits for their participation.

To reduce unsystematic variances in the performance of the study we used a study protocol that exactly defined the proceedings. In this protocol we noted all deviations and remarks the participants made while they were completing the tasks and registered confounding variables in the real field study.

3.3. Geocaching game in both environments

In the main part of the study the participants had to play a geocaching game using a smartphone (Google Nexus) which guided them through the real or the virtual city center of Chemnitz, Germany. To program the game we used the Actionbound app from Zwick and Rauprich (2016). This app is designed to create individual city rallies or scavenger hunts for smartphones and tablets, for discovering a city or other places. They are created using a web interface and then shared with others via a Quick Response (QR) Code or the app integrated public tour collection. The Actionbound app offers a variety of different game elements like maps, a compass, pictures, videos quizzes or QR codes. Our geocaching game consisted of seven places that the users had to visit over a total distance of 1.7 km. To track the participant's position, the Global Positioning System (GPS) signal of the smartphone was used, comparing the coordinates of the sought location with the participant's position for every location. A map (left part of Fig. 1) displaying the city center, the present position and the location of the next place was used for navigation. Upon arrival at the next place the participants saw a confirmation message (middle part of Fig. 1) and the coordinates of the following place were unlocked (right part of Fig. 1) (Brade et al., 2016). This procedure, pictured in Fig. 1 was the same for every location.

In the virtual field environment we made use of the functionalities of the VR software instantreality developed by the Fraunhofer-IGD (2016) to simulate the GPS signal for the Actionbound app. These GPS coordinates were then transmitted to the Fake GPS Location app (Lexa, 2016) which forwarded them via an android debug bridge port to the Google Nexus smartphone.

3.4. Independent variables: virtual versus real field environment

3.4.1. CAVE

To compare the real field environment with a highly immersive virtual field environment we decided to conduct the study in a CAVE (see left part of Fig. 2 and left part of Fig. 3). Slater and Wilbur (1997) documented that the level of immersion that a person experiences in a VR environment has a major influence on the reported presence. A highly immersive CAVE is therefore the preferred option for our study. The CAVE we used is located at Technische Universität Chemnitz. This five-sided CAVE, with an edge length of three meters, is based on the principles described by Cruz-Neira et al. (Cruz-Neira et al., 1993, 1992). Passive circular polarization is used to achieve stereoscopic vision. The images are computed by a cluster of 10 computers that are equipped with NVidia Quadro 6000 graphic cards. One additional control computer manages the synchronization of the cluster. The images for each side of the CAVE are displayed using rear-projection of 20 full HD projectors with passive polarization. One pair of projectors displays the upper half-image and a second pair displays the lower half-image. Edge blending is applied to adjust the light intensity in the overlapping areas. In order to track the position of the user inside the CAVE we used a passive optical infrared tracking system by ART with six cameras. The static virtual model of the city center of Chemnitz, Germany resulted from an architectural project. The model contained no sound.

All interactions with the virtual field environment were performed using gesture based navigation and the simulated GPS tracking of the smartphone. The gesture based navigation was implemented using the Microsoft Kinect system, developed by Lorenz et al. (2015). It allows the user to navigate through the virtual world in a standing position without having to wear additional devices. The gestures used for navigation are intended to come as close to natural walking as possible. To move forward the participants have to put the right foot in front, to move backwards they have to set it back. For rotation they have to turn their shoulders into the direction they want to turn; moving forward/backward and turning can be done simultaneously. After a short demonstration by the experimenter, the participants adopted the movements quickly.

3.4.2. Real field environment

The study in the real field environment was held in the city center of Chemnitz, Germany (see right part of Fig. 2 and right part of Fig. 3) In contrast to the virtual field environment, participants completed the geocaching game in the real field environment without the physical presence of the experimenter. Having the experimenter following the participants might have influenced how they behave and would therefore be a severe cofounder. In case of problems, the participants could call the experimenter and solve them by phone.

In the following sections we use the term **CAVE** for the virtual field environment and **real city** for the real field environment.

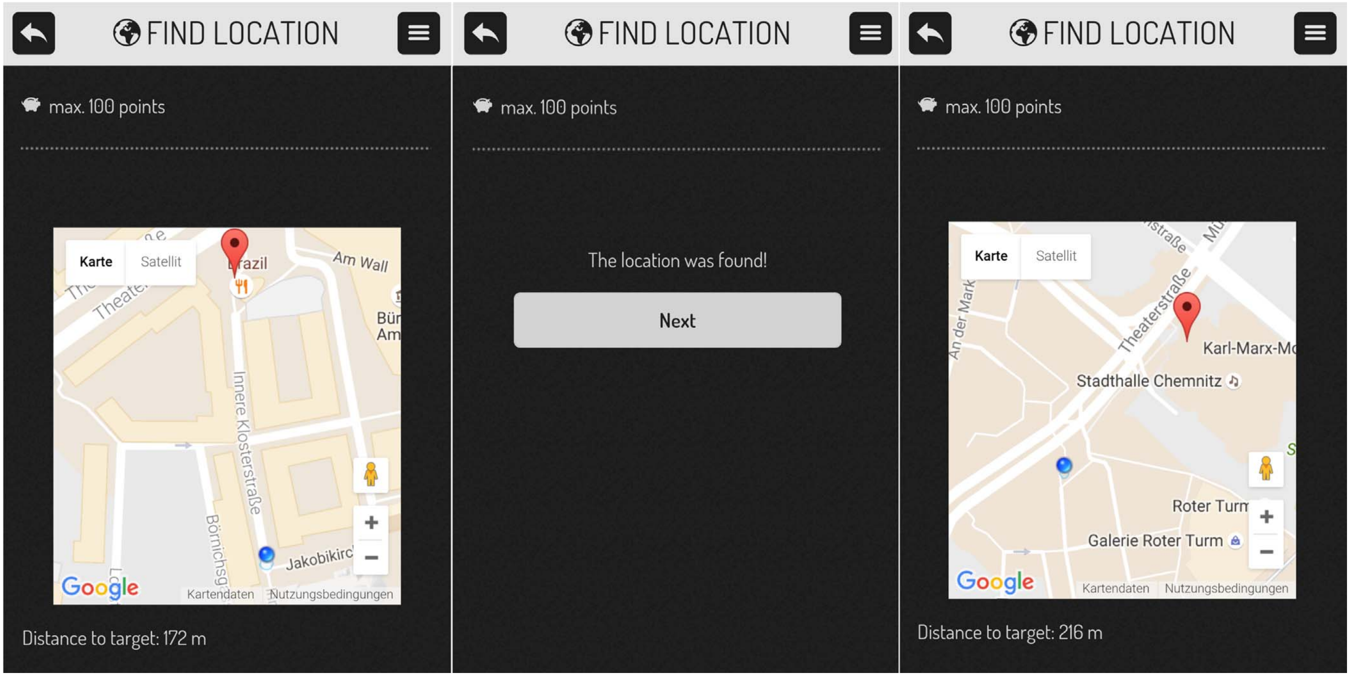

Fig. 1. Location 3 and 4 of the geocaching game.

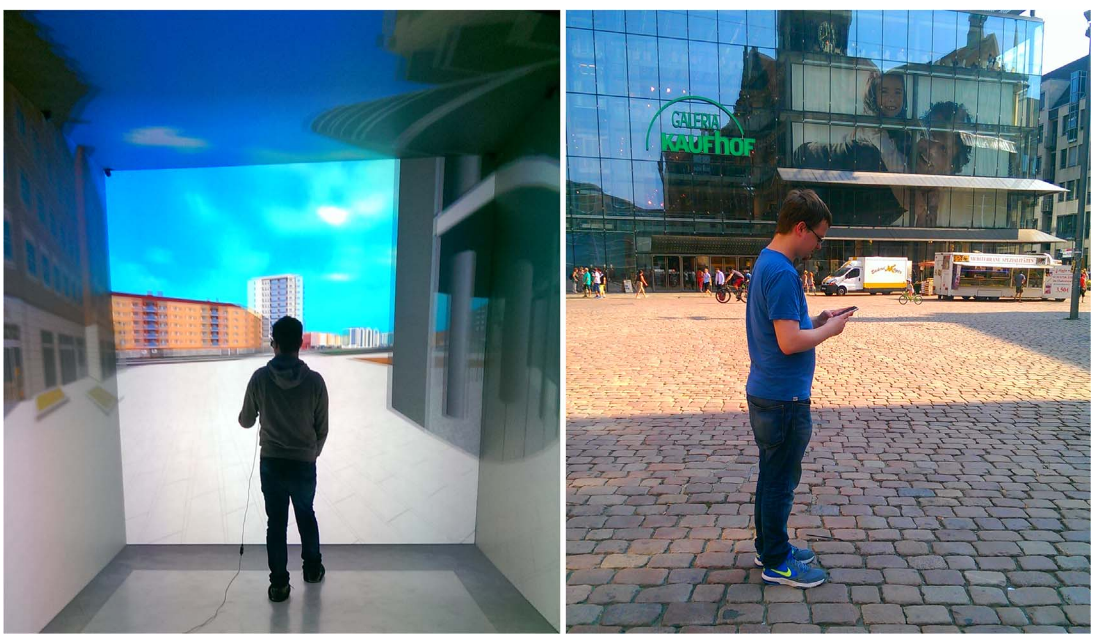

Fig. 2. Participant in the virtual field environment – CAVE (left) and in the real field environment (right).

Fig. 3. The shopping center Galerie Roter Turm in the virtual field environment (left) and in the real field environment (right).

3.5. Dependent variables: presence, user experience and usability

In both environments we measured the dependent variables: presence, user experience and usability.

3.5.1. Presence

We assessed the perceived presence with a shortened version of the ITC-SOPI (Lessister et al., 2001), which included only 12 instead of 44 items. The four factors, sense of physical space, engagement, ecological validity and negative effects were measured by the three top loading items per scale.

- *Sense of physical space:* indicates "a sense of physical placement in the mediated environment, and interaction with and control over parts of the mediated environment" (Lessister et al., 2001).
- *Engagement:* includes the "user's involvement and interest in the content of the displayed environment, and their general enjoyment of the media experience" (Lessister et al., 2001).
- *Ecological validity:* evinces the believability and the realism of the content as well as the naturalness of the environment (Lessister et al., 2001).
- *Negative effects*: summarizes "adverse physiological reactions" (Mania and Chalmers, 2004) e.g. motion sickness, dizziness of virtual environments.

The participants were asked to rate on a five-point Likert scale.

3.5.2. User Experience

One of the best validated questionnaires for assessing user experience is the UEQ by Laugwitz et al. (2008), which is why we choose it for our study. The UEQ contains 26 bipolar items divided into the following 6 scales:

- *Attractiveness*: characterizes the participants general impression towards the product
- *Perspicuity:* describes how difficult it is to understand how to use the product
- *Efficiency:* outlines the ability to use the product fast and efficiently
- *Dependability:* addresses the feeling of having control over the system
- *Stimulation:* describes how interesting and exciting the product is for the user
- *Novelty:* evaluates the products innovation and creativity

Besides attractiveness as a pure stance dimension, the scales are addressing two kinds of quality perception – pragmatic and hedonic quality. Pragmatic quality, described by the factors perspicuity, efficiency, and dependability, covers task-oriented quality aspects – typically usability factors as described above. In contrast, hedonic quality is characterized by the factors stimulation and novelty. Attractiveness is described by non-task oriented quality aspects, which should evoke emotion and a relationship to the product. The scales were assessed by a seven-point semantic differential.

3.5.3. Usability

The ten-item SUS (Brooke, 1996) was used to measure the perceived usability of the system. The rating of each statement was made on a five-point Likert scale.

3.6. Statistical methods

To evaluate the questionnaires we used non-parametric methods for the significance tests and the correlations. We conducted a Mann-Whitney test (unpaired two sample test) with the Monte Carlo method and present the one-tailed significance values (as our hypotheses are directed) in the result section. For the connection between the dependent variables Spearmans correlations were calculated. In both significance tests and correlations, the statistical significance was set at $p < 0.05$. Cohen's conventions were used to interpret size effect (r) for significant effects and correlations. A value of ± 0.10 represents a small effect, a value over ± 0.30 a medium effect and a value over ± 0.50 a large effect.

Beside the named dependent variables, we also collect data of the spatial ability, because it is important for the navigation task. Therefore we used the cube perspective test by Stumpf and Fay (1983), to determine if the spatial ability has an influence on the dependent variables. The data of the participants spatial ability was collected with an online application during the pre-assessment.

3.7. Sample

We analyzed the data of 60 participants, 31 participants in the virtual field environment and 29 participants in the real field environment. The sample mainly contained students of the Technische Universität Chemnitz (76.7%). In the CAVE condition 58.1% and in the real field environment 62.1% of the participants were female, and both groups had similar mean participant age (CAVE: 25.5 (SD=7.18); real city: 25.7 (SD=4.22)). Fig. 4 compares the participants' particulars between environments concerning self-assessment of their own sense of orientation and the variation in their previous experience with virtual reality systems (Powerwall, HMD, CAVE) and geocaching games.

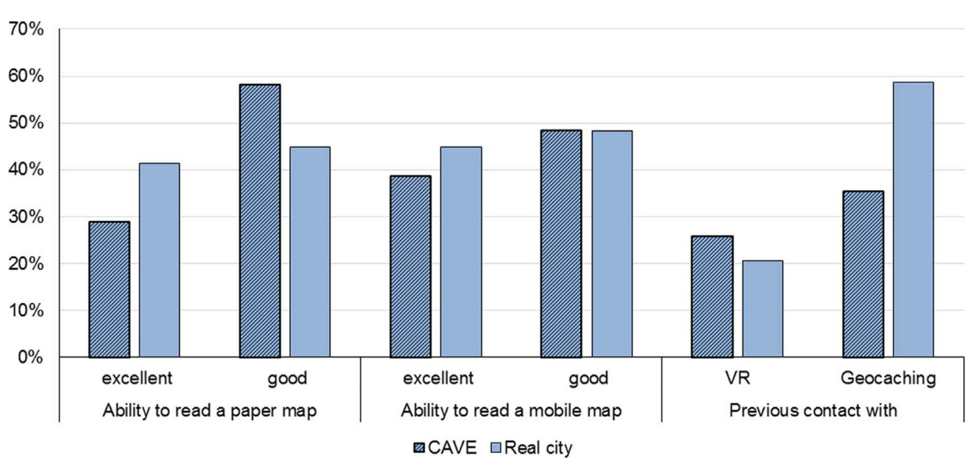

Fig. 4. Results of the self-assessment of participants' own sense of orientation and the variation in their previous experiences with virtual reality systems and geocaching games.

4. Results

In this section we present all the results from the study to later interpret them from the psychological viewpoint. The parts of the results relevant for the discussion of industrial/ergonomic impact were reported in a condensed form in (Brade et al., 2016).

4.1. Psychometric properties of the scales

The internal consistency of the psychometric scales was measured using Cronbach's alpha (CA) where a score over 0.7 indicated an acceptable internal consistency of the scale. The CA values for the scales of the ITC-SPOI, UEQ and SUS are listed in Table 3.

The CA values for nine of the 11 scales are higher or close to 0.7 and can therefore be seen as sufficient. The scales of efficiency and dependability (See Table 3) show a low CA value of 0.42 and 0.47. This may be explained by misinterpretation of the scales by the participants. Such interpretational problems are already reported as a possible reason for a small CA (Rauschenberger et al., 2013). Both scales will be used for further data analysis, but are to be interpreted with caution.

4.2. Effects of Sample Characteristics

To identify the influence of the spatial ability on the dependent variables we compared the results of the cube perspective test between the environments and calculated correlations of the spatial ability and the dependent variables: A pair-wise comparison between the CAVE and the real field environment showed no significant differences between the environments [U=435.5, p=0.42]. There was also no significant correlation between the results of the cube perspective tests and the presence factors, or the user experience factors. The association between the spatial ability and the usability was not significant in the real field environment, but there was a positive correlation for these factors in the CAVE (r=0.37). The influence of the spatial ability is therefore not notable and may be disregarded.

4.3. Differences in presence between the environments

Table 4 presents the means, standard deviations and medians (gray) of the four presence factors in each environment. Fig. 5 shows the means of the presence factors as bar charts. In the CAVE the means of engagement and negative effects are higher, whereas the means of sense of physical space and ecological validity are higher in the real field environment.

Significant differences between 3 of the 4 presence factors in the environments could be found. There were significant differences in the engagement scale [U=306.5, p=0.016, r=−0.28], the ecological validity scale [U=261.0, p=0.002, r=−0.36] and the negative effects scale [U=163.0, p=0.000, r=−0.56], but not for the sense of physical space scale [U=367.0, p=0.11].

Table 3
Cronbach's alpha measures for the ITC-SOPI, SUS and UEQ psychometric scales.

	Scale	CA
ITC-SOPI	Sense of physical Space	0.71
	Engagement	0.79
	Ecological validity	0.67
	Negative effects	0.62
SUS	Usability	0.62
UEQ	Attractiveness	0.87
	Perspicuity	0.64
	Efficiency	0.42
	Dependability	0.47
	Stimulation	0.79
	Novelty	0.85

Table 4
Means, (standard deviations) and medians (in gray) of the presence scales (rated from 1 to 5) for the two environments.

	CAVE	Real city
Sense of physical space	3.34 (0.89)	3.69 (0.85)
	3.67	3.67
Engagement	4.15 (0.73)	3.72 (0.87)
	4.33	4.00
Ecological validity	3.35 (0.69)	3.91 (0.91)
	3.33	4.00
Negative effects	2.09 (0.86)	1.24 (0.38)
	1.67	1.00

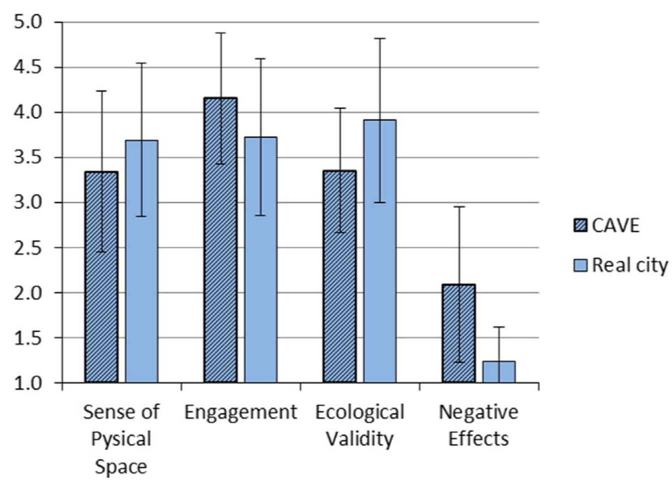

Fig. 5. bar charts of the means of the presence factors (rated from 1 to 5) for the two environments with error bars showing standard deviations.

Table 5
Means, standard deviations (white) and medians (gray) of the SUS scale in %for the two environments.

	CAVE	Real city
Usability	82.98 (9.23)	89.57 (5.43)
	85.00	90.00

4.4. Differences in usability between the environments

In Table 5 the means, standard deviations and the medians (gray) for the factor usability in both environments are shown. Based on the interpretation of the SUS score by Bangor et al. (2009) our usability results range from good (CAVE) to excellent (real city). A pair-wise comparison between CAVE and the real field environment shows significant differences in usability [U=254.5, p=0.001, r=−0.37].

4.5. Differences in user experience between the environments

Table 6 presents the means, standard deviations and the medians (gray) with the means of the user experience factors presented in Fig. 6. The means of the attractiveness, efficiency, stimulation and novelty scales are higher in the CAVE. On the other hand, the means of the perspicuity and dependability scales are higher in the real field environment.

There were significant deviations between the environments concerning the dependability [U=201.5, p=0.00, r=−0.48], novelty [U=144.5, p < 0.000, r=−0.58] (higher in CAVE) and stimulation [U=272.0, p=0.005, r=−0.34] (higher in the real city). The test shows

Table 6
Means, (standard deviations) and medians (gray) of the UEQ scales (rated from −3 (low) to 3 (high)) for the two environments.

	CAVE	Real city
Attractiveness	1.73 (0.75)	1.46 (0.03)
	1.67	1.67
Perspicuity	2.01 (0.66)	2.21 (0.79)
	2.00	2.50
Efficiency	1.28 (0.61)	1.07 (0.81)
	1.25	1.00
Dependability	1.05 (0.76)	1.79 (0.68)
	1.00	1.75
Stimulation	1.82 (0.91)	1.12 (0.89)
	2.00	1.50
Novelty	1.62 (0.86)	0.16 (1.15)
	1.50	0.00

no significant differences for the three remaining scales: attractiveness [U=386.5, p=0.174], perspicuity [U=359.0, p=0.088] and efficiency [U=382.5, p=0.157].

4.6. Influence of presence on usability and user experience

To find out if the presence factors were associated with the usability and the user experience factors, the correlations, shown in Table 7 and Table 8 were calculated. Overall there were more significant correlations in the CAVE than in the real field environment. In both environments attractiveness was associated with sense of physical space (sense), engagement (eng) and ecological validity (eco). Furthermore, stimulation and engagement were significantly correlated, in both environments. For the negative effects (neg) scale there were two significant correlations for the virtual environment but only one for the real environment.

The association between usability and the presence factors, showed low and insignificant findings in the real field environment. However, all presence factors correlate significantly with usability in the CAVE. The higher the sense of physical space, engagement and the ecological validity, the higher the participants rate the usability of the system. The scales of negative effects and usability show a negative association, so that the lower the negative effects, the higher the reported usability.

Table 7
Spearmans correlations of the UEQ-factors and the SUS with the presence factors for the virtual field environment (significant correlations are made bold).

	Sense	Eng	Eco	Neg
Attractiveness	**0.65**	**0.84**	**0.61**	−0.14
Perspicuity	**0.32**	**0.42**	**0.49**	**−0.36**
Efficiency	**0.44**	**0.46**	**0.32**	−0.11
Dependability	**0.32**	0.28	**0.65**	**−0.49**
Stimulation	**0.49**	**0.46**	**0.45**	−0.09
Novelty	**0.42**	**0.31**	0.28	0.20
Usability	**0.36**	**0.53**	**0.42**	**−0.50**

Table 8
Spearman's correlations of the UEQ-factors and the SUS with the presence factors for the real field environment (significant correlations are made bold).

	Sense	Eng	Eco	Neg
Attractiveness	**0.49**	**0.67**	**0.37**	0.26
Perspicuity	0.23	−0.12	0.25	−0.18
Efficiency	0.13	0.28	−0.01	0.10
Dependability	0.25	−0.04	−0.03	0.11
Stimulation	0.23	**0.63**	0.25	**0.33**
Novelty	0.28	**0.57**	0.19	0.20
Usability	0.10	0.19	0.07	0.20

4.7. Presence in virtual and real field environments compared to real laboratory environment

In addition to the comparison between the virtual and the real field environments concerning the perceived presence, we compared the results with the findings of Busch et al. (2014).

Fig. 7 shows the results of both studies in terms of presence. Both virtual environments are very similar at all four presence scales furthermore the two real environments have quite similar results. In addition, the differences named in Section 4.3 are in line with the comparison of virtual and laboratory environments.

4.8. Duration of task completion

The time to complete the geocaching task differed between the real and the virtual field environment. On average, the geocaching game in the virtual field environment lasted for 14 min and in the real field environment for 20 min. This difference can be explained by the maximum speed in the CAVE. The maximum speed of movement in the virtual environment is comparable with going jogging. The majority

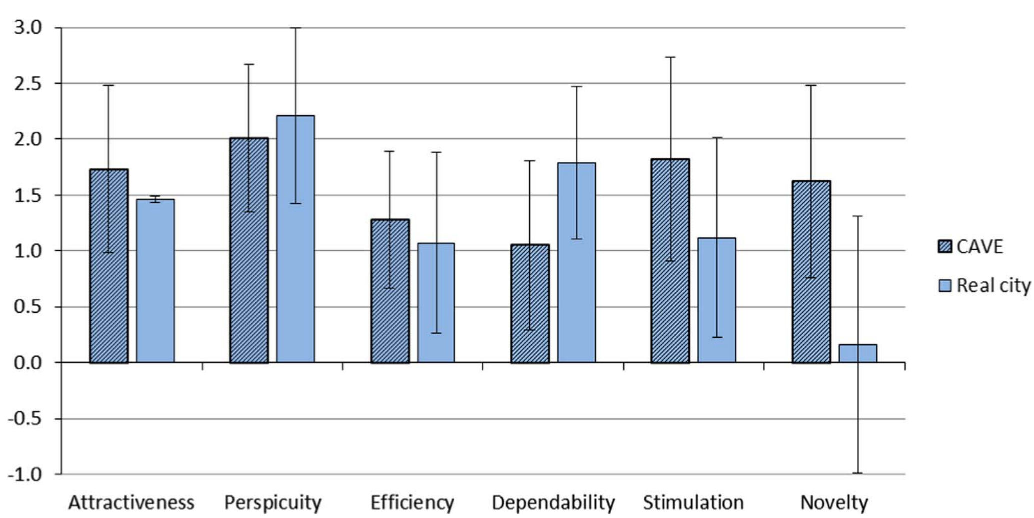

Fig. 6. bar charts of the means of the UEQ factors (rated from −3 (low) to 3 (high)) for the two conditions with error bars showing standard deviations.

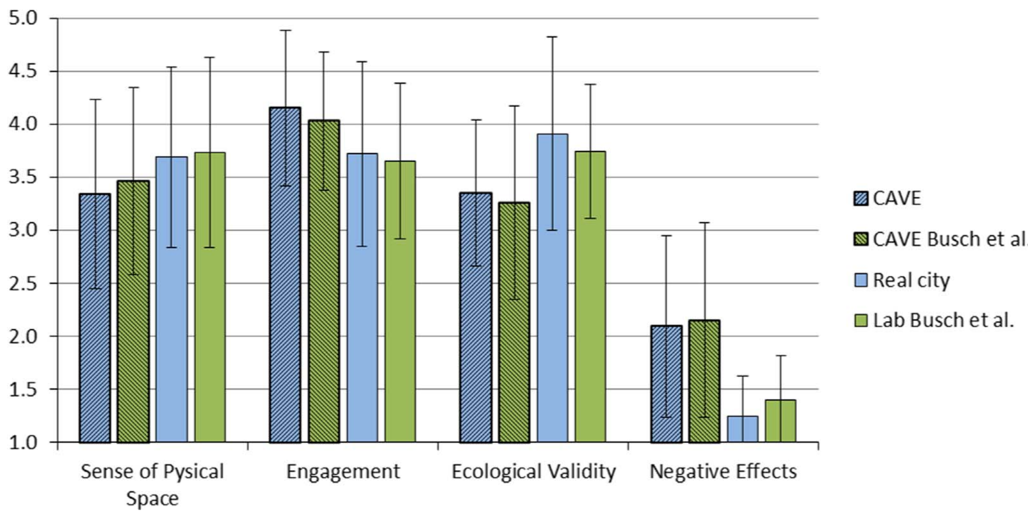

Fig. 7. Comparison of the presence results of the presented study and the study by Busch et al. (2014) showing the means and the standard deviations as error bars.

of the participants moved with almost maximum speed through the virtual city center, whereas the participants in the real city center preferred a slower speed in general.

5. Discussion

5.1. Summary of the study and important findings

In this study we analyzed the difference in effects of virtual and real field environments on presence, and the possible consequences for the self-reported user experience and usability. Our results show significantly higher values on the engagement and the negative effects scale for the CAVE, in contrast to the real field environment with a higher ecological validity. We are confirming previous work (Busch et al., 2014) that showed the same results or partially similar findings (Mania, 2001; Mania and Chalmers, 2004; Nisenfeld, 2003; Usoh et al., 2000). Our hypothesis H1 was supported; only the results of the engagement scale differed from our expectations where we received a higher value for the virtual field environment.

Our hypothesis H2 was fully approved as we measured significantly higher values in the real field environment. For the first time we could verify a significant correlation between the environment and usability that previous studies did not examine (Busch et al., 2014).

Hypothesis H3 was approved for the dependability as we can report higher measures for the real field environment, although this statement is limited due to the low CA value. Because we expected that the higher negative effect values in the virtual environment affect the perceived hedonic quality negatively, it is surprisingly, that we found higher values for the stimulation and novelty factors for virtual field environment. That means, that even when the negative effects are high, the hedonic quality is not impaired. For the other three scales: attractiveness, perspicuity and efficiency equal results can be reported. The analysis of the correlation between the presence factors and the user experience factors could verify a significant dependability of 18 of 24 combinations in the virtual field environment but only for 6 of 24 in the real field environment. Our results also verify the measures of previous studies (Patel and Nichols, 2004; Sylaiou et al., 2010) for a connection between presence and enjoyment of a virtual environment.

5.2. Interpreting the results of this experiment

If we want to use virtual environments to assess new products like mobile applications, their fundamental principles have to be evaluated. This is important to make sure that they really can replace real environments and the results of product evaluations in a virtual field environment are the same.

The higher negative effects we found in our presence evaluation confirms the current state of knowledge as effects like simulator sickness are well known and are therefore expected. The most interesting result of our presence evaluation is the differences in the engagement scale which is in contrast to the findings of Nisenfeld (2003), but in line with the results of Busch et al. (2014). This could imply that the CAVE used in this study and in the study of Busch et al. (2014) provided a higher immersion then the HMD setup of Nisenfeld (2003) and therefore leading to a more engaging experience. This implication should be verified in a future study with VR systems providing different levels of immersion. The confirmation of our results together with that of Busch et al. (2014) are very important for future studies as it shows that a highly immersive CAVE produces higher engagement values, which implies a higher psychological involvement and a higher user enjoyment. Neglecting this point of view when evaluating products in a virtual environment may lead to flawed results, because the positive or negative experience of the virtual environment may influence the participant's ratings.

The differences in the task completion time resulted from the maximum navigation speed in the CAVE that most participants preferred to move with, which is comparable to jogging. We think that there are two possible reasons why the participants choose to 'jog' in the virtual field environment but not in the real one. The first reason is, that going faster in the CAVE is not correlated with increased physical effort as in the real world. Secondly, it might be possible that the participants were not aware of the high speed they moved within the virtual world. However, this is not supported by the results for the presence factor of physical space where no differences between the real and virtual environment were found. Although we know that different locomotion methods induce a different presence (Lorenz et al., 2015) we did not assess the presence of the navigation method separately. Previous investigations (Guy et al., 2015; Lorenz et al., 2015) have already shown that the utilized navigation method is associated with a high presence and an easy, comfortable usage. Furthermore, we wanted to assess the presence of the entire high immersive virtual field environment setup. The influence of the navigation method is therefore included in the presence measurements of the whole system.

Another important result is the comparison of the measures of the ITC-SOPI for the real lab environment by Busch et al. (2014) and our real field environment. For all presence factors they show similar values for both real environments. This implies that both kinds of real environments (lab and field) are comparable concerning presence. These results suggest that either of the real environments would be suitable for this type of comparative study between virtual and real environments.

For usability we measured different results to Busch et al. (2014). In contrast to them we found significant differences for usability in the virtual field environment and the real field environment. One interpretation could be that a laboratory environment as used by Busch et al. (2014) and a virtual field environment are more similar than a real field environment and a virtual field environment in terms of usability. Another interpretation could be that the tasks the participants had to perform in our study were better suited for testing in a virtual field environment with the given technical setup and scenario. It could be speculated that our open world scenario using long established technology (GPS, geocaching) led to certain expectations on how the geocaching game should behave, so occurring problems had a stronger negative effect when the usability was rated. In contrast to this Busch et al. (2014) used an indoor internet of things scenario where the participants had to interact with novel, partly non-existing devices inside buildings. As the interaction with these new technologies is unfamiliar for most of the users they might expect more problems in the functioning of the technology and their tolerance towards failures might be higher, therefore influencing their rating of the usability. This might even affect how the participants tolerated the difference between the artificial navigation method in the virtual environment and natural walking in reality. However all of these aspects have yet to be examined in a future study.

As our study is the first one investigating user experience and how it is influenced by presence in a virtual and real field environment, there are few studies to compare our results to. Albrecht et al. (2013) researched user experience in an AR environment and documented significantly higher values for its hedonic quality. Our results verify these data as we also observed significantly higher scales for the hedonic factors stimulation and novelty in the virtual condition. Nonetheless, these comparisons must be made with caution, as AR and VR environments are different.

We could also verify a significantly higher dependability of the geocaching game in the real field environment, which indicates a higher pragmatic quality. As this result corresponds with the measures for the usability scale, we think that this statement is valid, despite the medium CA value of the dependability.

Concerning the connection of presence and UEQ factors, we found a medium correlation between presence and hedonic quality in the virtual field environment. This supports the findings of Patel and Nichols (2004) and Sylaiou et al. (2010) who have both documented a positive correlation between presence and enjoyment. When looking at each presence factor and its effect on the UEQ factors in both environments, there is a high correlation with the engagement scale. This means that the enjoyment of the experience is important for the user and independent of the environment, despite the slightly higher correlation with the virtual field environment. When comparing the other three presence factors we also found high correlation between the sense of physical space and ecological validity, and the UEQ factors, with a surprisingly low correlation with the negative effects. This is in contrast to the results for the real field environment where almost no significant correlations were measured. For assessing a product in a solely virtual field environment it is therefore important to reach a high presence of the user. We advise using a highly immersive VR system with a sound evaluation scenario and realistic virtual model to assure this. Otherwise evaluation results with only a low confidence in their correctness can be achieved.

One additional remark for the especially high values for the engagement scale is that due to the novelty of VR scenarios, most participants just enjoyed participating in VR. This positive feeling could influence the assessment of a product and should always be considered when only a virtual scenario is chosen for the evaluation. This effect could be offset by using a corrective factor which will need to be determined through future study. However, as VR is hitting the consumer market it is likely that people will get used to being in a virtual world so that this enjoyment factor might not be as relevant in the future. To confirm this assumption, replication of this study in a few years when VR has become an everyday experience might be very relevant.

One additional possibility to compare the real with the virtual environment would have been to use physiological signals (e.g. pulse, skin conductivity) to assess presence. Meehan (2001) performed such experiments but only for different VR scenarios (exciting vs. non-exciting). We decided against the inclusion of a physiological assessment for methodological and practical reasons. The means of locomotion in our scenario differs in the way it physically stresses the body (normal walking vs. slight movements whilst standing). Because of this difference the gathered data could not be compared between the conditions. We also would have to follow the participants in the real word scenario to note non-tasks related events. We think that following them would have changed the way they behave and perform the task. Also the technical set up for collecting physiological data would severely increase the effort preparing and conducting the experiment. In a future study it might be interesting to collect physiological data in a VR scenario and compare this with data from questionnaires, to see if there are links between the physical reaction and the psychological impression.

6. Conclusion

The current study shows that a virtual field environment is a tangible alternative to a real field environment when performing studies for evaluating products, if the influence of presence is considered, as it affects the user ratings for usability and user experience. A highly immersive virtual field environment with a realistic virtual model and a sound simulation of reality, provide the bases for reliable results of product evaluation. Virtual field environments are a good choice for assessing usability and user experience studies especially due to the controllability of confounding variables and the possibility of assessing early virtual prototypes of products. However, virtual and real field environments slightly differ in perceived presence, making improvements of the virtual environment necessary. The higher value for ecological validity in the real field environment demonstrates the need to improve the realism of virtual models and the stronger involvement of other senses like sound, touch or smell. Therefore, the achievement of a high ecological validity could become a quality goal for studies performed in a virtual environment giving confidence in the found results.

Besides the integration of further senses, the improvement of interaction techniques (i.e. for navigation) and an increased realism of the virtual model could also lead to increased presence. Our study shows the importance of keeping negative effects low, so that small problems with the technical setup do not influence the assessment of the independent variables. This is especially important for user experience evaluations in a virtual environment where all of these aspects have to be considered in order to obtain reliable results.

Holistic approaches combining real and virtual settings should also be considered. Future studies will need to investigate how the benefits of both kinds of environments can be combined together to create a realistic and controllable system. Using an AR environment where the assessed product is virtually blended into reality might prove as an ideal combination. However, in this case, the effect of the gap in realism between the virtual and real objects in terms of presence and their relation to usability and user experience needs to be investigated.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ijhcs.2017.01.004.

References

Albrecht, U.-V., Folta-Schoofs, K., Behrends, M., von Jan, U., 2013. Effects of mobile augmented reality learning compared to textbook learning on medical students: randomized controlled pilot study. J. Med. Internet Res. 15 (8), 182.

Bangor, A., Kortum, P., Miller, J., 2009. Determining What individual SUS scores mean: adding an adjective rating scale. J. Usability Stud., 114–123.

Barfield, W., Zeltzer, D., Sheridan, T., Slater, M., 1995. Presence and Performance within Virtual Environments, Virtual Environments and Advanced Interface Design. Oxford University Press, Inc., New York, USA, 473–513.

Brade, J., Lorenz, M., Klimant, P., Klimant, F., Putz, M., 2016. Virtual reality for industrial application – The influence of presence and its relation to usability and user experience. Adv. Mater. Res. 1140, 537–544.

Brooke, J., 1996. SUS - A Quick and Dirty Usability Scale, Usability Evaluation in Industry. Taylor & Francis Inc, Bristol, 189–194.

Busch, M., Lorenz, M., Tscheligi, M., Hochleitner, C., Schulz, T., 2014. Being There For Real – Presence in Real and Virtual Environments and its Relation to Usability. NordiCHI, ACM, Helsinki.

Coelho, C., Tichon, J., Hine, T.J., Wallis, G., Riva, G., 2006. Media Presence and Inner Presence: The Sense of Presence in Virtual Reality Technologies, From communication to Presence: Cognition, Emotions and Culture Towards the Ultimate Communicative Experience, Festschrift in honor of Luigi Anolli. IOS Press, Amsterdam, 25–45.

Cruz-Neira, C., Sandin, D.J., DeFanti, T.A., 1993. Surround-Screen Projection-Based Virtual Reality: the Design and Implementation of the CAVE, SIGGRAPH. ACM Press, 135–142.

Cruz-Neira, C., Sandin, D.J., DeFanti, T.A., Kenyon, R.V., Hart, J.C., 1992. The cave: audio visual experience automatic virtual environment. Commun. ACM 36 (6), 64–72.

de Kort, Y.A.W., IJsselsteijn, W.A., Kooijman, J., Schuurmans, Y., 2003. virtual Laboratories: Comparability of real and virtual environments for environmental psychology. Presence.: Teleoperators Virtual Environ. 12 (4), 360–373.

Duh, H.B.-L., Chen, V.H.-h., 2006. Usability evaluation for mobile device: a comparison of laboratory and field testsMobile HCI 2006. ACM Press, Helsinki, 181–186.

Fraunhofer-IGD, 2016. Instant reality.

Gorini, A., Capideville, C.S., de Leo, G., Mantovani, F., Riva, G., 2011. The role of immersion and Narrative in mediated presence: the virtual Hospital experience. Cyber., Behav., Soc. Netw. 14 (3), 99–105.

Guy, E., Punpongsanon, P., Iwai, D., Sato, K., Boubekeur, T., 2015. LazyNav: 3D Ground Navigation with Non-Critical Body Parts, IEEE Symposium on 3D User Interfaces, Arles, pp. 43–48.

Hassenzahl, M., Tractinsky, N., 2006. User experience - a research agenda. Behav. Inf. Technol. 25 (2), 91–97.

Kaikkonen, A., Kallio, T., Kekäläinen, A., Kankainen, A., Cankar, M., 2005. Usability testing of mobile applications: a Comparison between laboratory and field testing. J. Usability Stud. 1 (1), 4–16.

Kjeldskov, J., Skov, M.B., Als, B.S., Høegh, R.T., 2004. Is It Worth the Hassle? Exploring the Added Value of Evaluating the Usability of Context-Aware Mobile Systems in the Field, MobileHCI. Springer-Verlag, Berlin Heidelberg, 61–73.

Laugwitz, B., Held, T., Schrepp, M., 2008. Construction and evaluation of a user experience questionnaire, hci and usability for education and work. In: Proceedings of the 4th Symposium of the Workgroup Human-Computer Interaction and Usability Engineering of the Austrian Computer Society. Springer-Verlag Berlin, Graz, pp. 63–76.

Law, E.L.-C., Roto, V., Hassenzahl, M., Vermeeren, A.P.O.S., Kort, J., 2009. Understanding, scoping and defining user experience. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, pp. 719–728.

Lessister, J., Freeman, J., Keogh, E., Davidoff, J., 2001. A cross-media presence Questionnaire: the ITC-sense of presence Inventory. Presence.: Teleoperators Virtual Environ. 10 (3), 282–297.

Lexa, 2016. Fake GPS.

Loomis, J.M., Blascovich, J.J., Beall, A.C., 1999. Immersive virtual environment technology as a basic research tool in psychology. Behav. Res. Methods, Instrum., Comput., 557–564.

Lorenz, M., Busch, M., Rentzos, L., Tscheligi, M., Klimant, P., Fröhlich, P., 2015. I'm There! The Influence of Virtual Reality and Mixed Reality Environments Combined with Two Different Navigation Methods on Presence, IEEE Virtual Reality Conference 2015 Arles, France, pp. 223–224.

Mania, K., 2001. Connections between lighting impressions and presence in real and virtual environments: an experimental study, AFRIGRAPH. ACM Press, 119–123.

Mania, K., Chalmers, A., 2004. The effects of levels of immersion on memory and presence in virtual environments: a reality centered approach. Cyber. Behav. 4 (2), 247–364.

Meehan, M., 2001. Physiological Reaction as an Objective Measure of Presence in Virtual Environments(Dissertation). University of North Carolina.

Nisenfeld, S., 2003. Using Reality to Evaluate the ITC Presence. Unpublished Master Thesis.

Patel, H., Nichols, S., 2004. View of the future: overview of the experimental programme via quantitative meta-analysis., Virtual Reality design and evaluation workshop, Nottingham, pp.

Rauschenberger, M., Schrepp, M., Cota, M.P., Olschner, S., Thomaschewski, J., 2013. Efficient measurement of the user experience of interactive products. how to use the user experience questionnaire (UEQ). Example: Spanish Language Version. Int. J. Artif. Intell. Interact. Multimed. 2 (1), 39–45.

Schuemie, M.J., van der Straaten, P., Krijn, M., van der Mast, C.A.P.G., 2001. Research on presence in virtual reality: a survey. Cyber. Behav. 4 (2), 183–201.

Slater, M., Wilbur, S., 1997a. A framework for immersive virtual environments (FIVE): speculations on the role of presence in virtual environments. Presence.: Teleoperators Virtual Environ. 6 (6), 603–616.

Slater, M., Usoh, M., Steed, A., 1994. Depth of presence in virtual environments. Presence: Teleoperators Virtual Environ. 3 (2), 130–144.

Stumpf, H., Fay, E., 1983. Schlauchfiguren. Ein test zur Beurteilung des räumlichen Vorstellungsvermögens. Retrieved Göttingen.

Sun, X., May, A., 2013. A comparison of field-based and lab-based experiments to evaluate user experience of personalised mobile devices. Adv. Hum.-Comput. Interact., 1–9.

Sylaiou, S., Mania, K., Karoulis, A., White, M., 2010. Exploring the relationship between presence and enjoyment in a virtual museum. Int. J. Hum.-Comput. Stud. 68 (5), 243–253.

Tang, A., Biocca, F., Lim, L., 2004. Comparing differences in presence during social interaction in augmented reality versus virtual reality environments: An exploratory study, PRESENCE 2004, In: Proceedings of the 7th Annual International Workshop on Presence, Valencia, Spain, pp. 204–208.

Toet, A., van Schaik, M.G., 2012. Effects of signals of disorder on fear of crime in real and virtual environments. J. Environ. Psychol. 32 (3), 260–276.

Usoh, M., Catena, E., Arman, S., Slater, M., 2000. Using Presence Questionnaires in Reality, Presence: Teleoperators and Virtual Environments 9 (5), pp. 497–503

Zwick, S., Rauprich, J., 2016. Actionbound.

Jennifer Brade is a scientific assistant at the Division of Process Informatics and Virtual Product Development, Professorship for Machine Tools and Forming Technology, Technische Universität Chemnitz. Her research is focused on Human-Computer Interaction with the emphasis on Augmented Reality/Virtual Reality applications. In this context she is exploring the differences of virtual and real environments concerning presence, usability and user experience.

Mario Lorenz is a Research Associate at the Division of Process Informatics and Virtual Product Development, Professorship for Machine Tools and Forming Technology, Technische Universität Chemnitz and a visiting scientist at the Department of Orthopaedic Surgery, Traumatology and Plastic Surgery, University Hospital Leipzig. His research interests are focused on Augmented Reality/Virtual Reality applications for mechanical and medical engineering. Furthermore, he is researching the effects of presence in the context of Human-Machine Interaction.

Marc Busch is scientist at AIT Austrian Institute of Technology, holds a degree in psychology from the University of Vienna and works on user-centered design of interactive systems and technology acceptance. Furthermore, he is specialized in advanced quantitative and qualitative usability and user experience methodology, research methods and statistics in Human-Computer Interaction.

Niels Hammer is an Associate Professor at the Department of Anatomy, University of Otago, New Zealand. He is an MD and holds degrees as an Anatomist and Specialist Anatomist, with a background in Orthopedics and Trauma Surgery. His research is focused on the healthy and pathologically altered musculoskeletal system with focus on tissue biomechanics and numerical simulation.

Manfred Tscheligi is a Professor of Human-Computer Interaction at the University of Salzburg and Head of the Business Unit Technology Experience at AIT. He has been working in the area of Interactive Systems, Human-Computer Interaction, Usability Engineering, User Interface Design and User Experience Research for more than 20 years. He is a pioneer in establishing this field in Austria, an author of several publications and has been a distinguished speaker at conferences.

Philipp Klimant holds a diploma in Electrical Engineering from the University of Applied Sciences Mittweida. He joined the Technische Universität in 2007. His research focuses are Virtual and Augmented Reality, Machine and Factory Simulation, and Medical Engineering. In 2013 he received his PhD in Mechanical Engineering. Since 2011 he has been the Head of the Division of Process Informatics and since 2014, the Head of the new Division Process Informatics and Virtual Product Development. He is responsible for the VRCP laboratory (Virtual Reality Center Production Engineering). Since 2013 he has also been the Head of the Central Coordination Office of the Saxon Cluster of Excellence eniPROD.