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The Perception of Amplified Head Rotations in Virtual Reality

Abstract

The field of view of a typical virtual reality headset is very limited compared to the human eye. This leads to excessive head movement where the user need to twist both neck and body to get a full view of a virtual environment. By amplifying the head rotation so that the virtual rotation is faster than the physical, a more natural way of exploring the environment might be achieved.

This study used a between-group design with 10 users in each group, comparing amplified head rotation with non-amplified head rotation in a 360 degree video of a plaza in Vienna. The questions is how amplification affects head movement and motion sickness. A standardized simulator sickness questionnaire was used to get data on how the users felt during the experiment.

Results indicates that the amplification decreases physical head rotation and shows no clear signs of increased risk for motion sickness. The results indicates that amplification might be a good approach to require less movement from the user during a virtual reality experience.

1. Introduction

This study will be a small part of a pilot project called ”VR i Vården”, in English “VR in healthcare”, that will investigate how virtual reality (VR) can be used in cognitive behavioural treatment of agoraphobia. VR is a relatively new field and even if it has developed very fast the last years thanks to new VR-headsets like the Oculus Rift we still have not seen its full potential. The amount of applications for VR stretches from games and entertainment to education and therapy and we are likely to see much more over the coming years. But the technology is still not perfect and there are lots of areas that can be refined. Resolution and refresh rate of image and movement is quite good today but there are some problems showing immersive 3D-material on flat screens.

With the flat displays used today most consumer VR-headsets (e.g. HTC Vive or Oculus Rift) gives a field of view around 100 degrees while the human field of view is closer to 200 degrees (Warren et al. 1990). This limitation leads to the user having to move their head more than natural to look around in a virtual environment (Bruder et al. 2010). If you sit down, it might even be practically impossible to look behind you.

To address this problem this study has examined the effects of amplifying the virtual head rotation so that a bigger part of the virtual environment can be viewed with less movement of the head. Usually one-to-one mapping is applied for all VR devices, which implies no difference between the rotation in the VR environment and the actual head rotation(Regis Kopper, Cheryl Stinson, and Doug A). Accordingly is 50 degrees head rotation of the user also representing 50 degrees of head rotation in the VR environment. Having amplified virtual head rotation, in other words <u>not</u> a 1:1 mapping of the rotation, might have an impact on the user's spatial orientation, fatigue, performance, and cybersickness (Regis Kopper, Cheryl Stinson, and Doug A). While conducting an experiment in a VR environment there are several interesting parameters to take into account.

Exposure time. Longer exposure of VR results in greater issues with sickness (Stanney et al. 2003). To discourage sickness in VR environment earlier studies have shown that shorter, repeated exposures of VR is prefered to reduce the symptom (Sharkey et al. 1992) .

Speed. On the other hand; the speed of navigation through the virtual environment is an important factor in experience of sickness (So et al. 2001). Feeling sick increases significantly in speeds between 3m/s and 10m/s. After 10 m/s the effect, the increase in sickness, fades away (So et al., 2001). The speed levels primarily affects the level of vection (which causes nausea) during the first five minutes of a simulation. After 15 minutes, the speed level have little impact on vection(So et al. 2001), in other words the illusion of moving when you're motionless because your environment is moving. Having a slow simulation during a longer opening scene could therefore help decrease motion sickness (So et al. 2001).

Passive passenger. Being a passive passenger is also known to increase sickness compared to controlling the movement yourself. Having a virtual guiding avatar helps in predicting what route the simulation will take, thereby reducing sickness (Lin et al. 2004). This is same effect as looking straight ahead when sitting in the passenger seat of a car, compared to looking down on your phone.

Amplification. Earlier studies examining amplified head rotation in VR has found that amplification works quite well as a technique to easier get an overview of an virtual environment (Ragan et al. 2016). Users also find it quite useful and intuitive when using it in reasonable amount. If a linear amplification around 1:1,5 ratio is used there are no major problems concerning motion sickness compared to a 1:1 ratio (Ragan et al. 2016) and the users will calibrate their physical movement to adjust to the amplification quite fast (Steinicke et al. 2009).

Minimized imaged. Another way of handling the problem with the headsets limited field of view is to change the field of view on the display through minimizing the picture of the environment. This will lead to objects being presented smaller on the displays and a perspective that is slightly distorted (Steinicke et al. 2011). Used at a moderate level, a slightly enlarged virtual field of view still gives the user a natural experience (Steinicke) but for headsets with a large field of view Steinicke does not recommend a bigger increase of the virtual field of view than 15%, giving the method a quite moderate improvement if we want to come closer to the human eye’s field of view.

2. Preparations/Project Work

The VR environment where implemented using the Unity game engine. Two premade assets in Unity were used to minimise the development phase - Easy Movie Texture and Google CardBoard SDK. The environment was built to fit a Samsung Galaxy S6 Android phone.

A person can move their head in three dimensions, in VR terms these axis are usually called roll, yaw and pitch as shown in Figure 1. In our study we have looked at the yaw axis since it is most relevant to the neck rotation needed to compensate for the limited field of view. There are different ways to display the head rotation data but we choose to collect negative and positive yaw angles for each frame in a movie, resulting in a distribution shown by a histogram.

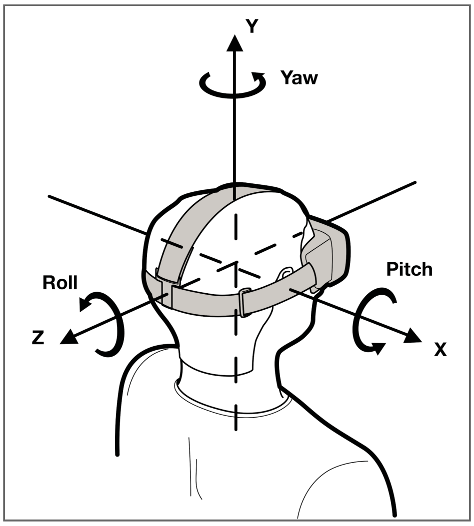

Figure 1*. Illustration of yaw, roll and pitch (Oculus VR, LLC 2016).*

The video was selected as a result of limitations made. As mentioned before, the risk for simulator sickness is increasing while moving between 3m/s and 10m/s, and if the subject is being exposed to the VR environment for a longer time. Due to this, an short movie was selected where the subject was not moving. Also, by letting the subject sit down during the test, the only movement the subject could manage was the head rotation, which the subject had full control of. As a supplement to the major project “VR i Vården”, the VR environment was chosen to illustrate a plaza, to complement the main purpose of treating agoraphobia, which can be expressed as fear of public plazas.

The head rotation was amplified by a nonlinear formula, adding 60 degrees to the angle of view as maximum. Meaning if the subject looked straight ahead there were no amplification, if the subject looked 30 degrees to the right the amplified angle would be 60 degrees and if the subject looked 90 degrees to the right the amplified angle would be 150 degrees, simulating the peripheral vision when looking over the shoulder.

Formula for the amplified head rotation: $v = p + sin(p * \pi \div 180°) * 60°$

where $v = Virtual\ Angle \quad p = Physical\ Angle$

In order to compare data from different subjects, the subjects needed to start the experiment looking at the same point. A scene with a pink cube to focus on was developed shown in Figure 2. When the subject had focused on the cube for 5 seconds the 360 degree video started and the head rotation data collection started.

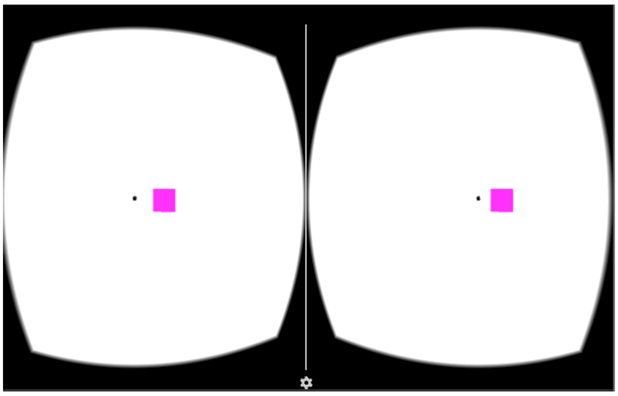

Figure 2. *Pink square to focus on when entering the VR environment.*

3. Method

The study consisted of two experiment groups with 10 subjects in each. The first group viewed the 360 degree video with normal, 1:1 ratio, between the physical head rotation and the virtual head rotation. The other group viewed a 360 degree video with amplified virtual head rotation.

3.1 Participants

The 20 subjects in this experiment were naive users between 19-28 years old, all of them students at KTH. 12 of them were male and 8 were female. The subjects were given little instructions on what to do in the VR environment since a specific task might have forced the users to experience the environment in a certain way which might have affected their head rotation.

3.2 Setup

The experiments were conducted at the usability lab at KTH. The subject entered one room where they answered questionnaires and then went into a second, quieter room with only two test leaders present, in that room they were seated in a chair and given instructions on what to expect and to focus on the pink square. A VR BOX Virtual Reality Glasses were used as VR headset, together with Bose Quietcomfort 25 headphones and the Samsung Galaxy S6 phone. The data were saved as a text file in the phone and later transferred to a computer.

3.3 Experiment 1

The Simulator Sickness Questionnaire (SSQ) (Kennedy et al. 1993) was used to get a quantitative result on the users experience, the subjects were asked to fill this in before and after watching the 360 degree video. After filling in the SSQ questionnaire the second time they were asked to answer a couple of open-ended questions about the test to get more qualitative data on their experience.

Some time was devoted to adjust the lenses of the VR-headset to make sure that the subject had an acceptable view of the scene before watching the 360 degree video. Then the subjects watched a 2 minute and 12 seconds long 360 degree video.

3.4 Experiment 2

The exact same procedure as Experiment 1, but this group had an amplified virtual head rotation as described in section 2.

4. Results

The result is presented in a comparison of physical head rotation in the two experiments, the virtual head rotation, the SSQ test and lastly a hypothesis test.

4.1 Physical Head Rotation

In a significance test of 95 % the physical head rotation of Experiment 2 were less than the physical head rotation of Experiment 1 (see section 4.4). It can safely be said that the test subjects do not look straight behind them during Experiment 2 with amplification (Figure 3) to the same extent as the subjects tends to do in Experiment 1 with no amplification (Figure 4). When studying the diagrams closer, it is possible to view a difference in shape too. First, the range of angles gives a hint of the difference in head rotation. Secondly, the physical head rotation in Experiment 2 (Figure 4) tend to concentrate their head movements closer to the center, compared to Experiment 1 (Figure 3).

As shown in all diagrams (Figure 3, Figure 4, Figure 5 and Figure 6), the peak has been offset by approximately 15° to the right in both Experiment 1 and Experiment 2, where the expected peak would be at 0°, looking straight forward.

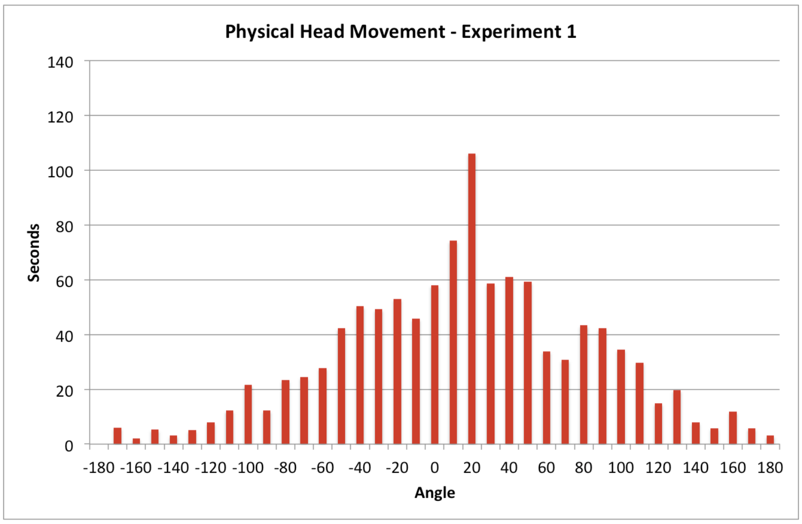

Figure 3: *A compilation of tracked physical head rotation from Experiment 1. Time spent per angle. (Figure 3 = Figure 5)*

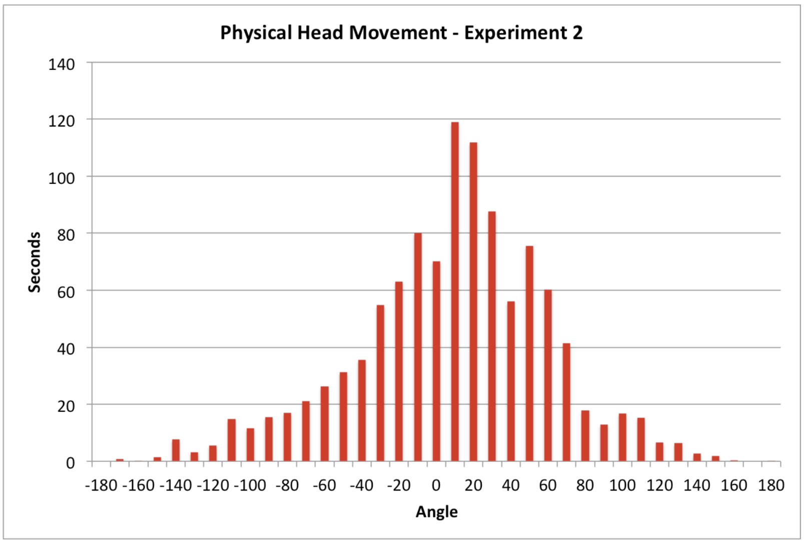

Figure 4: *A compilation of tracked physical head rotation from Experiment 2. Notice, the physical head rotation differs from the virtual head rotations (Figure 6).*

4.2 Virtual Head Rotation

In Experiment 2 (Figure 6) the subjects tend to have a more even distribution between the viewed angles in contrast to Experiment 1 (Figure 5) where the subjects tend to spend more time looking straight forward and around the center. This means that the users tend to view more of the environment when using the amplified headset than they do when using the non-amplified headset.

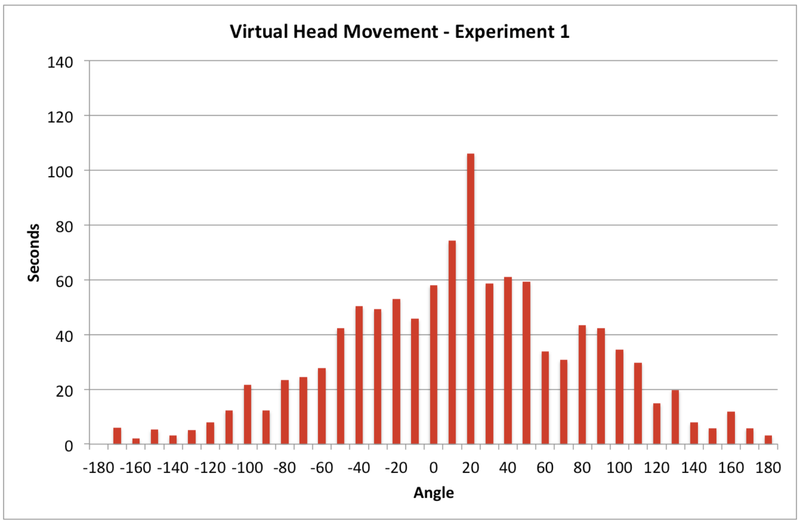

Figure 5: *A compilation of tracked head rotation from Experiment 1 (Same diagram as Figure 3).*

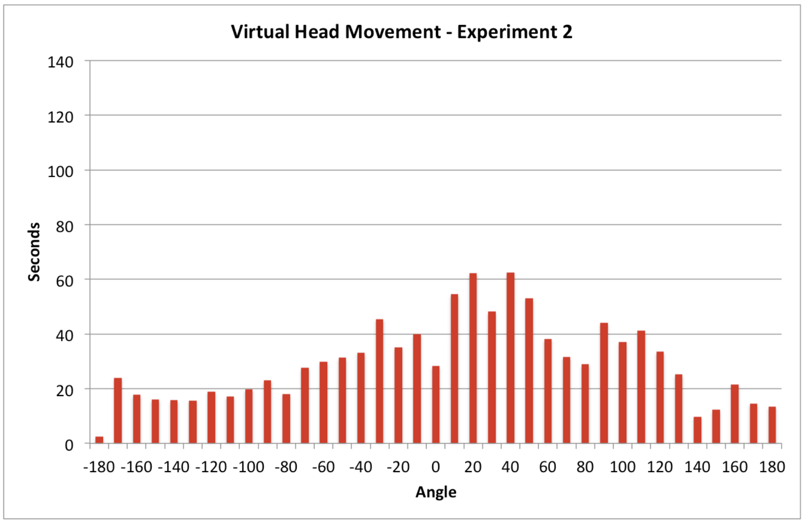

Figure 6: *A compilation of tracked head rotation in the VR environment from Experiment 2, with amplified head rotation.*

4.3 SSQ Test Result

The SSQ was done both before and after Experiment 1 (Figure 7) and Experiment 2 (Figure 8).

For the first experiment, where no amplification of motion was used there is a slight increase in both Nausea (8,6 to 12,4) and Oculomotor symptoms (14,4 to 22,7) and a considerable higher increase in the feeling of disorientation (9,7 to 45,9). The high increase in disorientation is mostly due to increase feeling of "blurred vision" (0,1 to 0,6) and “fullness of the head” (0,1 to 0,8) from the questionnaire. The total SSQ score for Experiment 1 was 13,0 before the test and 28,3 after the test.

Experiment 2 that used amplificated rotation had significantly higher values before the test was conducted (Overall score 28,6 versus 13,0 for Experiment 1) but shows no alarming increase in any of the sickness symptoms. Nausea decreased from 23.9 to 18.1 and Oculomotor symptoms and disorientation increased from 21,2 to 25,0 respectively 33,4 to 43,1. The decrease in Nausea was mostly due to decreases in the areas “sweating” (0,5 to 0,1), “burping” (0,4 to 0,1), and “difficulty concentrating” (0,5 to 0,2). Overall score increased slightly from 28,6 to 30,9.

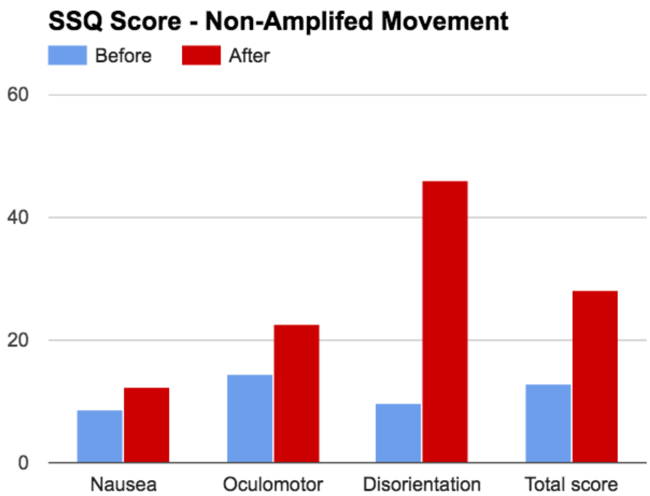

Figure 7: *A compilation of the Simulated Sickness Questionnaire for Experiment 1*

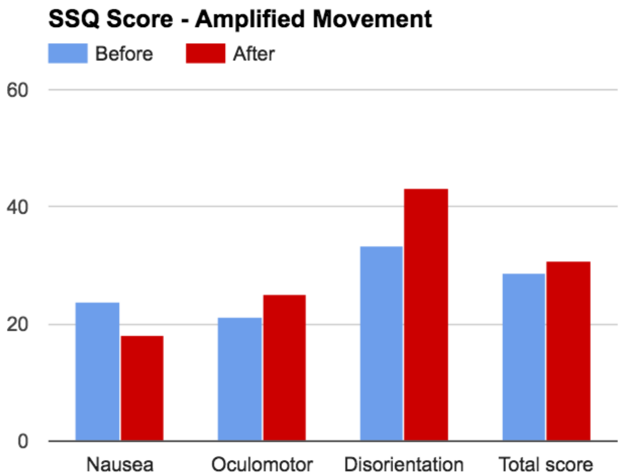

Figure 8: *A compilation of the Simulated Sickness Questionnaire for Experiment 2*

4.4 Hypothesis test

The mean value, γ, of the physical head rotation of Experiment 1 was $\pm 53°$ and for Experiment 2 $\pm 40°$ while transforming each angle to their absolute amount, making the standard deviation σ 0,43. Since the difference in mean value between the two experiments was 13°, we could rejecting the null hypothesis of no difference between the two.

Hypothesis test:

H_0: It is no different of the physical head rotation angle between Experiment 1 and Experiment 2.

$$\Rightarrow \gamma_1 - \gamma_2 = 0 \quad \Rightarrow \quad 53 - 40 \neq 0$$

H_1: It is a different of the physical head rotation angle between Experiment 1 and Experiment 2.

$$\Rightarrow \gamma_1 - \gamma_2 > 0 \quad \Rightarrow \quad 53 - 40 > 0$$

Standard deviation of the distribution:

$\alpha_{\gamma 1 - \gamma 2} = \sqrt{(\gamma_1^2 \div n + \gamma_2^2 \div n)}$, **where** n = number of angles

$\Rightarrow \alpha_{\gamma 1 - \gamma 2} * 1,65 = 0,43$ **where** 1,65 = z-value in a 95% significant level

So, $0,43 < \gamma_1 - \gamma_2 \quad \Rightarrow$ We can reject H_0

5. Discussion

As predicted the study shows that the subjects have a significant decreased physical head rotation during Experiment 2 compared with the head rotation in Experiment 1. This is because of the amplified head rotation in the VR environment in Experiment 2. Only one of the subjects in Experiment 2 noticed the amplification of the rotation which implies that the distinction of subject's physical head rotation in Experiment 1 and Experiment 2 mostly was subconscious.

There was a significant difference in the SSQ score before Experiment 1 versus Experiment 2. The participants of Experiment 2 scored higher in all areas with an overall score of 28,6 versus 13,0 for the participants in Experiment 1. Most significant difference was found in the symptoms "Dizzy" (0,1 vs. 0,4 for opened eyes and 0 vs. 0,7 for closed eyes), “Burping” (0 vs. 0,4) “Difficulty concentrating” (0,1 vs 0,5), “Sweating” (0,2 vs 0,5) and “Fatigue” (0,4 vs. 0,7). Experiment 1 was conducted between 10:00 and 12:30 while Experiment 2 was conducted between 13:00 and 17:00 so some of the differences might be explained by the time of day. Dizziness, difficulty concentrating and fatigue might increase during the day and the hours after lunch might affect the feeling of Nausea.

It is also important to emphasize that the video material in this experiment only durated for two minutes and that a bigger amount of video clips or a longer session might have had a more significant effect on the users feeling of motion sickness. Others aspect to have in mind is that this also was a non-moving scene which decreases the risk for motion sickness and that the users also were sitting down. This gave the user a fixed physical position that was realistic in relation to the virtual environment (i.e. they could have been seated at a chair/bench on the square) which might have had some impact on their experience. Due to the time limits for this project and an extensive developing phase to get everything working, the use of longer or moving video material was not a realistic goal.

After the experiment the subjects were asked a couple of open ended question to find out if they had perceived the head movements as natural. Unfortunately, the question was poorly worded and led to answers not correlating with our study. Therefore the answers were not included in the result, but the answers still adds some interesting insight. Only one subject in Experiment 2 (amplified rotation) answered that the virtual rotation seemed to be somewhat faster than the physical. The subjects seemed to be more disturbed by the weight of the headset or with problems focusing than the fact that their rotation was amplified. This indicates that amplification is possible to use without any severe problems when it comes to affecting the feeling of a natural head rotation.

In all of the experiments the diagram have an offset of approximately 15° to the right. We assume that this is because when the 360 degree video starts a logo appears to the right (Figure 9) and that the subjects therefore corrects their center more to the right.

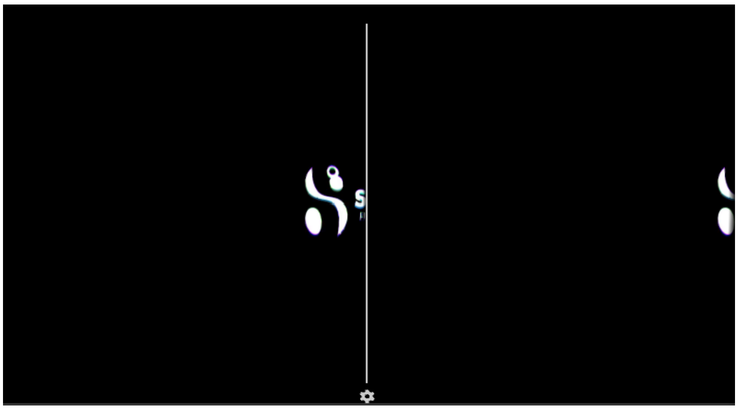

Figure 9. *Logo shown to the right when 360 degree video start.*

To conclude, in a short VR experience, amplified virtual head rotation enables the subjects to increase the number of watched angles in the VR environment without the typical excessive head rotation associated with a normal 1:1 ratio headset. An increased risk for simulator sickness could not be observed in this study.

6. Assessment of the project

We had to do a lot of preparations to be able to conduct this experiment. The whole project group was not familiar with Unity and had not worked that much with virtual reality before. This led to a quite extensive developing phase with several obstacles that consumed more time than was planned. This took some time from the design of the experiment itself and also made it harder to start with the report and other deadlines during the course since a lot of details were uncertain. At the same time the struggles with Unity also made us more comfortable with the game engine.

In hindsight it might had been good to have chosen a more simple, animated environment since we had a lot of problem getting the 360 degree video to work, but it is not certain that this would have been done any faster. Some extra time could have given us the opportunity to conduct a simple pilot study to avoid some of the problems mentioned below.

In our questionnaire we asked our subjects “Do you find your head movements to be natural?” and to explain briefly. The answers to this question had little to nothing to do with the head rotation. If we were to redo our experiment we would ask another question to get more relevant answers or have a semi-structured interview with the subject to get more qualitative data on their experience.

The video we used in our experiments was of a plaza in Vienna, in this setting it is hard for the subjects to see the amplification effect since the environment is quite complex. Therefore, it would be interesting to redo the experiment with a video, of a room for example, where the angle of view is more evident due to the perpendicular angles and static reference points.

There were no strict roles stated in the project draft since we felt confident being able to divide the task between us as the project evolved. There was a quite natural distinction between who focused on research and who had focus on developing since some of us already had experience with Unity.

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