THE EFFECTS OF VR DRIVING SIMULATION ON NOVICE DRIVER PERFORMANCE

Master Thesis

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2 Introduction

Virtual Reality (VR) has been around for more than half a decade. It was first mentioned in a U.S. Patent which was issued to Morton Heilig , who wanted to revolutionise the cinematographic experience (Burdea & Coiffet, 2003). During that time, technology posed a large barrier, but nowadays VR headsets are commercially available and widely used in many fields.

VR is an immersive, realistic and interactive experience, which allows for interaction with the system on several levels. It satisfies the visual, auditory and tactile senses of the user, thus providing an experience which is very similar to reality. The simulated world is referred to as a virtual environment (VE) (Davis, Nesbitt, & Nalivaiko, 2014; Lee, Kim, & Kim, 2017). Effects of VR are vastly different for each individual, they vary from discomfort, nausea, headache to even vomiting, while some users feel no different after VR usage (LaViola Jr, 2000).

Driving simulators have been around for many years now (Blaauw, 1982), and they are used in several areas, such as research (Fisher, Pollatsek, & Pradhan, 2006; George, 2004), education (Meuleners & Fraser, 2014) and entertainment.

Young drivers are involved in more than 25% of the accidents on the roads in OECD[1] countries, Organisations are trying to reduce this number with potentially more training or a more standardised education system (OECD & ECMT, 2006).

Educating young drivers in a driving simulator is a much safer (Cremer, Kearney, & Papelis, 1996), and potentially cost effective (Kappé, van Winsum, & van Wolffelaar, 2002) way to expand the possibilities of driver training. The availability of VR nowadays (Bellini, et al., 2016) helps tremendously in the implementation of it and adding another level of immersion to it.

3 Initial problem statement

Based on previous knowledge and the authors personal experience, we know that driving simulators are widely accepted for providing a sense of driving that is close to real life. However, before a more in depth research is conducted, it is unclear if a driving simulator focused on training student drivers would be a viable option. It is unknown if such a simulator would produce safer and more experienced drivers. Based on these thoughts the first step is to conduct a research regarding what technology is applied in this field and how effective it is. This research is aimed at providing some answers and produce a more detailed research question.

[1] Organisation for Economic Co-operation and Development

Based on this discussion, the initial problem statement is as follows:

Could a driving simulator be used as an educational tool in driving schools?

4 Background

4.1 History of VR

The idea of Virtual Reality (VR) has been around for more than 50 years now. On October 4, 1960 a U.S. Patent was issued to Morton Leonard Heilig, a cinematographer who had the idea of mounting small displays on the viewer's head to transform the classical cinematographic experience. At that time, it was quite hard to imagine how this would work, since display screens were not yet at a very advanced technological stage compared to today's hardware. For this reason, the HMDs were heavy and they required an arm to support the weight of the device. The supporting arm had potentiometers to measure where the user was looking. The first device designed in such fashion, was created by Ivan Sutherland. These problems are non-existent nowadays with lightweight screens and wireless technologies assisting positional and directional tracking (Burdea & Coiffet, 2003; Davis, Nesbitt, & Nalivaiko, 2014).

4.2 VR in education

Researchers agree, that VR technology has features that positively affect education. In the traditional educational practice, students are required to learn by assimilation, such as listening to a lecturer talk about a specific subject without any active participation. Many educational facilities are adopting a learning-by-doing methodology that gets the students involved. This teaching method allows for better information retention and mastering (Youngblut, 1998).

VR also allows for extending the limits of what schools can provide in regards to learning-by-doing environments. It circumvents physical, cost, and safety constraints that limit these institutions. (Youngblut, 1998; Lee, 2002; Cremer, Kearney, & Papelis, 1996)

4.3 Effects of VR

Exposure to virtual reality even nowadays is a novel experience for some. 'Seasoned' users, can still experience some undesired effects, which have implications on health and safety. In spite of VR has being around for almost half a decade, cybersickness is still an issue that cannot be overlooked, nor could it be completely eliminated through the years (Mousavi, Jen, & Musa, 2013).

Cybersickness is similar to simulator sickness and motion sickness in many aspects, though they cannot be confused. Motion sickness can be induced by purely vestibular impulses, with vision being an heightening factor (LaViola Jr, 2000). Simulator sickness symptoms are similar to the effects of motion sickness but they don't last as long and are less severe (Kennedy, Lane, Berbaum, & Lilienthal, 1993). Cybersickness purely occurs with visual stimulation (LaViola Jr, 2000), but an benefit to this, is that when the users close their eyes, the stimulus disappears.

Kennedy et al. (1997) distinguished three separate groupings of symptoms that can cause simulator sickness: nausea-, occulomotor- and disorientation induced sickness. These can have different causes, but some of them can overlap from one symptom to the another.

According to LaViola Jr. (2000), there are three theories as to why cybersickness occurs with VR exposure:

- The *sensory conflict* theory, which explains the occurrence of cybersickness by the conflict of the visual stimulus and the vestibular stimulus. Since there is no vestibular stimulus in VR only visual, the body does not know how to handle it.
- The *postural instability* theory, which states that one of the primary goals of humans is to maintain postural stability in their environment, where uncontrolled movements are minimized (e.g. walking on concrete versus walking on ice). However, this ability is severely restricted in VR, therefore cybersickness is likely to occur.
- The *poison* theory, which tackles this issue from an evolutionary standpoint. This suggests that when one ingests poison, it causes physiological effects which upset the vestibular and visual systems of the human body, which provokes an emetic response.

There may be other technological issues that could contribute to cybersickness as well, such as delay between an action being performed by the user and the response in the VE, errors in positional tracking and screen flickering (Davis, Nesbitt, & Nalivaiko, 2014; LaViola Jr, 2000).

Age, gender, illness and the amount of control the user has in the VE is another factor which contributes to cybersickness. Studies suggest older users are less susceptible to cybersickness. Women have been more affected by exposure to VR because they have wider fields of view compared to men, increasing the likelihood of noticing screen flicker. Physical conditions including, but not restricted to fatigue, hangover, or even a common flu, can increase sensitivity to cybersickness. The more control users have over their actions and movement, the less susceptible they are to cybersickness (Davis, Nesbitt, & Nalivaiko, 2014; LaViola Jr, 2000; Mousavi, Jen, & Musa, 2013).

4.4 Measuring cybersickness

The Simulator Sickness Questionnaire (SSQ) is widely accepted and adopted among researchers focusing on cybersickness. Kennedy et al. (1993) devised a set of questions which can measure an individual's level of sickness after being exposed to VR. The SSQ has 16 questions which measure the level of simulator sickness of users. They come in the form of self assessing different symptoms, which can be categorised into nausea, occulomotor or disorientation sickness. Participants have to answer each of the 16 questions with one of four possible answers (none, slight, moderate, severe). It is important to note that one symptom might contribute its values to more than one category (e.g. "Blurred vision" contributes to the occulomotor and the disorientation sickness as well) (Kennedy, Lane, Berbaum, & Lilienthal, 1993). The SSQ has to be completed before (pre-exposure) and after (post-exposure) participants have experienced VR. Results can be analysed after completion to obtain the level of cybersickness of the user (Kennedy, Lane, Berbaum, & Lilienthal, 1993; Lee, Kim, & Kim, 2017).

4.5 Driving as a skill

"As we sit on the cusp of the millennium, it is an arresting thought that just 100 years ago almost no-one drove a motorised vehicle." (Groeger, 2000)

The privilege of driving is a critical component of everyday life for a considerable part of the population (Groeger, 2000; Duncan, Williams, & Brown, 1991). It promotes independent living, self-sufficiency, and naturally, freedom (M. T. Schultheis, 2006).

Driving is a complex everyday task that involves several skills (Groeger, 2000) , among which are cognitive, perceptual, motor, and decision making skills. The driver of a vehicle must constantly monitor and adapt to the changing conditions, the environment, the traffic and the rules in place (George, 2004). Therefore driving requires constant alertness, which can affect driving performance, especially with novice drivers. As they gain experience, the time required to perform certain tasks, such as shifting gears, understanding the upcoming traffic sign, etc. decreases (de Winter, et al., 2009).

4.6 Young and novice drivers

Despite high education standards, young drivers (aged 16 to 24) are involved in about 27% of the driver fatalities across OECD countries[3], even though they represent only 10% of the population in these nations. While this is not only due to inexperience, with more practice, this could be significantly reduced. Research shows that about 120 hours of practice, could reduce the number of crashes by circa 40% (OECD & ECMT[4], 2006).

[3] The 34 OECD member countries are: Australia, Austria, Belgium, Canada, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States.

[4] European Conference of Ministers of Transport

"*Safe drivers are made and not born – extended practice should be recognised as a precondition for reaching higher cognitive skill levels. Thus, it is particularly important that substantial experience be attained in lower-risk conditions before unrestricted solo driving. High levels of accompanied practice before licensing for solo driving, conducted in a methodical manner that involves a variety of driving circumstances, will result in lower levels of fatalities.*" (OECD & ECMT, 2006).

Other than driving experience, licensing age and gender are the other most important factors in the above mentioned statistics (OECD & ECMT, 2006).

- Crash rates decrease as licensing age for solo driving increases. This can be due to immaturity, both physical and emotional and it poses a considerable risk.
- Men drive more than women and they are more prone to be involved in accidents. They are also more likely to over-estimate their driving ability.

It is clear that the education system should be improved on to make the roads safer, not only for drivers, but also their passengers and other traffic participants.

4.7 Driver education

Driving simulation is a great example where VR can be used to a great extent with an educational purpose. These simulators, accompanied with the use of realistic driving scenarios can provide a learning environment where performance can be accurately measured (M. T. Schultheis, 2006). This can prevent several complications, and confusion when starting driving education in a real life situation. Such issues are getting used to traffic signs and rules, basic controls of the car, getting accommodated with driving in traffic, problems that may cause problems at start (de Winter, et al., 2009).

In order to acquire a drivers licence, one must go through a training programme (theory and practice). This driving education is differs for every country. Below, a few examples will be presented of requirements for acquiring a category B vehicle, which is defined as: "*motor vehicles with a maximum authorised mass not exceeding 3 500 kg and designed and constructed for the carriage of no more than eight passengers in addition to the driver; motor vehicles in this category may be combined with a trailer having a maximum authorised mass which does not exceed 750 kg*" (The European Parliament And The Council Of The European Union, 2006).

In the United States of America, the standard education programmes consist of 30 hours of theory in a classroom, six hours observing a driver, and six hours driving. (Fisher, Pollatsek, & Pradhan, 2006)

In Denmark, driving education consists of 29 theory lessons, 45 minutes each, 4 sessions on a manoeuvring track, 16 lessons of driving on road, which includes topics that should cover most stages of driving and 4 lessons about the technical aspect of driving and of the car (Dansk Kørelærer-Union, 2018). Sikkertrafik.dk[5] states that in addition to these lectures, students have 8 hours of first aid practice as well.

As we can see, driving education differs from country to country, and the time required to complete it will be different for each individual as well.

4.8 Driving performance

Research has concluded that driving simulator performance can be used as a means to measure potential real life driving experience (Blaauw, 1982; de Winter, et al., 2009) with certain limitations.

Duncan (1991) has conducted a research where he determined that experience does not necessarily mean expertise in driving. The results of said experiment show, that gaining simple experience on the road does not mean an improvement in all aspects of driving skill. Bad habits can form during driving, and an enhanced driver training programme could be an answer to this.

Studies have drawn optimistic conclusions regarding training in a driving simulator and its potential effects on road safety. (Fisher, Pollatsek, & Pradhan, 2006; R. W. Allen, 2007)

De Winter (2009) theorised that three generic scores can reflect driver proficiency on a driving simulator:

- *Speed of execution*; The speed that a driver executes certain tasks with, should decrease with experience, leading to a performance increase. "*Beginner performance is slow and errorful*" (de Winter, et al., 2009). Repeated training results in an increase in experience, therefore, the required time to perform certain tasks should decrease accordingly.
- *Violations* are deviations from the prescribed rules that are in place to provide the traffic participants with the most safety. Violations describe what a driver is willing to do, meaning that they are to a certain extent, intentional. Paying attention to self-control, attitudes and norms can lead to a reduction of violations.
- *Errors* are the unsuccessful result of a planned action. "*They arise from information-processing problems and can be understood in relation to perceptual, attentional and*

[5] https://www.sikkertrafik.dk/raad-og-viden/i-bil/tag-koerekort#3110

judgemental processing of the individual" (de Winter, et al., 2009). Regular training should result in a reduction in number or errors a driver makes.

4.9 Driving simulation as an alternative

Driving simulators, compared to on-road driving and testing, are popular research tools. There is research showing that PC driving simulator training has a significant effect on the reduction of crashes for novice and young drivers (Fisher, Pollatsek, & Pradhan, 2006).

According to Meuleners et al. (2014) , Risto et al. (2014) and Godley et al. (2002) driving simulators have several advantages, such as:

- They offer a safe method for assessing performance, without physically endangering the driver even in dangerous virtual driving situations
- They are cost effective compared to on-road driving
- They are repeatable and customisable to specific scenarios
- Results can be accurately measured and analysed

Godley et al. also mentions some disadvantages too:

- Simulator sickness, which was elaborated upon previously
- Lack of physical sensations

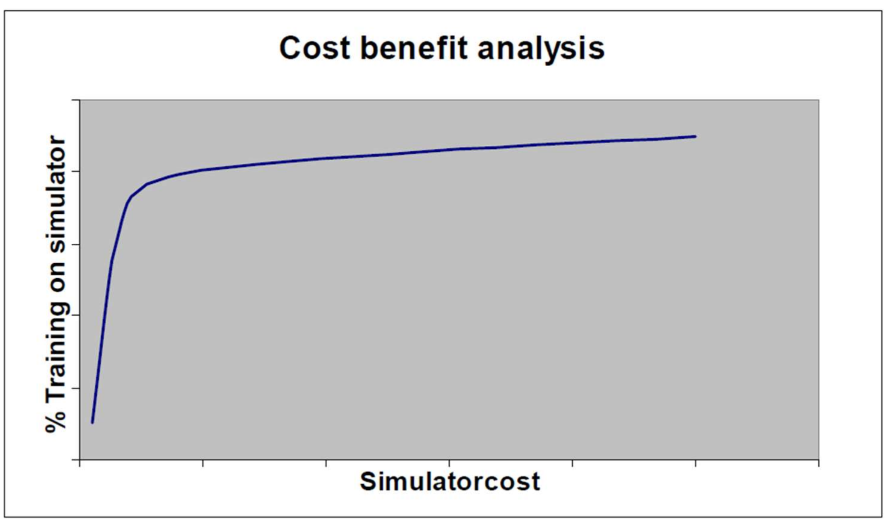

Figure 1: Cost benefit analysis (Kappé, van Winsum, & van Wolffelaar, 2002)

Kappé (2002) states that a high-cost, high-end driving simulator is not nearly as important as it may seem. A high learning value can be achieved with a cost effective setup as well (Kappé, van Winsum, & van Wolffelaar, 2002), as shown in Figure 1.

4.10 Simulator Configuration

"A good driving simulator is a lean, mean training machine" (Kappé, van Winsum, & van Wolffelaar, 2002)

Kappé et al. (2002) has conducted research on the viability of a cost effective driving simulator, and the conclusions were that hardware is not solely dependent on driver training effectiveness. Software and propper integration in the driving education are much more important for a driving simulator to be successful. (Kappé, van Winsum, & van Wolffelaar, 2002)

Allen et al. (2007) concluded that regarding hardware, "*near full size imagery is definitely indicated".* More specifically, wide aspect ratio screen setups or projections resulted in an increased training effectiveness.

5 Final problem statement

Based on the research conducted in the previous section, we can see that there are issues regarding driver education. Driving simulation is already being used to some extent in the education of new drivers, but the cost, customisability, and safety of it should not be underestimated. It has been proven that driving simulator experience can potentially be translated to real life driving.

Even after driver training been completed, the lack of experience of novice drivers is a concern. With a significant amount of driver fatalities having young drivers involved, solving this problem should be of high priority.

With these considerations in mind, the final research question is as follows:

Can a PC based VR driving simulator be used to improve non-experienced drivers performance while driving in a city?

Additionally, a question that will be analysed in conjunction with the above stated question is related to VR and simulator sickness:

Would drivers experience a decrease in simulator sickness after consecutive after exposure to a VR driving simulation?

6 Methods

This chapter will focus on the hypotheses that will be tested first, then describe the design of the experiment and the reasoning why specific choices were made. In the last section the development and implementation of the experiment will be discussed.

6.1 Hypothesis

After specifying the research question, it is possible to form a hypothesis that the experiment will be based on. This hypothesis should be clear and serve as the target that this experiment is trying to achieve. Our goal is to find statistical evidence to prove our experimental hypothesis while disproving the null hypothesis. This would mean that the experimental manipulation has an effect on the outcome of the test results (Field & Hole, 2003).

Finally, our null and experimental hypotheses for our main research question are as follows:

Null hypothesis:

There is no improvement in non-experienced drivers' performance after a VR driver training programme.

Experimental hypothesis:

There is significant improvement in non-experienced drivers' performance after a VR driver training programme.

Based on these hypotheses, we can define our variables. Our dependent variable, which is the one that we measure will be the drivers performance. The independent variable will be the challenges that the driver will be facing (Field & Hole, 2003).

For our secondary research question, our hypotheses are the following:

Null hypothesis:

There is no significant change in simulator sickness over the span of the VR driver training programme.

Experimental hypothesis:

There is a significant decrease in simulator sickness over the span of the VR driver training programme.

Our dependent variable for the above stated hypotheses is the simulator sickness score reported by the participants. The independent variable is time (the five occasions that the individuals experience VR)

6.2 Testing method

Since we want to measure improvement over time, the test used for the measuring the differences in the means of mistakes committed, is a repeated measures one way ANOVA test. This requires three or more experimental groups (driving sessions in our case) and the participants in each group have to be the same.

According to Field (2003), this is a very popular design, because of the following two advantages:

- Economy: They are time and resource effort, because the same participants are tested on multiple times, therefore the need for a large number of individuals is diminished. Although in this case, in the small timeframe that was specified, it was a challenge to gather participants willing to return five times.
- Sensitivity: We are measuring differences that have been created by the experimental conditions, and slight differences are more easily observed with this *within-subject design.*

For our secondary question, the same kind of test will be used and the three categories of symptoms (nausea, occulomotor, disorientation) will be separately analysed.

6.3 Requirements of the experiment

To conduct this experiment, the testing environment will have to include:

- A drivable *road system*, which in our case is a computer generated city. The name of the software used to generate the city, is CityEngine[6] by a company called Esri[7]. There were several issues present with the city that was generated and these will be elaborated upon in section 6.9.2.
- A drivable *car* within the environment with basic functional features, such as a steering wheel, pedals (clutch, brake, accelerator), gear shifting system, rear view mirrors and speedometer.
- *Traffic,* which follows the laws in place, to simulate an active and dynamic city.
- *Laws* in place, in the form of a pre-defined ruleset. For example: the specification of turning right only from the right lane, unless otherwise specified by traffic signs; the meaning of the colours of the traffic lights (red = stop, yellow = stop unless too close, green = go). A special note that was considered to be important to mention, is that this was an educational driving simulation, as opposed to a racing game, therefore rules have to be respected. The informational sheet that was presented to the participants and includes the above mentioned rules can be examined in Appendix 1.

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[6] https://www.esri.com/software/cityengine
[7] https://www.esri.com

- *Rules*, in the form of traffic signs. Only a small number of traffic signs was included to reduce the complexity of the system and the experiment All the implemented traffic signs are included in Appendix 2 with an official description from Køreklar (Borg & Stjernqvist, 2014). A few examples can be seen in Figures 2-4.

Figure 2: Stop sign

Figure 3: No right turn

Figure 4: Compulsory right turn

6.4 Design of the experiment

This study is aiming at improving driver performance, therefore, each individual will have to participate multiple times. Five sessions were selected as an appropriate number of training sessions that each person would have to go through. Each of the experiments were constructed to have a length between three and four minutes of driving without respecting any of the rules and driving at a constant speed of 40 km/h. This would be considered the time baseline. The reason for this baseline is that the car used to set this benchmark (the same car that was used for traffic) was not programmed to handle traffic in left hand turn conditions, therefore no rules or traffic were active during the time of the baseline measurement.

The sessions had various challenges, starting with basic rules, like stopping at a sign, a traffic light, respecting the compulsory/restricted turning sign. Each session offered a slightly bigger challenge, with more opportunities for mistakes.

When a mistake was made, the automatic alerting system would notify the participant of the error that was made by an image representation popup, and a notification sound. If a traffic sign was not respected, the sign would pop up, or a representation of the error in the form of a traffic sign (see Appendix 2 and Appendix 3).

The role of the researcher was of a navigator. More specifically, directing participants through the pre-determined route during each session. As the participants went through the tests, the feedback on mistakes and additional information was gradually reduced as well. For the first two occasions, the individual rules were explained again when encountered. During the third test, mistakes were explained after they occurred. For the fourth test, mistakes were not explained, but the alertness of the participant was tested by, for example, instructing them to “turn right at the next opportunity”, while at the next intersection, turning right was restricted. In this case, the correct action was to follow the road until a right turning opportunity arose. The fifth experiment did not provide the participant with any feedback from the system or the instructor when a mistake was made.

From the nature of the elevated challenges in consecutive driving sessions, randomization was not possible. This, however, provides a base where an average improvement or decrease in performance can be calculated after the tests have been concluded.

A pilot test was conducted for each route with an experienced driver to point out any flaws the system may have, for example traffic not behaving as expected, a traffic light not changing colours in the expected manner, issues with the roads, etc.

As mentioned in section 6.3, the city was computer generated, including the roads, which often had markings on them in the form of arrows at intersections. These markings in some cases were not consistent with the topography of the city. An example for this is, when at an intersection the arrow is pointing towards the right, indicating that traffic on the respective lane should be turning right, but there is no street towards the right. This inconsistency was negated by instructing the test participants to disregard any arrow markings on the road and only follow the traffic signs.

6.5 Course of the experiment

This section will describe the process through which every test participant had to go through each time they attended the test, meaning this was repeated five times for each individual.

A questionnaire was completed by each participant at the start of their test. General information about gender, driver license, driving experience, gaming and specifically racing game experience, and VR usage frequency. The first part of the simulator sickness questionnaire (SSQ) was to be completed afterwards. When completed, the participant was asked to take a seat at the driving simulator where the ruleset was presented to the individual. Adequate time was provided to allow for memorization. After finishing with the ruleset, the participant was asked to put on the headset and adjust it for comfortable fit. The driving session was preceded by a camera calibration, where the participants could position themselves in the car. Requirements were that they are able to see each of the three mirrors, the road ahead of the car, the speedometer and the surroundings of the car for appropriately monitoring the traffic while driving. The in-built headphones were not used in this experiment, to allow the instructor to direct the participants through the pre-determined routes. External speakers were used instead.

During the driving session, the individuals had to follow the instructors' directions, while adhering to the rules and restrictions in effect. The route being completed, the participants were asked to take off the VR headset.

After completion, the individuals completed the second part of the SSQ and the test was considered finished.

At any given moment during the driving session, the participants had the possibility to take of the VR headset if they felt nausea or other forms of severe discomfort and stop the test. In this case, results from the respective participant were to be discarded, but no such occasion was encountered.

6.6 Participants

The target group for this experiment had no specific request, apart from having close to no experience with driving in real life, and a good mental and physical health that would be acceptable for acquiring a driving license. No age or gender targets were specified, since that was not the goal of the experiment. In total, 12 individuals took part in the experiment (4 females and 7 males), however, one participant had to be discarded due to data corruption.

6.6.1 Recruitment

Testing was performed during a two week interval, and each participant having to participate five times, severely restricted the researchers options. Social media was put to good use, advertising the experiment publicly for increased exposure.

6.6.2 Scheduling

Having individuals test multiple times on separate days, is bound to create scheduling conflicts, therefore an online scheduling software, called Doodle[8] was used to resolve any problems that might have arisen otherwise.

6.7 Data acquisition

Data was gathered in two ways for the experiment. With questionnaires (see Appendix 4), and by automatically logging the performance of the participants while driving. The questionnaire focused on general information on the individuals and their experience with driving, VR, and measuring simulator sickness with the use of the simulator sickness questionnaire. Error logging occurred automatically when a mistake was committed by the test participant and saved for analysis

[8] https://doodle.com/

after concluding the testing phase of the experiment. In section 6.9.4, a snippet of code can be seen of the implementation of the logging system. The logs consist of timestamps of events, and the name of the events, which could be the start of the driving session, end of the session, and any errors that occurred between the previous two events.

6.8 Development and implementation

This section will elaborate on the development process of the driving process, and go into detail with some of the issues which occurred during implementation.

6.8.1 Technical characteristics of the testing system

As the test was developed for VR, it is natural that system requirements are higher than a what they would be for a conventional driving simulation or a racing game experienced on a flat screen. The experiment was running on an Asus built computer with an Intel® Core™ i7-7700 processor, running at 3.6 GHz[9], and 32 GB of DDR4 memory modules. The graphics card used, was am NVIDIA® GeForce GTX1080 Ti, with 11 GB of video memory. Haptic feedback was used un addition to VR to increase the level of immersion of the participants. This was provided by a ButtKicker® Power Amplifier BKA300-4, and a ButtKicker LFE[10] (low frequency effects) transducer, which is also called a “Silent Subwoofer” by the manufacturer. The steering wheel used for the experiment was a Thrustmaster T500RS[11] wheel with force feedback and a three pedal setup (clutch, brake, accelerator). The gear shifter was a TH8A Add-On Shifter[12] from Thrustmaster with 7 speeds and reverse.

The head mounted display was an Oculus Rift, which has an integrated OLED display with a resolution of 1080 x 1200 for each eye. These screens run at 90Hz (Oculus, 2015). The HMD has integrated over-ear headphones as well, but these were not usable, since the instructor had to provide the participants with directions while they were driving. An external speaker system was used instead.

6.8.2 Environment

The VE was a city generated by CityEngine, and as mentioned already in 6.3, the implementation was not problem free. The biggest problem was the fact that the model was big, and included a very high number of triangles, which required a considerable amount of processing power. The way the model was generated meant that occlusion culling could not remove very much of the load. In Fig. 5 illustrates one GameObject being selected and the red highlights where the

[9] https://ark.intel.com/products/97128/Intel-Core-i7-7700-Processor-8M-Cache-up-to-4_20-GHz
[10] https://thebuttkicker.com/buttkicker-lfe/
[11] http://www.thrustmaster.com/products/t500rs
[12] http://www.thrustmaster.com/products/th8a-add-shifter

same model is present throughout the city. Since this is one object, with one mesh, if one is visible to the main camera, all of them will be rendered. The city had 830 GameObjects similar to the one described above, which reduced the effect of occlusion culling significantly.

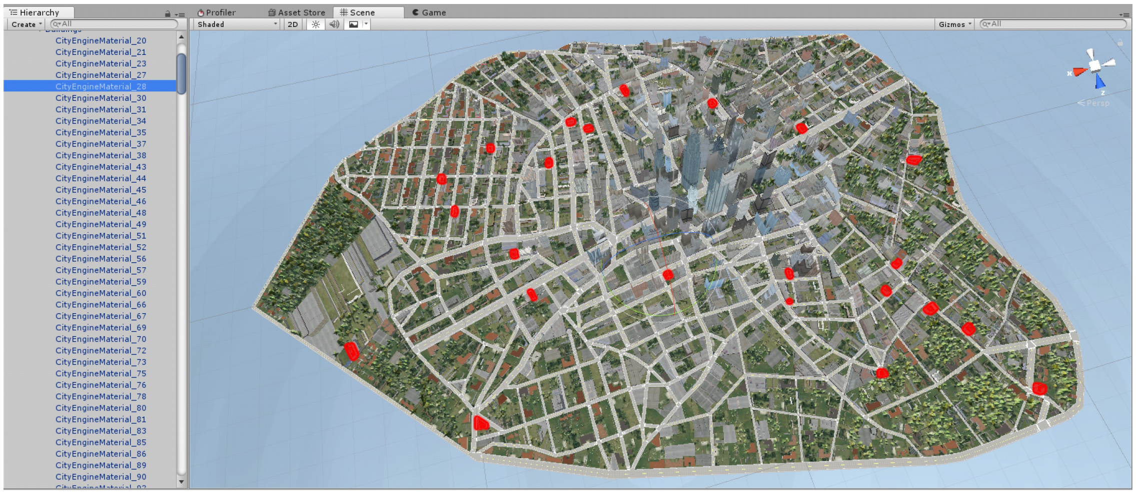

Figure 5: Spread of the mesh of a single GameObject

Optimization was achieved by removing some objects which were not visible (e.g. roofs of buildings) and reducing the building textures from 1024 to 128 in Unity. This, however produced very blurry building texturing, but it is not believed to affect anything, since the buildings are included only to create the feeling of a city, therefore irrelevant for the results. In Fig. 6 illustrates the comparison between a texture of size 128 and 1024 in Unity.

Figure 6: Texture size comparison. 128 (left) and 1024 (right)

6.8.3 Scene building in Unity

After adding the city model, traffic and pedestrians, traffic rules were implemented. These consist of traffic lights, or traffic signs. Figures 7 and 8 show an intersection with traffic lights and one with a stop sign intersection with the addition of turning restriction.

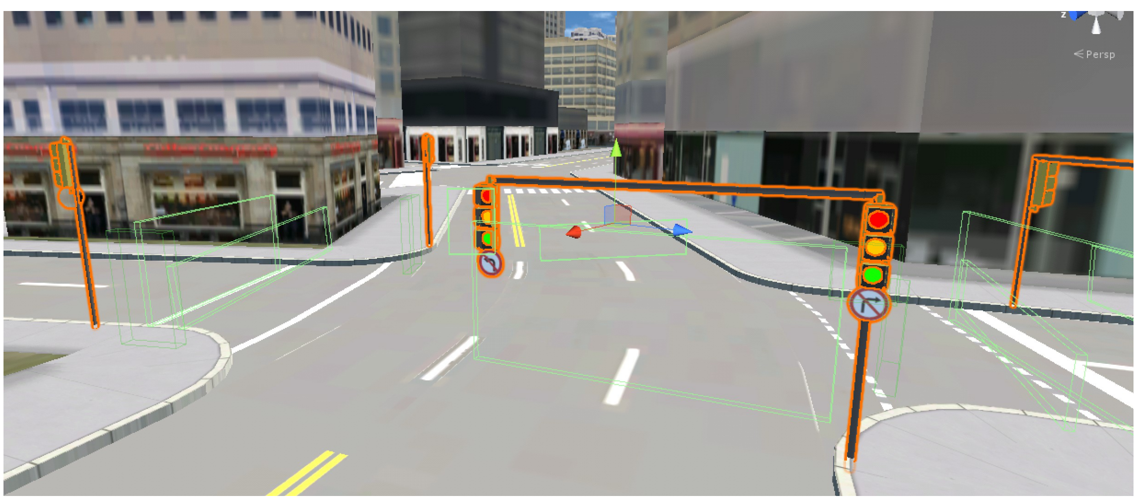

Figure 7: Intersection with traffic lights and turning restriction

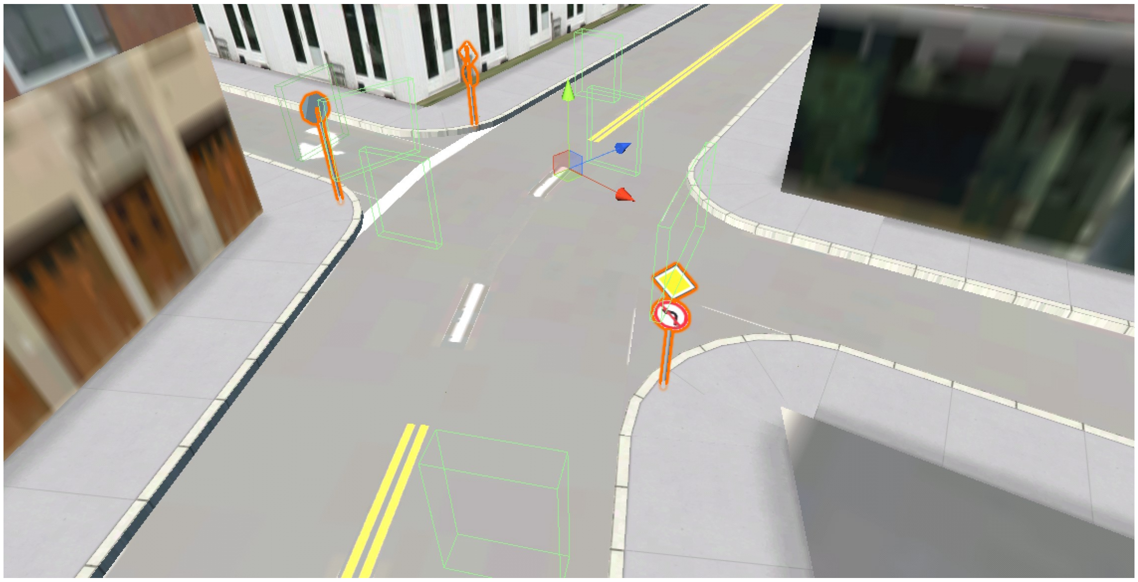

Figure 8: Stop sign intersection with additional turning restriction

The colliders ensure that the traffic follows the rules the same way the test participants have to. Both traffic and pedestrians, follow a pre-determined spline and stop whenever they encounter a collider until it gets disabled, meaning that they are free to continue (e.g. pedestrian crossing a street or car stopping at a stop sign.

6.8.4 Logging

Errors and the time it took for the driver to finish the course was logged during runtime. For each session a new log file was created with the date and time the test occurred. This log file included each event that occurred during the driving session with timestamps of when the event happened relative to starting the experiment. Figures 9 and 10 demonstrate logging process.

```
public class StopColliderScript : MonoBehaviour {

    private void OnTriggerEnter(Collider other)
    {
        if(!other.isTrigger && LayerMask.LayerToName(other.gameObject.layer) == "Player")
        {
            GlobalVariables.instance.logging.Log(Time.timeSinceLevelLoad + " Yield");
            GlobalVariables.instance.alerts.Alert(2);
        }
    }
}
```

Figure 9: Script attached to the collider at the stop sign

```
private void Start()
{
    filename = System.DateTime.Now.ToString("dd-MM-yyyy_hh-mm-ss") + ".txt";
    path = System.Environment.GetFolderPath(System.Environment.SpecialFolder.Desktop) + "/Logs/5/";
    //path = Application.dataPath + "/Logs";
    writer = new StreamWriter(path + "/" + filename, true);

}

public void Log(string message)
{
    writer.WriteLine(message);
}
```

Figure 10: Logging script

6.8.5 Stop sign

Stop signs represented a challenge, since it is hard to decide when it is safe to cross or not, and difficult to take lane changes into consideration. Therefore a system with colliders was created with a counter. When a car on the priority road was approaching, it hit the *incomingCollider* and a counter was incremented by one. When a car left the intersection, it hit the *outgoingCollider* and the counter was reduced by one. When the counter was 0, the *stopCollider* (which logs errors and stops traffic cars from driving through) was disabled and it was safe to proceed. The counter was restricted to only positive integers, to compensate for the case when a car doesn't hit the *incomingCollider* but it hits the *outgoingCollider.* Figure 11 illustrates the arrangement of the colliders for a stop sign intersection.

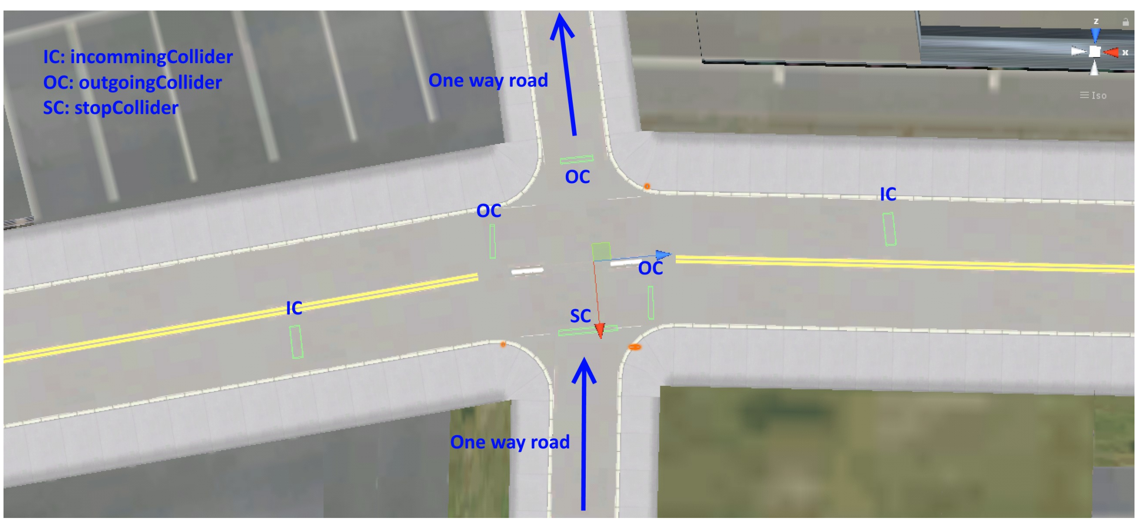

Figure 11: Stop sign intersection in detail

7 Results

The following section will present the results that were gathered during the experiment. Illustrations will be used where necessary. In the discussion section we will elaborate on the meaning of the results.

7.1 Errors

Firstly we will look at some descriptive statistics of our data in Table 1.

We can see that we have no missing data, and the mean of the number of errors constantly decreases for each test. This is what we expect but the One-Way Repeated Measures ANOVA test will tell us if there is a significant difference between the tests.

Descriptive Statistics

	Mean	Std. Deviation	N
Test1	6.55	3.588	11
Test2	5.09	3.239	11
Test3	4.18	2.359	11
Test4	3.27	2.328	11
Test5	3.18	1.940	11

Table 1: Descriptive statistics

Figure 12 shows the means for each of the tests. The black bars represent the 95% confidence intervals.

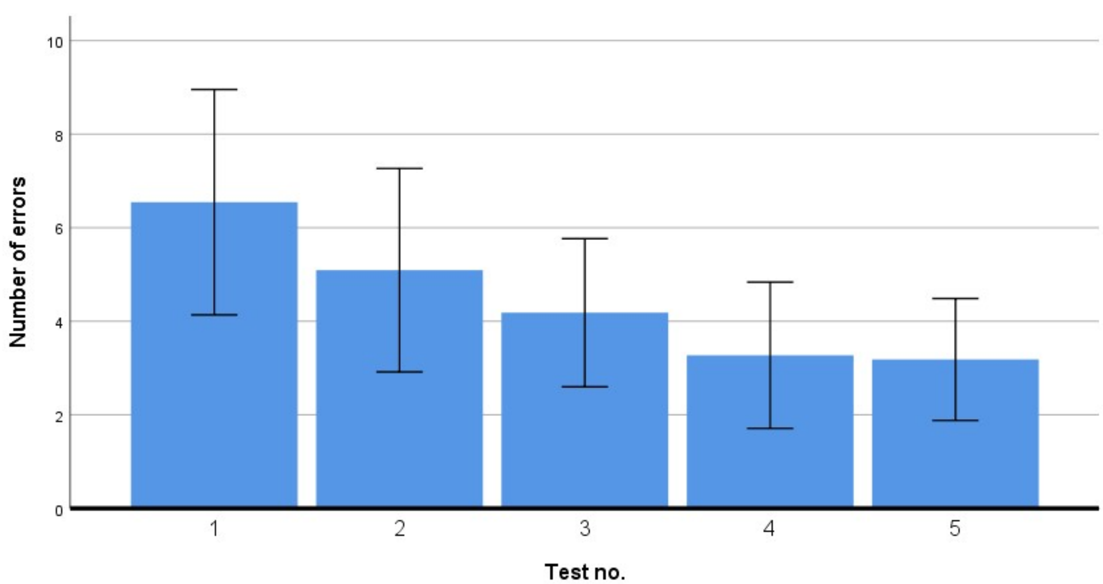

Figure 12: Means with the confidence intervals

For our test to be valid, we have to be sure that the relation between each pair of tests are similar. This is known as sphericity. Mauchly's test can tell us if the variances of differences between the tests are equal. Table 2 shows the results of Mauchly's test. The test indicated that the sphericity assumption has not been violated, $\alpha 2(9) = 4.322$, $p < .05$.

Mauchly's Test of Sphericity[a]

Measure: Performance

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b] Greenhouse-Geisser	Epsilon[b] Huynh-Feldt	Epsilon[b] Lower-bound
Test	.598	4.322	9	.892	.801	1.000	.250

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept
Within Subjects Design: Test

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Table 2: Mauchly's Test of Sphericity

Results of the One-Way Repeated Measures ANOVA test are illustrated in Table 3. Sphericity was not been violated, therefore we will be only looking at the "Sphericity Assumed" rows of the table. The results $F(4,40) = 4.474$ $p = .004$ suggests that there is a significant difference between at least two of the means.

Tests of Within-Subjects Effects

Measure: Performance

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Test	Sphericity Assumed	86.545	4	21.636	4.474	.004
	Greenhouse-Geisser	86.545	3.206	26.996	4.474	.009
	Huynh-Feldt	86.545	4.000	21.636	4.474	.004
	Lower-bound	86.545	1.000	86.545	4.474	.061
Error(Test)	Sphericity Assumed	193.455	40	4.836		
	Greenhouse-Geisser	193.455	32.058	6.034		
	Huynh-Feldt	193.455	40.000	4.836		
	Lower-bound	193.455	10.000	19.345		

Table 3: Results of the ANOVA test

The Bonferroni post hoc test results can be seen in Table 4. We can see that the only significant difference was between tests one and five, CI_{95}= .008 (lower) 6.71(upper), $p = .049$. Other comparisons were not significant ($p > .05$).

Pairwise Comparisons

Measure: Performance

(I) Test	(J) Test	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
1	2	1.455	1.039	1.000	-2.266	5.175
	3	2.364	.897	.250	-.850	5.577
	4	3.273	1.037	.102	-.439	6.985
	5	3.364*	.937	.049	.008	6.719
2	1	-1.455	1.039	1.000	-5.175	2.266
	3	.909	1.156	1.000	-3.230	5.048
	4	1.818	.861	.610	-1.267	4.903
	5	1.909	.803	.388	-.966	4.785
3	1	-2.364	.897	.250	-5.577	.850
	2	-.909	1.156	1.000	-5.048	3.230
	4	.909	.948	1.000	-2.487	4.305
	5	1.000	.953	1.000	-2.415	4.415
4	1	-3.273	1.037	.102	-6.985	.439
	2	-1.818	.861	.610	-4.903	1.267
	3	-.909	.948	1.000	-4.305	2.487
	5	.091	.653	1.000	-2.248	2.430
5	1	-3.364*	.937	.049	-6.719	-.008
	2	-1.909	.803	.388	-4.785	.966
	3	-1.000	.953	1.000	-4.415	2.415
	4	-.091	.653	1.000	-2.430	2.248

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Table 4: Pairwise comparisons

The results demonstrated in this section support the experimental hypothesis that there is a significant difference in a non-experienced drivers' performance after a VR driver training programme. The negative tendency of the means suggest that there was an improvement in driver performance. It also shows us that this difference is significant only between the first and last training session.

7.2 Time

Table 5 illustrates the mean time differences for each test in seconds. The percentage row shows the change of the mean times compared to the baseline, which was measured using a car traveling at a maximum speed of 40km/h without any regard for rules, just driving on the pre-determined path.

Subject	Test1	Test2	Test3	Test4	Test5
Baseline	238	192	250	197	223
Average	505	429	494	389	402
Difference	267	237	244	192	179
Percentage Diff.	1.12	1.23	.98	.98	.80

Table 5: Time differences for each test

From Figure 13 we can see the potential speed increase in completion times. After computing Pearson's r (r = -.78, n = 5, p = 0.11), we can conclude that there is a small negative correlation between the number of tests completed and the time it takes to complete the tests.

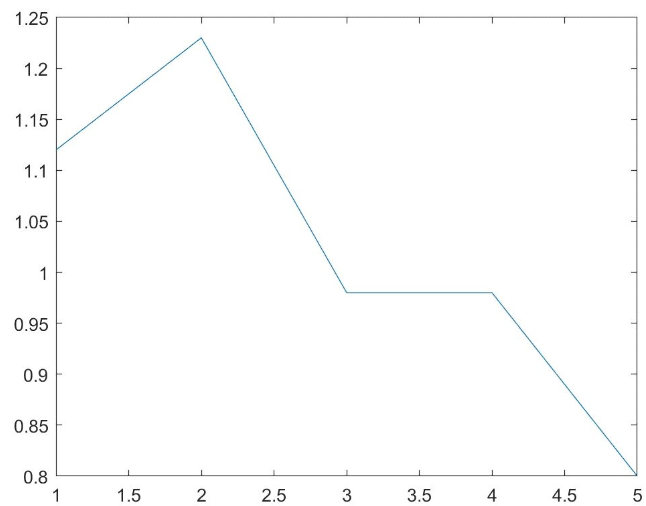

Figure 23: Evolution of speed over the span of the tests

7.3 Simulator sickness

Simulator sickness can be separated into three major categories of symptoms: nausea, occulomotor and disorientation (Kennedy, Lane, Berbaum, & Lilienthal, 1993). These three symptoms will be analysed separately in this section. One-Way Repeated Measures ANOVA tests will be used to test for differences, and detailed reports of the tests can be found in Appendix 5,6 and 7.

7.3.1 Nausea

Results (see Appendix 5) show that nausea induced sickness was significantly different over five driving sessions, $F(1.5, 15.08) = 12.267$, $p < .05$.

Mauchly's test showed that the assumption of sphericity was violated, $\alpha^2 = 28.58$, $p < 0.05$. To correct the degrees of freedom, the Greenhouse – Geisser correction was used ($\varepsilon = .377$).

Post hoc Bonferroni tests revealed that there is a significant difference only between the first session and any of the other four sessions. This is illustrated in Table 6. Other comparisons were not significant (all $p_s > .05$).

Pairwise Comparisons

Measure: Nausea

(I) Test	(J) Test	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
1	2	14.744*	3.245	.011	3.122	26.365
	3	20.815*	4.782	.014	3.689	37.940
	4	21.682*	5.766	.037	1.032	42.332
	5	25.151*	6.338	.026	2.453	47.849

Table 6: Bonferroni comparisons of the first test with the other four tests

Looking at the means of the scores in Fig. 14, we can see the decreasing nature of the nausea induced sickness over the five sessions and the significance of the test described above, we can conclude that there was a significant improvement in nausea induced simulator sickness.

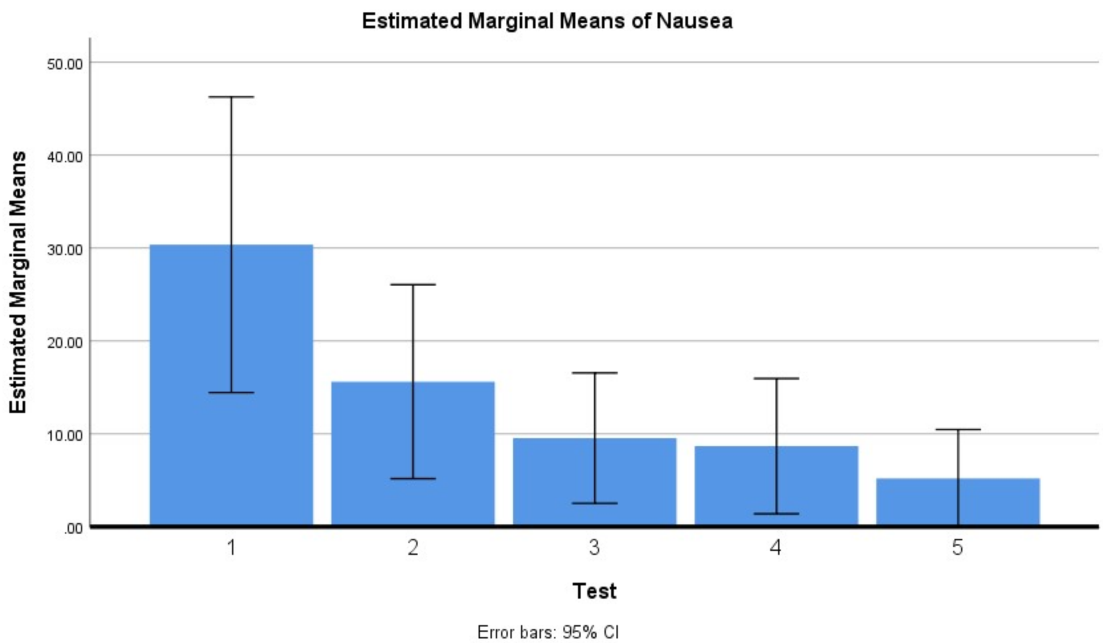

Figure 14: Means of Nausea induced sickness over the duration of five sessions

7.3.2 Occulomotor

According to the results (see Appendix 6), there was a significant difference in the levels of occulomotor induced simulator sickness over the span of the five driving sessions, $F(2.04, 20.4) = 4.942$, $p < .05$.

Mauchly's test revealed that the assumption of sphericity was violated, $\alpha^2 = 19.22$, $p < 0.05$, therefore, Greenhouse – Geisser correction was used to correct the degrees of freedom ($\varepsilon = .510$).

Bonferroni post hoc tests revealed a rather interesting result. According to these comparisons, there is no significant difference ($p > .05$) between any of the reported occulomotor score means. Field (2003) states that one possibility could be that the post hoc test does not have the power to detect such differences.

The histogram depicting the means of the scores again shows a downwards tendency, just like the nausea induced scores.

7.3.3 Disorientation

Results for the disorientation induced simulator sickness (see Appendix 7) show that there is a statistical significance between them, $F(1.19, 11.96) = 6.253$, $p < .05$.

According to Mauchly's test the sphericity assumption was violated, $\alpha^2 = 50.144$, $p < 0.05$. Greenhouse – Geisser degree of freedom was used to correct it ($\varepsilon = .299$).

Same as the occulomotor induced sickness results, pairwise comparison did not show any significance (all $p_s > .05$).

These scores have a decreasing tendency as well just like the other symptom categories across the span of the five driving sessions.

8 Discussion

The one way repeated measures ANOVA test revealed that the tests support our experimental hypothesis and there is a significant improvement in driver performance over the span of five VR driver training sessions. The difference was statistically different only between the first session and the last one, which is the desired result, although, it also tells us that the improvement is slow and incremental. This has to be considered when trying to implement this method with an educational purpose, since if the improvement isn't drastic enough, real life driving sessions might still be more effective, and cost friendly. This experiment only took part of what driver training is, therefore a direct comparison is not reasonable, further research should be done before a conclusion could be drawn about whether it is beneficial to use as a potential replacement of real life driver training. Even if it is effective enough, the recommendation would be that VR driving training simulators shouldn't be a full replacement, rather an addition to the already in place educational structure. It can be tailored to reproduce specific unsafe or unethical situations which wouldn't be possible otherwise, therefore it could be a unique and effective way of educating novice drivers.

The speeds it took to complete each test, decreased as the completed number of tests increased but by a very small amount, which would hopefully change with a larger sample size.

With a larger sample size and longer tests (resulting in more data per test), clustering could be analysed and possibly the density of the mistakes made in relation to time could lead to interesting conclusions (e.g. after one mistake there was a higher chance of more happening right after, induced by confusion, divided attention). For this test this was out of scope, but it would be interesting to find a correlation between the number of mistakes and the time they happen.

The scores from the simulator sickness questionnaire show that there was a significant improvement in all aspects of cybersickness. This could be the result of the participants adapting to the situation. This is a positive result also in regards to the usability of the simulator that was used in this experiment. Stanney et al. (1997) labelled the levels of symptoms (Fig. 15) and according to their study, after the score of 20, a simulator is considered to be "*bad*". Only the Disorientation and Nausea scores were above that value and only for the first test, followed by a considerable drop in sickness levels across all categories (nausea – 15.6, occulomotor – 9.6 and disorientation – 8.8). This is a very positive result, the knowledge of which can be taken further when developing other simulators in the future.

SSQ SCORE	CATEGORIZATION
0	No symptoms
<5	Negligible symptoms
5-10	Minimal symptoms
10-15	Significant symptoms
15-20	Symptoms are a concern
>20	A bad simulator

Figure 15: SS level categories according to Stanney el al.

In conclusion, educating novice drivers using VR driving simulators could be a very effective tool that could potentially make the roads safer by developing more novice drivers with much more expertise at the time of getting their driver license.

9 Future work

To further test the viability of the VR driving simulators, more extensive research should be conducted with much more complex systems to simulate real life driving situations as close as possible.

There are already driving simulators in the education sector, but not using VR according to the background research, therefore it could be beneficial to test whether there is a significant difference between the driving simulators depending on display hardware used.

10 Acknowledgements

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12 Appendix

1. Rules

Rules

Turning

Turn left only from the leftmost lane (unless otherwise specified by traffic signs)

Turn right only from the rightmost lane (unless otherwise specified by traffic signs)

When changing lanes, ensure yourself that you will not run into the side of another car coming from behind.

Traffic Signs

Turning right compulsory

Turning left not allowed

Turning right not allowed

Maximum speed allowed

Stop and give way to all drivers

Priority

Traffic Lights

Each traffic light is responsible for the lane below it.

If there is another traffic sign attached to the traffic light, you must respect the sign as well as the colour of the light

Your Car

This is a car with manual gear shifting, which has 7 Speeds. 6 Forward gears (1,2,3,4,5,6) , and One reverse (R)

How to shift gears:

1. Release Accelerator Pedal
2. Press clutch
3. Shift Gear
4. Release Clutch
5. Accelerate

Your car has 3 fully functional rear view mirrors, on the left, on the right, and in the middle, use them when needed.

Alerts

When a mistake was made, the respective traffic sign will show up on your screen and will stay there for 5 seconds.

Other than the previously mentioned traffic signs, three other alerts may show up and they are as follows:

You hit a pedestrian

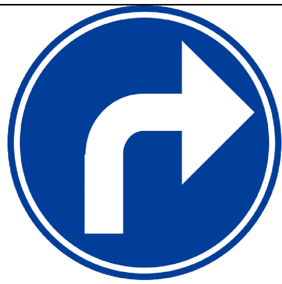
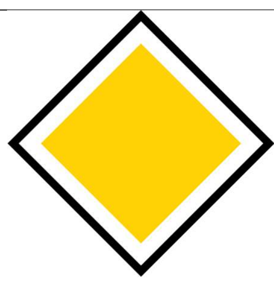
You ran a red light

You got into a crash

Remember! This is not a racing game, this is a city driving simulation, with traffic laws in place. Please treat it as such.

Thank you and good luck!

2. Traffic signs

Sign	Description (Danish)	Description (English)
	Påbudstavle: Påbudt kørselsretning	Compulsory direction control sign: Compulsory turning
	Forbudtstavle: Højresving forbudt	Restriction sign: Right turn prohibited
	Lokal hastighedsbegrænsning	Local speed limitation
	Hovedvej. Færdslen fra sideveje har ubetinget vigepligt.	Main road. Traffic flow from byway has full stop.
	Stop. Kørende skal stoppe ved stoppelinien før fremkørsel I kryds eller ved jernbaneoverkørsel og har derefter ubetinget vigepligt.	Stop. Driver must stop at stop line before entering the intersection or before crossing railway and has no right of way.

3. Alerts other than traffic signs present and used in the city

	The driver got into a car crash
	The driver ran a red light
	The driver hit a pedestrian on a pedestrian crossing

4. Questionnaire

Driving simulator questionnaire

We will collect some general data about you, and your driving experience

* Required

Number of your test *
It's your first second... fifth test during this experiment. Please enter a number.

Your answer

Gender *

- ◯ Female
- ◯ Male

Age *

Your answer

For how long have you had a drivers license? *
In years. If none, enter 0. Please enter a number

Your answer

How much do you drive on a monthly basis? (In KM) *

Your answer

Would you consider yourself a gamer? *

- ◯ Yes
- ◯ No

Do you play driving games? *

- ◯ Yes
- ◯ No

How often do you use VR? *

	1	2	3	4	5	
Never	◯	◯	◯	◯	◯	Daily

NEXT

Driving simulator questionnaire

* Required

Pre-exposure simulator sickness questions

We will use this as a baseline for testing how much the test affected you, regarding simulator sickness.

Select below if any of the symptoms apply to you now. You will be asked to fill this again after the test. *

0 - None, 1 - Slight, 2 - Moderate, 3 - Severe

	0	1	2	3
General Discomfort	○	○	○	○
Fatigue	○	○	○	○
Headache	○	○	○	○
Eye strain	○	○	○	○
Difficulty focusing	○	○	○	○
Increased salivation	○	○	○	○
Sweating	○	○	○	○
Nausea	○	○	○	○
Difficulty concentrating	○	○	○	○
Fullness of head	○	○	○	○
Blurred vision	○	○	○	○
Dizzy (eyes open)	○	○	○	○
Dizzy (eyes closed)	○	○	○	○
Vertigo	○	○	○	○
Stomach awareness	○	○	○	○
Burping	○	○	○	○

BACK NEXT

Driving simulator questionnaire

Proceed to the driving experience

After you have completed the driving experience, you will continue filling out the questionnaire.

BACK NEXT

Driving simulator questionnaire

* Required

Post-exposure simulator sickness questions

Select again below if any of the symptoms apply to you now. *
0 - None, 1 - Slight, 2 - Moderate, 3 - Severe

	0	1	2	3
General Discomfort	○	○	○	○
Fatigue	○	○	○	○
Headache	○	○	○	○
Eye strain	○	○	○	○
Difficulty focusing	○	○	○	○
Increased salivation	○	○	○	○
Sweating	○	○	○	○
Nausea	○	○	○	○
Difficulty concentrating	○	○	○	○
Fullness of head	○	○	○	○
Blurred vision	○	○	○	○
Dizzy (eyes open)	○	○	○	○
Dizzy (eyes closed)	○	○	○	○
Vertigo	○	○	○	○
Stomach awareness	○	○	○	○
Burping	○	○	○	○

BACK SUBMIT

5. Nausea induced sickness repeated measures ANOVA testing results

Descriptive Statistics

	Mean	Std. Deviation	N
Test1	30.3545	23.68464	11
Test2	15.6109	15.54331	11
Test3	9.5400	10.45055	11
Test4	8.6727	10.83917	11
Test5	5.2036	7.82470	11

Mauchly's Test of Sphericity[a]

Measure: Nausea

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b] Greenhouse-Geisser
Test	.034	28.584	9	.001	.377

Mauchly's Test of Sphericity[a]

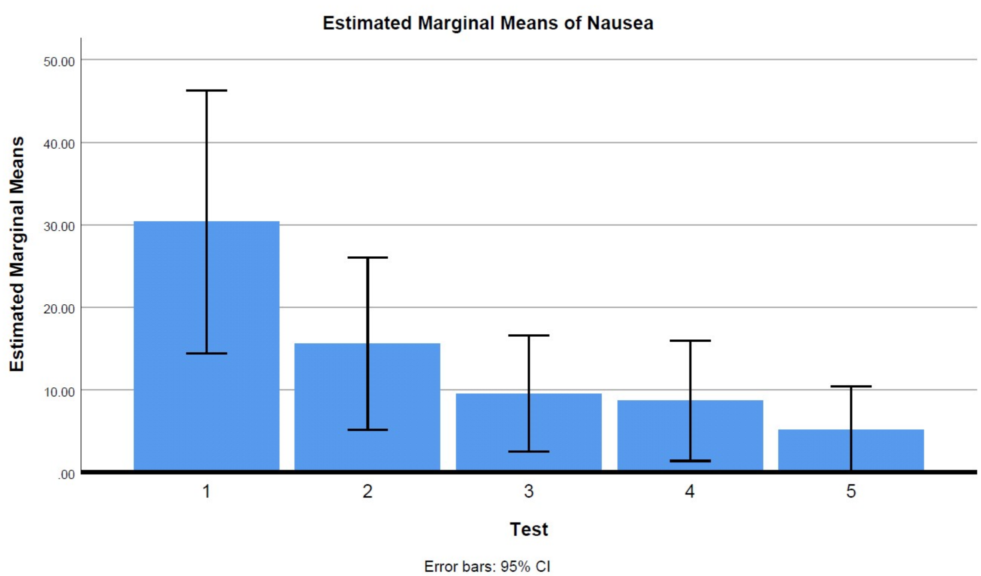
Measure: Nausea

	Epsilon[b]	
Within Subjects Effect	Huynh-Feldt	Lower-bound
Test	.430	.250

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept
Within Subjects Design: Test

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.



Tests of Within-Subjects Effects

Measure: Nausea

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Test	Sphericity Assumed	4352.009	4	1088.002	12.267	.000
	Greenhouse-Geisser	4352.009	1.509	2884.416	12.267	.001
	Huynh-Feldt	4352.009	1.719	2531.634	12.267	.001
	Lower-bound	4352.009	1.000	4352.009	12.267	.006
Error(Test)	Sphericity Assumed	3547.798	40	88.695		
	Greenhouse-Geisser	3547.798	15.088	235.140		
	Huynh-Feldt	3547.798	17.191	206.381		
	Lower-bound	3547.798	10.000	354.780		

Estimated Marginal Means

Pairwise Comparisons

Measure: Nausea

(I) Test	(J) Test	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
1	2	14.744*	3.245	.011	3.122	26.365
	3	20.815*	4.782	.014	3.689	37.940
	4	21.682*	5.766	.037	1.032	42.332
	5	25.151*	6.338	.026	2.453	47.849
2	1	-14.744*	3.245	.011	-26.365	-3.122
	3	6.071	2.954	.669	-4.508	16.650
	4	6.938	3.425	.703	-5.330	19.206
	5	10.407	4.159	.313	-4.489	25.303
3	1	-20.815*	4.782	.014	-37.940	-3.689
	2	-6.071	2.954	.669	-16.650	4.508
	4	.867	2.715	1.000	-8.856	10.591
	5	4.336	2.359	.959	-4.113	12.786
4	1	-21.682*	5.766	.037	-42.332	-1.032
	2	-6.938	3.425	.703	-19.206	5.330
	3	-.867	2.715	1.000	-10.591	8.856
	5	3.469	1.939	1.000	-3.476	10.414

6. Occulomotor induced sickness repeated measures ANOVA testing results

Descriptive Statistics

	Mean	Std. Deviation	N
VAR00001	17.2273	13.59798	11
VAR00002	9.6473	10.22087	11
VAR00003	6.2018	5.69074	11
VAR00004	5.5127	9.02683	11
VAR00005	4.8236	5.11043	11

Mauchly's Test of Sphericity[a]

Measure: Occulomotor

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b] Greenhouse-Geisser
Test	.102	19.222	9	.026	.510

Mauchly's Test of Sphericity[a]

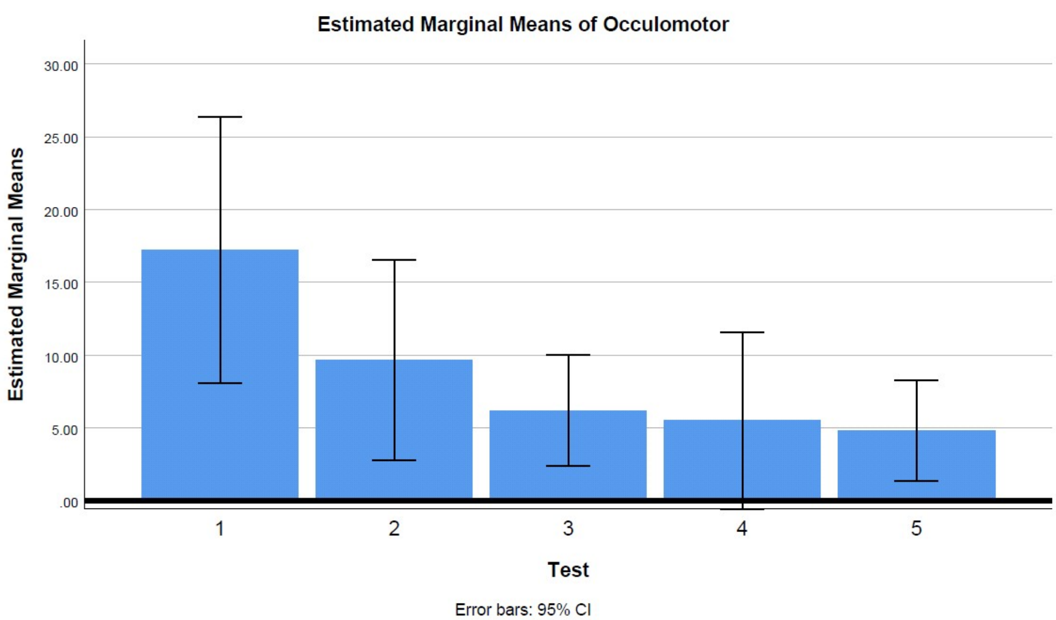
Measure: Occulomotor

	Epsilon[b]	
Within Subjects Effect	Huynh-Feldt	Lower-bound
Test	.642	.250

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept
Within Subjects Design: Test

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.



Tests of Within-Subjects Effects

Measure: Occulomotor

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Test	Sphericity Assumed	1155.396	4	288.849	4.942	.002
	Greenhouse-Geisser	1155.396	2.040	566.268	4.942	.017
	Huynh-Feldt	1155.396	2.568	449.839	4.942	.010
	Lower-bound	1155.396	1.000	1155.396	4.942	.050
Error(Test)	Sphericity Assumed	2337.953	40	58.449		
	Greenhouse-Geisser	2337.953	20.404	114.585		
	Huynh-Feldt	2337.953	25.685	91.025		
	Lower-bound	2337.953	10.000	233.795		

Pairwise Comparisons

Measure: Occulomotor

					95% Confidence Interval for Difference[a]	
(I) Test	(J) Test	Mean Difference (I-J)	Std. Error	Sig.[a]	Lower Bound	Upper Bound
1	2	7.580	3.232	.410	-3.996	19.156
	3	11.025	3.736	.145	-2.356	24.407
	4	11.715	4.498	.263	-4.393	27.822
	5	12.404	4.487	.200	-3.666	28.474
2	1	-7.580	3.232	.410	-19.156	3.996
	3	3.445	2.774	1.000	-6.488	13.379
	4	4.135	3.594	1.000	-8.737	17.006
	5	4.824	3.276	1.000	-6.909	16.556
3	1	-11.025	3.736	.145	-24.407	2.356
	2	-3.445	2.774	1.000	-13.379	6.488
	4	.689	1.900	1.000	-6.114	7.493
	5	1.378	1.378	1.000	-3.558	6.314
4	1	-11.715	4.498	.263	-27.822	4.393
	2	-4.135	3.594	1.000	-17.006	8.737
	3	-.689	1.900	1.000	-7.493	6.114
	5	.689	2.157	1.000	-7.037	8.415
5	1	-12.404	4.487	.200	-28.474	3.666
	2	-4.824	3.276	1.000	-16.556	6.909
	3	-1.378	1.378	1.000	-6.314	3.558
	4	-.689	2.157	1.000	-8.415	7.037

7. Disorientation induced sickness repeated measures ANOVA testing results

Descriptive Statistics

	Mean	Std. Deviation	N
VAR00001	36.6982	42.34643	11
VAR00002	8.8582	12.86787	11
VAR00003	5.0618	7.02299	11
VAR00004	5.0618	7.02299	11
VAR00005	3.7964	6.50202	11

Mauchly's Test of Sphericity[a]

Measure: Disorientation

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b] Greenhouse-Geisser
Test	.003	50.144	9	.000	.299

Mauchly's Test of Sphericity[a]

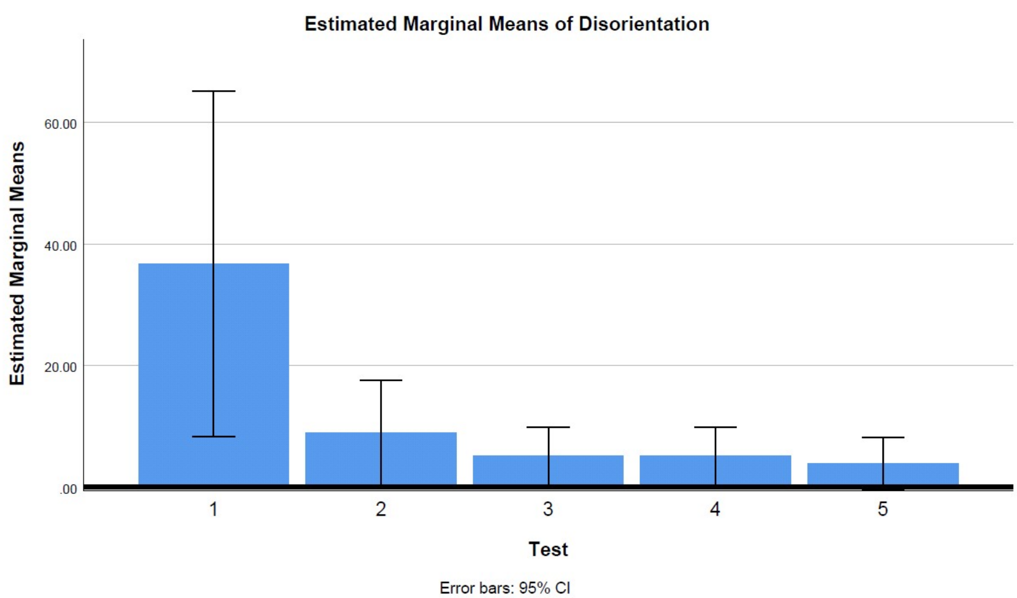
Measure: Disorientation

Within Subjects Effect	Epsilon[b] Huynh-Feldt	Lower-bound
Test	.317	.250

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept
Within Subjects Design: Test

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.



Tests of Within-Subjects Effects

Measure: Disorientation

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Test	Sphericity Assumed	8617.320	4	2154.330	6.253	.001
	Greenhouse-Geisser	8617.320	1.196	7205.225	6.253	.024
	Huynh-Feldt	8617.320	1.267	6800.679	6.253	.022
	Lower-bound	8617.320	1.000	8617.320	6.253	.031
Error(Test)	Sphericity Assumed	13782.076	40	344.552		
	Greenhouse-Geisser	13782.076	11.960	1152.365		
	Huynh-Feldt	13782.076	12.671	1087.664		
	Lower-bound	13782.076	10.000	1378.208		

Pairwise Comparisons

Measure: Disorientation

					95% Confidence Interval for Difference[a]	
(I) Test	(J) Test	Mean Difference (I-J)	Std. Error	Sig.[a]	Lower Bound	Upper Bound
1	2	27.840	10.108	.203	-8.360	64.040
	3	31.636	11.431	.199	-9.303	72.576
	4	31.636	12.321	.280	-12.491	75.763
	5	32.902	13.175	.316	-14.284	80.088
2	1	-27.840	10.108	.203	-64.040	8.360
	3	3.796	3.300	1.000	-8.022	15.615
	4	3.796	4.235	1.000	-11.371	18.964
	5	5.062	4.701	1.000	-11.774	21.898
3	1	-31.636	11.431	.199	-72.576	9.303
	2	-3.796	3.300	1.000	-15.615	8.022
	4	.000	1.877	1.000	-6.722	6.722
	5	1.265	2.941	1.000	-9.266	11.797
4	1	-31.636	12.321	.280	-75.763	12.491
	2	-3.796	4.235	1.000	-18.964	11.371
	3	.000	1.877	1.000	-6.722	6.722
	5	1.265	2.264	1.000	-6.842	9.373
5	1	-32.902	13.175	.316	-80.088	14.284
	2	-5.062	4.701	1.000	-21.898	11.774
	3	-1.265	2.941	1.000	-11.797	9.266
	4	-1.265	2.264	1.000	-9.373	6.842