KNOWLEDGE ACQUISITION AND CYBER SICKNESS: A COMPARISON OF VR DEVICES IN VIRTUAL TOURS

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Virtual reality (VR) is a widely used platform for Product Lifecycle Management (PLM) support. Visualization of a virtual prototype in any phase of product or process design is important for making decisions about further development, testing and simulations. While the designers working on a particular product know its exact appearance, other personnel taking part in the development may need to use some advanced virtual reality devices, such as a **Computer Aided Virtual Environment** (CAVE), or a **Head Mounted Display** (HMD). The goal of the following study is to compare them and discuss their advantages and disadvantages while taking a tour in a reference model of a virtual plant. 45 students were exposed to a virtual model on a LCD monitor, HMD Oculus Rift, and a stereoscopic projection screen. We tested the rate of understanding the environment and possible cyber sickness symptoms.

KEYWORDS
virtual reality, visualization, CAVE, HMD, factory layout, cyber sickness, knowledge acquisition

1. INTRODUCTION

Virtual reality is nowadays an inseparable part of the development of a new product or process. The digital factory concept supports the whole product lifecycle. One of many parts of this concept is visualization, simulation and factory layout validation.

Production plant layout is still very often designed as a 2D top view drawing, which is usually simplified and degraded into simple rectangular blocks often with a text note. This approach is accompanied by a high risk of overlooking details which can result in collisions between moving or static objects in the layout. Such 2D layouts are not a suitable base for ergonomic analyses. Other than that, 2D layouts can be hard to interpret by anyone else apart from the developers (sometimes even while standing in the actual workplace with the layout printout in hand).

There is certainly a reason for making layouts in 3D as they can be used to carry out the analyses. Another use of 3D layouts is in virtual training of new employees prior to being deployed on a production floor. Various processes can be visualized as well as the whole factory floor layout. A new employee can be trained without interfering with production. The goal of this training is to provide practical familiarization with the functions of various company processes. New employees can be safely virtually trained in the manufacturing process on a model of their future workplace and then can fluently move on to work at their real workplace.

These layouts can be evaluated on personal PCs, which are usually powerful enough to display even large layouts. Another option is a stereoscopic projection device like CAVE/PowerWall/StereoWall or a Head Mounted Display for even better immersion.

Each of these three options has advantages and naturally also disadvantages which will be examined and discussed in this paper. The question is which kind of device is most suitable for a particular kind of virtual tour or training. Currently there are many suppliers of CAVE devices, but these are very expensive with considerable demands on construction space. The advantage over a HMD is a high viewer capacity. On the other hand, HMDs can be attached to a common workstation, they are portable and provide much better immersion into VR, although only for a single user.

We have one of each of these devices available for research and development of virtual environments. We have also experienced **cyber sickness** issues using them, which could be a huge concern when deciding the best virtual reality device for training and education applications. If so, it would go directly against the Technology Acceptance Model by Fred D. Davis [Davis 1989]. Regular use of these devices got us used to the sickness and made us resistant to the symptoms. Another question is, whether **the amount of learned knowledge is considerably better** in one device than in another, thus being worth an investment higher than a middle-end personal computer.

2. COMPARED VIRTUAL REALITY DEVICES

Three devices were compared. The main goal of this comparison was to find how these devices can support the goal of providing a 3D virtual production plant tour. The comparison focuses on a virtual tour in a virtual plant model made using Source Engine expanded with the DIGITOV package (see Fig. 1) which is a computer game based platform for making virtual production floor and enterprise models. This environment was developed at our workplace (more in MM Science, December 2013).

Figure 1. Examples of visualisations from the DIGITOV package

Option 1: Regular PC workstation

This is the most common solution. Most work in CAD systems is done on regular PC workstations with a regular LCD screen mostly without the possibility of stereoscopic projection. A PC is best used for long-time work because it is comfortable, but with limited possibilities to view the layout in a group. Also, the level of immersion is not high, which could lead to a decreased rate of knowledge acceptance, but cyber sickness symptoms are not expected. Although we have a PC workstation with 3D screens available, we decided to compare regular screens, because they are the most likely to be available, thus not needing any extra investment.

Option 2: Stereoscopic projection wall

This device consists of a projection wall with a projector capable of stereoscopic projection, using either the passive or the active method (one wall CAVE). Usually this is accompanied by a tracking device to accommodate the stereoscopic projection to one particular user. A huge advantage is that these projection walls are usually compatible with common stereoscopic frameworks like nVidia 3D View.

Option 3: Head Mounted Display – Oculus Rift DK2

Oculus Rift DK2 is currently a development version of commercially available head-mounted display devices for personal home use to be released by the end of 2015. It consists of a Full HD LCD screen, which is viewed through lenses providing nearly a full field of view. It is a new gaming device which has only been on the market a few months (January 2015), so commercial use is very limited for now. While the gaming compatibility is good, there is so far no compatibility with commercial CAD systems.

Oculus Rift DK2 renders the virtual environment with barrel distortion to make the perspective more realistic. Also, a negative chromatic aberration of the lens is rendered to compensate for it (see "rainbow-coloured edges" in Fig. 2). Each eye sees half of the screen through a lens and this resolution is spread to the user's whole field of view.

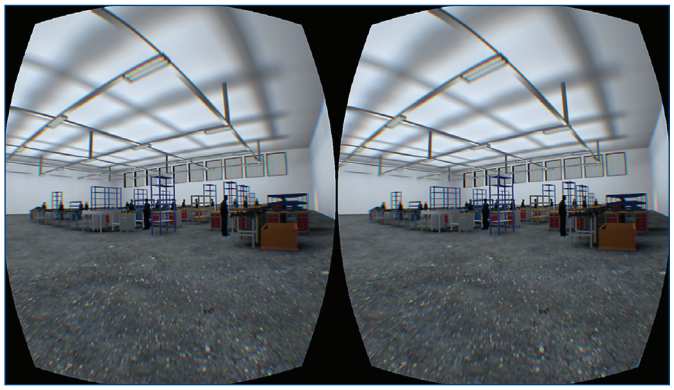

Figure 2. Reference model visualization in Oculus Rift DK2 (image for left and right eye)

Oculus is a new phenomenon in the computer gaming industry. It provides virtual reality with a much higher level of immersion, incomparable with a computer screen or 3D projector. We expect this device will find its way into industrial and scientific visualization, either in its current or in the final version.

3. EFFECTS OF VIRTUAL LEARNING AND CYBER SICKNESS

Highly immersive virtual reality applications are known to cause motion sickness symptoms. Several surveys have been conducted about the severity of the symptoms caused by various virtual reality devices. According to [Jaeger 2001] this could have been caused by the level of visual rendering of textures at that time. Today's computers are capable of almost photorealistic rendering, so this is probably not the cause. Various sources [Naqvi 2013, Wa 2011, Pölönen 2013] proved stereoscopy to be one of the major aspects causing motion sickness and various types of discomfort during VR exposure. As the Oculus Rift DK2 device is a stereoscopic VR projection device, there is a question whether the symptoms will be the same as or worse than those occurring while watching a stereoscopic movie. A study comparing a consumer-targeted Oculus Rift DK1 (previous version of DK2) with a professional HMD Nvis SX60 [Young 2014] reported that Oculus Rift DK1 had much more occurrences of the sickness symptoms, but the test subjects were better at navigation and distance estimation tasks wearing Oculus Rift.

The symptoms of cyber sickness have been known as simulation sickness symptoms since 1993. According to the Simulation Sickness Questionnaire [Kennedy 1993], the symptoms include nausea, stomach awareness, blurred vision, vertigo, and concentration difficulty. These symptoms can be of great importance if virtual reality is used as a platform for initial training of new employees.

Various studies confirmed that using virtual reality for such training in general makes sense. Comparison of the knowledge acceptance does not differ very much when doing an exercise in reality or taking part in a virtual training session. More interestingly, the use of various types of controllers of the virtual reality simulation did not have much of an effect [Velaz 2014, Gavish 2013, Bertram 2015, Peruch 1998]. On the other hand, comparison of large and small displays (more accurately the size of the field of view) did enhance the knowledge acceptance rate [Tan 2006]. This study has also shown that males are better at this task than females and that this gender gap was decreased when viewing a virtual environment on a big screen. Spatial knowledge acceptance depends on whether the virtual model is just viewed or navigated actively by the user [Conniff 2010, Christou 1999], although [Gaunet 2001] did not prove a difference.

4. COMPARING THE DEVICES

The question is how to compare these devices. It is known that stereoscopic projection can cause some inconveniences such as blurred vision, slight dizziness or nausea. We, some of our colleagues, and university students have experienced these symptoms while looking at a stereoscopic projection wall or watching a 3D movie in a cinema as well as in the Oculus Rift DK2.

Another thing to think about when deciding on the optimal virtual reality projection device, is whether the quality of immersion has an effect on learning facts from an educational virtual environment. A PC workstation and the Oculus Rift DK2 HMD are intended to be used by a single user, but a stereoscopic projection on a stereoscopic wall can be displayed for more viewers.

This raises two questions. The first is whether the side effects of Oculus Rift make this device unusable as a personal visualization device in industry and if these side effects are really such a big concern when considering purchasing the device. There is another question: Whether one can learn more from the virtual environment using a "better" VR device than a simple PC.

5. METHOD

A group of 45 students was exposed to a virtual tour after which they were asked to fill a questionnaire aimed at the occurrence of cyber sickness symptoms and the level of knowledge acquisition. The symptoms they were asked about directly were: dizziness, headache, blurred vision and nausea, including a blank field to fill in other symptoms or to describe their discomfort. We asked them for the symptoms they had either before or after the exposure. Other questions were aimed at how much knowledge about the virtual production floors was received. The subjects were asked what was the product being assembled on the line and they had to pick the correct top-view of the production plant layout.

They were exposed to virtual reality on a regular PC workstation and a PC workstation with Oculus Rift DK2 connected and set up (see Fig. 3b). They navigated themselves through the models for three minutes, using a keyboard for walking and opening doors and a mouse for turning. When using the Oculus, one can look around by physically turning one's head to a limited degree which is very realistic and provides a high level of immersion.

In the stereoscopic projection laboratory (see Fig. 3a), a group of students was exposed to a passive, but narrated virtual tour – they just viewed the model while standing in front of the screen. Each of the students went through all of these models, filling a questionnaire immediately after exposure. Each device displayed a different virtual production floor model. Test participants had to recognize particular layouts and answer questions about perceived layouts. They also had to answer cyber sickness questions.

Figure 3. Exposure: a) stereoscopic wall, b) HMD Oculus Rift

6. HYPOTHESIS

We believe that more immersive virtual reality devices will provide a greater understanding of the space and the participants will acquire more knowledge while taking a narrated tour in the stereoscopic projection wall. We also expect similar results when comparing the PC with the Oculus Rift DK2. On the other hand, there is a big advantage for the PC and the Rift over the stereoscopic projection wall as the users will be allowed to navigate the environment on their own.

As for the cyber sickness symptoms, we expect few or no occurrences on the PC viewed model. There will be some slight symptoms while watching the stereo projection and we expect most people will feel slightly more severe discomfort with the Oculus Rift HMD.

We believe that there will be a difference between participants that are used to working with 3D programs like CADs or 3D graphical modeling tools, computer gamers and people who frequently go to stereoscopic cinemas or have home stereo-TV. We think that the spatial perception will be better for people who are used to these devices and that they will be more resistant to cyber sickness symptoms. We will call them '3D users' and 'non- 3D users'.

7. RESULTS

After we conducted the experiment, we obtained some very surprising results. First of all, it was found that a self-navigated tour on a PC was exactly as efficient for acquiring knowledge as a narrated tour watched in stereoscopy, while Oculus Rift achieved about two thirds of this score. Fig. 4 shows total points achieved by all of the participants (participants acquired these points for success answers examining the knowledge acquisition – correct layout assignment, shape of manufacturing belt, etc.). Our hypothesis that 3D users would be better in this task was correct – these users were more than twice as good.

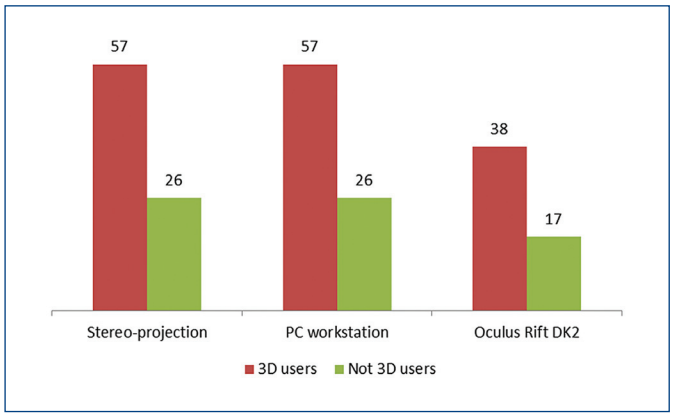

Figure 4. Knowledge acquisition (points achieved for each group)

The results for the cyber sickness symptoms were the same as predicted for the PC workstation. Only a single 3D user answered that some severe symptoms occurred, but it was immediately after exposure in the Oculus Rift DK2, so these symptoms could have been left over from the previous exposure. More interestingly, the overall count of symptoms was the highest in the stereo projection as shown in Fig. 5.

According to the results after separating occurrences of less severe from more severe symptoms, it was found that although the stereo-projection had more overall occurrences, they were much more serious in the Oculus Rift DK2. During the experiment, one participant in the stereo-projection had to take off his glasses and leave the exposure. However, this one particular participant then went to the PC station and the Rift afterwards and did not mark any symptoms.

The following Fig. 6 shows how many participants experienced more severe cyber sickness symptoms. It is very interesting that Oculus Rift had a slightly bigger effect on 3D users than non-3D users. It also has to be mentioned that only a single 3D user had a severe symptom, but there were 12 non-3D users with severe symptoms.

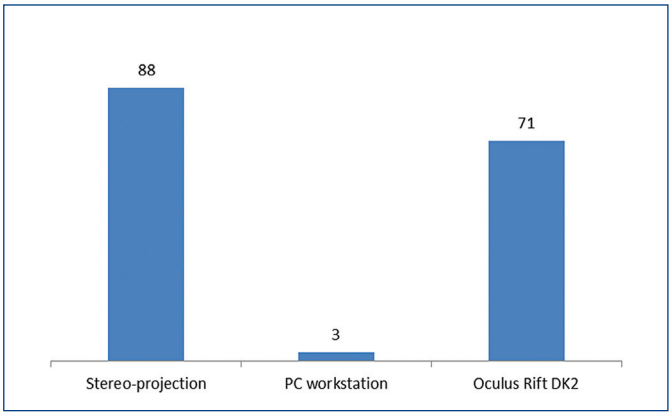

Figure 5. Overall count of different cyber sickness symptoms

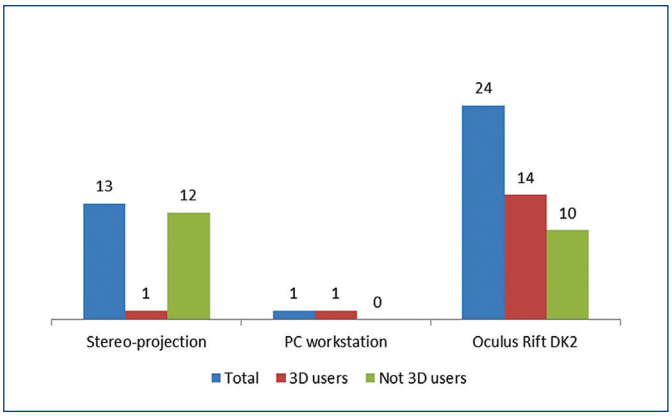

Figure 6. Participants perceiving more severe cyber sickness symptoms

8. DISCUSSION AND CONCLUSION

Although the results were exactly the same, we believe that there can be a difference when the tour is navigated by a narrator and viewed on a stereoscopic projection wall or when it is navigated by the participant without any narration and taken on a regular PC workstation. There is a question for a further research, whether a participant navigated tour using the stereoscopic projection wall would have benefits over the tour on a PC workstation.

As for the results in Oculus Rift DK2, we think that there could be two causes for the worse results in knowledge acceptance. The first is that the Oculus Rift was a totally new immersive experience for most participants. Their concentration could be negatively affected by the astonishing immersion. We think that the second reason is the cyber sickness symptoms that could also have a negative effect on concentration.

The cyber sickness symptoms proved to be an issue while taking a tour with a stereoscopic projection wall and with Oculus Rift DK2. Although there were more overall symptoms in the stereo projection, Oculus Rift DK2 caused almost twice as many participants to experience more severe symptoms. The PC workstation caused only one of the 45 users to experience cyber sickness, but as mentioned in this article, this case was challenged by other circumstances.

It is safe to say that the PC workstation is suitable for taking virtual tours navigated by the participants themselves. The stereoscopic projection can be used for mass narrated tours with very similar or the same results for accepting new spatial knowledge, but there is a possibility of cyber sickness symptoms. On the other hand, the Oculus Rift DK2 did not prove to be very suitable because severe cyber sickness symptoms can almost certainly occur. It has to be said that the Oculus Rift device is still in its developmental phase and we believe that the final version will have most of these disadvantages reduced or even eliminated.

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