Presence Within a Mixed Reality Environment

PAUL VAN SCHAIK, Ph.D,1 TRIECE TURNBULL, M.Sc.,1 ANNA VAN WERSCH, Ph.D,1 and SARAH DRUMMOND, M.Sc.2

ABSTRACT

Mixed reality environments represent a new approach to creating technology-mediated experiences. However, there is a lack of empirical research investigating users’ actual experience. The aim of the current exploratory, non-experimental study was to establish levels of and identify factors associated with presence, within the framework of Schubert et al.’s model of presence. Using questionnaire and interview methods, the experience of the final performance of the Desert Rain mixed reality environment was investigated. Levels of general and spatial presence were relatively high, but levels of involvement and realness were not. Overall, intrinsic motivation, confidence and intention to re-visit Desert Rain were high. However, age was negatively associated with both spatial presence and confidence to play. Furthermore, various problems in navigating the environment were identified. Results are discussed in terms of Schubert’s model and other theoretical perspectives. Implications for system design are presented.

INTRODUCTION

For several decades, computers have become increasingly important aspects of many people’s lives. Since their arrival, computers have served many purposes and have become extremely popular among the younger generation, mainly via their use of computer games.1 Perhaps this popularity is due to some of the attractive properties which computer games bring about in that they stimulate curiosity, and they provide users with a challenge and the opportunity to enter a world of fantasy.1–3,3a However, in the late 20th century, a new type of medium known as virtual environments (VEs) was developed.3b VEs are three-dimensional interactive digital environments that allow users to look, move around in, and experience an imaginary world. Different types of VE exist, ranging from high-end fully immersive systems to low-end PC-based desktop systems. Many of the VE designs in the past have been concerned with mimicking perceptual experiences within galleries, exploratoria, and theme parks. However, more recent VE designs have attempted to extend the qualities of VEs and use a mixed reality approach.4 Mixed realities are created by the combination of both virtual and real world environments. Properties used to produce this spatial environment allow users not only to interact with physical information, but also digital information in an integrated way.5 This benefits users of mixed reality designs as they are not only able to share the physical and virtual spaces, but also to communicate with each other whilst touring the same VE.6 Touring and exploring visual complex structures and systems such as those in VEs has not only been found to offer a high degree of realism,7,8 but also presence,7 both of which allow users to become immersed in the VE they choose to engage in.8 Although the basic concepts of presence and immer-

1Psychology Section, School of Social Sciences and Law, University of Teesside, Teesside, United Kingdom.
2Department of Computer Science, University of Durham, United Kingdom.
sion can be applied equally to both mixed reality and VEs, the basic premise of presence and immersion have been challenged. Presence is seen as a crucial facilitator to achieve the aims of VEs, such as effective interactive storytelling,9 and presence has been an aim of entertainment applications of VEs for a long time.10

Slater and Wilbur11 define presence as being “A state of consciousness, the (psychological) sense of being in the virtual world,” a concept that some12,13 claim is distinguishably different from that of immersion. Slater and Wilbur support this claim by defining immersion as “The extent to which the computer displays are capable of delivering an . . . illusion of reality to the senses of the human participant.” However, Sadowski and Stanney14 state that immersion, whether psychological or physiological is far simpler than has been suggested by Slater and his colleagues, in that immersion is a belief that the user feels “present” in the virtual world. This claim supports previous findings by many15–18 who suggest immersion occurs as a direct outcome of being present and participating in the virtual world. Many theoretical models differ in exactlying presence and immersion of users in VEs. However, Schubert et al.7 suggest that the two positions will be difficult to reconcile, as immersion is objectively quantifiable and presence is a subjective experience, which can only be measured through a person experiencing it. Therefore, for the purpose of this paper, presence is defined as the sense of being in the virtual world.7 The term presence will also be used throughout the remainder of this paper as it is not only influenced by external factors,11,19–22 but also internal factors.15,18,23

Three types of presence—personal, social, and environmental—have been distinguished.15 In relation to VEs, personal presence is the measurement that an individual feels present and the reasons for their feelings of presence. Social presence24 (or co-presence) refers to the degree to which an individual feels present in the virtual world, based on the interaction with other users. Environmental presence refers to the extent to which users actually acknowledge their own existence in the VE and the reaction they have to it. Different factors have also been found to influence the forms of presence, in relation to VEs. These include ease of interaction; user-initiated control; pictorial realism; length of exposure; social factors; internal factors and finally, system factors.15 However, these forms of presence are not experienced in isolation and therefore presence within VEs is based not only on variables associated with the system, but also those relating to individual factors.25 Although various factors influencing presence have been identified, a theoretical understanding of presence in relation to these factors is required to make scientific progress. Schubert et al.7 offer a spatial-functional mental model within the framework of embodied cognition26 for this purpose.

Schubert et al.’s7 spatial-functional model suggests that presence develops as a result of two cognitive processes. These are representations of bodily actions as possible actions in the VE and the suppression of antagonistic sensory information. Although Schubert et al.7 agree with many11,18,22,27 that VEs need to be similar or as close to real world images as possible for presence to occur, they also claim that users need to construct a mental model within the VE that represents physical reality. Once users of a VE have developed such a model, they are then able to play an active part and take control over their actions. Although becoming immersed in the VE leads to a greater presence, as Schubert et al.7 cogently argue, users need to perceive that they are capable of taking on the role they are governing within the VE. Users who place themselves in the depicted space, by navigating and manipulating objects, and by interacting with others are more likely to experience presence as they mentally and physically (although hypothetically) remove themselves from the real world into the virtual world. By engaging in this process users are constructing a mental representation that is different from the real world. However, in order to do this, users have to suppress conflicting sensory outputs such as distracting stimuli associated with the VE hardware or the real environment. Hence, users need to allocate all their attention to the task within the VE if presence is to be heightened.

The spatial-functional model of Schubert et al.7 conceptualises presence in VEs in a distinctive way, in that it offers a psychological explanation for the combination of spatial presence and involvement. However, the links between cognitive processes and the subjective presence needs to be clarified in order to characterise the elements that relate to the model. According to Schubert et al.,7 presence is not an unconscious experience; instead they claim the conscious presence in VEs follows from their model, in that presence is an outcome of cognitive processes that requires mental representation as a conscious act. The conscious act of presence is an effect of interpreting one’s own mental construct. Therefore, conscious presence should reflect the sense that users are situated in and act from within a VE as well as the sense of being able to allocate their attention on the VE by ignoring the real environment. On reviewing Schubert et al.’s7 psychological model that related to presence in VEs, but by extension
also to MREs, a brief description will now be given
of the MRE used for the present research.

Desert Rain was a mixed reality environment
(MRE) and was introduced to the public in 1999, as
a joint enterprise between the Blast Theory group
and the NOW Ninety9 festival, both in association
with the University of Nottingham. A combination
of the Blast Theory’s innovative artistic vision, and
the collaborative state-of-the-art virtual reality tech-
nology from the university, allowed the creators to
develop what they describe Desert Rain to be: a
game, an installation and a performance.28 The aim
of the current study was to establish to what extent
the Desert Rain MRE was able to generate presence
in visitors and to identify factors associated with
presence.

MATERIALS AND METHODS

Quantitative and qualitative research methods
were employed in order to establish participants’
experience of the MRE (in terms of spatial pres-
ence, involvement and realness) and intention to
re-visit, and confidence and motivation to play
Desert Rain.

Design

Visitors who participated in Desert Rain were
asked to complete a questionnaire, based on previ-
ously published inventories and newly designed
questions. Subsequently, participants took part in
semi-structured interviews in order to identify some
of the issues associated with Desert Rain that were
not included in the questionnaire.

Participants

Participants were first-time visitors of the Desert
Rain MRE and recruited during a two-day event
where Desert Rain was performed in the Red Parcel
Office in Middlesbrough, May 2002. (This was the
final performance of Desert Rain.) Because a conve-
nience sample was used, selection of participants
on the basis of gender and age was not possible. In
total 21 participants consented to participate in this
study (17 males and 4 females). Age ranged roughly
from 16 to 50 years, with 14% being under 16 years
of age, 43% 17–30 years, 24% 30–45 years, and 19%
45 years and over. A majority of 11 participants
(52%) had had experience of playing computer
games.

Materials

The questionnaire (see Appendix) measured four
constructs related to the use of VEs and computer
games (spatial experience and motivation to play)
and interactive computer systems more generally
(intention and confidence). The IPQ (Igroup Presence
Questionnaire) was developed based on a compre-
hensive set of well known previous presence ques-
tionnaires and factor structure was extensively
tested and validated.7 The questionnaire consisted
of three specific multi-item presence sub-scales and
a single-item general presence sub-scale. The items
used 7-point Likert scales, with named end-points
depending on questionnaire items. Reliabilities of
IPG sub-scales were comparable with those obtained
in previous research7: for spatial presence Cron-
bach’s alpha = 0.84 (previously 0.79), for involve-
ment alpha = 0.68 (previously 0.75) and for realness
alpha = 0.69 (previously 0.69). The other sections
used 5-point Likert scales, all with named end-
points strongly disagree to strongly agree. Intention to
re-visit items (alpha = 0.91) were based on the The-
ory of Planned Behavior,29 the confidence to play
items (alpha = 0.84) were based on Hill et al.30 and
the motivation to play items (alpha = 0.56) were de-
rived from the work of Malone1 respectively. Addi-
tional items measured demographic details. For the
purpose of semi-structured interviews, an inter-
view guide was used. Finally, video recording and
audio equipment was used at certain times to gather
visitors’ on-the-spot reactions and communication
with each other. However, due to organisational
constraints imposed by the performance of Desert
Rain it was not possible to systematically record all
interaction in the MRE and only the screen and
sound for one of the visitors interacting with the
virtual world in the Desert Rain performance could
be recorded at any one time.

Mixed reality environment

Although Desert Rain31 was mainly based on the
Gulf War, other combat situations from television
news, computer games and Hollywood films were
also incorporated to provide a virtual warfare envi-
ronment. The Desert Rain MRE offered a three-
dimensional quality of several curtains of rain made
up of fine water spray (one for each visitor) into
which images could be projected. Teams of six visi-
tors were sent on a 20-min mission to find one of six
human targets (all having different perspectives on
the Gulf War) and to enter the final room simulta-
nously. In order to reach first their target and sub-
sequently the final room, visitors had to navigate around the virtual world exploring a hotel, a desert and underground bunkers. Desert Rain was a collaborative MRE, that is, visitors used a live audio link as a communication facility to discover each other’s positions and to help trailing members.

Characteristics of the mission, suspense of knowing if the final room was to be reached in 20 min, a dramatic event at the interface between the physical world and the virtual world, and support from and interactions with team members were potential factors associated with increasing visitors’ presence. However, the goal of this paper is not to attempt to experimentally manipulate these factors and pin-point the exact properties of the game that contribute to presence, but instead to investigate visitors’ presence and gather their views on the relatively new medium of MRE as exemplified by Desert Rain for the first time. The current study investigated the final performance of Desert Rain. Photographs of a previous performance are available at www.crg.cs.nott.ac.uk/events/rain/screens/.

Procedure

Before entering the Desert Rain MRE, visitors were fitted with a dark raincoat and a hat. They were given minimal standard instructions verbally, were told they had to find their target and the final room, and were given a plastic card the size of a credit card on which the name of their target was printed. On arrival they were asked to stand on a footpad and position headphones provided, in such a way that they were comfortably in place. The footpad was the navigation device, and visitors’ movement through the virtual world was controlled by their position on the footpad at any moment in time. The headset was used for communication and the other players and the actors. In front of each visitor was a rain screen (“rain curtain”), four meters across; it provided a surface of fine water spray which held the projected image of a virtual world. Co-visitors in the virtual world were represented by avatars. Most of the time the rain curtain for each visitor was used to project the virtual world. The exception was that when a visitor found their target in a dramatic event; the curtain was used as the interface between the virtual world and the physical world (“mixed reality boundary”) through which an actor approached the visitor. All visitors started their interaction with the Desert Rain MRE at the same time. Once they had found their target, they crossed the mixed reality boundary. Successful visitors who found the final room in the virtual world were encouraged to help trailing visitors find their target and the final room. Irrespective of whether they had found their target and entered the final room, after 20 min the rain curtain ceased to operate, and all visitors removed their hats and coats and walked through a tunnel leading to the end of the performance, where they were shown a video of characters who described their experiences of the Gulf War. They then proceeded to an interview room, where they completed the questionnaire and semi-structured interviews.

RESULTS

Descriptive statistics and confidence intervals were calculated to establish levels of presence and other outcome measures. Correlation co-efficients were used to investigate associations between outcome measures and participant characteristics.

Overall scores were calculated for the IPQ subscales spatial presence, involvement and realness,

<table>
<thead>
<tr>
<th>Scale, subscale, or item</th>
<th>Mean</th>
<th>SD</th>
<th>95% confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>IPQ</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>General</td>
<td>0.95</td>
<td>1.75</td>
<td>[0.16; 1.75]</td>
</tr>
<tr>
<td>Spatial presence</td>
<td>0.75</td>
<td>1.39</td>
<td>[0.12; 1.39]</td>
</tr>
<tr>
<td>Involvement</td>
<td>0.10</td>
<td>1.18</td>
<td>[-0.44; 0.63]</td>
</tr>
<tr>
<td>Realness</td>
<td>-0.96</td>
<td>1.12</td>
<td>[-1.47; -0.45]</td>
</tr>
<tr>
<td>Intention to re-visit</td>
<td>0.99</td>
<td>0.70</td>
<td>[0.68; 1.31]</td>
</tr>
<tr>
<td>Confidence to play</td>
<td>0.98</td>
<td>0.81</td>
<td>[0.61; 1.35]</td>
</tr>
</tbody>
</table>

*For this item, negative scores signify a high level of confidence.*
and for the constructs intention to visit and confidence, but not for motivation because of low reliability. Descriptive statistics and confidence intervals (Tables 1 and 2) showed higher than average (neutral score of 0) levels of general presence, spatial presence, intention to re-visit and confidence to play, a neither low nor high level of involvement and a lower than average level of realness. Levels of motivation were higher than average for enjoyment and accomplishment, but neither high nor low for reward (Tables 1 and 2).

Associations between constructs were investigated using Pearson correlations (for pairs of scales and sub-scales) and Spearman correlations (for pairs involving one or two scale items), with significance tests using a multi-stage Bonferroni procedure. Because the study was exploratory in nature, a significance level of 0.10 was used. The following pairs of variables possessed statistically significant correlations: spatial presence and general presence, \( r = 0.71, p < 0.001 \), involvement and general presence, \( r = 0.64, p = 0.002 \). Other pairs of variables with > 20% variance overlap were reward and general presence, \( \rho = 0.60, p < 0.005 \), and reward and spatial presence, \( \rho = 0.54, p < 0.05 \).

Associations between outcome measures and participant characteristics were analysed with Spearman correlations, using a multi-stage Bonferroni procedure and a significance level of 0.10. The following pairs of variables possessed significant correlations: age and spatial presence, \( \rho = -0.70, p < 0.001 \), age and confidence to play, \( r = -0.64, p = 0.001 \), age and experience with playing computer games, \( r = -0.68, p = 0.001 \).

Findings from the semi-structured interviews were organised into four main sections were produced using thematic analysis: positive aspects of, feelings about, problems with and changes to Desert Rain. From this, general themes were identified to express the views of visitors.

Positive aspects associated with the Desert Rain MRE included how real the environment was. Many of the visitors reported that this perception was more pronounced when reaching the end of Desert Rain, where—in the “video room”—they were then presented with the targets’ different perspectives on the Gulf War.

The majority of visitors \( (n = 14) \) felt isolated in the Desert Rain MRE. Two of the female visitors, both inexperienced and over thirty, reported that this was a frightening experience and that this would prevent them from engaging in a MRE experience similar to Desert Rain. Although nine visitors of Desert Rain reported that touring the MRE was relatively easy, lack of instructions about what to do once in the MRE led to feelings of anxiety and loneliness.

Some of the problems experienced by visitors of Desert Rain related to the design of the virtual world. Visitors identified two main problems. Firstly, 18 out of the 21 visitors reported that, although the purpose of an orientation tool (“the map”) presented in the virtual world was to aid in interacting with and touring the world, in fact it led to confusion as it did not seem consistent with the actual virtual world. The remaining three visitors reported not seeing a map on the screen. The second problem visitors \( (n = 9) \) experienced was that the interface was too dark at times and too bright at other times. Although they reported expecting the bunkers to be dark, they did not expect other locations to be as dull and uninspiring.

Even though visitors did not suggest many changes, a large majority \( (n = 19) \) did express the desire to be presented with better instructions, and to have a preview or practice run prior to the MRE commencing. Thirteen of the visitors also reported the Desert Rain MRE could be improved dramatically if the graphics and interface were more modern and in line with existing VEs.

**DISCUSSION**

**Levels of presence and other outcomes**

Our results demonstrate that to some extent visitors felt spatially present in the virtual world, but did not perceive the virtual world as real. Their level of involvement was neither low nor high. Visitors did intend to visit Desert Rain or similar performances and felt confident to play. Their levels of motivation to play ranged from relatively high to average. Furthermore, general presence was strongly positively associated with spatial presence and involvement. To a lesser extent, there was a positive association of a perception of playing Desert Rain as rewarding for good performance with general presence and spatial presence. Although age and
experience with playing computer games were strongly correlated, age—but not experience with computer games—was strongly negatively related with spatial presence and confidence to play. Correlations between experience with computer games and these two outcome variables were also negative, but considerably lower.

Although by current standards the graphic quality of the virtual world was relatively low and overall level of realness as measured by the IPQ was low, at times visitors experienced the virtual world as being real. Negative feelings when visiting Desert Rain included isolation, fear, anxiety and loneliness. Problems in interacting with the virtual world included poor quality of orientation support and extreme levels of light (too dark or too bright). The main suggested improvements were better instructions and quality of graphics.

When interpreting our findings in the light of Schubert et al.'s7 spatial-functional model of presence, spatial presence and involvement—both as measured by the IPQ—are considered as indicators of the processes of constructing a spatial-functional model of the virtual world and suppression of incompatible stimuli from the real world respectively. From the results on spatial presence, it appears that to some extent visitors were able to construct a spatial-functional model with virtual world stimuli as a result of their interaction with the virtual world. However, the results on involvement indicate that the virtual world did not facilitate visitors' in suppressing incompatible stimuli from the real world.

The failure to support this process may be due to usability problems that visitors experienced when interacting with the MRE. First, visitors identified a lack of instructions and practice, which, if provided, might have prevented problems in the first place. Second, a lack of orientation was apparent, which led visitors to use the orientation tool (“the map”) and the communication facility (the “live link,” a room with six numbered boxes, one for each visitor). Third, the orientation tool itself suffered from poor usability, as reported by visitors in the current study and visitors in a previous performance of Desert Rain.31 Fourth, poor usability was also a characteristic of the communication facility; this was identified from observation of visitors’ attempts at communication as captured on video and also found by Shaw et al.31 The designers of Desert Rain were aware of the potential of usability problems to adversely affect visitors’ experience in the virtual world; therefore they communicated with individual trailing visitors and sometimes, as a “divine intervention,” moved visitors closer to desired locations within the virtual world. The lack of realness reported by visitors may also have interfered with the suppressing of incompatible input; however, there was only a moderate, but positive, correlation between realness and involvement and realness is not a sine qua non for involvement. For instance, anecdotal evidence shows that computer users can be completely captivated in “non-realistic environments” such as MS-Word! On the other hand, the failure of the virtual world to support suppression of incompatible stimuli might have resulted in a lack of realness to some extent. Principally, the lack of realness is more likely due to the poor quality of graphics and extreme brightness and extreme darkness at times within the virtual world. Nevertheless, participants experienced some parts of the performance as real. This experience may have been enhanced by physical features of the MRE, that is the steady sound of falling spray and the humidity generated by the rain curtain system.

Although visitors did intend to re-visit Desert Rain or visit similar performances and felt confident playing Desert Rain, these two outcomes were not correlated with any other outcomes or participant characteristics. Perhaps our first time-visitors believed that with more practice they would perform better, in particular considering that their first performance only lasted 20 min. On the other hand, cognitive dissonance may have been responsible for their responses. Visitors had paid to visit Desert Rain and may have made themselves believe that the experience had been worth their money.

Overall, visitors felt enjoyment and to some extent accomplishment, but their perception of the MRE as rewarding them for good performance was reduced. This may indicate that playing Desert Rain was more intrinsically motivating (enjoyment, accomplishment) than extrinsically motivating (rewarding). In this sense, Desert Rain appears to be similar to recreational activities (e.g., walking and cycling) as opposed to competitive sports, which are intrinsically rather than extrinsically motivating.34

A lack of orientation in the Desert Rain MRE was a frequently reported problem. This is a common experience in VEs. Indeed, people are often very disoriented when they initially navigate a large-scale VE; they ultimately develop accurate route- and survey-type spatial knowledge, but the process of developing this knowledge typically takes a long time.35 According to Ruddle et al.,35 “one reason for this is people must explore the environment and integrate information from many different positions because they cannot resolve all the detail necessary
for efficient navigation from a single position if a human’s eye perspective is used.” However, visitors in Desert Rain had only 20 min to explore the Desert Rain MRE and accomplish their mission at the same time. Two main types of strategy have been identified to improve orientation in VEs\(^{36}\): (1) the provision of navigation tools and mediators and (2) “organizational remedies.” The first category includes maps within a VE, landmarks, trails, and direction finding aids, which have been found to be effective to varying degrees. If maps are used, as in Desert Rain, then their relation with the VE or MRE needs to be clear. Another issue associated with the use of maps, which applies to Desert Rain, is that this becomes harder if navigators need to know not only where they themselves are within the virtual world, but also where other navigators are. Furthermore, a lack of landmarks in the desert may have increased the lack of orientation. The second category of strategies to improve orientation in VEs consists of two sub-categories: implicit and explicit sectioning. When employing implicit sectioning, the space has an understandable structure that can be made apparent to navigators, for example the rectangular grid structure of Manhattan, which will affect navigation strategy. Obviously, in artistic environments it may be desirable to strike a balance between familiarity and novelty, but a completely incomprehensible structure will lead to problems in wayfinding. The desert within the Desert Rain MRE may have suffered from an inherent lack of structure because of the nature of deserts in general, similar to open-ocean environments.\(^{36}\) Indeed, a limitation of this strategy is that it cannot be applied when the space does not have an understandable inherent structure. In the case of an open-ocean environment, where there are too few objects to organise into a navigable environment, the space can be explicitly organised using explicit cues. This is called explicit sectioning. This strategy proved highly effective in combination with the use of a map.\(^{36}\)

Navigation consists of two tasks: wayfinding (the cognitive element of navigation) and motion (the motoric element). In terms of navigation problems, so far wayfinding has been considered. Motion was also a potential problem in the Desert Rain MRE, where the mapping of changes in position on the footpad and movement within the MRE were not always consistent.

More generally, navigation problems can be seen as usability problems that can detract from the actual purpose of a VE and mask effects of VE content on users, as demonstrated by Fencott et al.\(^{9}\) Even if there are no navigation problems this does not imply that a VE will fulfil its purpose; content is crucial for this to happen.\(^{9}\)

Answers to open-ended questions indicated that disorientation was likely a major problem when visiting the Desert Rain virtual world. Negative feelings experienced by visitors of Desert Rain commonly occur in VEs when participants are disoriented; indeed, anxiety, feeling uncomfortable and generally unhappy are commonly reported.\(^{36}\)

The suggested changes to Desert Rain and improved instructions could eliminate or reduce visitors’ uncertainty, anxiety and fear without at the same time giving away information that would reduce the impact of the artistic performance. Better graphics could be used to improve the coding of attractors and retainers and to avoid shocks; however, in general this will not be sufficient to produce a compelling VE; irrespective of the quality of graphics, content needs to be designed from the perspective of narrative potential.\(^{24}\)

**Factors associated with presence and other outcomes**

Visitors’ perception of Desert Rain as rewarding them when they performed well for their effort was positively associated with general presence and, more specifically, spatial presence. This association can be interpreted as another indication that conscious active exploration of an environment, such as the Desert Rain MRE, is required to build a spatial-functional model.\(^{7}\) On the other hand, it may have been a positive attribution, similar to that observed in the study of users’ interaction with Web sites. Spool\(^{37}\) found that when users successfully performed tasks using Web sites they reported lower system response times. However, in reality response times were not lower.

There was a strong negative association of age with spatial presence and confidence to play. Decreasing confidence to play in older visitors may have reflected a poorer skills in understanding instructions in relation to the MRE and in navigating the MRE. This lack of successful interaction with the MRE may have interfered with or obstructed the process of constructing a spatial-functional model. It may be suspected that a lack of experience with playing computer games, which was characteristic of older visitors, caused difficulty in navigation and thereby lower spatial presence. However, it appears from the lower, but negative, correlation of this factor with spatial presence, that this may not have been the case. Rather, other factors associated with older age may have resulted in decreasing spatial presence with increasing age. On the other hand, age may have been a proxy for experience, but—because
we measured experience using a dichotomous item—the true association of experience with spatial presence and confidence may have been severely underestimated. The negative association of age with spatial presence and confidence is consistent with the finding that older adults take more time to learn using computers and experience more usability problems interacting with computers.

Analysis of the experience of Desert Rain from other perspectives

Within the framework of embodied cognition, the current study was conducted from the perspective of Schubert et al.’s spatial-functional model of presence, used their instrument for measuring presence and interpreted the measurements in terms of their model. Other theoretical perspectives may be useful as well for analyzing and interpreting the results of the experience of visiting Desert Rain. We will consider Fencott’s model of Perceptual Opportunities (POs), Whitfield’s categorical-motivation model of aesthetics, and Barnard’s Integrated Cognitive Systems, as well as the perspective of the designers of Desert Rain.

Fencott’s model of POs consists of a set of syntactic categories, that can be seen as attributes of any object that might possibly be placed in a VE. The different categories have different purposes and it is the planned interaction of POs that produces the overall structure that the designer of a VE aims to achieve. Fencott et al. investigated the effectiveness of different ways of coding one type of PO (attractors) in terms of users’ navigation choices in a VE. The application of POs to Desert Rain will be illustrated with some types of PO. Shocks are the perceptual equivalents of software bugs and, because they are noticed and break the perceptual illusion of non-mediation, they detract from presence. Example of shocks in Desert Rain include extremely unrealistic levels of brightness (extremely bright or extremely dark) and unexpected and at times inconsistent mapping of change in visitors’ position on their footprint to their movement in the virtual world. Surprises (including attractors and rewards) appeal directly to the particular aesthetics of VEs and, because they are noticed and enhance the illusion of non-mediation, enhance presence. Attractors aim to draw attention of a visitor to areas of interest, rewards, that seek to deliver the specific objectives of the VE and collectively, therefore, its purpose. Attractors are the means by which navigators are invited into setting goals for themselves. Although attractors such as a target appearing in the desert did occur in the Desert Rain virtual world, which should enhance presence, there was generally a lack of differentiation within the desert, which would decrease levels of presence. An example of a very powerful reward occurred with the exchange of the target card for a magnetic swipe card from a visitor to one of the actors. From the behind the rain curtain, an actor approached a visitor, went through the curtain and then, without speaking, requested the card from the visitor. Initially visitors may have perceived the actor to be a projection in the rain curtain; however, as the actor got closer and closer visitors will have realised that the actor was a physical person approaching them from a very close distance. Although this is beyond the scope of the current study, in order to comprehensively analyse Desert Rain in terms of POs, a perceptual map—a configuration of a set of POs—would have to be created, which can be used to show how a visitor would accumulate over time a set of experiences, which maintain a sense of purposive presence.

Lindgaard and Whitfield emphasise the importance of aesthetics and its relationship to cognition and emotion in human-computer interaction. They use Whitfield’s categorical-motivation model of aesthetics to account for results from experimental research on aesthetic preference. The model distinguishes two categories (of objects): (1) those that are largely formed and closed to articulation and (2) those that are ill-formed and open to further articulation. Within the first category, affect would be strongest for prototypic stimuli, such as the view of the desert landscape from the hotel room in Desert Rain. Within the second category, affect would be strongest for novel ‘arousing’ stimuli that yet have sufficient redundancies so that they will be assigned to a category. An example in Desert Rain would be an actor approaching the visitor in the dramatic event at the rain curtain.

Barnard’s Interactive Cognitive Systems (ICS) architecture provides a unified framework for studying emotion and cognition. This framework has been used to account for experimental results of humans interacting with VEs. For example, from the framework a correct prediction was made that participants interacting with a VE would prefer a path with a high level of detail. Applied to Desert Rain, an increase in level of detail in the desert as represented on screen would be predicted to result in stronger affect.

The current study focused on presence and other outcomes during the 20 min that visitors spent on their mission in the Desert Rain virtual world. Although actual success of the aim of the mission (all six visitors find the final room within the virtual world) was not recorded, it was found that the method that the creators of Desert Rain envisaged—
visitors meeting and exchanging information—suffered from poor communication support.

Implications for MRE design

It was not the aim of this paper to criticise the final performance of Desert Rain. However, our results have various implications for the design of MREs and VEs more generally. First, disorientation is a problem in large VEs in general and this was also apparent in Desert Rain. Consequently, orientation of support needs to be considered when designing VEs. In order to avoid disrupting presence, the requirement of having a map should preferably be eliminated by careful design of VE content, using a perceptual map. Second, our results reveal a dilemma posed by individual differences between users, in particular in terms of age and, most likely, other age-related factors. These differences result in different levels of skill in navigating VEs and associated aesthetic appreciation of VE quality, which prevents an ‘optimal’ experience of the same VE for different visitors. This means that a ‘one-size fits all’ approach is not suitable. A solution could be to design different versions of the same VE or to select level of skill within the VE prior to visiting. Indeed, various computer games support this idea through a progression via different levels of the game. Third, our results draw attention to the fallacy of the incompatibility between usability and creativity. In the context of web design a tension between creativity and usability has been identified. However, according to Nielsen, this tension is only apparent rather than real and there is ample scope for creativity once usability considerations have been carefully addressed within a design. Usability also needs serious consideration in the design of VEs because poor usability will interfere with users’ presence, in particular, as appears from our results, it may obstruct the suppression of incompatible stimuli from the real world. Fourth, although problems associated with extreme brightness levels that were experienced in the Desert Rain virtual world may not be typical of VEs in general, they do indicate the importance of designing VEs with appropriate levels of brightness.

Limitations

By the nature of the performance studied (final performance of an MRE), our study used a non-experimental design, which did not allow for experimental manipulation of factors affecting presence and identification of the exact properties of the game that contribute to presence. Despite this and the relatively small sample size, high ecological validity was possible, because the research did not interfere with the Desert Rain performance and therefore did not alter the experience that visitors would have otherwise.

The focus of our measurement of presence was within the context of Schubert et al.’s spatial-functional model of presence and focused on individual presence. Although co-presence is arguably an important aspect of collaborative MREs such as Desert Rain this was not measured. Shaw et al. reported that it was difficult for visitors to co-ordinate their actions and activities with each other; this was confirmed by the present study. Therefore, although social interaction factors will affect presence, addressing usability problems—including poor communication support—is likely a pre-requisite before social factors have a positive impact, both at the level of individual visitors (individual presence) and at the level of the team (co-presence). Interaction with an environment is a crucial factor in developing a spatial-functional representation required for presence, as follows Schubert et al.’s model. Therefore, considering this and the fact that most of the time and the most intense experience in the Desert Rain performance was spent in the mission to reach the final room, our analysis focused on this experience rather than the essentially non-interactive, much shorter and less intense part of the performance that followed.

Measuring experience in playing computer games as a dichotomous variable may have prevented us from establishing an association of this experience with presence and other outcome measures. In order to avoid this problem, it is important that future research employs scales with a larger range to measure this experience.

Only a limited amount of interaction could be recorded and only from the perspective of one visitor from a team of six. This meant that interaction with the MRE and between team members could not be analysed systematically and fully. In particular, but not only, the level of visitors’ success at their mission in Desert Rain was not recorded, neither at the individual level (visitors’ success in finding their own target and the final room) nor at the group level (the team’s success in terms of all visitors finding the final room).

CONCLUSION

Disorientation, poor graphics, a lack of instructions, individual differences between visitors, and negative feelings—including isolation, loneliness, anxiety and fear—appeared to be major problems
APPENDIX: QUESTIONNAIRE ITEMS

**Question 1. Spatial experience**

Your experience of the ‘virtual world’ in a cubicle standing on a footpad facing a screen. You’ll see some statements about your experiences. You can use the whole range of answers. There are no right or wrong answers. Your opinion counts. Answer all these questions and refer only to this experience.

1.1 How aware were you of the real world surrounding while navigating in the virtual world? (i.e. sounds, room temperature, etc.)?

<table>
<thead>
<tr>
<th>Extremely aware</th>
<th>-3</th>
<th>-2</th>
<th>-1</th>
<th>0</th>
<th>+1</th>
<th>+2</th>
<th>+3</th>
<th>not aware at all</th>
</tr>
</thead>
</table>

Moderately Aware

1.2 How real did the virtual world seem to you?

<table>
<thead>
<tr>
<th>Completely real</th>
<th>-3</th>
<th>-2</th>
<th>-1</th>
<th>0</th>
<th>+1</th>
<th>+2</th>
<th>+3</th>
<th>not real at all</th>
</tr>
</thead>
</table>

1.2 I had a sense of acting in the virtual space, rather than operating something from outside.

<table>
<thead>
<tr>
<th>fully disagree</th>
<th>-3</th>
<th>-2</th>
<th>-1</th>
<th>0</th>
<th>+1</th>
<th>+2</th>
<th>+3</th>
<th>fully agree</th>
</tr>
</thead>
</table>

1.3 How much did your experience in the virtual environment seem (‘was consistent with’) like your real world experience?

<table>
<thead>
<tr>
<th>not consistent</th>
<th>-3</th>
<th>-2</th>
<th>-1</th>
<th>0</th>
<th>+1</th>
<th>+2</th>
<th>+3</th>
<th>very consistent</th>
</tr>
</thead>
</table>

moderately consistent

1.5 How real did the virtual world seem to you?

<table>
<thead>
<tr>
<th>About as real as</th>
<th>-3</th>
<th>-2</th>
<th>-1</th>
<th>0</th>
<th>+1</th>
<th>+2</th>
<th>+3</th>
<th>Indistinguishable from the real world</th>
</tr>
</thead>
</table>

| An imagined world | -3 | -2 | -1 | 0 | +1 | +2 | +3 |

1.6 I felt present in the virtual space.

<table>
<thead>
<tr>
<th>fully disagree</th>
<th>-3</th>
<th>-2</th>
<th>-1</th>
<th>0</th>
<th>+1</th>
<th>+2</th>
<th>+3</th>
<th>fully agree</th>
</tr>
</thead>
</table>

1.7 I was not aware of my real environment.

<table>
<thead>
<tr>
<th>fully disagree</th>
<th>-3</th>
<th>-2</th>
<th>-1</th>
<th>0</th>
<th>+1</th>
<th>+2</th>
<th>+3</th>
<th>fully agree</th>
</tr>
</thead>
</table>

1.8 In the computer generated world I had a sense of “being there” not at all

| not at all | -3 | -2 | -1 | 0 | +1 | +2 | +3 |

| fully agree | -3 | -2 | -1 | 0 | +1 | +2 | +3 |

1.9 Somehow I felt that the virtual world surrounded me.

<table>
<thead>
<tr>
<th>fully disagree</th>
<th>-3</th>
<th>-2</th>
<th>-1</th>
<th>0</th>
<th>+1</th>
<th>+2</th>
<th>+3</th>
<th>fully agree</th>
</tr>
</thead>
</table>

1.10 I felt present in the virtual space.

<table>
<thead>
<tr>
<th>fully disagree</th>
<th>-3</th>
<th>-2</th>
<th>-1</th>
<th>0</th>
<th>+1</th>
<th>+2</th>
<th>+3</th>
<th>fully agree</th>
</tr>
</thead>
</table>
1.11 I still paid attention to the real environment.

<table>
<thead>
<tr>
<th>fully disagree</th>
<th>fully agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>-3</td>
<td>+3</td>
</tr>
<tr>
<td>-2</td>
<td>+2</td>
</tr>
<tr>
<td>-1</td>
<td>+1</td>
</tr>
<tr>
<td>0</td>
<td>+0</td>
</tr>
<tr>
<td>+1</td>
<td>-1</td>
</tr>
<tr>
<td>+2</td>
<td>-2</td>
</tr>
<tr>
<td>+3</td>
<td>-3</td>
</tr>
</tbody>
</table>

1.12 The virtual world seemed more realistic than the real world.

<table>
<thead>
<tr>
<th>fully disagree</th>
<th>fully agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>-3</td>
<td>+3</td>
</tr>
<tr>
<td>-2</td>
<td>+2</td>
</tr>
<tr>
<td>-1</td>
<td>+1</td>
</tr>
<tr>
<td>0</td>
<td>+0</td>
</tr>
<tr>
<td>+1</td>
<td>-1</td>
</tr>
<tr>
<td>+2</td>
<td>-2</td>
</tr>
<tr>
<td>+3</td>
<td>-3</td>
</tr>
</tbody>
</table>

1.13 I felt I was just seeing pictures.

<table>
<thead>
<tr>
<th>fully disagree</th>
<th>fully agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>-3</td>
<td>+3</td>
</tr>
<tr>
<td>-2</td>
<td>+2</td>
</tr>
<tr>
<td>-1</td>
<td>+1</td>
</tr>
<tr>
<td>0</td>
<td>+0</td>
</tr>
<tr>
<td>+1</td>
<td>-1</td>
</tr>
<tr>
<td>+2</td>
<td>-2</td>
</tr>
<tr>
<td>+3</td>
<td>-3</td>
</tr>
</tbody>
</table>

1.14 I was completely captivated by the virtual world.

<table>
<thead>
<tr>
<th>fully disagree</th>
<th>fully agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>-3</td>
<td>+3</td>
</tr>
<tr>
<td>-2</td>
<td>+2</td>
</tr>
<tr>
<td>-1</td>
<td>+1</td>
</tr>
<tr>
<td>0</td>
<td>+0</td>
</tr>
<tr>
<td>+1</td>
<td>-1</td>
</tr>
<tr>
<td>+2</td>
<td>-2</td>
</tr>
<tr>
<td>+3</td>
<td>-3</td>
</tr>
</tbody>
</table>

Response format for questions 2, 3, and 4

<table>
<thead>
<tr>
<th>Strongly disagree</th>
<th>Disagree</th>
<th>Undecided</th>
<th>Agree</th>
<th>Strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Question 2. Intention

2.1 I plan to visit Desert Rain if it is offered again in Middlesbrough.
2.2 I want to visit Desert Rain if it is offered again in Middlesbrough
2.3 I expect to visit Desert Rain if it is offered again in Middlesbrough.
2.4 I plan to visit a performance similar to Desert Rain if it is offered in Middlesbrough.
2.5 I want to visit a performance similar to Desert Rain if it is offered in Middlesbrough.
2.6 I expect to visit a performance similar to Desert Rain if it is offered in Middlesbrough.

Question 3. Confidence

In this question and the following question by ‘playing this game’ is meant: finding your target and finding the exit in the virtual world.
3.1 I will never understand how to play this game.
3.2 Only a few experts really understand how this game works.
3.3 It is extremely difficult to learn playing this game.

Question 4. Motivation to play

4.1 This game is an enjoyable challenge.
4.2 Achieving success in this game makes me feel like I’ve accomplished something.
4.3 This game rewards me when I do something well.

REFERENCES


Address reprint requests to:
Dr. Paul van Schaik
Psychology Section
School of Social Sciences and Law
University of Teesside
Middlesbrough, TS1 3BA, U.K.

E-mail: p.van-schaik@tees.ac.uk