Evaluating Experiences in Different Virtual Reality Setups

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Abstract. This paper describes the evaluation of three different scenarios in the fully immersive room-based virtual environment DAVE (Definitely Affordable Virtual Environment) and a head-mounted display, the Oculus Rift. The evaluation focuses on comparing the two immersive environments and three different scenarios (observation, emotion in a roller coaster, and interaction) in regards to typical virtual-reality characteristics, such as immersion, engagement, but also on cybersickness and the overall experience. First results indicate the DAVE environment better supports scenarios, which require the user to directly interact with the environment. The roller coaster scenario creates stronger immersion and a higher nausea-level, while the interactive task is more engaging in terms of fun.

Keywords: Virtual reality · Immersion · Cybersickness · Oculus Rift · CAVE

1 Introduction

Over the last years, the potential of immersive virtual environments (VE) has been described for various application scenarios. In particular the current trend of affordable head-mounted displays (HMD) allows a wide range of users to access different virtual reality (VR) applications. Such immersive experiences are not only interesting for entertainment, gaming, and simulations, but also for training and education scenarios [1,2].

However, in particular in learning and training applications different scenarios often require different interactions and activities in the virtual reality. For example, specific training tasks would require rich and realistic user interactions (e.g. learning how to use a specific machine). Other tasks require more freedom in the environment such as the possibility to freely examine the objects

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and the environments. For other experiences often only the observation and the experience of the virtual scenario is sufficient.

Different virtual reality devices and setups support different degrees of freedom, of immersion, and interactions with the environment. In a room-based fully immersive virtual environment (such as a CAVE) users are still able to see their own body and set in relation to the virtual world. It is possible to use additional tools in a natural way (e.g. a map or a smart phone) and interact directly with other users. Head-mounted displays support more flexible forms of experiences and activities, for example show a different body for the user or trick the sense of orientation. However, they often give users not the possibility to directly interact with the environment, since the representation of the own body is missing or poorly represented. Different forms of interaction are challenging, since consumer HMDs only give a limited range of sensors for tracking the body [3].

To design rich learning and training scenarios in a virtual environment it is not only necessary to focus on the different interactivities, but also to design the experience with consideration of different virtual reality characteristics and problems to create a sound user experience. This in particular includes immersion and cybersickness.

In this work we present a first comparison of different activities (observations, strong emotions, interactions) in two virtual reality systems (CAVE, Oculus Rift DK2) with focus on typical virtual-reality characteristics, such as immersion and engagement, but also on the potential issue of cybersickness.

2 Background and Related Work

Significant research and development efforts of different VR experiences have discussed and shown the potential of immersive VR already very early [5,6].

2.1 Comparing Experiences in Virtual Reality Environments

Tan et al. [4] compare and evaluate gaming experiences in the *Oculus Rift*. They used a Oculus Rift DK1 and a traditional computer with monitor setup to play a first-person shooter game (Half-Life 2). The test persons had to play the game on each system and then they answered two main question. Ten test persons were participating. The first main question was about the experience using the Rift compared to a standard PC setup. The second question was about what to take care about when designing games for the Rift based on the findings about the peoples experience. The study shows that most participants experienced cybersickness 8 on a scale from 1 to 10 and that cybersickness only occurs on the Oculus Rift. They say that: "cybersickness was a strong factor in modulating peoples gaming experiences using the Rift."

Kim et al. [7] compared three different VR Systems with two tasks for each system (A 3×2 study). The Systems used were a standard PC without any VR elements, a HMD with limited peripheral vision and a fully immerse CAVE environment (DiVE). The two tasks where a low stressful and a high stressful

task where the participants had to find cards with a certain word-color combination. The difference was, that in the low stress task the color and name of the words was congruent and in the high stress task they were not. Additionally in the high stress version of the tasks, the participants were influenced by averse simulations (loud noises, flashes and occasional tactile vibrations). The study focused on cybersickness, presence, and emotional changes. Additionally the time to find the cards was tracked and a galvanic skin sensor was used to measure sympathetic autonomic arousal. The result showed, that there were higher emotional arousal values in the DiVE and HMD compared to the desktop system but there were also differences between the VR devices. In the DiVE the emotional changes were mainly positive whereas with the HMD the effects were negative. Overall the participants showed the highest SCR changes with the DiVE, with the HMD the changes were moderate. In the end the findings showed, that a CAVE like environment is best used to evoke happy emotions whereas a HMD device is advantageous to evoke negative emotion. The desktop system resulted in the smallest changes overall and moderate task performance. This knowledge can be used e.g. in psychological studies because it gives insight in which technologies are viable to use for which treatments. A HMD device can therefore maybe be used to treat anxiety disorders.

2.2 Cybersickness

As VR-devices become more and more popular, there is still a big obstacle to overcome to make it an enjoyable experience for everyone, namely cybersickness. Cybersickness symptoms in virtual reality environments are similar so motion sickness (e.g. nausea, disorientation, discomfort, vomiting). The sensitivity and grade of cybersickness differs from person to person and thus is hard to keep track of. Most studies rely on self-reported tests after using VR devices and so it highly depends on every participant, how the results of the study develop.

Davis et al. compare the two HMDs Oculus Rift DK1 and Oculus Rift DK2 [8]. In a follow-up paper Davis, Nesbitt, and Nalivaiko [9] introduce new techniques to explicitly measure cybersickness. The idea is to create certain tasks and actions that induce cybersickness and with help of these it would be possible to measure psychological conditions and objectively quantify cybersickness symptoms. The paper also refers to older studies and sets different approaches to measure this condition into contrast to find well suited ways of finding an objective measurement. The study was held with 30 participants and with the use of two different virtual roller coasters. With these two different coasters it was possible to find relations between e.g. the level of detail, the level of user interaction and the nausea condition of each participant.

In conclusion the study found, that the coaster with more complex realism (Helix) causes a higher level of nausea offset compared to the other and is therefore suggested for further studies regarding objective measurement of cybersickness. Such studies are necessary to bring VR further to the possibility of everyday usage because only with cost effective and objective measurements, which still have to be found, this will be achievable [9].

Polcar and Horejsi [10] compared three devices with a group of 45 students. The devices were a regular PC workstation, a Stereoscopic projection wall (CAVE, PowerWall, StereoWall) and an HMD (Oculus Rift DK2). After the test participants had to fill out a questionnaire about cybersickness, their symptoms, and the level of knowledge acquisition. The goal was to find a comparison of these devices. In the third part of the paper, they describe the effects of virtual learning and cybersickness. In conclusion there found no big difference of knowledge acceptance by doing a training exercise in reality or in a virtual world. While different controllers did not have much effect on the results, a larger display enhances the knowledge acceptance rate. In this study males achieved a better performance at this task than females. This effect decreased when the virtual environment was viewed on a bigger screen.

3 The Setting

For this study we used 2 ((a) Oculus Rift DK2, (b) DAVE) × 3 (tasks based on (1) observation, (2) emotion, (3) interaction) experiment setup with focus on comparing immersion, cybersickness, and the overall experiences.

3.1 Virtual Environments

Oculus Rift. The Oculus Rift is a Head Mounted Display developed by Oculus VR since 2012. The first commercial version was released in March 2016. For this paper the second pre-released developer kit (DK2) of mid 2014 was used[1]. In this version the display has a full HD resolution which is divided vertically showing the stereoscopic image for both eyes. Compared to prior HMDs the Oculus Rift was able to increase the field of view to 110° by using lenses and adjust the rendered images accordingly. An optical tracking system is used in combination with an orientation sensor for the localization of the users head. A sitting and a standing setup is possible but the range of movement is limited to less than two meters because of the cable-based video transmission.

DAVE. The Definitely Affordable Virtual Environment (DAVE) is an immersive projection room with three side walls and one floor projection [12]. The projection screens are 3.3 m wide and 2.7 m high. (see Fig. 1). Stereo projectors with HD resolution are updated at 60 Hz. Stereoscopic shutter glasses are used, similar to the ones also known from 3D TV sets or 3D cinemas. In addition, an optical head tracking system allows a correct parallax and creates an undistorted view for the main user. Within the 3.3 by 3.3 m the user can walk around an object to see it from all sides. A big advantage compared to most HMDs is the very wide field of view. Such a CAVE provides a visually convincing immersive experience and while allowing the user to see her own body.

[1] https://www.oculus.com/dk2/.

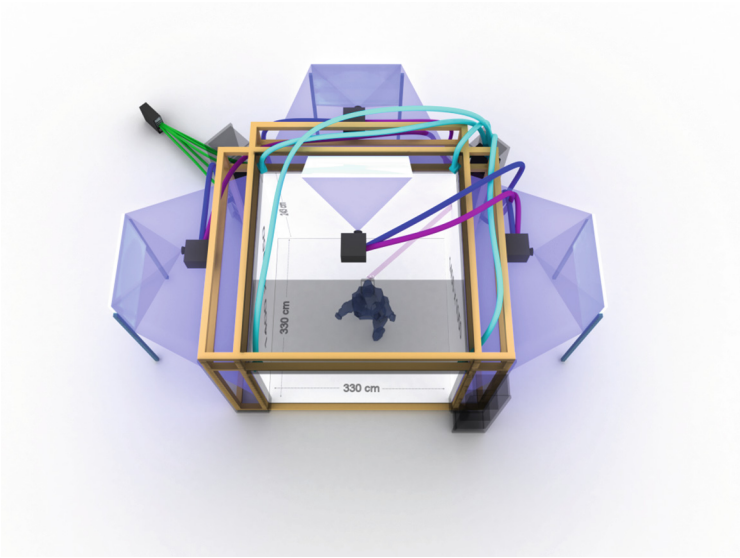


Fig. 1. The DAVE: A four-sided CAVE-like immersive environment

3.2 The Implemented Scenarios

For the study three different scenarios (see Fig. 2) were implemented with the goal to create three different experiences (observation, strong emotion, and interaction).

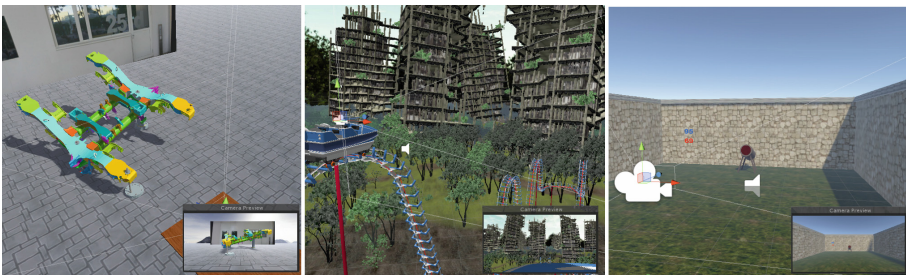


Fig. 2. The three scenarios from left to right: complex model for observation, roller coaster and catch-the-ball game

Task 1 (Observation). The first task was mostly focused on letting people become familiar with the systems. It was just a stationary scene where the participants had to find a certain object on a big model (see Fig. 3-a). Participants had to move around to find the object. The difference between the task with the Rift and in the DAVE was the object on the model they had to find.

Task 2 (Emotion). This was the dynamical task where the study participants had to take a ride in a virtual roller coaster once with the DK2 (see Fig. 3-b) and once inside the DAVE. The users only had to sit on a chair and experience the virtual ride. Afterwards they had to describe their feelings while riding. Some of the test persons experienced quite a lot of cybersickness during this task but for none it was enough to interrupt the ride. The task was exactly the same with the Rift and in the DAVE.

Task 3 (Interaction). The last task was a dynamical scene where the study participants had to interact with the virtual environment. The goal of this task was to catch or deflect as many balls as possible in a certain time. The balls came flying towards the user from a virtual canon. This task created mostly positive reactions from all participants because it was much fun to play. There was no difference between the task with the DK2 (see Fig. 3-c) and in the DAVE. In both setups a Microsoft Kinect was used for detecting the users hands.

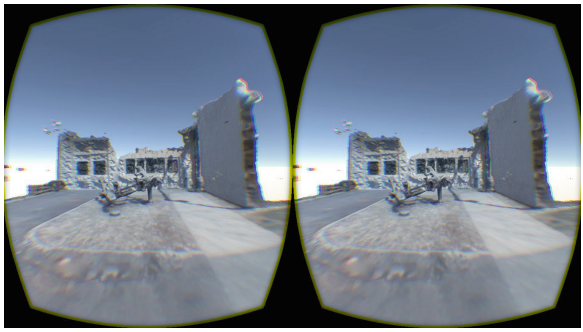
4 Preliminary Study

To evaluate the different scenarios we devised a study setup which should shed light on the participants' experience in the two virtual environment setups with focus on different aspects, such immersion, nausea level, and engagement. The tasks, as described above, were designed to cover activities focusing on (1) observations, (2) emotions, and (3) interactions in virtual environments.

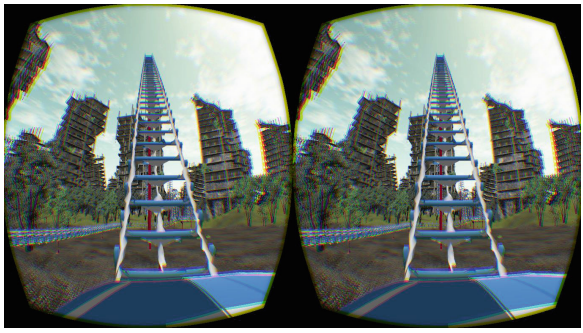
In a first study we compared the two different virtual reality environments with 8 persons. One environment was an HMD and the other one was the DAVE. The participants had to do three tasks in each of these two virtual environment. Before they started with task 1, they had to fill out a pre-questionnaire. After each task they rated the immersion, nausea level, overall experience, and fun. After completing all 3 tasks in the DAVE, they filled out a post-questionnaire At the end they had to fill out the task questionnaire of part two and a specific cybersickness questionnaire.

4.1 Participants

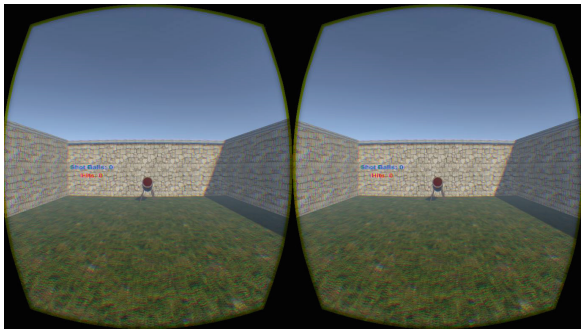
To evaluate the scenarios 8 participants (5 female) between 21 and 48 (M = 28.38, SD = 8.29) were recruited. After a first introduction, participants completed an pre-survey with demographic information (e.g. age, gender, profession), experience with games and virtual realities. 6 participants are students. On a Likert-scale between 1 (not at all) and 5 (definitely) the participants rated their experiences in computer usage with a arithmetic mean of 3.13 (SD = 1.36) and their experience wit video games with a mean of 2.0 (SD = 1.6). All of them mentioned that they are not experienced with Virtual Reality. Only 2 play often or relatively often computer games. 3 like playing video games. 4 have heard of a CAVE/DAVE environment, 1 of them has already used one. 4 have heard of the Oculus Rift, 3 have already used one.



(a) Task 1 - Observation



(b) Task 2 - Emotion



(c) Task 3 - Interaction

Fig. 3. The three different tasks as rendered in the Oculus Rift DK2.

4.2 Setup

The virtual reality Oculus Rift Developer Kit 2 (DK2) and the DAVE environment as described in Sect. 3 were used for the evaluation. For the task design the scenarios (Task 1: Observation, Task 2: Emotion, Task 3: Interaction) as described in the previous section were used. Figure 4 illustrates the three tasks in the DAVE.

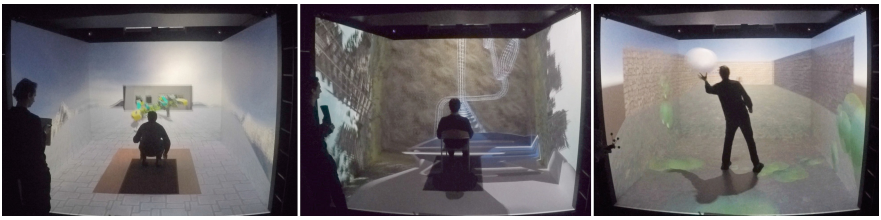


Fig. 4. The tasks in the DAVE; from left to right: Task 1 - Observation: The participants were asked to find a specific part of the machinery by observing the scene; task 2 - Emotion: The participants had to ride a roller coaster; task 3 - Interaction: In a mini game the participants had to catch balls shot in a random angle at them.

4.3 Method

Immersion, Experience, and Engagement. To evaluate aspects such as immersion and fun we used two different measures. (1) After each task we asked the participant to rate immersion, fun, and if they have liked the experience on a Likert scale between 1 (not at all) and 10 (very) to receive immediate feedback. (2) After they have completed all three tasks for one device we asked them to complete slightly modified version of the Game Engagement Questionnaire (GEQ) [11]. GEQ is designed to measure engagement in games. It provides a set of 19 questions (we used 18 for our study) to measure absorption, flow, presence, and immersion. Since we measure the "game engagement" after the interaction with each setup we are able to compare these values for the two different virtual reality setups.

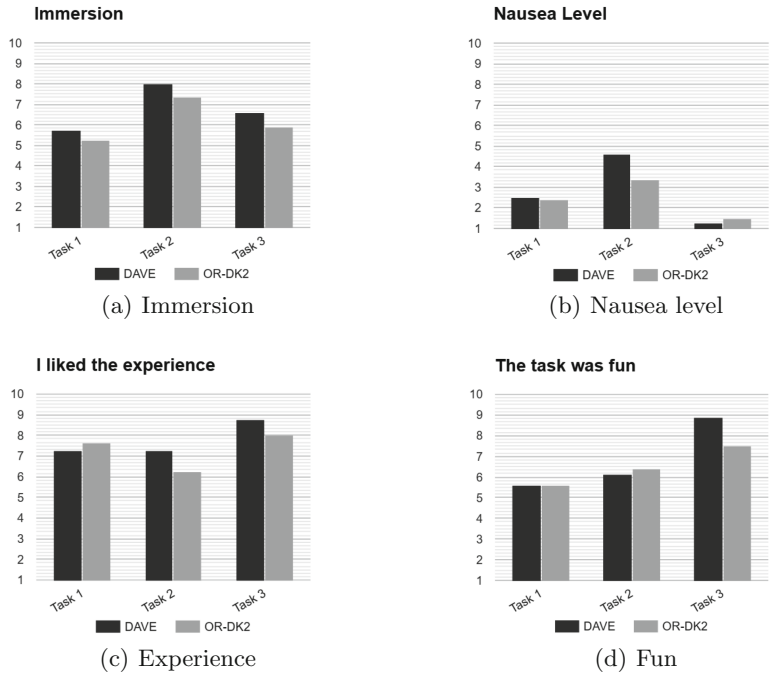
Cybersickness. As also described in [9] we used a subjective individual rating of the participant's perception of their nausea level to evaluate cybersickness. The participants were asked after each task to rate their nausea level between "0 - no discomfort" to "10 - feeling like vomiting".

5 Findings

5.1 Experiences

Immersion. Participants rated their immersion level on a scale from 1–10 after each tasks slightly higher in the DAVE. They rated in particular the rollercoaster experience as immersive (see Fig. 5(a)). Looking at the GEQ (see Fig. 6) the overall immersion-level in the DAVE is also rated higher compared to DK2.

Cybersickness. After each task the participants were asked to describe their nausea-level on a scale between 0 - no discomfort" to "10 - feeling like vomiting". Figure 5-b gives an overview of the participants' nausea level in the two different virtual environment. The value was for both devices very high after the Rollercoaster task (Task 2). The nausea level difference between DAVE and DK2 indicates that this feeling is only slightly higher in the DAVE.



(a) Immersion (b) Nausea level

(c) Experience (d) Fun

Fig. 5. Subjective rating of immersion, nausea level, experience, and fun after each tasks - 1 (not at all) 10 (very)

Fun and Overall Experience. As illustrated in Fig. 5(c) the participants mentioned to like all experiences, but task 3 was rated highest. They also mentioned to have most fun in the interactive experience (see Fig. 5(d)). Figure 6 illustrates the four main (absorption, presence, flow, and immersion) concepts as a result the 18 different GEQ-questions. All engagement metrics were described as slightly higher in the DAVE compared to DK2. In particular Immersion as factor of engagement was rated extremely high in the DAVE environment.

5.2 The Tasks

7 out of 8 participants would prefer the DAVE over DK2 for the observation tasks. Reasons for that were described as "more realistic interactions" or "better graphics". Participants rated the difficulty of finding the object in the DK2 ($M = 2.5$, $SD = 1.41$) slightly higher compared to the DAVE ($M = 2.0$, $SD = 1.07$).

7/8 rated their experience in the virtual roller coaster as a fun experience. Three had a fear emotion at some point of the ride. Four would want to use this simulation again. Two would prefer DK2 for this simulation ("movement more realistic in DK2"), six the DAVE ("feels more real").

On a scale between 1 (not at all) and 5 (very) participants described the fun while playing the minigame with an arithmetic mean of 3.88 ($SD = 1.25$).

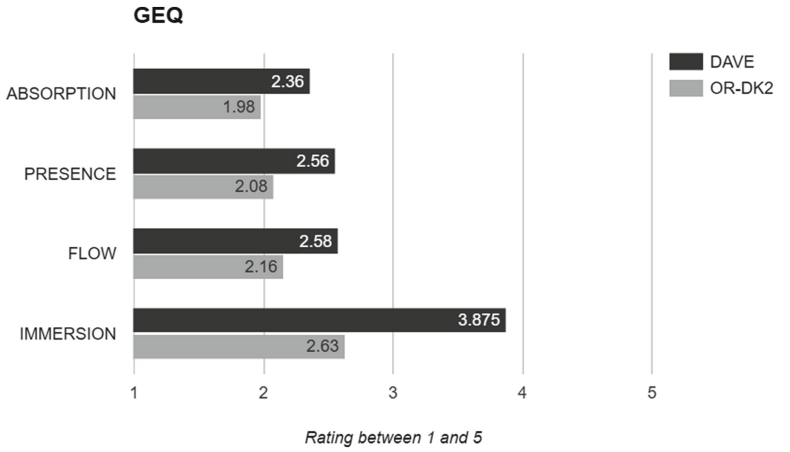


Fig. 6. Game Engagement Questionnaire (GEQ).

6/8 would be interest in further developed versions of this game. 7 would prefer the DAVE over the DK2 to play this game ("not so heavy glasses", "display of hands not realistic in DK2", "hand movements more realistic in DAVE").

6 Conclusion and Discussion

The presented study is designed as the beginning of many tests with this setup and gives a first overview. Early results indicate, that a DAVE environment gives participants more freedom in regard to body perception, small-scale movement, and more realistic images. However, all tasks were mainly designed for small movements in a limited space. While the roller coaster scenario (designed to create strong emotions) gives participants a strong feeling of immersion and creates a higher nausea level, the interactive playful task is rated as a more fun task.

Further studies should also include scenarios, which require participants e.g. to travel distances. Also due to the small study setup and the natural differences between the two virtual reality environments (HMD vs. room-based virtual environment) many key limitations are given. Given the current rapid development of HMDs, it will be important to extend the current study with the latest HMD-technologies and other platforms. Future studies investigating more specific emotions and different forms of interactions with a larger participant base will extend the present findings.

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