The Effects of Virtual Weather on Presence

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Abstract. In modern societies people tend to spend more time in front of computer screens than outdoors. Along with an increasing degree of realism displayed in digital environments, simulated weather appears more and more realistic and more often implemented in digital environments. Research has found that the actual weather influences behavior and mood. In this paper we experimentally examine the effects of virtual weather on the sense of presence. Thereby we found individuals (N=30) to immerse deeper in digital environments displaying fair weather conditions than in environments displaying bad weather. We also investigate whether virtual weather can influence behavior. The possible implications of theses findings for presence theory as well as digital environment designers will be discussed.

Keywords: computer game, virtual weather, weather effects, tele-presence, performance.

Introduction

Weather is an important factor in everyday life: Almost all newscasts contain weather forecasts, the actual weather determines the way we dress, and many conversations start with comments about the actual weather. In terms of lay psychology, weather is assumed to have an important impact on mood and behavior [1],[2]. Although people in industrialized countries spend on average 93% of their time inside [3], the effects weather can have on mood, cognition, behavior, and the frequency of diseases are still evident (cf. [4]). Modern people spend much more time inside their homes and are exposed to an increasing amount of media influences: According to the Middletown media studies which aim to assess the media usage in the United States [5], the average time spent in front of the television is between 278 and 350 minutes per day. Computers are used between 85 and 199 minutes per day and thus making computers the second important media device. The reasons for computer usage are diverse: Work and leisure, communication or gaming. The latter are enjoying a particularly fast-growing popularity: The average time spent with playing computer games is up to 154 minutes a day [5]. There are more and more people, especially adolescents, who spend plenty of their time in front of computer screens playing games (cp. [6]).

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We see at least three reasons why the investigation of the potential effects of virtual weather are an important field of study. First, we think that it is necessary to explore if virtual weather has similar psychological effects as real weather. This would be highly relevant for users as well as for digital environment designers. Second, we believe that the understanding of presence might grow if the sensation of presence is stronger in mediated environments displaying fair weather conditions than in environments displaying bad weather. Last but not least, investigating the effects of virtual weather in well-controlled studies can help to better understand the psychological effects of physical weather.

Weather and Behavior

Humans adapt after a period of exposure to local climate and weather conditions. Therefore, all usual activities can be performed under various circumstances through a wide range of weather conditions [7]. Thus, the influence of weather on human behavior has been shown in various contexts. Zacharias, Stathopoulos and Hanqing [8] investigated the influence of microclimate in terms of sunlight, temperature, and wind on presence at public plazas. Thereby, temperature and intensity of sunlight determine amount and behavior of the people present at plazas. Other research has found high temperatures and violent behavior to be related [9],[10], although it is not clear whether this relation results from more outdoor presence under good weather conditions [11] or from increased aggression as a consequence of high temperatures [9].

The effect of the local weather on stock prices from exchanges has been shown by Saunders [12]. Against the assumption of a rational market, the major stock indices rise with sunny weather and diminish when the sky is cloudy. Weather effects are not only affecting professional traders but also ordinary consumers. In his investigation of the associations between daily weather and daily shopping behavior, Parsons concludes that the weather influences the initial decision of whether to shop or not [13]. Once the consumer is inside the store, other weather variables such as humidity and sunshine hours may affect the mood of the consumers and thus their shopping behavior.

Weather also affects driving behavior. Edwards found drivers to slow down in misty or rainy conditions compared to when the weather is good [14]. Even though the reduction in speed is significant it is interesting that the average speed-reduction is often too little and therefore only a gesture of appreciating the increased risk of driving under adverse conditions rather than a sufficient measure to efficiently cope with the increased risk [14].

Weather and Mood

The relation of weather and mood has been frequently investigated. Sanders and Brizzolara found low levels of humidity to be associated with good mood [15]. Similarly, high levels of sunlight [16],[17], high barometric pressure [18], and high temperatures are related with good mood [16],[19]. In contrast, high temperatures have also been associated with low mood [18]. However, Clark and Watson [20] as well as Watson [2] failed to find relations between mood and daily weather. Keller et al. [4] provide an explanation for the mixed results. One factor moderating the influence of temperature and sunlight is season: Increasing temperatures in spring are generally appreciated, whereas the aggravation of a heat wave in summer results in lowered mood. In addition, Keller et al. found people resent having to stay indoors (e.g. due to

their work) when the weather is pleasant, whereas those who can benefit from good weather outside experience an improvement of their mood.

Seasonal Effects

Seasonal changes in mood and behavior, also known as seasonality, have been extensively studied. Rosenthal was the first to describe the seasonal affective disorder (SAD) [21]. This disease is a form of depression with onset in fall or winter and recovery in spring. Along with low mood, atypical symptoms like prolonged sleep, weight gain or carbohydrate craving are common. Seasonal variations are not only observed in people suffering from SAD but also experienced by the general population. Harmatz et al. found that mood reaches a low point in the winter [22]. Additional evidence for the lowered mood in winter is provided by Dam, Jakobsen, and Mellerup who found that about 50% of the normal population show a minor degree of SAD symptoms during northern winters [23]. As exposure to sunlight and artificial bright light effectively treats SAD [24], deprivation of light is assumed to cause SAD. A mood improving and vitalizing impact of artificial sunlight has been shown even for non-depressed people [25]. Effects are often observed immediately after the first exposition to sunlight [26].

Virtual Environments and Presence

With the development of virtual environments the question to what extent an individual actually feels located in these worlds emerged. Thus, Minsky [27] coined the term telepresence to describe the state of consciousness that gives the impression of being physically present in a technically mediated environment. We think that presence is a core concept to investigate the psychological impact of virtual environments in general and of virtual weather in particular. According to Lombard and Ditton presence is a perceptual illusion of non-mediation [28]. Sadowski and Stanney describe presence as a belief that one has left the physical environment and feels 'present' in a virtual environment [29]. This sensation is related to immersion. According to Steuer, immersion can be categorized along two dimensions: the breadth of immersion (i.e. number of sensory channels involved) and the depth of immersion (i.e. resolution of the stimulus) [30]. In the last decades vast socio-technological developments have emerged. Virtual environments that mimic parts or aspects of the physical world are becoming more and more popular. Nowadays millions of users plunge into virtual worlds such as World of Warcraft, Second Life, or Google Earth. These environments are in most cases accessible via personal computers. Increasing bandwidth and progress in computer graphics as well as tough competition among developers have resulted in the rapid evolution of visually compelling virtual environments.

However, the two dimensions of immersiveness described above are not the only ones to influence the sensations of presence. Sacau, Laarni and Hartmann pointed out that not only media factors but also user factors determine the sensation of presence [31]. Among those they identified the individual's cognitive abilities, domain specific interest, spatial visual imagery, and willingness to suspend disbelief. Recently, Wirth et al. developed a process two-level model of spatial presence [32] which integrates user and media characteristics. Another central presence model was introduced by Riva, Waterworth and Waterworth [33]. It is based on Damasio's [34] model of the

self and includes three conceptual layers of presence. The authors emphasize the importance of the link between presence and emotion [33].

Virtual Environments and Weather

The designers of three-dimensional digital worlds have ultimate design options. They chose the shape of the virtual environment—the scenery could be a medieval market place or a modern city centre, a moon crater as well as a coronary vessel. One of the main aims of the designers is a high degree of realism, which is believed to be required to immerse the user in a visually convincing environment [35]. For this purpose, designers often implement weather conditions in their applications. Evidently, implementing virtual weather features is not appropriate for all environments when a high degree of realism is intended. The coronary vessel for example should be more convincing with high-resolution textures and realistic shadowing than with any virtual weather effect. In contrast, for "outdoor" environments the virtual weather effects should increase perceived realism of the scene. So far, various virtual weather effects have been developed. For example, fog rendering reduces the observable depth in the scene and snowfall can be realistically represented by means of particle systems [35]. However, more common weather conditions in VEs are fair weather (sunlight), cloudy sky and rain. To our knowledge, the psychological effects of virtual weather have not been investigated yet.

Hypothesis

The sensation of presence depends on user as well as media characteristics [31]. In combination with the close relationship between presence and affect [33] the motivation to plunge into a VR should therefore depend on the virtual weather conditions as real weather conditions influence mood [15][16][17][18][19]. In addition, there might be an even more direct effect: In the physical environment, people avoid to be exposed to bad weather conditions [8]. This might also apply for virtual environments as the sensation of presence implies the departure from the physical environment and the arrival in the mediated environment [29]. As digital media devices are typically located inside, the sensation of presence in virtual environments displaying bad weather conditions would result in leaving a dry space and experiencing adverse virtual weather conditions. Hence, we present the following hypothesis:

> *Hypothesis:* Fair virtual weather conditions increase feelings of presence, whereas bad virtual weather conditions decrease feelings of presence.

Method

Design

In this study a between subjects design was used. Participants played a computer game. The independent variable weather condition had two levels: fair weather and rainy weather. The dependent variables were presence, breaks in presence and gaming performance.

Participants

A sample of 30 individuals participated in the experiment. Mean age was 28.2 years (SD = 5.23); with a range from 18 to 37 years. The majority (76.5%) of the participants were male. Participants were free to end their participation whenever they wanted.

Materials

We used a commonly available desktop PC running the racing-game "Superbike World Championship" [36] which allows for setting the weather condition in advance (cp. Fig 1 and Fig 2). The racing track used in this experiment was "Phillip Island". All participants used the same motorbike ("Ducati"). This game and the particular track were chosen because it can be played by operating the keyboard arrow keys. In addition, in a pre-test, we found the game appealing to novice and expert players alike. More importantly, driving characteristics (i.e. acceleration, deceleration, maximum velocity, and road grip) turned out to be equal in both weather conditions. In addition, even if a crash occurs, the game can be continued. The only consequences of falling off the bike are longer lap times. Another argument for this game was the fact that riding a motorcycle typically implies being more exposed to the weather conditions than steering a car.

Fig. 1. Fair weather condition

Fig. 2. Bad weather condition

Procedure

All participants were individually tested. When the participants entered the laboratory, the computer was already running and the game weather settings window was open but not visible to the participant. Participants were assured confidentiality and anonymity of their data and they filled out a demographic questionnaire. Participants were also asked about their gaming habits on a seven-point-scale (0 = "never"; 6 = "daily"). Then, participants were assigned to the two experimental conditions so that the two groups were matched for gaming experience according to the 7-point assessment. One experimenter welcomed the participant and administered the demographics questionnaire. The second experimenter chose the adequate weather condition according to the gaming experience indicated by the participant. Then, the participant was guided to the computer and instructed. After three test rounds to familiarize with the steering interface and racing track, the task would begin. The aim was to complete as fast as possible five rounds on the racetrack. There was no time limit. Mean time needed to complete the five rounds was at 9.4 minutes (*SD* = 1.3). After having completed the race the participants filled out the presence questionnaire. Only after the experiment, the purpose of the study was mentioned.

Dependent Variables and Measures

Presence. An adaptation of the Dinh presence scale was used [37]. This instrument was developed in the context of an extensive investigation of physical presence in virtual environments depending on the sensory richness of the display and consists of

13 items (Example items: In general, how realistic did the virtual world appear to you?; How strong was your sense of "being there" in the virtual environment?). It adopts the items of established measures [38] and was found to be valid for the assessment of presence. However, the internal consistency of the scale is not reported [37]. For this investigation, a major advantage of this instrument was the fact that the items fit very well the gaming experience. Participants provided their judgments on seven-point scales (1 = “not at all”; 7 = “very much”).

Attention allocation. The entire test time was video recorded. As Bracken suggests [39], we coded for breaks in presence when eye fixations were outside display. This measure serves as indicator for the attention allocation as an increased amount of fixations outside the display is inversely related to the sensation of presence.

Performance. The time the participants needed to complete five rounds on the race track was assessed using the time measurement features embedded in the game.

Results

To analyze our hypothesis predicting increased presence in a virtual environment displaying fair weather and decreased presence in environments displaying bad weather we calculated independent samples *t*-tests. As predicted, for the first presence indictor—the presence questionnaire score—fair virtual weather ($M = 4.33$; $SD = .63$) resulted in stronger sensations of presence than bad virtual weather ($M = 3.95$; $SD = .42$). As in this case Levene’s test for equality of variances turns out to be significant ($F = 4.96$; $p = .03$), we report the t-test for equal variances not assumed, $t(24.48) = 1.97$; $p = .03$, $d = .71$, (one-tailed), thus corroborating our hypothesis.

Table 1. Bivariate correlations

DV	Presence	Breaks in Presence	Racing Time
Presence	–	-.10	.33*
Breaks in Presence		–	-.33*
Racing Time			–

Note: * < .05, one-tailed.

The second indicator for presence—attention allocation towards the display—showed the same pattern of result. Based on behavioral data, this further corroborates our hypothesis. Fair virtual weather resulted in less breaks in presence in terms of fixations outside the display (M = 5.36; SD = .57) than bad virtual weather (M = 5.93; SD = .87), $t(26) = -2.05$, $p = .03$, $d = .78$, (one-tailed).

We further analyzed the performance in terms of time needed to complete the five rounds. The results revealed no difference between the two conditions fair virtual weather (M = 9.37; SD = 1.30) and bad virtual weather (M = 9.44; SD = 1.35), $t(28) = -.14$, $p = .89$, $d = .05$, (two-tailed).

For exploratory reasons, bivariate correlations between presence, breaks in presence, and racing time were calculated (cp. Table 1). Thereby, increased sensations of presence were associated with longer racing times and more breaks in presence resulted in faster racing times. In addition, there was a tendency that fewer breaks in presence led to higher presence levels.

Discussion

Although nowadays many virtual and digital environments simulate weather phenomena, the impact of virtual rainfall or sunlight has not yet been explored. Our result suggests that virtual weather can be an important determinant of presence and should therefore be further considered by VE designers as well as VR-researchers.

Media characteristics such as immersiveness were found to influence the sensation of presence. Virtual weather can be considered as a media characteristic. In the real environment, fair weather conditions are associated with positive mood whereas in the context of gaming presence and positive mood are positively related. Correspondingly, the virtual weather characteristics influenced our participants as if the weather was real. Similar to the physical environment, our participants avoided to mentally locate themselves in a virtual environment with adverse weather conditions. Most noteworthy, the results from this study are not only based on subjective ratings but also on observable behavior in terms of attention allocation towards the game.

In addition, the driving speed was equal in both conditions. This further indicates that the two weather conditions did not result in different driving characteristics. Hence, the differences in the sensations of presence can be attributed to the virtual weather being the only difference between the two conditions.

In this study, we also raised the question if virtual weather has similar behavioral implications as real weather. In real life, drivers slow down when they have to drive under rainy weather conditions. In our virtual environment, however, the weather condition did not influence driving speed. This could result from the fact that computer games are often played because actions, which would be dangerous in real life, can be taken without any serious consequences. In the game used here, an accident is by no means a physical or financial threat as it would be in real life. However, this does not implicate that our participants did not experience presence. Further evidence for this conclusion comes from the score levels of the presence questionnaires.

A noteworthy exploratory finding is that the subjective presence ratings are negatively related to the racing performance. A possible explanation could be that more experienced gamers experienced less presence in that particular game because it was

not challenging enough. In contrast, the less experienced gamers had stronger sensations of presence due to novelty and performed worse due to lack of training. Another point for this interpretation is that more breaks in presence were related to faster racing times. This could further indicate that experienced gamers still had attentional resources available and thus outperformed the inexperienced gamers.

This study has several limitations, which we want to describe here. One important point is that we used a somewhat out of date racing game. In newer games the virtual weather is connected with corresponding driving characteristics. Thus, as a consequence the virtual weather effects were not as natural as they would be in a more advanced environment. However, if virtual weather even matters in such an environment, then we would expect stronger effects in current environments. Yet another point is the actual physical weather. We did not include it as a factor in our design because our sample is too small to study possible interactions between physical and virtual weather. A more representative sample could further strengthen the confidence in our findings.

Future research should directly look at the effects of virtual weather in terms of emotions and mood. If there is as similar effect of virtual weather on emotions and mood, then digital environment designers should consider implementing appropriate weather for the mood they want to induce. A scary online game might be even more compelling with bad virtual weather whereas a virtual work environment displaying fair weather conditions might help to prevent signs of seasonal affective disorder in someone who suffers from northern winters.

Replications of this study could be highly relevant for the developers and users of many virtual environments applications such as online-marketing, cyber-therapy, online gaming, or e-learning. Thereby digital and virtual environments displaying the individually preferred weather conditions could be an increasingly attractive alternative to the physical environment.

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