University of Applied Sciences

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Strukton Rail

Graduation report

Visual style in a virtual reality safety trainer

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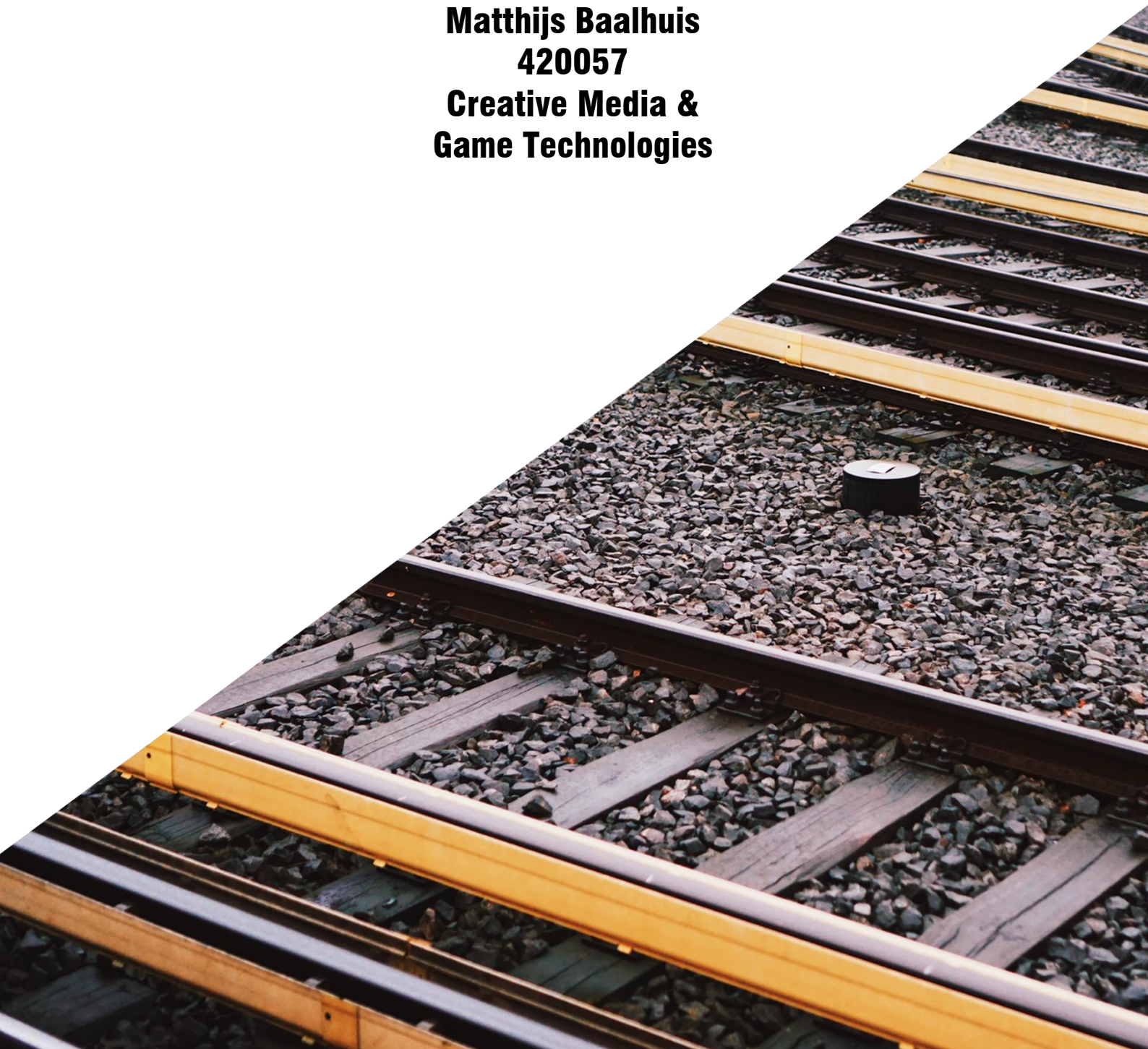

Graduation report

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Date
June 18, 2019

Preface

In 2015 I entered the Game Design and Production course, now known as Creative Media and Game Technologies. I was unsure if the study really suited me, but I started to develop a passion for 3D art and game development. Over the years I learned that the Creative Media and Game Technologies bachelor's degree could be applied to many fields, including serious gaming. Providing solutions for companies with technology that are rapidly advancing is the future. In this future lays my career which I will pursue with upmost motivation. After close to four years I am ready to take the final step towards the start of my career.

Before diving into my research, I would like to thank my graduation coach, Herman Statius Muller. His support, feedback and involvement during the project helped me to achieve what I wanted to achieve. I would also like to thank Alejandro Moreno Celleri for supporting the project team as well as steering us into the right direction. Max Klostermann gave me some final tips for retrieving my results which I very much appreciated. Of course, I would like to thank Pieter Cornelissen for offering the opportunity to work on such a wonderful project. Furthermore, I would like to thank everyone else who was involved in the project as well as the project team for their drive and motivation throughout the semester.

Abstract

As Strukton Rail faces absence under employees that work on railroad construction sites, a change must be made. Part of this absence is caused by occupational accidents. With modern-day technology, Strukton Rail would like to explore the possibilities of a virtual reality training simulator to increase risk awareness among their employees with regard to working at heights. Such increased awareness could lead to less incidents and a subsequent decrease in employee absenteeism.

In this paper, a closer look is taken at which visual style would suit a virtual reality training simulator. Specifically, the research explores how the visual style can enhance the learning objectives that Strukton would like to achieve. User tests and questionnaires are used to explore the extent in which the visual style enhances learning objectives.

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Introduction

Whenever you leave for work in the morning you expect to come home safe and healthy. For construction workers this is not always the case. Every so often there is a report of an occupational accident in which machinery gets damaged or people suffer from injuries.

The most important aspect of working on construction and railway sites is safety. Awareness of risks is crucial for all employees involved. In 2017, the ILT (Human Environment and Transport Inspectorate) inspected 75 Dutch railroad construction sites. Their annual report shows that 28 (37%) of them were deficient. Next to that there were 39 reports about work situations of railroad workers concerning workplace security and the entering or leaving a site with maintenance equipment (Ministry of Infrastructure and Water Management, 2017, p. 9). It was also stated that in 2017 there were a total of 4212 reports of occupational accidents in The Netherlands. This has increased with four percent in 2018 to a total of 4368 accidents. Last year, 70 of these accidents were fatal with a total of 71 deaths. Most of these accidents are caused by collisions, falling objects, moving machinery and falling from heights (Ministry of Social Affairs and Employment, 2019).

As the rate of occupational accidents is not decreasing, new approaches could provide the needed change. With the current development of high-tech devices, new immersive training methods in virtual reality (VR) could introduce solutions. In a successful VR experience the user is immersed and should feel deeply involved in the simulation. There are multiple ways to let the user feel involved, but in this research report the focus will be on methods to enhance learning objectives with a visual style. Saxion university of applied sciences, has offered the opportunity to collaborate and research this topic together with Strukton Rail. Seven other students will contribute to the project and together we will develop a solution for our client.

Company background and objectives

Strukton Rail is an international player with groundbreaking solutions for rail infrastructure and electrical systems in rolling equipment. Their employees are working on railway systems day and night to make sure that trains are running everywhere and on time. The result: optimum quality tracks and functionalities in a train, pioneering in terms of innovation and technology. A railway that is safe, reliable, and available to all. The company functions as a full-service provider, providing cross-border solutions in the field of rail infrastructure, railway vehicles and mobility systems. They operate on an international basis and have long-term operations in the Netherlands, Sweden, Denmark, Belgium, Italy and Australia.

Strukton Rail wants to explore the potential of new training methods as traditional training cannot fully prepare employees for the situations encountered on real railroad sites. The project aims to explore the possibilities of virtual reality to increase employee awareness and facilitate training. An immersive digital experience by use of a head-mounted display (HMD) could familiarize Strukton's railroad workers with possible dangers that could occur in their field of expertise. A training scenario involving risk awareness, environmental variables such as weather conditions, realistic sound and a visually compelling style are to be delivered to Strukton Rail.

Scope of the research

The virtual reality training simulation requires an environment and assets. Since there are four other graduates working on this project, the focus of my research will be on setting a visual style and creating assets for the simulation. Specifically, I want to study how the learning objectives of the simulation can be enhanced, visually. In the final product, trainees should recognize a work environment, their tools, machinery and most importantly their personal-protective-equipment (PPE). The final simulation will contain a few potential risks and should enhance the learning objectives of the simulation.

Main question

- How can the learning objectives concerning risk awareness for working at heights be visually enhanced in a virtual reality training simulator for trainees of Strukton Rail?

Sub questions

- What are Strukton's learning objectives and how can they be incorporated in a virtual reality training simulator?
- Which visual style is suitable for a virtual reality training simulator regarding working at heights?
- Which visual elements can improve the learning objectives for trainees and how do they improve them?

Methodology and approach

Data for this research will be sourced from information provided by Strukton, and available literature and studies. Employees from the company will test the prototype and fill in

questionnaires that I can process for my research. Gameplay will be observed to use the feedback in further development. Interviews with the client about prototypes of the product should help the development towards a finalized product.

Problem statement

With new railroad workers employed at Strukton awareness of risks and safety is crucial. A consultant in business improvement and safety, health and environment at Strukton, mentioned that absenteeism is a large problem because of occupational accidents. It causes high costs and increases the workload for other employees. Traditional training does not always fully prepare employees, so a safe environment that represents situations encountered in the real world could be a possible solution. By use of an HMD and a set of controllers, trainees could enter a simulation with the purpose of learning experientially; the form of learning by actively trying.

A study on Alen3D AT, a virtual reality training system for maintenance and operation of high-voltage overhead power lines, showed that virtual reality training works better than traditional training. The traditional training involved theoretical classes and field training, the virtual reality training involved an experiential approach in a safe environment as well as field training. Two groups were evaluated the report shows that the VR group scored 21.62% better than the traditional group (Bobadilla, I.G., Figueroa, G.A., García, A.A., Ramírez, M.P. & Román, J.M., 2016, p. 36).

Another study on construction safety training using VR showed that it has advantages over traditional training. Test subjects generally scored better on risk prevention and identification, however the training simulation seemed to be limited. The scenarios built for the experiments gave a clear depiction of the situations but were limited in sophistication and reality (Barak R., Perlman, A. & Sacks, R., 2013, p. 13).

VR training simulations regarding construction jobs already exist, but none of them specifically fit Strukton's requirements for scenarios regarding Dutch railway constructors. As I described earlier, Strukton wants to prepare their employees as good as possible for the work they have to conduct, so to prevent incidents and possible resulting absenteeism. Working at heights, among other jobs in the construction sector, can be a factor of accidents and absenteeism. As proven by several studies, training simulations in VR can be successful. Strukton would like to see innovative ideas concerning VR training and risk awareness. An immersive virtual learning experience that depicts real life situations could bring the solution

Strukton is looking for. For an interactive and educational learning experience a visually appealing style is essential. Specifically, the visuals should enhance the learning objectives.

Working at heights scenario

Nowadays most trains are powered by electricity. The power lines are located above the rail road. To maintain these, a railroad worker must work at significant heights. Strukton uses a variety of different machines to work at heights. One of these machines is a KROL (crane on rail wheels) with an elevating work platform attached to it to reach the power lines, signal posts or support beams. When construction workers perform tasks, they must always work safely.

Figure 1. Strukton employees working at heights (Strukton, 2019).

To set up a scenario, a few learning objectives need to be defined. A safety instructor from Strukton explained the most important safety measures when working at heights. Employees should always check their tools and equipment prior to the job. Next to that, the operator should pick the right personal protective equipment to perform the job. Fall protection has been standardized as personal protective equipment within Strukton Rail. The fall protection, in this case a safety harness with a fall arrest block, should always be clamped to a sturdy anchor point. A fall arrest block prevents construction workers from falling out of an elevating work platform when working at heights.

Next to the safety measures described by Strukton, there are more safety measures to take when working on an elevating work platform. The surface that the work platform is placed on should preferably be horizontal. The driving speed should be adjusted depending on the condition of the floor, condition of the terrain, the view and the operating conditions. To prevent the machine from falling over or swinging heavily, the operator should always check for obstacles on the tracks. The operator should avoid driving with the platform being elevated high up in the air, because the driving speed can cause the basket to sway or vibrate. The gate to enter the work platform should always be closed when it is being used. Tasks should only be performed from within the basket, bringing tools is allowed. Lifting heavy materials is not what the elevating work platform is designed for (Logistart, 2016, p. 7-13).

These are the learning objectives that Strukton would like to emphasize in the virtual reality training simulator. The scenario could be implemented as a simple protocol in a virtual environment. The protocol would be like the real-life situation, the trainee will have to check the PPE's, environment and other factors mentioned previously. The trainee will then perform a simple task such as tightening a bolt while working from an elevating work platform. As described in my scope, I will focus on the visual style that suits the scenario, therefore I will not go in depth about the protocol. To design a suitable virtual environment for the training simulator, visual styles and their application to the learning objectives should be explored.

Theory

Visual styles

We rely on visual cues that are necessary to orient and perceive our surroundings. There are different visual techniques to create an artificial world. Game dimensionality can differ between 2-dimensional and 3-dimensional graphics, in this case I am mainly looking into 3-dimensional styles. As graphics hardware has improved over the years, we are now able to create entire worlds in virtual reality. Users can experience an artificial world from a first-person perspective by wearing an HMD. Games do not necessarily have to be visually realistic, other visual styles can be perceived as real in the sense of it being spatially accepted. Non-photorealistic rendering (NPR), a rendering technique that does not aspire to photorealism, can be used to illustrate 3D objects in an artistical way (Vilanova A., 2001, p. 1). NPR techniques can be applied to support in storytelling, expression and to depict an artistically aesthetic look. Immersion depends on many factors, including graphical presentation. NPR is often easier to comprehend and can be used to highlight certain parts of an image. Certain types of NPR styles have simple graphics; therefore, it runs fast in real-time on moderate hardware systems (Masuch M. & Röber N., 2005, p. 6-7).

Photorealism is a term that is used in art studies to refer to photographic likeliness with reality. Aki Järvinen, an experienced game professional and academic who teaches game design with focus in Virtual Reality and Augmented Reality applications, researched the audiovisual elements and styles in computer and video games. According to Järvinen photorealism simulates environments and characters familiar from film and real life (Järvinen A., 2002, p. 121).

A study on the impact of visual realism on the authenticity of educational simulation in the Czech Republic has underlined this statement. A group of 48 students was shown a simulation of historic events in two different visual styles. Half of the group reviewed a realistic

version of a simulation about Czechoslovak contemporary history, the others reviewed a cartoon version about the same subject. Results have shown that most of the students preferred a realistic representation, because it was more authentic, attractive and most importantly a better source of information (Brom C., Selbacherova T. & Sisler V., 2014, p. 527-528).

Perception

Humans experience the world through senses. External stimuli influence the sensory systems of the human body. The brain can act on these stimuli to extract information from the surrounding world. Experience and knowledge are mainly derived from our senses as we created a consistent picture of reality (Lumen, n.d.). In VR, however, the world is artificial. The artificial world is non-existent, but the human brain can be tricked into perceiving the simulated world as being real. In this case visual realism can be associated with how close the artificial world resembles a possible situation in the real world (Carr, K. & England, R., 1995, p. 53).

A study from 2018 showed that visual realism is essential in educative games. A group of 14 people was divided into two groups. One group studied a 2D geographical map that portrayed a detailed visualization of a town. The other group studied the same 2D geographical map, but in this case, it was a much more simplified and symbolized version. After studying a specific route through the 2D maps, both groups were placed in a VR environment by use of an HMD. Four out of seven participants in the symbolized environment were able to follow the correct route, while all participants in the realistic environment were able to follow the correct route. Four out of seven participants in the realistic environment were able to complete the task without any mistakes, while two out of seven participants in the symbolized environment were able to complete the task without any mistakes. In this study the level of realism influenced the given task significantly. Participants in the realistic environment were able to navigate through the map more easily compared to the ones placed in a symbolized environment. The realistic environment had a closer resemblance to the real world, so it can be assumed that the participants who experienced the realistic version were more likely to remember the surroundings. The symbolized environment was more monotonous which most likely led to people becoming lost within the walkthrough (Herman L., Kubicek, P., Krejčí, M., Málek, F. & Stachoň, Z., 2018, p. 6-7).

A study on immersion in a tri-dimensional chess game has shown similar results. Subjects were asked to copy a sequence of moves from a chess board in a virtual world to a chess board in the real world. 24 subjects were divided over two groups with two levels of immersion. One group witnessed the chess game on a monitor (exocentric) while the other

group witnessed the chess game through an HMD (egocentric). Next to that there were two types of environments; realistic and plain. Results proved that the egocentric subjects performed better as well as the subjects in a realistic environment. Feeling present in the environment did not immediately improve performance for the subjects, since it relates to how well the subject would perform the task in real life. It can be assumed, however, that the realistic environment made it easier to derive knowledge from the real world. (Kooper R., Linakis V., Slater M. & Usoh M., 1996, p. 163).

User interface in VR

Almost all games and applications have a user interface (UI). The interaction design is supposed to reduce learning how to use the application. The user should be able to understand how to use certain functions without instructions. An intuitive UI will make the product easier to use which results in a good experience. Bad UI's will hinder and agitate the user (Cao, J., Zieba, K., Stryjewski, K. & Ellis, M., 2015, p. 9).

Since tracked controllers are to be used in this application the interaction design works differently compared to most computer applications. Desk-top styled interfaces become unusable in virtual reality, instead the user should be able to intuitively interact with their surroundings. The ultimate VR experience would be to have an unnoticeable user interface. Removing the boundary between the user and the virtual world is to be considered the ultimate challenge. However, the current state of VR still puts constraints on the interaction design. Choosing an appropriate UI design depends on the content and goal of the application (Craig. A.B., Sherman. W.R., 2019, p. 73-74).

Visualization plays an important role in simulation. A study on a crane operating simulation made by students from a university in Singapore has shown to be successful when it comes to safety awareness. The trainees could drive a simulated crane in an artificial plant. The students created a 3D control room that trainees could interact with. With a mixture of 3D visualization and 2D elements, such as proximity warnings and other possibly dangerous situations, they managed to create a training simulation system to help trainees improve their operational skills and safety awareness (Cai P., Cai Y., Chandrasekaran I., Chen Y. & Wu X., 2017, p. 47-58).

Literature evaluation

In a virtual environment the sense of sight can be stimulated through an HMD. According to several studies on visual styles regarding simulation; the closer an artificial world

resembles a possible real world, the more perceptually believable the simulation becomes. Based on the theory I found, photorealism simulates environments and characters familiar from film and real life and most importantly it can be a more precise form of information. On the other side of the spectrum, non-photorealistic rendering can be expressive and artistically appealing to look at. It is often perceived more easily and can be used to highlight certain parts of an image. Both visual styles have their advantages, but to balance it out, it would be wise to consistently apply both visual styles in the training simulator.

From an educational perspective it would be better to pick a realistic style for the surroundings, tools and personal-protective-equipment over a symbolized style as it is more likely to create a connection between experience and knowledge derived from reality in virtual reality. Feeling present within an artificial environment does not immediately improve performance, however it could be great for practicing and preparing for the real environment. The user interface and user experience design should be clear and consistent, to avoid frustration for the user. This can be achieved with non-photorealistic shaders to highlight or outline objects. Visual guidance can be displayed in a symbolized way, such as arrows and other 2D indicators. The combination of both visual styles should guide the trainee through the simulation.

Implementation

PBR and cel-shading

In my literature evaluation I mention both photorealism and non-photorealism. To prepare for my research method I studied physically-based-rendering (PBR) and cel shading. PBR is a rendering technique that focuses on the interaction between light-rays and surface matter (Substance Academy, n.d.). Cel shading is a non-photo-realistic rendering technique which is used to make 3D computer graphics appear flat. This involves using less shading color instead of the shade gradient, or tints and shades, used in most design techniques for video games. (Jones S., 2017).

Visualizing

To display the two visual styles, Allegorithmic's Substance Painter, a tool used to create textures for 3D models, and a cel shaded shader in the Unity game engine, were used. For the photorealistic style PBR textures in Substance Painter were created. A set of maps as a base to work with were generated. After that, adding the correct colors and material settings such as

roughness and metallic settings, were applied. Lastly, generators were applied to create micro surface details, dirt and rust. The result closely resembles a real-life object, visually.

Creating a cel-shaded object was much less time consuming, because it only requires flat colors (without gradients). The Unity cel-shader that was found in the asset store removes gradients and keeps hard shadows. All micro-surface detail is lost. As the object is simplified it becomes easier to perceive.

Purpose

After the styles had been set, I could research the effect of both in user tests. I began developing assets in a photorealistic style as it was easy to revert to a cel-shaded style. I performed several experiments, mentioned in my method of the research, to find out which visual style to pick for the overall simulation. The experiments were related to clarity, recognition, presence and visual feedback. The purpose was to discover which visual style should be picked for the overall simulation or if parts of both visual styles in combination would be an option.

Method of the research

For this project I wanted to research how a visual style can enhance the learning objectives of the training simulation. To come to an answer, I applied multiple research techniques. In the first stages of the project I brainstormed together with the project team (see figure 2). We wrote our thoughts down individually and passed them around for the other project members to add new ideas. A word that caught my attention was photorealism. According to my theory a photorealistic scene would be the correct visual style for a simulation as it derives experience and knowledge from reality and is more perceptually believable. To confirm that this was the best suited approach, I prepared a user test for two Strukton employees.

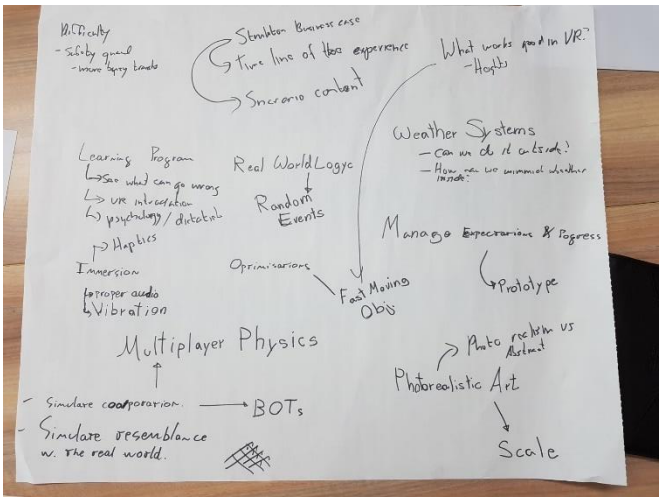


Figure 2. Brainstorm session at the beginning of the project.

Approach employee user test

The employees were asked to wear an HMD to experience a simulation. In the simulation the user could explore a bridge situated in a city environment. The city contains several textured buildings and a rail track. The employees could control a simple representation of a crane to move around. Figure 4 depicts the realism of the environment. After the simulation, the employees filled in two questionnaires. One questionnaire involved work related questions to review their experience and the other questionnaire was about the simulation. There were multiple categories in the questionnaire, including a category about the visual style.

Figure 4. Part of the environment that could be explored in the simulation.

Approach student questionnaire

To validate the proper style for a virtual reality training simulation and to find out how photorealism and non-photorealism influences people, I prepared a questionnaire (see appendix C for the questionnaire) regarding the difference between photorealism and non-photorealism. Students in game and art related studies at Saxion University as well as students from completely different studies and universities were asked to give their opinion on several images. The questions were related to clarity, recognition, presence and visual feedback of the experience in the simulation. Three categories were presented with two of the same images in different styles. The first category was about the virtual environment shown in figure 5.

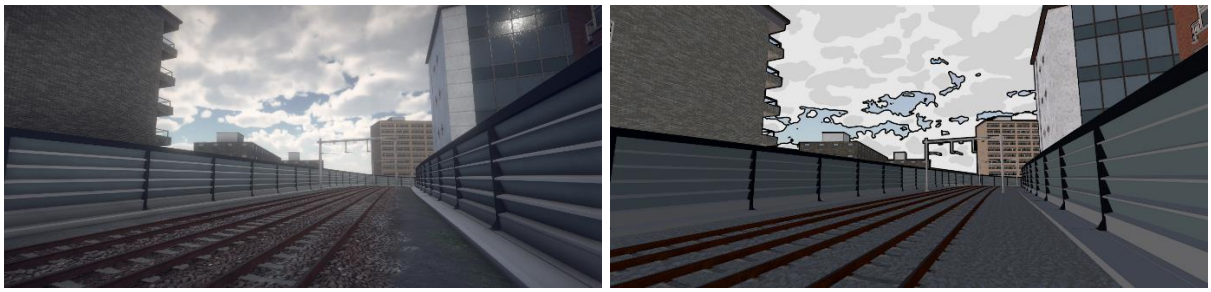


Figure 5. A photorealistic environment (left) and cel shaded environment (right).

The participants were asked several questions about the environment. They were asked to do the same for the category regarding objects displayed in figure 6.

Figure 6. 3D model of a photorealistic hardhat (left) and a celshaded hardhat (right).

In the last category the participants were asked questions about two hint indicators depicted in figure 7. One of the indicators was animated, it would rotate and change color, while the other indicator was entirely static. The purpose of this last category was to discover if the hint indicators were related to either of the visual styles.

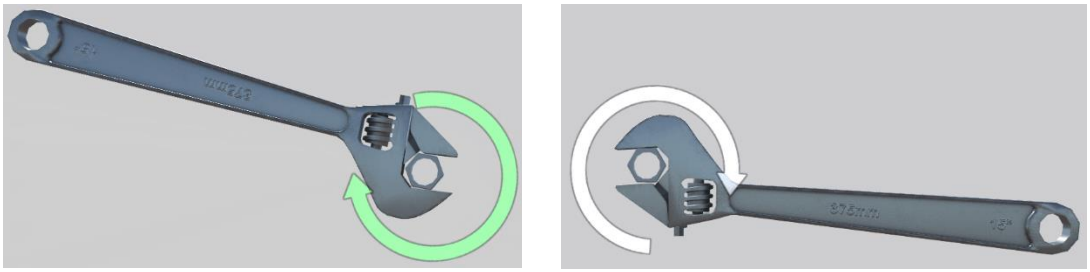


Figure 7. A rotating hint indicator that turns green and red depending on the direction that the wrench is rotated in (left) and a static indicator (right).

Finally the participants were asked which of the images they could remember best. They wrote down what they could remember from the images without looking at them. The purpose of it was to discover if either of the visual styles left a better impression or if they were equal.

Approach final user test

In the final user test, a Strukton employee was asked to test the simulation. To discover if the employee learned about risk awareness, I prepared potential risks in the scene. The hardhats used by Strukton's construction workers contain a UV-indicator on the back. After a certain amount of time the sun rays turn it from red to white (see figure 8). That means that the hardhat is brittle and should not be used anymore. The simulation contained two versions of the hardhat, one with a red indicator and the other with a white indicator. Next to that I placed large branches on the rail track to see if the employee reviewed the environment for possible obstacles. Finally, I created a rusty version of the clamp in the simulation that is used to secure the user to the basket. The rust indicates that the clamp is unsafe as it could break easily. Faulty material should always be avoided according to Strukton, so I observed the employee's gameplay to see his response and actions. After testing the simulation, I interviewed the employee about potential risks and the learning objectives.

Figure 8. A hardhat in good condition (left) and a faulty hardhat (right).

Research results

Employee questionnaire

During the first test-play session we invited two Strukton employees; a safety officer and a high voltage fitter from Strukton Rail. They were asked to play an early stage of the project. The high voltage fitter works at heights while the safety officer does not (see appendix D and E for the job-related questionnaires). Figure 9 shows the opinions of both employees after testing the simulation.

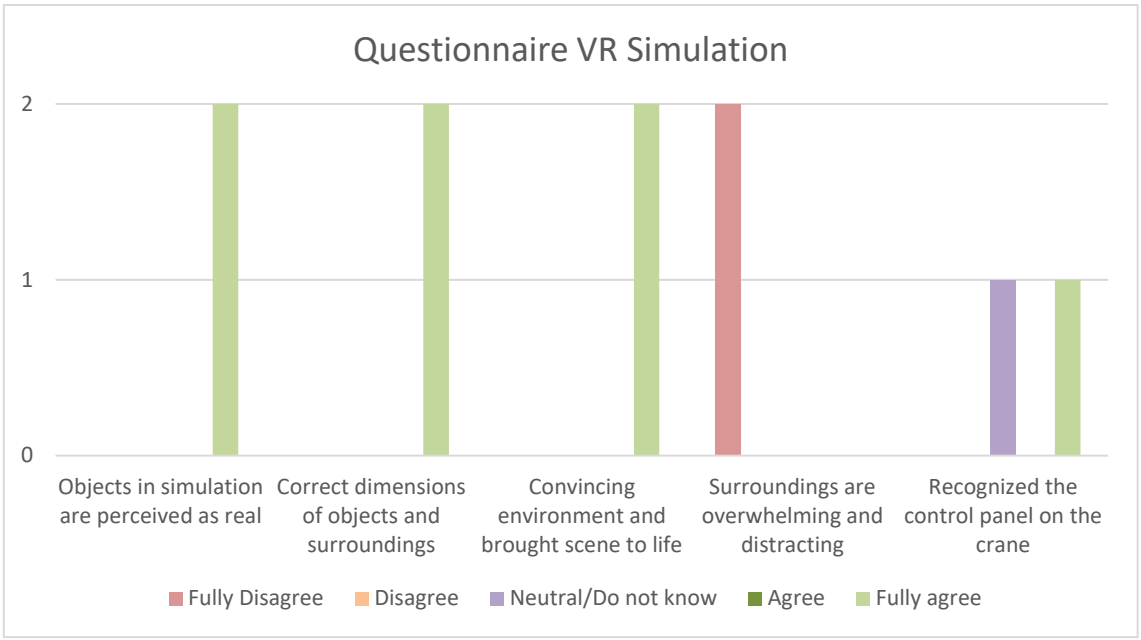


Figure 9. Questionnaire results regarding the visual style in an earlier stage of the project.

Analyzing the employee questionnaire

Both employees agree that the photorealistic visuals are perceived as real (see appendix F and G for the simulation related questionnaires). They also agree that the dimensions of the objects and surroundings are correct. The overall visuals are convincing and bring the scene to life. The visuals were not overwhelming and did not distract them from the simulation. One of the employees was neutral about the control panel on the elevating work platform while the other recognized it.

Unfortunately, the safety officer could not answer all the job-related questionnaires. He knows a lot about safety measures when working at heights. While he does not work at heights, he did recognize most parts of the control panel on the elevating work platform. After testing the simulation, he answered that he absolutely sees potential in a training simulation to learn about risk awareness. Next to that he would prefer a virtual reality training over the traditional training method by Strukton.

The high voltage fitter answered that he is well experienced in his job and knows how to work at heights. According to him the traditional training method is reasonable, but there is room for improvement. He always checks his PPE's and surroundings to work safely. He also mentioned that he never followed a training course for working at heights. He had an occupational accident where he injured his hand. He explained that extra safety awareness might have prevented the accident, but it would have been unlikely to. In the simulation, he recognized the control panel, but did not know how to use it, because the symbols on it were

missing. The high voltage fitter was neutral about the potential of a training simulation and he disagrees to pick a simulation over a traditional training. He did however agree that a combination of both the traditional training method and the training simulation could provide positive results.

Student questionnaire

In this questionnaire the participants were asked several questions about images regarding the photorealistic and cel shaded style. A group of 14 students participated and shared their opinion on the visual styles.

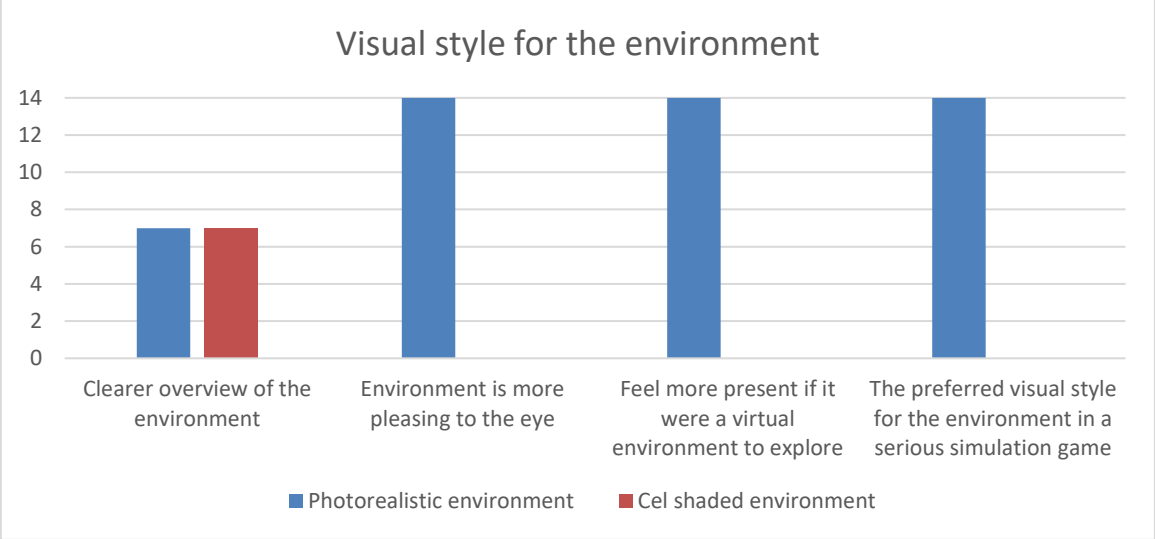


Figure 10. Questionnaire results regarding the visual style for the environment in the virtual reality training simulator.

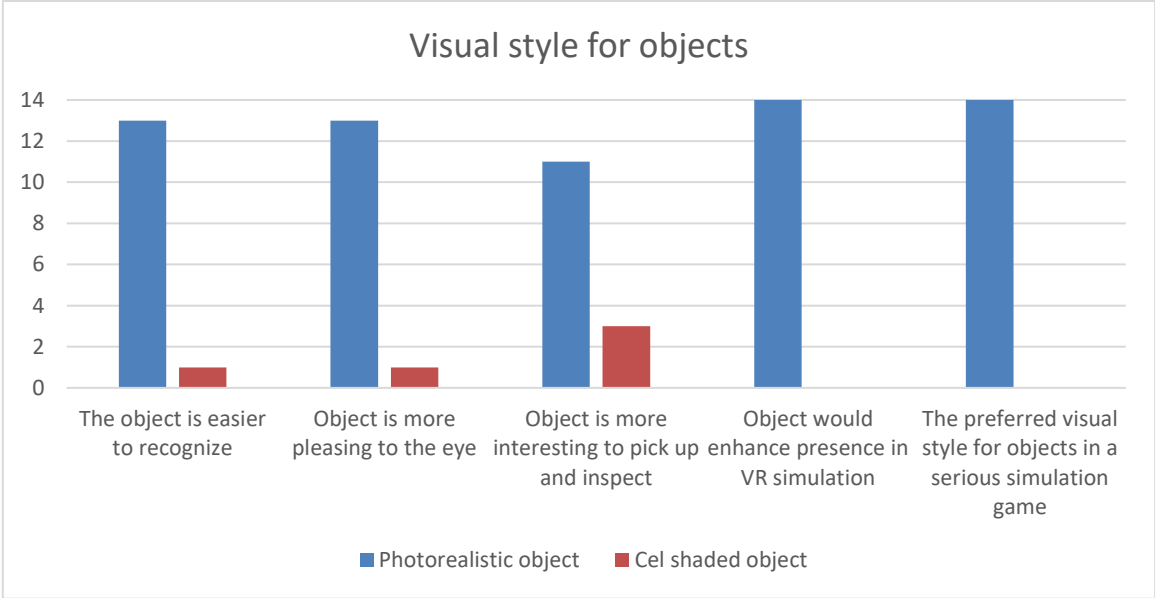


Figure 11. Questionnaire results regarding the visual style for objects in the virtual reality training simulator.

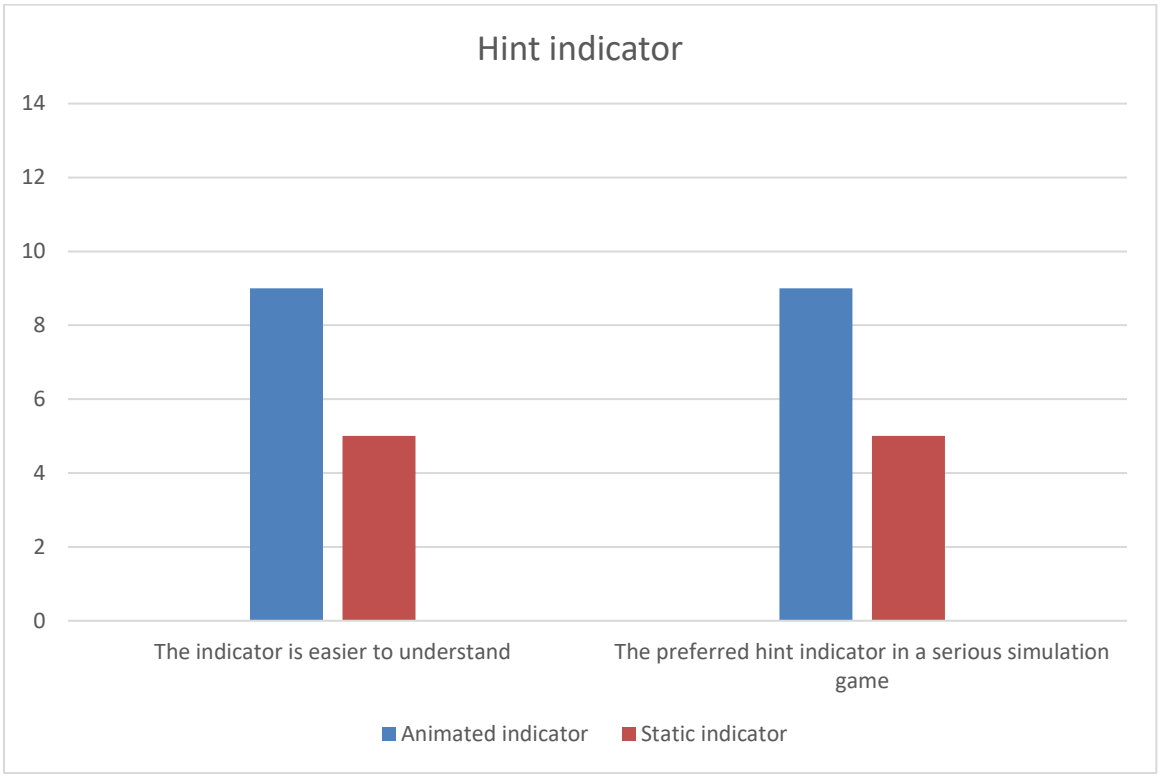


Figure 12. Questionnaire results regarding the hint indicators in the virtual reality training simulator.

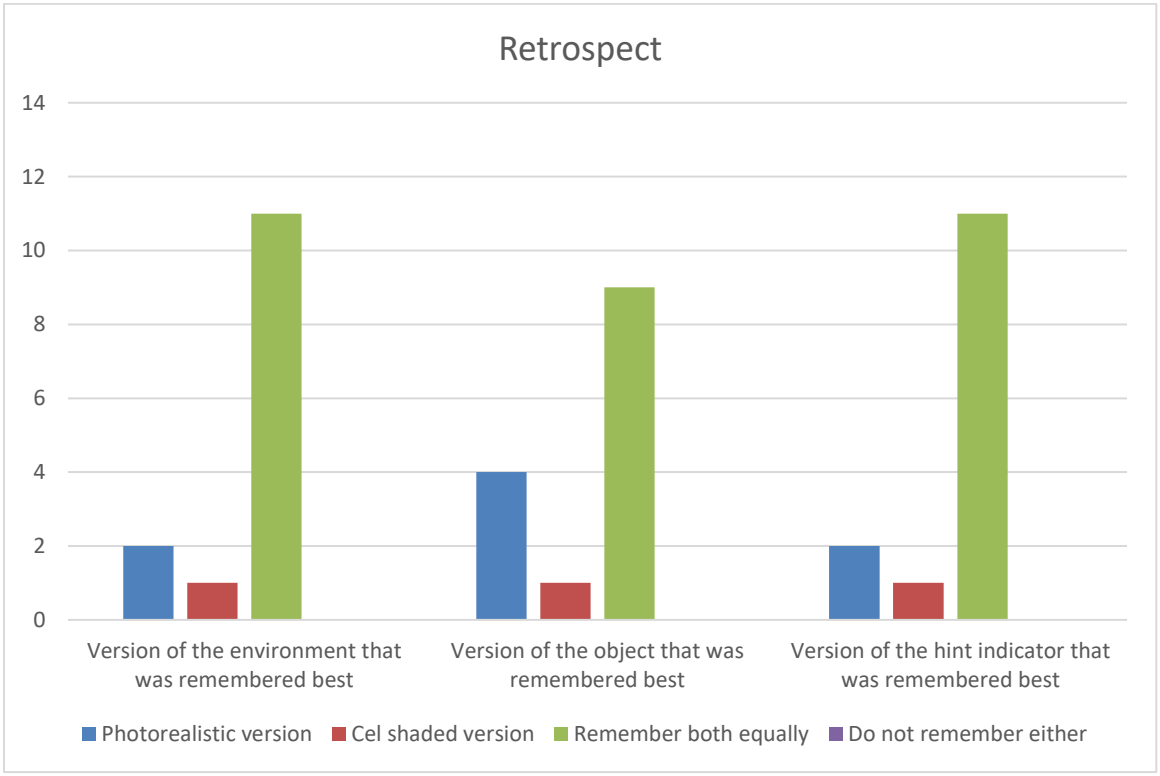


Figure 13. Questionnaire results regarding the remembrance of the visual styles.

Analyzing the student questionnaire

The research results reveal that photorealistic virtual environment is preferred over the cel shaded environment, because it is more pleasing to the eye and it would make the user feel more present. However, according to the results displayed in figure 10, 7 out of 14 (50%) participants claimed that the cel shaded version gave a clearer overview of the environment. It can be assumed that the clearer overview was caused by the outlines and flat colors of objects. The environment looks more complex compared to a single object, so the outlines and flat colors provide distinction between objects. Figure 11 shows that 13 out of 14 (92,9%) participants consider the photorealistic object easier to recognize and find it more pleasing to the eye, while only 1 (7,1%) participant preferred the cel shaded object. 11 out of 14 (78,6%) would find it more interesting to pick up and inspect the photorealistic object. All participants agree that the photorealistic object would make them feel more present and that it is the preferred visual style for objects in a virtual reality simulation. It can be assumed that photorealistic style for objects creates a stronger connection between the virtual and real world, because it appears that most participants find the photorealistic object pleasing to the eye and easier to recognize. The three participants that preferred to pick up and inspect the cel shaded object, most likely picked this option due to the clarity and simplicity of the visual style. Like the results of the cel shaded environment, the outlines and flat colors make the object easier to inspect as there is a clear distinction between details of the object. Regarding the hint indicators, figure 12 reveals that 9 out of 14 (64,3%) participants prefer an animated indicator that turns green when the wrench is rotated in the correct direction and turns red when it is rotated in the wrong direction. 5 out of 14 participants (35,7%) prefer a static hint indicator that does not rotate or change color. Some participants find the rotation and change in colors distracting, while the majority agrees that it is a better form of visual feedback. This does not necessarily add up to the visual style. It does however teach the user what to do visually, which contributes to the learning objectives. The retrospective part of the questionnaire, shown in figure 13, clarifies that 11 out of 14 (78,6%) participants remember both environments equally, 2 out of 14 (14,3%) participants have a better recollection of the photorealistic environment and one participant (7,1%) has a better recollection of the cel shaded environment. Regarding the objects, 9 out of 14 (64,3%) participants remember both objects equally, 4 out of 14 (28,6%) participants have a better recollection of the photorealistic object and only one participant (7,1%) has a better recollection of the cel shaded object. The higher number of participants who

had a stronger recollection of the photorealistic object compared to the photorealistic environment is most likely due to the micro surface detail that was visible on the hardhat. The participants who picked the photorealistic object could remember the dirt and scratches on the helmet, while the cel shaded object did not have any. Micro surface detail plays a less important role in the images of the environment. The user does not have to focus on a single object, so the micro surface details are less noticeable as they blend together with multiple objects. The photorealistic and cel shaded environments look more similar in comparison to the hardhat, therefore more participants are likely to remember the environments equally. An interesting remark by one of the participants was about the available time and budget. Though the photorealistic visual style is preferred by most of the participants, it could be a trade off with the cel shaded style. The cel shaded style is faster and easier to create which influences the amount of manhours a company must spend on it.

Based on these results, the photorealistic style is the recommended choice for the environment and objects. To clarify the scenario, certain objects can be outlined and highlighted in a flat color. These are elements of a cel shaded visual style. The animated, color changing hint indicator is recommended as it provides more visual feedback, but the difference between an animated or static hint indicator would not influence the simulation significantly.

Final user test

For the final user test, the safety officer tested the simulation once more (see appendix H for the results). During the simulation, he did not notice there was a difference between the two hardhats. He accidentally picked the correct hardhat and continued with the simulation. He did see that the clamp, that is used to secure yourself to the elevating work platform, was rusty and mentioned that it would be unsafe to use. He also reviewed his surroundings and saw several tree branches that covered the rail tracks. He mentioned that the elevating work platform would derail in real life if he would try to drive over them. In this case, he initially avoided the tree branches, but for testing purposes he asked permission to drive over them (which currently has no consequences yet). While operating the elevating work platform, he stayed within reasonable reach of the basket of the elevating work platform.

Analyzing the final user test

After testing, the safety officer remembered two potential risks; the rusty clamp (faulty PPE) and the tree branches on the railroad (dangerous obstacle). He mentioned that he did not notice the difference between the two hardhats, but that it was a good learning point for him.

He explained that the UV-indicator of the hardhat is often overlooked and could be an important learning objective that can easily be visualized in a virtual reality training simulator. To prevent trainees from accidentally picking the correct option, he recommended a feedback system that confirms the user's choice in the simulation. He mentioned that he was able to put a link between the virtual world and the real world. The rust on the clamp made him consider that it was potentially a faulty piece of personal-protective-equipment. The visual style in the simulation, in this case photorealism, influenced his decision-making. He agreed that the simulation was visually appealing and that the headlight and construction lamp in the scene give an excellent representation of a real-life situation. Overall the visual elements such as textures, materials, lighting and the representation of real-life situations taught him new lessons, influenced his behavior and improved his learning objectives.

Conclusion, discussion and recommendation

Conclusion

After a semester of research I can conclude that the learning objectives concerning risk awareness for working at heights can be enhanced visually in a virtual reality training simulator. In this research I performed several steps to answer my main research question.

First, it is important to determine the learning objectives that will be implemented into the simulation. In this case, Strukton wants trainees to learn about the safety measures that they must take when they work at heights. The quality of tools and equipment, the correct choice of personal-protective-equipment, the proper use of fall protection, the correct use of the elevating work platform and the reviewing of the surroundings for potential dangers are of importance when it comes to working at heights. The scenario can be shaped into a simple protocol, where the trainee is required to perform a task at height. The task takes place in a virtual reality simulation. In the simulation, the trainee should become aware of potential risks that could also occur in the real world.

Secondly, I studied which visual style would fit the training simulation scenario. Based on the literature I analyzed, the artificial world becomes more perceptually convincing if it resembles a possible real world. Photorealism simulates environments and characters familiar from film and real life, it is also a more precise form of information. Non-photorealistic-rendering is perceived more easily compared to photorealism and can be used to highlight certain parts of an image. The findings illustrate that it would be the best choice to pick a photorealistic style for the environment, tools and personal-protective-equipment as it relates to knowledge derived from reality. Regarding the user interaction and experience, it would be

best to use a non-photorealistic shader to highlight and outline objects to guide the user during the simulation. Based on the theory I should consistently use both visual styles in the simulation.

The research results confirm that a photorealistic style suits the environment and objects in a virtual reality training simulator. Both of Strukton's employees agree that the photorealistic visuals are perceived as real, the dimensions of the objects and surroundings are correct and that the overall visuals are convincing and bring the scene to life. Next to that, all 14 participants that were invited to participate in my questionnaire about the visual style in a VR training simulator substantiate this decision. Though all participants agree that a photorealistic style suits a virtual reality environment, half of them consider that a cel shaded environment provides more clarity. It can be assumed that outlines and flat colors provide distinction between objects. The same 14 participants agree that a photorealistic style suits objects in a virtual reality simulation; however, some participants are more interested in picking up and inspecting a cel shaded object. Like the environment, it can be assumed that outlines and flat colors provide distinction between details, which makes it easier to inspect the object. A photorealistic visual style generates a stronger connection to real life, but a cel shaded visual style provides clarity. Using elements from a cel shaded visual style, such as the outlines and flat colors should be used to guide the trainee.

To find out if a photorealistic style does enhance the learning objectives, I performed another user test with the safety officer. To see if he was aware of potential risks, I set up a few dangerous situations. He experienced and remembered two out of three dangerous situations. He explained that he overlooked one dangerous situation and accidentally picked the correct option. According to him it was a good learning point, but it should be notified to the trainee that he picked a good or bad option. Next to that, he was able to put a link between the virtual and real world and he agrees that the photorealistic visual style influenced his decision-making. Overall, visual elements such as textures, materials, lighting and the representation of real-life situations, improved the learning objectives.

Discussion

In my research I compared two visual styles to see how they would influence a user's behavior. Specifically, I researched if they enhanced the learning objectives in a virtual reality training simulator. I decided to pick a photorealistic and cel shaded visual style, because the difference between both visual styles is drastic. The outcome of this research strongly depends on the type of project and its content. Photorealism is not always the correct choice, because it can be very time consuming to achieve the visual style. It depends on the time and budget that

the company is willing to invest into the project. A cel shaded visual style requires less effort, therefore less manhours and might still offer a solution to what the client is looking for. The learning objectives play an important role in the project as well. If the simulation is not intended to educate and test trainees, less time could be spent on recreating a lifelike situation.

Recommendation

In a virtual reality training simulation, photorealism is the visual style that is mostly preferred; it suits the environment and objects. Accurate textures, materials and lighting in the simulation make it easier for the trainee to derive knowledge from real-life in the virtual world. Photorealism generates a lifelike experience that will influence the decision-making of the trainees. Use of outlines and highlights will distinguish details in the virtual world and will guide the trainee. An example of this could be to apply it to interactive objects.

Gameplay-wise a notification must be given to the player depending on the choices they make. This is important, because it prevents trainees from overlooking possible risks. The notification should be positive when the player picks the correct option, and negative when the player picks the incorrect option. This way the trainee knows that there was a potential risk when they accidentally pick the correct option. It is also important to educate the player about the consequences of unsafe situations.

Parts of the development phase were difficult, because the machines that were used in the simulation are very complex. 3D artists, that work in the gaming industries, are (usually) not mechanical engineers. Remodeling machines, such as the elevating work platform, is inaccurate and too time-consuming. Acquiring 3D models from manufacturers will reduce the workload significantly. Working with blueprints and 3D scans is an unreliable process, because it is a process based on guessing and intuition. Optimizing, texturing and implementing accurate existing 3D models is a necessity when it comes to complex machinery.

References

Barak R., Perlman, A. & Sacks, R. (2013, September 26). *Construction safety training using immersive virtual reality.* Retrieved, March 5, 2019, from https://www.tandfonline.com/doi/pdf/10.1080/01446193.2013.828844?needAccess=true&redirect=1

Bobadilla, I.G., Figueroa, G.A., García, A.A., Ramírez, M.P. & Román, J.M. (2016, January 13). *Virtual reality training system for maintenance and operation of high-voltage overhead power lines.* Retrieved, March 5, 2019, from https://link.springer.com/article/10.1007/s10055-015-0280-6?fbclid=IwAR3tOGr_2fzWIKoggIwGopz95H4IcbLlB6QWKFjMoyyZA9ymU6L_3lKE_LY#Sec17

Brom C., Selbacherova T. & Sisler V. (2014, October). *The Impact of Visual Realism on the Authenticity of Educational Simulation: A Comparative Study*. Retrieved, May 22, 2019, from https://artemis.ms.mff.cuni.cz/main/papers/Visual_Realism_ECGBL_2014.pdf

Cai P., Cai Y., Chandrasekaran I., Chen Y. & Wu X. (2017). *Simulation-Enabled Vocational Training for Heavy Crane Operations.* Retrieved, May 23, 2019, from https://www.researchgate.net/publication/310495837_Simulation_and_Serious_Games_for_Education

Cao, J., Zieba, K., Stryjewski, K. & Ellis, M. (n.d.). *Consistency in UI Design Creativity Without Confusion.* Retrieved May 23, 2019, from https://edoc.site/uxpin-consistency-ui-design-creativity-without-confusion-pdf-free.html

Carr, K. & England, R. (1995). *Simulated and Virtual Realities elements of perception.* Retrieved, March 23, 2019, from https://books.google.nl/books?hl=nl&lr=&id=PLdLOjHIh-cC&oi=fnd&pg=PA53&dq=what+is+visual+realism&ots=kPFdrWZE_H&sig=IimNXUGWqAkNSkt1oM40yChi3aI#v=onepage&q&f=false

Craig. A.B., Sherman. W.R. (2019). *Understanding Virtual Reality: Interface, Application, and Design.* Cambridge, MA: Morgan Kaufmann.

Herman L., Kubicek, P., Krejčí, M., Málek, F. & Stachoň, Z. (2018, June 23). *The Role of Hue and Realism in Virtual Reality.* Retrieved, March 23, 2019, from https://www.researchgate.net/publication/325619353_The_Role_of_Hue_and_Realism_in_Virtual_Reality

Järvinen A. (2002, June). Gran Stylissimo: *The Audiovisual Elements and Styles in Computer and Video Games.* Retrieved, May 22, 2019, from http://www.digra.org/wp-content/uploads/digital-library/05164.35393.pdf

Jones S. (2017, November 7). *What is cel-shading - Plus our pick of cel-shaded games.* Retrieved, June 5, 2019, from https://www.fanatical.com/en/blog/what-is-cel-shading

Kooper R., Linakis V., Slater M. & Usoh M. (1996, July 4). *Immersion, Presence and Performance in Virtual Environments: An Experiment with Tri-Dimensional Chess.* Retrieved, May 24, 2019, from http://delivery.acm.org/10.1145/3310000/3304216/p163-slater.pdf?ip=145.76.115.167&id=3304216&acc=ACTIVE%20SERVICE&key=0C390721DC3021FF%2E0876A34FF42AD0F5%2E4D4702B0C3E38B35%2E4D4702B0C3E38B35&__acm__=1558694392_87e52027835433f0832f9094863a76c8

Logistart (2016). *Lesboek Hoogwerker Logistart.* Retrieved, June 7, 2019, from https://www.logistart.nl/wp-content/uploads/Hoogwerker-Theorieboek-Nederlands-Logistart-Veiligheidsopleidingen.pdf

Lumen (n.d.). *Sensory Processes*. Retrieved, June 18, 2019, from https://courses.lumenlearning.com/boundless-psychology/chapter/sensory-processes/

Masuch M. & Röber N. (2005, January). *Game Graphics Beyond Realism: Then, Now, and Tomorrow.* Retrieved, May 15, 2019, from https://www.researchgate.net/publication/252486461_Game_Graphics_Beyond_Realism_Then_Now_and_Tomorrow

Ministry of Infrastructure and Water Management. (2018, November 11). *Veiligheid op het spoor.* Retrieved, March 4, 2019, from

https://www.rijksoverheid.nl/documenten/rapporten/2018/11/27/bijlage-ilt-rapport-jaarverslag-spoorwegveiligheid-over-2017

Ministry of Social Affairs and Employment. (2019, February 26). *Inspectie SZW roept bedrijven op meer te investeren in veiligheidscultuur.* Retrieved, March 4, 2019, from https://www.inspectieszw.nl/actueel/nieuws/2019/02/26/inspectie-szw-roept-bedrijven-op-meer-te-investeren-in-veiligheidscultuur

Substance Academy (n.d.). *Light and Matter: The theory of Physically-Based Rendering and Shading.* Retrieved, June 6, 2019, from https://academy.substance3d.com/courses/the-pbr-guide-part-1

Vilanova. A. (2001, July). *Non-photorealistic Rendering.* Retrieved, May 19, 2019, from https://www.researchgate.net/publication/236973460_Non-Photorealistic_Rendering

Glossary

The following list of words identify the terms referred to in this report.

Augmented reality (AR)	Augmented reality (AR) is an interactive experience of a real-world environment where the objects that reside in the real-world are enhanced by computer-generated perceptual information.
Cel shading	Cel shading is a type of non-photorealistic rendering designed to make 3-D computer graphics appear to be flat by using less shading color instead of a shade gradient or tints and shades.
Elevating work platform	An elevating work platform is a mechanical device used to provide temporary access for people or equipment to inaccessible areas, usually at height.
Fall arrest block	Fall arrest is the form of fall protection which involves the safe stopping of a person already falling.
Fall protection	Fall protection is the use of controls designed to protect personnel from falling or in the event they do fall, to stop them without causing severe injury.
Head mounted display	A head-mounted display is a display device, worn on the head, that has a small display optic in front of one (monocular HMD) or each eye (binocular HMD).
Hyperreality	Hyperreality, in semiotics and postmodernism, is an inability of consciousness to distinguish reality from a simulation of reality, especially in technologically advanced postmodern societies.

Krol	Crane on railroad wheels (KRaan Op Lorries).
Occupational accident	An occupational accident is a "discrete occurrence in the course of work" leading to physical or mental occupational injury.
Non-photorealistic-rendering (NPR)	Non-photorealistic rendering (NPR) is an area of computer graphics that focuses on enabling a wide variety of expressive styles for digital art. NPR is inspired by artistic styles such as painting, drawing, technical illustration, and animated cartoons.
Personal Protective Equipment (PPE)	Personal protective equipment (PPE) is protective clothing, helmets, goggles, or other garments or equipment designed to protect the wearer's body from injury or infection.
Photorealism	Photorealism is a genre of art that encompasses painting, drawing and other graphic media, in which an artist studies a photograph and then attempts to reproduce the image as realistically as possible in another medium.
Physically-based-rendering (PBR)	Physically based rendering (PBR) is an approach in computer graphics that seeks to render graphics in a way that more accurately models the flow of light in the real world.
Serious gaming	A serious game or applied game is a game designed for a primary purpose other than pure entertainment.
Shader	In computer graphics, a shader is a type of computer program that was originally used for shading but which now performs a variety of specialized functions

Texture	In graphics software, textures are used to provide 2D or 3D objects with a specific surface structure and appearance.
User interface (UI)	The user interface (UI), in the industrial design field of human–computer interaction, is the space where interactions between humans and machines occur.
Virtual reality (VR)	Virtual reality (VR) is an experience taking place within simulated and immersive environments that can be similar to or completely different from the real world.

Appendix

Appendix A (reflection)

Bold words in-text refer to justifications/proof listed below each category of competences, some can be found in paragraphs of my research report or appendices instead.

I. Technological competences

1. Technical research and analysis The starting professional has a thorough knowledge of the current digital technologies within that part of the field of work the training course aims at. The starting professional is capable of conducting technical research and analysis.
During the kick-off of the project, the client provided an example (**link A**) of an existing virtual reality training simulator. The simulation was a good example of the interaction and functionality of a training simulator but was not visually appealing. With knowledge of the current digital technologies gained from a previous project developed for Thales (**link B**), I knew that I could create something much more visually appealing. In the Thales project I was responsible for many of the assets which were done in a photorealistic visual style. In an earlier stage of developing the simulation for Strukton (**link C and E**), I performed a user test with two employees from Strukton (**see appendix F and G**). They verified that the objects were perceived as real and that the environment brought the simulation to life. The user test motivated me to continue developing game assets, such as buildings for the environment, in a photorealistic style.

2. Designing, prototyping and realizing The starting professional is capable of creating value by iteratively designing and prototyping, based on a (new) technology, creative idea or demand articulation. The starting professional shows an innovating, creative attitude at defining, designing and elaborating a commission in the margin of what is technically and creatively feasible.
The client explained that, because of occupational accidents, they face absenteeism. To improve risk awareness for Strukton's employees that work at heights, Strukton wanted to explore the possibilities of a virtual reality training simulation. For my research I defined the visual style for the simulation. By experimenting I was able to define the visual style for the product. In the first prototype of the project (**Link D**), the gameplay was not immersive. The client explained that the environment lacked detail and felt empty. In the next iteration (**Link E**) I added buildings to the environment. The player was situated in the middle of a city on a bridge. As mentioned in the previous competence, two of Strukton's employees were enthusiastic about the visual style of the simulation. In one of the latest iterations (**Link F**) of the prototype I filled up the environment with more buildings and a skybox (panoramic type of image used to fill up the background and sky). I added hardhats, an obstacle on the rail track, and other details to the simulation. Next to that, I prepared a final user test for the safety officer, in this environment. The results (**Appendix H**) show that the details of the photorealistic visual style in the simulation influenced his decision-making and enhanced the learning objectives. Iteration by iteration I built value for the product. The product is a creative and innovative start of increasing risk awareness, which reduces occupational accidents. This is of high value for Strukton, because it will lead to a reduction in absenteeism for their employees who work at heights.

Appendix A (reflection)

3. Testing and rolling out The starting professional is capable of repeatedly testing the technical results, that come into being during the various stages of the designing process, on their value in behaviour and perception. The starting professional delivers the prototype/product/service within the framework of the design, taking the user, the client and the technical context in due consideration.
To avoid miscommunication and create iterations, we invited the client and employees from Strukton to test several prototypes. In the **method of the research** section of my report, I defined three approaches to justify my theory. I conducted user tests and questionnaires. The results of these experiments can be found in the **results** section of my report. After setting up an initial scenario, the first user test confirmed that photorealism was of interest in developing a virtual reality training simulation. The next experiment proved that photorealism was the correct choice for a simulation, compared to a cel shaded visual style. The cel shading, however, can be used to clarify objects by use of highlights and outlines. Finally, I adjusted the scenario and conducted a user test to confirm my research questions. Photorealism did indeed influence the user's decision-making. The participant agreed that the visual style enhanced the learning objectives.

Link A: Tengo Interactive VR Training Solutions for Russian Railways
Link B: Thales Project Showcase
Link C: User test with a Strukton employee
Link D: First prototype of the simulation
Link E: Early impression of the project showcasing my buildings
Link F: One of the latest iterations

Appendix A (reflection)

II. Designing competences

4. Investigating and analysing The starting professional is capable of substantiating a design commission by means of research and analysis. The starting professional, in his/her investigation activities, shows to have a repertoire of relevant research skills at his/her disposal and is able to select from this repertoire the proper method, given the research circumstances. Is capable of developing prototypes as a communication tool within the context of implementation.
Research and analysis are necessary to create a design. During the Smart Research course (part of the Smart Solutions Semester) I learned how to write a basic report. The guidelines (**Link G**) provide the basic structure based on the graduation report. With use of these guidelines and the graduation manual, I set up a preliminary implementation plan (**Link H**). I was struggling to define my research questions, so my research questions changed a lot. After multiple meetings with my graduation coach, Herman Statius Muller, I changed the structure and my research questions again, and created a final implementation plan (**Link I**). The meetings with my graduation coach can be found on my graduation blog (**Link J**), a place where I mostly kept track of my meetings and notes. I also learned and applied the 'ball structure' provided in the learning materials of the module. I brainstormed for terms that could be of interest for my research (knowledge analysis) and searched for existing projects (360 scan). Both can be found in a document I wrote near the beginning of the semester (**Link K**), I analyzed and stripped references that I did not need. Herman also provided a set of research mapping cards that I could use for finishing touches in my research. While progressing through my research I investigated and analyzed the client's request and described it in my **introduction**.

5. Conceptualizing The starting professional proves capable of being able to get to realistic (cross-sectoral) demand articulation and project definition. The starting professional is capable of developing an innovative concept that creates value on the basis of his/her own idea or demand articulation.
The clients demand was for the project team to create a virtual reality training simulator. The goal of the simulation is to increase risk awareness for employees that work at heights, to reduce absence within Strukton. This problem statement has been articulated and substantiated with proof in my research. I found multiple studies on similar subjects and was able to steer the client's problem towards my role within the project team; defining a visual style that enhances learning objectives. In my **method of the research** section I describe how I could test and validate the concept of enhancing learning objectives visually in a virtual reality training simulator.

Appendix A (reflection)

6. Designing The starting professional is capable of shaping concepts and elaborate these in a substantive, graphic and/or aural way.
To go from concept to design, Aram Mutlu, one of the minor students in our project team, created multiple scenarios (**Link L**). Eventually we decided that the trainee should pick their personal-protective-equipment in the 'menu' room. The trainee could then proceed to perform a task on the railway. The trainee was required to tighten a bolt on a catenary system, high up in the air. The protocol is also described in the **working at heights scenario** section of my report. I was responsible for creating the buildings, hardhat and elevating work platform in the scenario. I designed my concept and validated it with user tests.

Link G: Smart Research Report Structure
Link H: Preliminary implementation plan
Link I: Final implementation plan
Link J: Graduation Blog to keep track of meetings
Link K: Brainstorm and 360 scan
Link L: Concept scenarios

III. Organisational competences

7. Enterprising attitude The starting professional sees opportunities and possibilities and knows how to translate them from a marketoriented point of view into (new) concepts, products, services, in order to thus get to creating value and new revenue models. **8. Enterprising skills** The starting professional has enterprising skills in order to be able to function both as an employee and independently. The starting professional is capable of converting commercial skills into innovative products, services or collections; bearing commercial feasibility in mind.
The project is intended for trainees who will learn about risk awareness for working at heights. This simulation will be valuable to Strukton but can also be used as a demo for other companies to invest into. Next to that, my research is not only limited to this project. The principles that I researched and described in my **conclusion** and **recommendation** can be applied to many sorts of training simulators. Strukton explained that they are very multidisciplinary. I investigated and discovered that Strukton also performs maintenance on high voltage cabinets, the rail track itself (placing and welding heavy materials), bridges (working at heights and high voltage fitting) and other construction/infrastructure related jobs that can involve dangerous situations. Guidance and risk awareness for trainees that perform these jobs can be offered in a virtual reality training simulator, like the current project, but in a different scenario and corresponding protocol.

Appendix A (reflection)

9. Working in a project-based way The starting professional shows him/herself capable of being able to accept, set up and carry out projects from an engagement with stakeholders, whether or not in cooperation with others as a team. The starting professional shows that he/she is capable of cooperating with others in a (multidisciplinary) team in a productive way, reaching a good balance between introducing his/her own expertise and relying on the complementary expertise of others. The starting professional shows him/herself capable of directing team members.
The client demanded requirements that should be implemented into the virtual reality training simulator. Roles were assigned to each team member and the tasks were divided through Trello, a collaboration tool to organize projects into boards. We assigned a team leader who was responsible for communication, and a scrum master who was responsible for tracking the sprint progress and product backlog. We played planning poker every start of the sprint to estimate the amount of effort that every task in the sprint backlog would take. After two weeks we would check if we finished a sprint and move to the next sprint. We involved the client to define a MoSCoW (**Link M**); the list of prioritized large tasks/epics. The client and two Strukton employees were invited multiple times to test the simulation, and to give feedback. We used their feedback to update our MoSCoW and Trello board. Within the project team we used a communication tool called Slack. In Slack we would update each other about project related news, but also graduation related items. I shared references about project information (**Link N**) as well as sources for the graduation report (**Link O**) that I thought others could use too.

10. Communication The starting professional shows him/herself capable of presenting both his/her person and his/her work professionally and well-groomed to third parties. The starting professional shows him/herself capable of being able to communicate with a client about choices and progress in the design process.
Communication wise the team and I invited our client for several meetings. We also visited the Strukton office in Utrecht for a professional meeting and to get a tour through the building. We visited Strukton Rolling Stock in Enschede to see the technical components that construction workers maintain on the railway. When the client was not available to visit Enschede, we proposed a Skype meeting (**Link P**). I was also responsible for communication (**Link Q**) when our communication person was unavailable due to sickness. The meetings were about the progress of developing the product. The client would give feedback and tips, which we used to update our product backlog and planning. A video of the professional product can be found here (**Link R/Appendix B**). Since the minor immersive media is officially not over, we will continue to work on the product until the end of the semester. If Strukton allows it, I will upload a video to my website (my website is still under construction and will be updated after graduation to prepare for job applications).

Link M: MoSCow
Link N: Proof that I shared relevant project-related references
Link O: Proof that I shared relevant graduation-related sources
Link P: Skype meeting
Link Q: Proof that I communicated with the client
Link R: Video of the professional product

Appendix A (reflection)

IV. Professional competences

11. Learning ability and reflectivity The starting professional shows him/herself to be a 'reflective practitioner' by constantly analysing and adjusting his/her own action, fostered by feedback of others. The starting professional shows him/herself permanently directed and capable of being able to keep up with relevant developments in the field of expertise. The starting professional is able to further develop and deepen the craftsmanship, the personal substantiation of the professional situation and his/her creativity.
During the graduation semester I analyzed and adjusted my actions based on feedback that I received from five involved parties; the client, the target audience, my graduation coach, the minor immersive media (team) coach and my project team. The client would share feedback on the product through (skype/phone call) meetings and by e-mail. The target audience would visit us to test the simulation, afterwards we collected feedback through questionnaires and by talking about their experience. The product improved over time; the empty looking simulation advanced by an environment that made the scene come alive. My graduation coach, Herman Statius Muller, helped me with my thesis, but he also mentioned interesting topics that could be of interest in the project. Herman offered great help when I was struggling to formulate my research questions. He also helped me to set up a proper structure for my thesis and made sure that I was on track with my progress. The minor immersive media project coach, Alejandro Moreno Celleri, visited us every Friday afternoon to check the team progress and to test the simulation. Finally, I regularly asked members from the project team to confirm my designs (**Link S**). Regarding my thesis, I exchanged my report with a fellow team member, Luca Frösler, to proofread each other's report.

12. Responsibility The starting professional has a capacity for empathy with other sectors and shows awareness of ethical issues in his/her role as a designer and is able to explicitly make such considerations in accounting for choices in the design process.
While working on this project I learned new information by searching literature and writing a literature evaluation. I learned how to validate the choices I made based on theory by conducting user tests and questionnaires. The theoretical framework connected to the practical use in my research. I learned how a photorealistic visual style can be combined with elements from a non-photorealistic visual style for a VR application. Next to that, I learned how they can be applied in a virtual reality training simulator to enhance the learning objectives for trainees. In other projects (e.g. Thales project), I applied the photorealistic visual style but at the time I did not exactly know why it would suit the VR simulation. I felt a great responsibility, drive and motivation to deliver a visually appealing product with a purpose.

Link S: Proof that I asked my team for their opinion

Appendix B (proof video)

https://www.youtube.com/watch?v=UgUEcimkOAE

Appendix C (student questionnaire)

Questionnaire Visual Style and Interaction

For my graduation I would like to ask you a few questions about different visual styles and interaction for a virtual reality training simulator.

There is space for remarks at every section and at the end of the questionnaire.

Thank you!

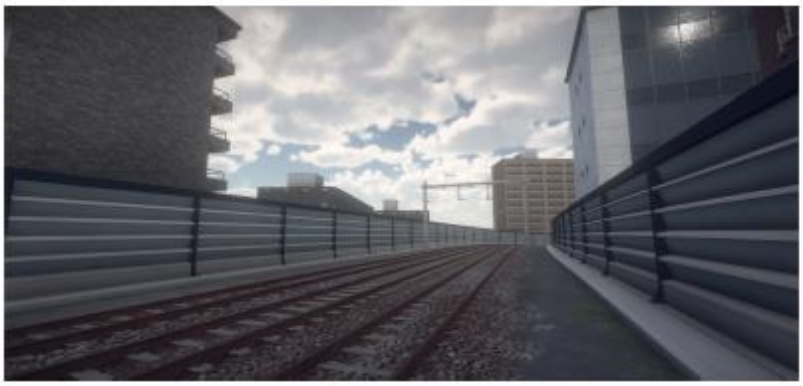
*Vereist

1. **Your name:** *

Visual style for the environment

There are two images displaying a 3D-modeled environment in different visual styles. I would like you to compare both images and answer the questions listed below.

Photorealistic environment



Cel-shaded environment

2. **Which image do you think gives a clearer overview of the environment?** *
   Markeer slechts één ovaal.
   - ◯ The photorealistic environment.
   - ◯ The cel-shaded environment.

3. **Which environment do you find more pleasing to the eye?** *
   Markeer slechts één ovaal.
   - ◯ The photorealistic environment.
   - ◯ The cel-shaded environment.

4. **Which image would make you feel more present if it were a virtual environment for you to explore?** *
   Markeer slechts één ovaal.
   - ◯ The photorealistic environment.
   - ◯ The cel-shaded environment.

Appendix C (student questionnaire)

5. **Which visual style, regarding the environment, would you prefer in a serious simulation game?** *
Markeer slechts één ovaal.

- ◯ The photorealistic environment.
- ◯ The cel-shaded environment.

6. **Are there any remarks you would like to make?**

_____

_____

_____

_____

_____

Visual style for objects

There are two images displaying a 3D-modeled object in different visual styles. I would like you to compare both images and answer the questions listed below.

Photorealistic object

Cel-shaded object

7. **In which image do you think the object is easier to recognize?** *
Markeer slechts één ovaal.

- ◯ The photorealistic object.
- ◯ The cel-shaded object.

Appendix C (student questionnaire)

8. **Which object do you find more pleasing to the eye?** *
Markeer slechts één ovaal.

- ◯ The photorealistic object.
- ◯ The cel-shaded object.

9. **Which object would you find more interesting to pick up and inspect?** *
Markeer slechts één ovaal.

- ◯ The photorealistic object.
- ◯ The cel-shaded object.

10. **Which object would make you feel more present in a VR simulation?** *
Markeer slechts één ovaal.

- ◯ Photorealistic object
- ◯ Cel-shaded object

11. **Which visual style would you prefer for objects in a serious simulation game?** *
Markeer slechts één ovaal.

- ◯ The photorealistic object.
- ◯ The cel-shaded object.

12. **Are there any remarks you would like to make?**

_____

_____

_____

_____

_____

Hint indicator

There are two images displaying a hint indicator. Please pick the option you think suits best regarding hint indicators.

Animated indicator

This image was animated in the online version of the questionnaire.

Static indicator

13. **Which of the indicators do you find easier to understand?** *
Markeer slechts één ovaal.

- ◯ The animated indicator.
- ◯ The static indicator.

Appendix C (student questionnaire)

14. **Which hint indicator would you prefer in a serious simulation game?** *
Markeer slechts één ovaal.

- ◯ The animated indicator.
- ◯ The static indicator.

15. **Are there any remarks you would like to make?**

_____

_____

_____

_____

_____

Retrospect

In this section I would like you to try to remember the images you were shown (without returning to the previous pages).

16. **Which image, regarding the environmental images, can you remember best?** *
Markeer slechts één ovaal.

- ◯ The photorealistic environment.
- ◯ The cel-shaded (flat colored/cartoon) environment.
- ◯ I remember both images equally.
- ◯ I do not remember either of the images.

17. **Could you list as many items that you can remember from this environment?**

_____

_____

_____

_____

_____

18. **Which image, regarding the images of the object, can you remember best?** *
Markeer slechts één ovaal.

- ◯ The photorealistic object.
- ◯ The cel-shaded (flat colored/cartoon) object.
- ◯ I remember both images equally.
- ◯ I do not remember either of the images.

19. **Could you describe what this object was and if it had any details?**

_____

_____

_____

_____

_____

20. **Which of the two animations, regarding the wrench/bolt interaction, do you remember best?** *
Markeer slechts één ovaal.

- ◯ The version with the animated indicator.
- ◯ The version with the static indicator.
- ◯ I remember both animations equally.
- ◯ I do not remember either of the animations.

Additional notes

If there is any extra information you would like to share, please write it here.

21.

_____

_____

_____

_____

_____

Appendix D

Age/Leeftijd: 31
Profession/Beroep: Service midden /hoogspanning

	Slecht	Matig	Redelijk	Goed	Zeer goed
EN: How experienced are you in doing your job? NL: Hoe ervaren bent u in het uitvoeren van uw werk?				X	
EN: When you started this job, how well prepared were you? NL: Hoe goed was u voorbereid toen u aan deze baan begon?				X	
EN: How would you rate the current training methods regarding working at heights? NL: Hoe zou u de huidige trainingsmethoden van werken op hoogte beoordelen?			X		
EN: How well do you know how to control a mobile working platform? NL: Hoe ervaren bent u met het besturen van een hoogwerker (in dit geval een ~~kreef~~)?				X	
EN: How well can you perform tasks from a mobile working platform? NL: Hoe goed kunt u uw werk uitvoeren vanaf een hoogwerker?				X	

Appendix D

	Nooit	Zelden	Af en toe	Vaak	Altijd
EN: How often do you work at heights? NL: Hoe vaak werkt u op hoogte?				X	
EN: How often do you follow a training programme to work at heights? NL: Hoe vaak volgt u een trainingsprogramma voor werken op hoogte?	X				
EN: How often do you review your surroundings for possible risks? NL: Hoe vaak controleert u uw omgeving op mogelijke risico's?				X	X
EN: How often do you review your PPE's for possible faulty equipment? NL: Hoe vaak controleert u uw PBM's (persoonlijke beschermingsmiddelen) op defecte materialen?					X
EN: Have you ever felt unsafe when working at heights? NL: Heeft u zich ooit onveilig gevoeld tijdens het werken op hoogte?				X	

Appendix D

EN: What tasks do you do mostly when working at heights?
NL: Welke taken voert u het vaakst uit wanneer u op hoogte werkt?

- inspectie
- montage
-
-

EN: Which tools do you mostly use for these jobs?
NL: Welk gereedschap gebruikt u het vaakst voor deze taken?

- Alles (schroevendraaier t/m haakse slijper
-
-
-

EN: Which training methods prepared you to work at heights?
NL: Welke trainingsmethoden hebben u voorbereid om op hoogte te kunnen werken?

- geen (alleen omgaan met apparaat)
-
-
-

EN: Are there any factors that cause you to work uncomfortably/unsafe when working at heights?
NL: Zijn er factoren die ervoor zorgen dat u zich ongemakkelijk/onveilig voelt wanneer u op hoogte werkt?

Ja/~~Nee~~

If yes, which factors?
Zo ja, welke factoren?

- de hoogte
-
-

EN: Have you ever had or seen an occupational accident when working at heights?
NL: Heeft u ooit een ongeval gezien of meegemaakt tijdens het werken op hoogte?

Ja/~~Nee~~

If yes, what caused the accident and what was the consequence?
Zo ja, wat was de oorzaak van het ongeval en wat was het gevolg?

beknelling hand, onoplettendheid - ziektwet.

Appendix D

Could this accident have been prevented if more time was spent on risk awareness?
Zou dit ongeval kunnen zijn voorkomen als er meer tijd was besteed aan risicobewustzijn?
mogelijk maar niet waarschijnlijk

EN: Additional information that you would like to share with us:
NL: Extra informatie die u ons wilt meegeven:

Appendix E

Age/Leeftijd: 29
Profession/Beroep: Veiligheidskundige / Safety Officer.

	Slecht	Matig	Redelijk	Goed	Zeer goed
EN: How experienced are you in doing your job? NL: Hoe ervaren bent u in het uitvoeren van uw werk?					
EN: When you started this job, how well prepared were you? NL: Hoe goed was u voorbereid toen u aan deze baan begon?					
EN: How would you rate the current training methods regarding working at heights? NL: Hoe zou u de huidige trainingsmethoden van werken op hoogte beoordelen?				X	
EN: How well do you know how to control a mobile working platform? NL: Hoe ervaren bent u met het besturen van een hoogwerker (in dit geval een krol)?					
EN: How well can you perform tasks from a mobile working platform? NL: Hoe goed kunt u uw werk uitvoeren vanaf een hoogwerker?					

Appendix E

	Nooit	Zelden	Af en toe	Vaak	Altijd
EN: How often do you work at heights? NL: Hoe vaak werkt u op hoogte?	X				
EN: How often do you follow a training programme to work at heights? NL: Hoe vaak volgt u een trainingsprogramma voor werken op hoogte?			X		
EN: How often do you review your surroundings for possible risks? NL: Hoe vaak controleert u uw omgeving op mogelijke risico's?					X
EN: How often do you review your PPE's for possible faulty equipment? NL: Hoe vaak controleert u uw PBM's (persoonlijke beschermingsmiddelen) op defecte materialen?				X	
EN: Have you ever felt unsafe when working at heights? NL: Heeft u zich ooit onveilig gevoeld tijdens het werken op hoogte?	X				

Appendix E

EN: What tasks do you do mostly when working at heights?
NL: Welke taken voert u het vaakst uit wanneer u op hoogte werkt?

-
-
-
-

EN: Which tools do you mostly use for these jobs?
NL: Welk gereedschap gebruikt u het vaakst voor deze taken?

-
-
-
-

EN: Which training methods prepared you to work at heights?
NL: Welke trainingsmethoden hebben u voorbereid om op hoogte te kunnen werken?

-
-
-
-

EN: Are there any factors that cause you to work uncomfortably/unsafe when working at heights?
NL: Zijn er factoren die ervoor zorgen dat u zich ongemakkelijk/onveilig voelt wanneer u op hoogte werkt?

Ja/Nee

If yes, which factors?
Zo ja, welke factoren?

-
-
-

EN: Have you ever had or seen an occupational accident when working at heights?
NL: Heeft u ooit een ongeval gezien of meegemaakt tijdens het werken op hoogte?

Ja/Nee

If yes, what caused the accident and what was the consequence?
Zo ja, wat was de oorzaak van het ongeval en wat was het gevolg?

De lift maakte een snelle daalbeweging met een klap op de grond. Door deze impact brak een monteur zijn been.

Appendix E

Could this accident have been prevented if more time was spent on risk awareness?
Zou dit ongeval kunnen zijn voorkomen als er meer tijd was besteed aan risicobewustzijn?

Ja, vermoedelijk stond de stabilisering van de kraal uit.

EN: Additional information that you would like to share with us:
NL: Extra informatie die u ons wilt meegeven:

Appendix F

Age/Leeftijd: 37
Profession/Beroep: Service midden en hoog spanning

Visueel

EN: I perceived the objects in the simulation as real.
NL: De voorwerpen in de simulatie zagen er echt uit.

Volledig mee oneens	Mee Oneens	Neutraal / Ik weet het niet	Mee Eens	Volledig mee Eens
				X

EN: The dimensions of objects and the surroundings were correct.
NL: De voorwerpen en de omgeving in de simulatie waren qua grootte correct.

Volledig mee oneens	Mee Oneens	Neutraal / Ik weet het niet	Mee Eens	Volledig mee Eens
				X

EN: The environment looked convincing and brought the simulation to life.
NL: De omgeving zag er overtuigend uit en bracht de simulatie tot leven.

Volledig mee oneens	Mee Oneens	Neutraal / Ik weet het niet	Mee Eens	Volledig mee Eens
				X

EN: The environment was too overwhelming and distracted me from my task.
NL: De omgeving was te overweldigend en heeft mij afgeleid van mijn taak.

Volledig mee oneens	Mee Oneens	Neutraal / Ik weet het niet	Mee Eens	Volledig mee Eens
X				

EN: I recognized the (prototype) control panel of the Krol and knew how to use it.
NL: Ik herkende het (prototype) bedieningspaneel van de Krol en wist hoe ik hem moest gebruiken.

Volledig mee oneens	Mee Oneens	Neutraal / Ik weet het niet	Mee Eens	Volledig mee Eens
		X		

Appendix F

Algemeen

EN: I see potential in this training simulation in order to learn about risk awareness.
NL: Ik zie potentie in deze training simulatie om meer te leren over risicobewustzijn.

Volledig mee oneens	Mee Oneens	Neutraal / Ik weet het niet	Mee Eens	Volledig mee Eens
		X		

EN: I prefer a virtual reality training simulation over the traditional training method.
NL: Ik geef de voorkeur aan een virtual reality-trainingssimulatie boven de traditionele trainingsmethode.

Volledig mee oneens	Mee Oneens	Neutraal / Ik weet het niet	Mee Eens	Volledig mee Eens
	X			

Appendix G

Age/Leeftijd: 29
Profession/Beroep: Veiligheidskundige / Safety Officer.

Visueel

EN: I perceived the objects in the simulation as real.
NL: De voorwerpen in de simulatie zagen er echt uit.

Volledig mee oneens	Mee Oneens	Neutraal / Ik weet het niet	Mee Eens	Volledig mee Eens
				X

EN: The dimensions of objects and the surroundings were correct.
NL: De voorwerpen en de omgeving in de simulatie waren qua grootte correct.

Volledig mee oneens	Mee Oneens	Neutraal / Ik weet het niet	Mee Eens	Volledig mee Eens
				X

EN: The environment looked convincing and brought the simulation to life.
NL: De omgeving zag er overtuigend uit en bracht de simulatie tot leven.

Volledig mee oneens	Mee Oneens	Neutraal / Ik weet het niet	Mee Eens	Volledig mee Eens
				X

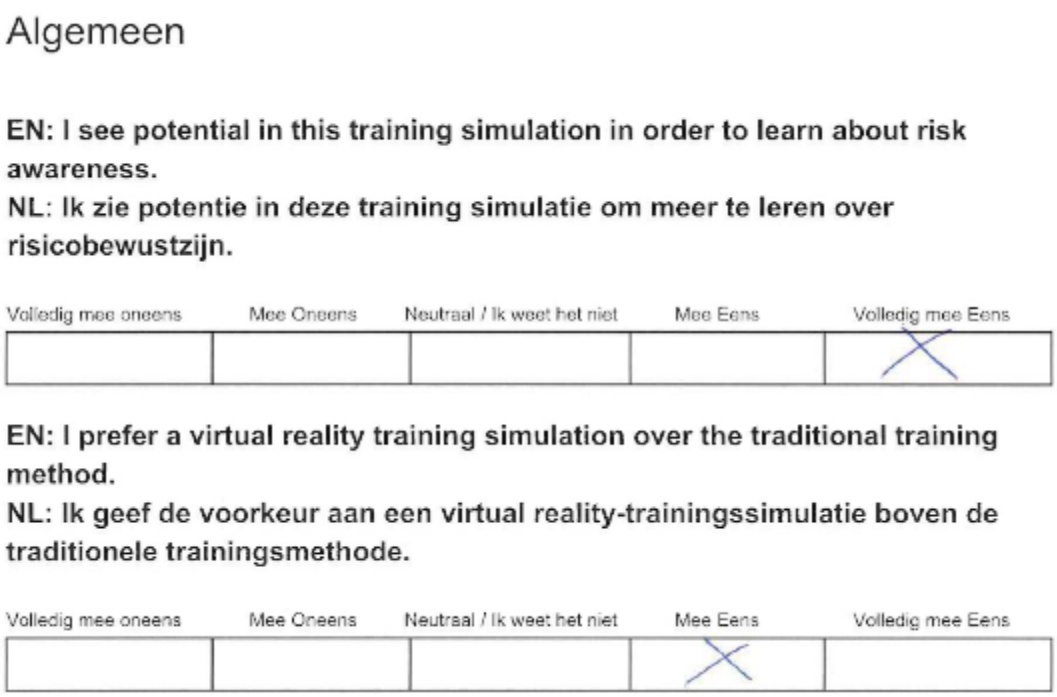
EN: The environment was too overwhelming and distracted me from my task.
NL: De omgeving was te overweldigend en heeft mij afgeleid van mijn taak.

Volledig mee oneens	Mee Oneens	Neutraal / Ik weet het niet	Mee Eens	Volledig mee Eens
X				

EN: I recognized the (prototype) control panel of the Krol and knew how to use it.
NL: Ik herkende het (prototype) bedieningspaneel van de Krol en wist hoe ik hem moest gebruiken.

Volledig mee oneens	Mee Oneens	Neutraal / Ik weet het niet	Mee Eens	Volledig mee Eens
				X

Appendix G



Algemeen

EN: I see potential in this training simulation in order to learn about risk awareness.
NL: Ik zie potentie in deze training simulatie om meer te leren over risicobewustzijn.

Volledig mee oneens	Mee Oneens	Neutraal / Ik weet het niet	Mee Eens	Volledig mee Eens
				X

EN: I prefer a virtual reality training simulation over the traditional training method.
NL: Ik geef de voorkeur aan een virtual reality-trainingssimulatie boven de traditionele trainingsmethode.

Volledig mee oneens	Mee Oneens	Neutraal / Ik weet het niet	Mee Eens	Volledig mee Eens
			X	

Appendix H

Age: 29
Profession: Veiligheidskundige/Safety Officer

Observed and interviewed by: Matthijs Baalhuis

During gameplay

	Yes	No
Did the participant notice the difference between the two hardhats?		x
Did the participant pick the correct hardhat (with red indicator)?	x	
Did the participant notice the rusty and unsafe clamp that is used to work at heights?	x	
Did the participant notice the dangerous obstacles on the railroad?	x	
Did the participant try to avoid the dangerous obstacles on the railroad?	x	
Did the participant stay within reasonable reach of the basket?	x	

Q&A after gameplay

Which potential risks can you remember from the simulation?

- The clamp was rusty
- The branches on the railtracks

How were you able to tell that which hardhat you had to use?
I did not notice a difference between the hardhats, but retrospectively it is an important learning point.

How did you know that the clamp would be a potential risk?
The clamp was very rusty and seemed to open when I dropped it.

Why did you decide not to drive through the obstacle on the railroad?
In real life the Krol would derail, so I decided not to drive through it. The simulation is a safe environment, so I could try it and see the consequence.

Appendix H

Do you think that you used the Krol in a safe manner? Why/why not?
Yes, when I move upwards I get the feeling that I should stay within the basket of the elevating work platform.

Did you feel like you made a strong connection between risks in the real world and risks in the virtual world? Why/why not?
The visuals give a good representation of how it would be in real life, so yes.

Would you say that the visual style, in this case photorealistic, influenced your choices? Why/why not?
Yes, the visual representation influenced the way I made choices in the simulation.

Do you think that purely because of the visual style (so the realistic visuals that you have witnessed) you have learned something from the simulation?
Yes, for example the uv-indicator on the back of helmet is something that is often overlooked. In the simulation it could be an important learning objective.

Remarks by the participant:

- The light on the helmet is very strong, that gives a good representation of the lighting.
- The construction lamps in the simulation are important, because in real life the construction workers often work in light that comes from one angle.
- Visually the game looks good.
- It would be useful to have more feedback, otherwise the trainee might accidentally pick the correct choice without knowing there was a wrong one (which happened in this case).