CHALMERS
UNIVERSITY OF TECHNOLOGY

# Interaction Design for VR Application in Manufacturing

## An exploration and evaluation of interaction design solutions to best support practices in the production context

Bachelor Thesis

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## Abstract

Several studies indicate that virtual reality can be a beneficial tool for assembly training in manufacturing. However, there are no clear guidelines of how to design an efficient virtual learning environment in terms of user experience. The aim of this thesis is to evaluate how to design a virtual learning environment that gives the user an efficient assembly training without endangering the user experience. There are several aspects that need to be taken into consideration when designing a virtual learning environment such as interaction design, user experience and cognitive learning theory. Previous studies show advantages of using reality-based interaction design and imply that deviation from reality should only be considered to benefit the virtual environment. Although the connection between reality trade-offs, user experience and the learning process is not yet confirmed. To investigate this, two different assembly scenarios were implemented and evaluated with user testing. The chosen task for the evaluation was to assemble a drone. The two scenarios consisted of Scenario 1 which was reality inspired and Scenario 2 which was trade-off inspired. During the user tests, each participant interacted with one scenario and then performed the drone assembly in reality. The completion time and the number of incorrect assembled components were measured. In addition, the user experience was measured with a questionnaire. Previous studies imply that the reality-based scenario should be most suitable for virtual reality training. It was therefore expected that participants who tested Scenario 1 would complete the assembly in reality in a shorter period of time and with fewer misplacements than participants who tested Scenario 2. The obtained test results show no significant difference in neither average assembly time, nor number of misplaced components between Scenario 1 and Scenario 2. Therefore the theory cannot be confirmed nor discarded by the test results. However, from the cognitive learning theory it can be argued that a simplified interaction design is enough to learn the sequences of an assembly task with similar complexity. Another conclusion is that when creating a virtual learning environment, the resource efficiency, the implementation time and the efficiency of the training itself should be considered. Hence, the virtual learning environment that requires the least number of resources is the most profitable.


**Keywords:** *VR, Virtual Reality, HCI, Human-computer Interaction, Interaction Design, Reality-based Interaction, Assembly, Assembly Training*

## Preface

This Bachelor thesis (15 credits) describes the exploratory work that was performed in order to seek answers regarding how to design a virtual learning environment within the production industry. The thesis was written during the period January to May 2019, by four students from Mechanical Engineering (300 credits) and one student from Information Technologies (300 credits). The work was executed at the Department of Industrial and Materials Science at Chalmers University of Technology, Gothenburg, Sweden, with examiner Prof. Johan Stahre and supervisor, PhD student, Liang Gong.

## Acknowledgements

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# 1 Introduction

In a world with constantly progressing technologies, sectors must keep up with the latest trends and demands. Virtual reality (VR) is an example of such technology. The technology introduced into the market in the early 1990s. Since then, VR has become a fast-growing industry within different fields (Angel, 2018).

Since the concept of VR is relatively new, there are varying definitions of its actual meaning. One definition is given by Berg et al. who describe VR as a set of technologies that create an immersive experience where the user can interact with a world beyond reality (Berg & Vance, 2017). VR can be divided into three main categories, ranked by the sense of immersion or degree of presence it provides: non-immersive systems, semi-immersive projection systems and fully immersive systems (Mujber, Szecsi, & Hashmi, 2004).

The constant progress has also resulted in a widespread area of applications such as the military, health care, education and sports (Angel, 2018). Another example is the manufacturing industry that must constantly face new customer demands and meet the competition of other companies. This leads to new requirements which in turn create the need to reduce the time and the cost involved in taking a product from conceptualization to production. Hence, companies are forced to rely on new technologies such as VR, in the area of manufacturing (Mujber, Szecsi, & Hashmi, 2004).

In his work, Wright states that several studies have confirmed that VR can be a beneficial tool for assembly training in manufacturing (Wright, 2017). Some mentioned benefits are: it enables safety training for hazardous situations that cannot be safely replicated in the real world, it allows trainees to become familiar with all the assembly operations in a reality-based layout and employee performance can be recorded and evaluated to improve future training programs (Wright, 2017). However, how to get the best use out of this technology is a rather unexplored question. For instance, the usability and interaction design approaches are not always very clear when it comes to different application areas. Assembly training is one of those areas where there are few guidelines for what design decisions to consider when designing a virtual world for assembly purposes.

## 1.1 Aim and issue under investigation

The aim of this thesis is to increase the understanding of different types of VR systems used for assembly training in manufacturing. Thus, the goal of this thesis is to evaluate which interaction design brings the most benefits in VR training. In other words, the aim is to understand how to design a virtual learning environment that gives the user an efficient assembly training without endangering the user experience.

To achieve this goal, the following research questions will be investigated:

- Is reality-based interaction best suitable, in terms of efficiency and user experience, when designing a virtual assembly training environment?
- If not, when is it profitable to make trade-offs from the reality-based interaction design?

## 1.2 Case background

The available resources for the thesis consisted of the equipment provided at the Stena Industry Innovation Lab (SII-Lab). The lab is used as a facility to test and to demonstrate the next generation of smart production systems with the aim to create new advanced solutions. Development of virtual learning environments is a crucial part of this process where efficient interaction design is an unexplored area. To investigate the research questions of this thesis, two different virtual scenarios, that represent one of the workstations at SII-Lab, were created and evaluated. Different design approaches supported by previous research were used when implementing the scenarios to test what interaction design is preferred when creating a virtual learning environment.

## 1.3 Research process

The first part of this thesis includes a theoretical study comparing different types of interaction design, in order to increase the understanding of how virtual environments should be designed. The focus of the study is on previous research of virtual interaction design combined with cognitive learning and assembly training. The thesis continues with an empirical study to evaluate the most suitable interaction design for virtual assembly training. The evaluation will be conducted with user tests at SII-Lab at Chalmers University of Technology. The different stages of the research process can be viewed in Figure 1.


*Figure 1.* Process chart showing the stages of the research process followed during the thesis. A theoretical study followed with an empirical study and evaluation.

### 1.4 Delimitations

This thesis will entirely focus on fully immersive VR, whereas Augmented Reality (AR) and Mixed Reality (MR) will be excluded as well as non-immersive VR and semi-immersive VR. Both AR and MR require interaction with the physical surrounding and are therefore not as flexible as VR. Non- and semi-immersive VR are unable to provide a realistic user experience compared to the fully immersive VR.

The thesis will focus on VR within the area of training operators in manufacturing. The possible areas of applications where VR interaction would be preferable are endless. Therefore, the limitations are based on the interests of the group and available assets. Furthermore, the project had a limited time frame and the drone factory in SII-Lab was under construction during the thesis work. This led to the decision that only two scenarios will be tested together with one kind of input device.

### 1.5 Thesis outline

This report is divided into 7 chapters. After the introduction, Chapter 2 contains a theoretical study about guidelines for interaction design when designing a virtual environment. Furthermore, the theoretical study also includes other areas of importance when designing a virtual learning environment like ergonomics, cognitive learning and ethical aspects.

In Chapter 3 the design process and the test method for the VR-test and the real world assembly test is described. The VR-test consisted of two designed scenarios, also described. The test results are presented in Chapter 4. The discussion and the conclusions from the literature study and the empirical test can be found in Chapter 5 and 6. Finally, Chapter 7 contains recommendations on future work.

# 2 Theoretical study

There are several aspects that need to be taken into consideration when designing a virtual learning environment, for instance interaction design and user experience. This thesis will mainly focus on different types of interaction design in a VR learning environment although some research from similar fields of study such as AR and MR can be relevant. Therefore, they will not be excluded in the research process. Other search words included in the research were: Immersion, Reality-based Interaction Design, Cognitive Learning, User Experience, Human-computer Interaction and Virtual Assembly Training.

VR used for assembly training in manufacturing is a constantly developing area which makes the publication date of previous articles highly important for this study. To understand the design process connected to virtual assembly training the following sections will be presented: the concept of reality-based interaction design, the need of immersive VR, aspects on user ergonomics and cognitive learning.

## 2.1 Reality-based interaction

Creating digital icons that mimic their real world counterparts is a well-known concept in graphical interface design called skeuomorphism (The Interaction Design Foundation, 2018). The purpose is to create interface objects that are already familiar to the users and thereby easier to interact with. Klaus Göttling presents several examples of skeuomorphism in his article, for instance the recycling bin icon is used as an icon on computers for discarding files (Göttling, 2017). Allowing users to apply prior knowledge from the real world in the digital interface may help users understand the interaction principles of the interface faster. For example, digital buttons are designed to look raised to give users the impression that the object can be pressed down. Input fields give the impression that they could be filled by the hollow design (Moran, 2015).

Skeuomorphism is used to mimic reality in the interface design but when creating a virtual environment, the same principles need to be applied on the interaction design. In 2008 Jacob et al. published an article proposing reality-based interaction (RBI) as a framework for the new generation of interfaces applied to human-computer interaction (HCI) (Jacob, et al., 2008). The RBI framework is a unifying concept, connecting a large subset of interaction styles, which makes it possible to compare and analyse different design opportunities for digital interaction. The framework has can been used as a support for interaction design conclusions in recent thesis (Sutcliffe, et al., 2018) pointing out the difficulties designer faces when creating applications in VR. The RBI principles are based on, and limited to four different themes from the real world (Jacob, et al., 2008):

***Naïve physics:*** Naïve physics is not seen as a single unified discipline but a collection of concepts regarding humans understanding of basic physical principles. Within the field of artificial intelligence, Naïve physics refers to humans' common sense knowledge about the physical world (Davis, 1990). The same definition can be applied for RBI, where graphical interfaces should be designed to give users a sense of gravity, friction and velocity (Jacob, et al., 2008).

***Body awareness and skills:*** Proprioception is the awareness of a humans' own body parts, their positions and movements relative to the surroundings. In the RBI framework, body awareness refers to the understanding that humans have of their own bodies (Jacob, et al., 2008).

***Environment awareness and skills:*** Environment awareness refers to humans' intuitive feeling about orientation in the real world. When designing a virtual environment, it is important to create a user interface that support this feeling (Jacob, et al., 2008). For instance, using shadows and lighting to create depth in the virtual world.

***Social awareness and skills:*** In the real world, humans develop both verbal and non-verbal skills for communicating with others. These social interaction skills are mainly based the human awareness of the presence of others (Jacob, et al., 2008). In VR it is important to create the illusion of presence for users to be able to communicate with one another (Jerald, Immersion, Presence and Reality Trade-Offs, 2016).

Basing interaction design on pre-existing real world knowledge has a lot of benefits such as reducing the mental effort to understand and operate a system. Research shows that familiarity is one of the key elements in the learning process (Carnegie Mellon, 2018) which supports the RBI framework when designing a virtual learning environment. Opponents claim that there is no longer a defined line between the digital and the real world, which makes reality-based design inefficient. Therefore, the RBI framework does not be considered when designing a virtual learning environment. On the other hand, Göttling argues that humans can never become as accustomed to the digital world as we are to the physical world and reality-based design will continue to be helpful (Göttling, 2017). Hence, a virtual environment should primairly be designed on the basis of RBI with exceptions to desired qualities that can improve the user experience or task efficiency (Jacob, et al., 2008).

Reality trade-offs presented in *The VR Book* are mainly focused on computer generated characters and how their appearance affect users (Jerald, Immersion, Presence and Reality Trade-Offs, 2016). Jerald also includes trade-offs within interaction fidelity which allows user actions in the digital world that differ from reality. For example, grabbing an object at a distance or teleporting in the virtual world that does not require physical movement. Within the RBI research (Jacob, et al., 2008) trade-offs are presented in six different categories, expressive power, efficiency, versatility, ergonomics, accessibility and practicality. Further on, it is claimed that interaction design should only differ from reality to increase the user experience within the presented six categories. Trade-offs are strongly connected to the task and vary depending on the purpose of the interaction design. Expressive power, efficiency and ergonomics are some relevant categories to consider for assembly training.

## 2.2 Immersion

User experience defines the perceptions and responses within an interactive system (Tcha-Tokey, Christmann, Loup-Escande, Loup, & Richir, 2018). One goal is to make the user feel a sense of presence, of "being there", although they are not there physically (Jerald, Immersion, Presence and Reality Trade-Offs, 2016). Jerald further explains how immersion and the user together build presence. Since immersion is the only part which can be controlled in the design the process, it is a crucial key element to provide good user experience when the user interacts with an immersive virtual environment. Hart et al. explain that it is important for a developer to consider how users get immersed in VR (Harth, et al., 2018). Furthermore, the authors state the importance of the users' preferences to achieve a successful immersive virtual environment. Hence, VR developers must learn their users' varying preferences toward immersion (Harth, et al., 2018).

In order to become immersed within a virtual world the user must feel the sensation of being in an environment beyond reality. Therefore, it is not enough to include sensory feedback techniques, such as haptic and tracking systems, to create an immersive experience. These approaches have shown to play a significant role in enhancing interactivity (Harth, et al., 2018), which in turn leads to a deeper immersion but it is crucial to also investigate different user preferences. Only then, will VR produce a deeper immersion and attract a bigger range of user groups (Harth, et al., 2018). The guidelines for creating an immersive are divided into three blocks based on each other: Physical Foundation, Basic Realism and Beyond Novelty (Michalak, 2017).

**Physical foundation** refers to requirements regarding safety, comfort and the user's ability to be free from outside distractions (Michalak, 2017). These requirements help the user to trust a system, which in turn enhances the immersion.

Both physical and social safety are important. If the assembly training includes interaction between more than one person and the virtual environment, it is important for the users to know how others will see them and if they can hear each other (Michalak, 2017). If physical safety is not assured, the user might experience health related symptoms such as headache and nausea (Jerald, Eye Strain, Seizures, and Aftereffects, 2016). When wearing a head mounted display the user can feel eye fatigue and irritation. This due to visual conflicts between how users focus on objects in the real world and how this is done in VR (Jerald, Eye Strain, Seizures, and Aftereffects, 2016). Also, flicker can cause eye fatigue, often as a result of low refresh rates of the display or flashing lights.

During the VR sessions users can also experience physical fatigue and in worst case injuries (Jerald, Hardware Challenges, 2016), Jerald further explains some causes to the physical fatigue. Walking and standing can be exhausting even outside VR, but unlike the real world hands and arms cannot rest on tables or benches in VR. Michalak stresses the importance of having a boundary feedback, of some kind, to prevent collision between the user and the real world (Michalak, 2017).

It is important to inform the user about the social interaction but also to make sure that the user is aware of possible physical risks such as motion sickness, eye fatigue, injuries, and aftereffects. Therefore, those with migraine or those who often feel motion sick should consider avoiding VR (Jerald, Eye Strain, Seizures, and Aftereffects, 2016). Furthermore, VR is should not be used by anyone with epilepsy.

**Basic realism** refers to how natural and realistic the virtual world is perceived and how good the interaction between the user and the virtual environment turns out (Michalak, 2017). As mentioned before a high frame rate is desirable to avoid eye fatigue but also to create a realistic virtual environment and to keep the user immersed (Michalak, 2017). Adequate resolution of the environment is crucial but how realistic it should be is differs between objects. For example, too much realistic rendered human characters are perceived as uncomfortable (Jerald, Immersion, Presence and Reality Trade-Offs, 2016). Therefore, it is enough to reach a convincing level of reality when modelling living characters (Michalak, 2017).

To make the virtual environment even more realistic the aural effects are important. As in the real world sound should appear louder near the source than far away (Michalak, 2017). Similarly, when turning around, the sound is expected to change. Furthermore, Michalak discusses the importance of using real sounds to make the user feel more at home, for example a glass which lands on a stone floor has a special sound.

Naturally users want to interact with everything in the virtual environment and it is therefore desirable to make clear for the user which parts are interactable (Michalak, 2017). Furthermore, Michalak states that it is more important to make sure the interaction yields in proper responses that are timed with each other. This includes, both aural and visual feedback but also haptic feedback that can add a sense of touch.

When VR is used for training, it is important that crucial movements are realistic. As a result the training requires less effort and skills learned in VR can easily be applied in the real world (Jerald, VR Interaction Concepts, 2016). Although it is preferable that the actions support a wider range of inaccuracy, for example a bottle can be placed and balanced on a table even if it is not put exactly vertical (Jerald, Perceptual Stability, Attention, and Action, 2016).

**Beyond novelty** refers to how it is not sufficient with a great VR environment if the content and experience of it make it impossible to feel something beyond what is possible in the real world (Michalak, 2017). With assembly training the intention is to learn a task and therefore the focus should be on that rather than on the VR itself (Michalak, 2017). A rapid adaption to the environment and an understanding of how to interact with it are desirable when learning the assembly steps. Michalak further explains how good tutorials could be effective where the user learns how to move, use eventual controllers and perform special movements such as teleporting, picking up goods or using tools.

Assembly training could sometimes be perceived as mundane, VR has the possibility to make it more entertaining and challenging (Jerald, High-Level Concepts of Content Creation, 2016). By giving both positive and negative feedback the user could get rewards to maintain the engagement and hints to avoid eventual frustration (Jerald, Perceptual Models and Processes, 2016).

### 2.3 Ergonomics when designing VR

When designing a virtual environment, the placement of the user interface needs to be taken into consideration to create good ergonomics and oculomotor comfort for the user (Hart, 2014). Oculus VR Inc created the draft *Best practice for virtual reality development* containing guidelines for VR developers to maximize 1) oculomotor comfort, 2) bodily comfort, and 3) a positive user experience. In a reflection on this draft, Hart (2014) states that "These are the key items that will likely appear in all of the high-quality VR experiences over the next few years." (para. 7). The guidelines imply that the user interface should be placed on a minimum distance of 50 cm from the user and fit within the centre of the screen (Hart, 2014). The same results were supported by researcher Alex Chu in his presentation at the Samsung Developer Conference (Chu, 2014). He also presented recommendations for developers when transitioning from 2D to 3D design. Combined with previous research on visual ergonomics for monitoring placement (Ankrum, 1999), Mike Alger created guidelines for how 2D content should be presented in a 3D virtual environment. His conclusion is that content surrounding the user should be placed at a distance that matches the focal distance of the hardware within the viewing area of 15-50° below horizontal eye level (Alger, 2015). These guidelines are important to follow when designing VR to ensure good ergonomics for users.

### 2.4 Cognitive learning

Cognitivism is a relatively new learning theory and has been the prior focus within the field of study since the mid-1950s. Both theoretical and empirical studies have been done on different cognitive processes such as memory, attention, concept formation, and information processing (Winn & Synder, 1996). According to Kaya Yilmaz this makes cognitivism a multifaced theory based on several different theorists' contributions. Cognitivism implies that learning processes can be explained by analysing the mental process, focusing on how knowledge is stored and processed by the learner (Yilmaz, 2011). In general, cognitive learning can be divided into three parts (The benefits of cognitive learning, 2018),

- comprehension – understanding how topics fits into a larger picture
- memory – building on past knowledge to improve recall
- application – reflecting on topics and creating new connections.

Instead of focusing on memorization like the more traditional learning theories, cognitive learning aim to make the learner more aware of the learning process and thereby creating a more efficient way of learning. It is claimed that cognitive learning theory can result in both easy and long-lasting learning of new information (Sincero, 2011).

As a part of cognitivism, the Cognitive Load Theory focus on how information should be presented so the learner fully understands the content. The theory was first presented by John Sweller in 1988 and is based on the model of human information processing (Sweller, 1988). If our cognitive memory capacity is limited, Sweller claims that cognitive load imposed by task information may reduce the learning ability (Sweller, 1988). Sweller also presents evidence that scientific learning can be enhanced by giving instructions guided by cognitive load theory. The connection between Cognitive Load Theory and assembly tasks was discovered by Hitendra K. Pillay in when testing and evaluating different types of task instructions. The study showed that for learning an assembly task the use of physical models as instructional information gave the best result in both number of correct placements and in total assembly time (Pillay, 2006).

In the aspects of cognitive learning theory, VR is not always the most efficient way of learning comparing to traditional classroom techniques. The result from a study made by Jocelyn Parong and Richard E. Mayer, showed that students giving scientific information on a well-designed slideshow performed better on a post-test than the group given information through immersive VR. The results also showed that students in the VR group scored higher in motivation, interest, and engagement ratings (Parong & Mayer, 2018). This can be supported by the interest theory (Parong & Mayer, 2018) and by studies on development of virtual learning studios and VR application in manufacturing (Brough, et al., 2007), (Wright, 2017). Based on these results previous it can be argued that VR is a profitable method used for assembly training. Apart from the recognition factor, there is no clear connection between virtual assembly training and cognitive learning theory, even though they are strongly associated.

## 2.5 Ethical, social and health aspects

As mentioned earlier in Chapter 1, the potential use of VR in manufacturing increases as a combination of new VR technology entering the market and the digitization of the manufacturing industry. The advantages of using VR as a training tool are supported by previous research and the positive effects are predominant. Still, research also indicates social disadvantages that need to be taken into consideration when using VR (Kenwright, 2019). Most ethical concerns that could emerge as a social problem later on, are connected to motion sickness and users' difficulties to distinguish the virtual world from the real world. Several studies show the risk of experiencing motion sickness both during and after the use of VR. In *The VR Book,* Jerald mentions that many users report feeling sick after using VR technology and implies that this is perhaps the greatest challenge of VR. As an example, he mentions the space shuttle simulator "Mission: Space" at Epcot in Walt Disney World (Jerald, Adverse Health Effects, 2016). In a report from 2005, Johnson mentions the simulator as the single ride causing the most hospital visits due to nausea and chest pain since 2001 (Johnson, 2005).

Through the past decades, several researchers have investigated the correlation between presence in VR and cybersickness. Even though there are results supporting both positive and negative correlation, Weech et al present the conclusion that increasing presence in VR could reduce cybersickness, and vice versa (Weech, Kenny, & Barnett-Cowan, 2019). The same conclusion was made by Jerald, who implies that VR applications should be designed to reduce severity and duration to avoid negative effects such as nausea and headache (Jerald, Motion Sickness, 2016). Another ethical aspect is the long-term effects of VR. Hugh Langley presents previous studies within the area but conclude that the long-term consequences of VR need to be further investigated (Langley, 2017).

## 2.6 Summery

According to the research presented above, basing interaction design on reality is claimed to be the best way of creating a virtual environment. It has been proposed that the design should be based on the RBI framework and deviations from reality should only be made when the profit is clear. The reality-based design is also supported by the Basic realism of immersive

VR guidelines presented in Section 2.2. However, Michalak claims that it is not enough with a great virtual environment if the content and experience of the environment makes it impossible to feel something beyond what is possible in the real world. This implies that some trade-offs from reality are necessary for creating immersion.

When using VR as a tool for assembly training, learning theories such as cognitivism needs to be taken into consideration. The connection between reality trade-offs, user experience and the learning process of assembly training in VR is supported by previous research but not yet confirmed.

# 3 Development and testing process

Based on the theoretical study in Chapter 0, the research questions from Section 1.1 could not be entirely answered. Briefly, previous studies show advantages of using RBI design and imply that deviation from reality should only be made when the trade-offs are profitable for the user experience. However, there are still gaps in need of further investigation. The questions if, and when it is profitable to make trade-offs from the reality were still unanswered. Hence, a user test was conducted to investigate this.

The approach used when designing the test was to presume real world based assembly training in VR as a base and then investigate when it could be preferable to omit some reality-based design implementations. Therefore, two different scenarios were created in order to detect which trade-offs and which interactions are preferred in a user interface. To test the scenarios in a realistic setting, one of the workstations at the SII-Lab's drone factory was used. In order to compare the two different scenarios, the test needed to be executed at a station with enough complexity. Workstation 3 was the only station in the production line that fulfilled this requirement. It consists of 6 steps and 14 sub-steps (see Appendix A) and was therefore selected for the test. The main tasks of Workstation 3 were to assemble the battery, radio control receiver and propellers with nuts and bolts. Only step 2-6 of the assembly were implemented and tested due to the project's time limit. The important parts of the assembly training in VR were considered to be

- authentic components
- instructions of how to perform each sub-step
- the ability to interact with the drone and the components
- the ability to receive feedback if the step was performed correctly or not.

In addition to the assembly, general VR requirements were considered such as safety and ergonomics, presented in Section 2.3.

The two created scenarios were called Scenario 1 and Scenario 2 where the first was reality inspired and the second was trade-off inspired. Controllers with touchpad and buttons (HTC Vive) were used as the only input device when testing the scenarios. To evaluate the efficiency of each scenario, user tests were conducted where each participant interacted with one scenario and then performed the assembly of the drone in reality. The completion time and the number of incorrect assembled components were measured. The user experience was measured with a questionnaire that was answered by the participants once the user tests were finished.

### 3.1 Description of the scenarios

**Scenario 1** was designed to mimic the real world. The environment was programmed to resemble the chosen workstation at SII-Lab. The workstation in the lab had instructions displayed on a tablet, therefore Scenario 1 also had instructions on a screen behind the workbench as shown in Figure 2.


*Figure 2.* Working environment in Scenario 1. Instructions are displayed on a screen and the components are stored in boxes.

Visual feedback was given through colour changes and written instructions. When a component was assembled correctly, the colour of the component changed to green for a short period of time and the screen showed the next assembly instruction. The purpose of the change in colour was to show the user if the component was assembled correctly.

A point cloud scan of SII-Lab was used as a body to create an environment as close to reality as possible. Furthermore, some objects in SII-Lab were not directly linked to the assembly task such as the conveyer belt. These components were still presented in the virtual environment to create a closer connection to the reality. The necessary components of the assembly were placed in boxes and labelled with the type of component. The boxes were all placed on a table next to the workbench. This design decision was based on the equipment setup in real life where the users must collect the right components for each assembly step themselves.

The drone was placed in the middle of the workbench and the instruction screen was placed on the left side, behind the table with the components. The reason for this placement of the screen was to prevent the user from looking at the instructions while assembling the drone. This design encourages the user to reflect on and remember the instructions which might lead to a better understanding of the assembly tasks. The screen was programmed to show written and visual instructions for the current assembly step. A description of the component, placement, and information about the total completion rate was included in the instructions. When a component was correctly assembled according to the instructions, the content on the screen changed to the assembly instructions of the next component.

**Scenario 2** was designed to test some trade-offs from reality. The environment was programmed to be less detailed and the feedback was provided through visible zones on the drone further on referred to as drop zones. As shown in Figure 3, each drop zone matched the form and the size of a specific component to reveal where a component should be assembled.

The environment in this scenario had a minimalistic workbench and a plain white floor. The drone was placed in the middle of the workbench. Instead of boxes with components, there was an invisible pop-up area on the left side of the drone where a new component appeared for each new assembly step.

When an assembly step was completed, the component that should be used in the next step appeared next to the drone and was highlighted in green. When the user picked up the component, the highlight disappeared. Simultaneously, a drop zone of the component, placed at the assembly position of the drone, was highlighted with the same shade of green. This sequence of colour highlights was implemented to give the user a hint where the component should be assembled on the drone.

The green drop zone was visible until the component was placed correctly. Then a new component appeared next to the drone and its corresponding drop zone was highlighted on the drone, and a new component. When all steps were completed, the final feedback was given through a text message displayed in front of the user: “Well done, all steps are completed!”.

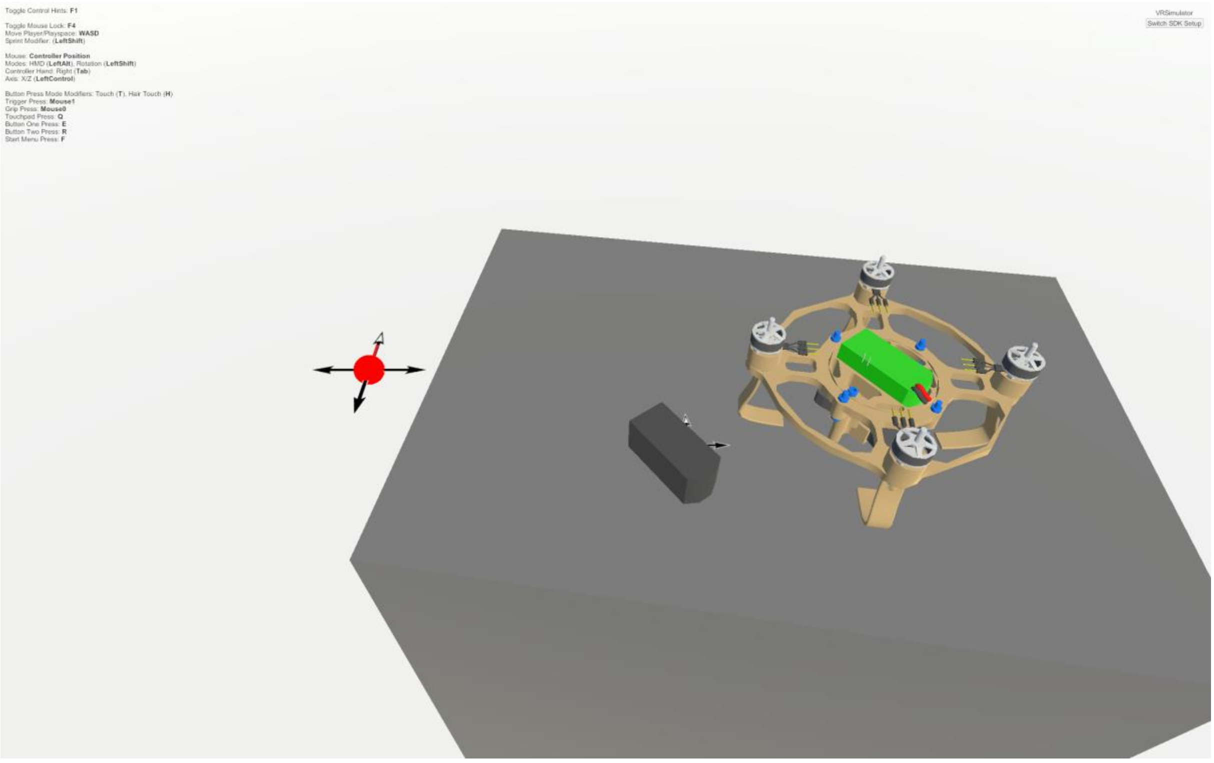


*Figure 3.* Working environment in Scenario 2. A component has appeared next to the drone. The green drop zone shows where the component should be placed.

A summary of the differences between the two scenarios is presented in Table 1. The most significant differences were how instructions and feedback were given how components were presented on the workbench.

Table 1

*Summary of the two scenarios' structure.*

| **Scenario 1** | **Scenario 2** |
|---|---|
| Environment | |
| • Point cloud scan of SII-Lab<br>• Mimicking the real workstation's appearance<br>• Including other objects from the lab that are not directly linked to the task | • A workbench in a minimalistic environment |
| Instructions | |
| • Written instructions and pictures displayed on a screen | • Coloured drop zones show the correct assembly position |
| Feedback | |
| • If incorrect, the component does not snap to the drone<br>• If the assembly step is executed correctly, the component turns green and the instruction screen shows the nest assembly instructions | • If incorrect, the component does not snap to the drone<br>• If the assembly step is executed correctly, the component turns green and the next component appears |
| Assembly | |
| • Components are collected from their original place, the user must pick the correct component<br>• Assembly time in VR correspond to the real time | • Components pop up and are collected from an invisible pop-up area<br>• Speeded up assembly time |

### 3.2 Hardware and software

To enable interaction with the VR environment, different hardware and software tools were necessary. During the user tests, a head-mounted display of model HTC Vive Headset was used and rendered on a computer. In SII-Lab the most used input device was the HTC Vive Controllers which are affordable devices that are commonly used for interaction with virtual environments (Caggianese, Gallo, & Neroni, 2019). Therefore, the controllers were selected for the interaction with the two scenarios during the user tests. To track the position of the controllers in space, the HTC Vive Base Station was used. The base station was tethered to the computer and placed in front of the user.

During the interaction with the virtual environment, the user held one controller in each hand. Through the trackpad and buttons on the controller and gestures, the user was able to interact with the virtual environment.

The virtual environments for the two scenarios were implemented with Unity which is a development platform editor that supports features and functionality for creating 3D environments. The editor was extended with a Virtual Reality Toolkit (VRTK) through the Asset Store provided in Unity. VRTK is a collection of premade solutions, concepts and scripts that are useful for building virtual environments. Premade interaction solutions, such as using and grabbing objects, were used in the implementation of the assembly of the drone components. Another solution, that was used to program the assembly steps in both scenarios, was Snap Drop Zone. This solution was also provided by VRTK and it contains functionality that allows the developer to create predefined zones where a valid interactable object can be dropped. When dropped, the object snaps to the valid drop zone.

The Snap Drop Zone also provides the possibility to make a coloured mesh rendered from the component that should snap into the drop zone. This could be used to show where the component should be placed. The highlight colour of each drop zone was disabled in Scenario 1 whereas in Scenario 2 the highlight colour was visible for all the drop zones. The Unity scripts were programmed with the #C language and Steam VR from the VRTK was used for the HTC Vive Controllers.

### 3.3 Deviations from the scenario designs

When programming the designed scenarios, a few deviations from the original plan had to be done. In this section, these deviations will be presented together with the final solutions. In order to achieve a better completion rate, the user could drop the component at a fairly large distance from the correct assembly position on the drone. The component did not need to be rotated as the instruction implied, which would be necessary in the real assembly. Hence, the only requirement for a successful assembly in VR was that the component was dropped within the accepted distance from the corresponding drop zone. The reason for the chosen distance, was the size of the components. A few components, such as the cover nuts, were very small. Therefore, assembling the smaller components accurately in VR would have been difficult, especially when no haptic feedback was given, and the graphical display clarity was limited in the virtual environment.

Most deviations occurred when developing the reality-based scenario in VR. For instance, details, such as the use of assembly tools, were supposed to be implemented in Scenario 1. Another example concerns one of the assembly steps where a set of four identical bolts was included. The idea was to allow the user to pick up any of the bolts and assemble it in one of the four correct spots on the drone. However, problems occurred when programming the logic for this assembly step. To avoid the problems, detailed instructions were provided on a screen. The instructions explained which one of the identical components in the box that should be picked up first and where it should be assembled. Therefore, a specific component had a specific drop zone in both VR scenarios, even though the identical components did not have this limitation in reality.

To present feedback in the Scenario 2 the intention was to use timer functions to change the colours. However, the timer functions did not work as expected and an alternative solution was implemented. The component that should be picked up was coloured green simultaneously as the drop zone on the drone was also coloured green. When the user picked up the component and moved it slightly closer to the drone, the component changed to its actual colour while the drop zone on the drone remained green. When placed correctly, the component turned green again. As this happened the next component appeared, with a green colour, to indicate that it should be picked up. The previously assembled component remained green on the drone until the user picked up the next component, and not until then the corresponding drop zone appeared with a green highlight. This alternative solution might cause confusion due to colours not changing before grabbing the next component.

## 3.4 Test method

As mentioned in the beginning of this chapter, a user test was conducted to investigate the research questions that could not be answered by the theoretical study. To investigate if, and when, it is profitable to make trade-offs from a RBI design the two scenarios were tested. The test in SII-Lab was performed by 22 people, 10 of them were women. The majority of the participants were students at Chalmers University of Technology and 15 participants were of age18-25 whereas 6 of them were 26-35 years old. Only one participant belonged to the age group of 36-45 years.

The user tests were alternating between Scenario 1 and Scenario 2 so that every other participant tested a different scenario (see Appendix B). The test consisted of four parts:

introduction, VR-test, real world assembly test and evaluation. A complementary step to testing process, was a demonstration of the two VR scenarios. The demonstration was performed for approximately 25 employees working within different fields of information technology. They work at companies, such as Volvo Cars, Volvo Group, SKF and IAC and were able to give valuable recommendations and professional opinions on the interaction design.

### *3.4.1 Implementation*

To make the user tests as identical as possible and to avoid sources of errors, a test manuscript in Swedish was used (see Appendix B) because all the participants had a Swedish mother tongue. First, a general introduction was given, and a few safety questions were asked. Depending on the answers to the questions, the participators could be advised not to participate in the test, especially if they had epilepsy or experienced severe problems with motion sickness before.

If the participator passed the safety questions a tutorial of what should be done and how to use the controllers was held before the VR-test begun. While the participator performed the VR-test, team members collected data and ensured the participator's safety. One of the team members timed the participator during the test and counted the number of misplacements. The participator was timed from the first component was touched until the last component was placed correctly. A misplacement was counted if the wrong component was grabbed and tried to be assembled or if the right component was tried to be assembled incorrectly. The collected data was filled in a form (see Appendix C). The other team member kept track of the participator to prevent collisions between the participator and objects in the real world.

Directly after the VR-test, the participator was requested to perform the same assembly task again, but at a real workbench with real components. However, this test did not provide the participator with any feedback or instructions. The participator had to use a hex key for one of the screws, this without having performed it in the virtual environment. This test was measured in the same way as the VR-test. After the test, the number of components that were missing or incorrectly assembled were counted. The collected data was reported in the same form as the VR-test (see Appendix C). Finally, the participator was asked to fill in a questionnaire about the experience of the VR scenario in comparison to the real assembly.

### *3.4.2 Evaluation*

There were both quantitative and qualitative types of data that were retrieved from the tests. Together these could give answers to which interaction design was the most suitable in terms of efficiency and user experience. The quantitative data was retrieved from both the VR-test and the real assembly test when counting misplacements or missing components and also by timing the participants.

From the questionnaire both quantitative and qualitative data were also retrieved through scale questions and one open-ended question (see Appendix D). The questions were mainly focused on the trade-offs and the user experience. In order to collect qualitative data, participants were asked to answer an open question about their personal opinions and their overall experience of the test. The analysis of the data was performed by comparing all measurable variables with each other and between the two scenarios.

# 4 Results

During the test each participant had to test one of the two training scenarios in VR to learn how the assembly sequences of the drone in reality. Scenario 1 was RBI inspired whereas Scenario 2 was trade-off inspired and had a minimalistic design compared to Scenario 1. The aim of the test was to evaluate which interaction design has the most benefits for a learning virtual environment.

As mentioned in the previous chapter, test results were collected both during and after the user testing. Qualitative and quantitative data were measured such as number of misplacements and user experience of for instance of immersion and motion sickness. The results of the collected data are presented in the following subchapters together with feedback given by the group of representatives from different companies tested and evaluated both scenarios. In summary, the results show no significant differences between Scenario 1 and Scenario 2.

## 4.1 Quantitative results

To measure effectiveness, the assembly time was the first data measured. Figure 4 presents the total assembly time both in VR and in reality. The user tests showed that the assembly time in VR was higher for Scenario 1 than Scenario 2.

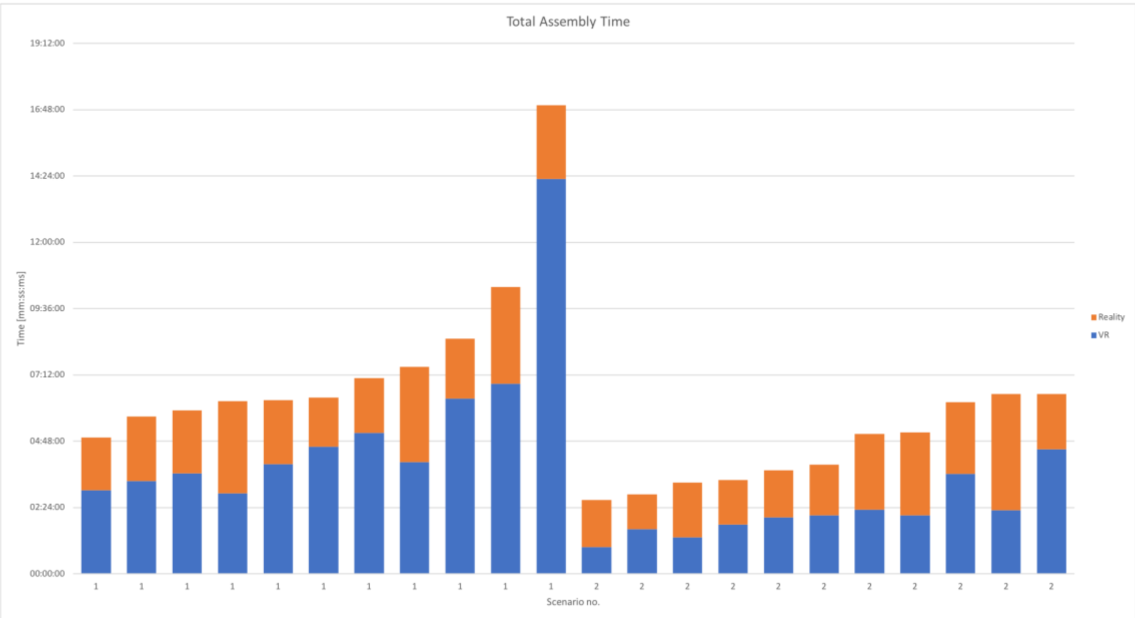


*Figure 4.* Chart of the total assembly time. The blue columns represent time in VR and the orange assembly time in reality.

However, as shown in Figure 5 the assembly time in reality did not vary significantly between the two test groups. The average time to assemble the drone in reality for users who tested Scenario 1 in VR was 02:30 [mm:ss], and the time for users who tested Scenario 2 was 02:15 [mm:ss].

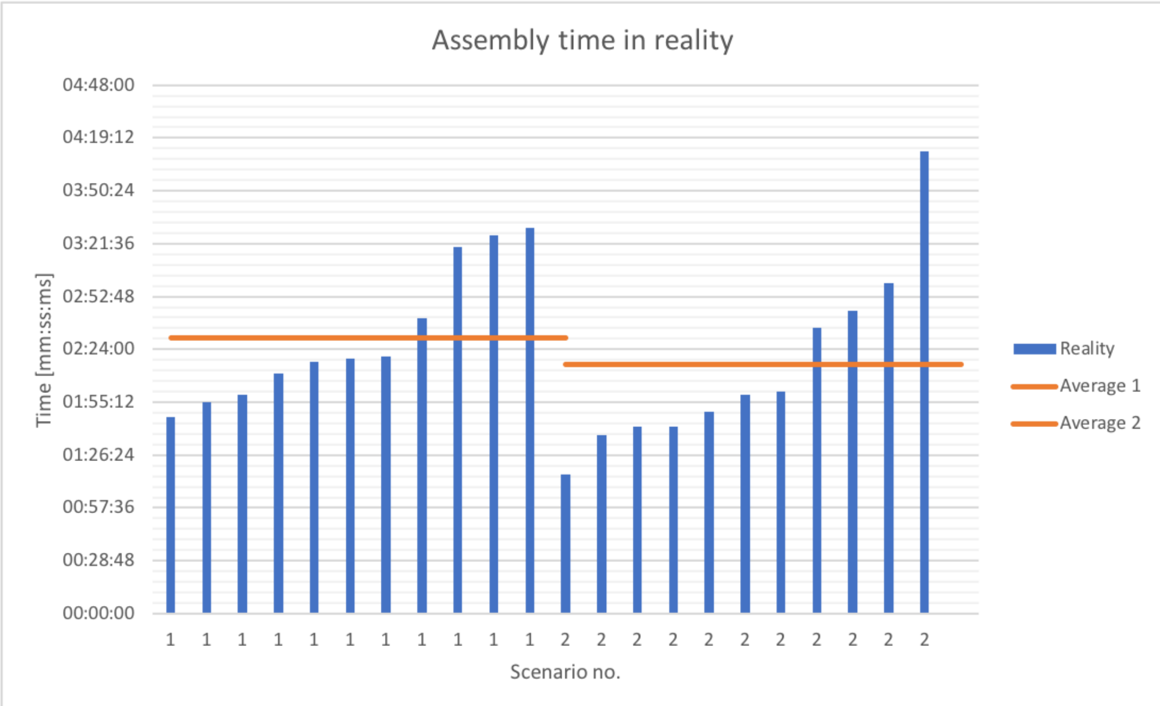


*Figure 5.* Chart of the assembly time in reality. The blue columns represent assembly time in reality and the orange horizontal lines show the average time for each scenario.

Further, the correlation between assembly time and previous experience of assembly work or experience of VR were analysed. The coloured columns in Figure 6(a) represent the participants who had previous experience of assembly work before participating in the test, and the faded columns represent the ones with no previous experience. In the same way, the coloured columns in Figure 6(b) represent the participants with previous experience of VR. The test results show no clear correlation between the assembly time and previous experience. Although it implies that participants with previous experience of VR assembled the drone slightly faster in the virtual environment than participants who had not.

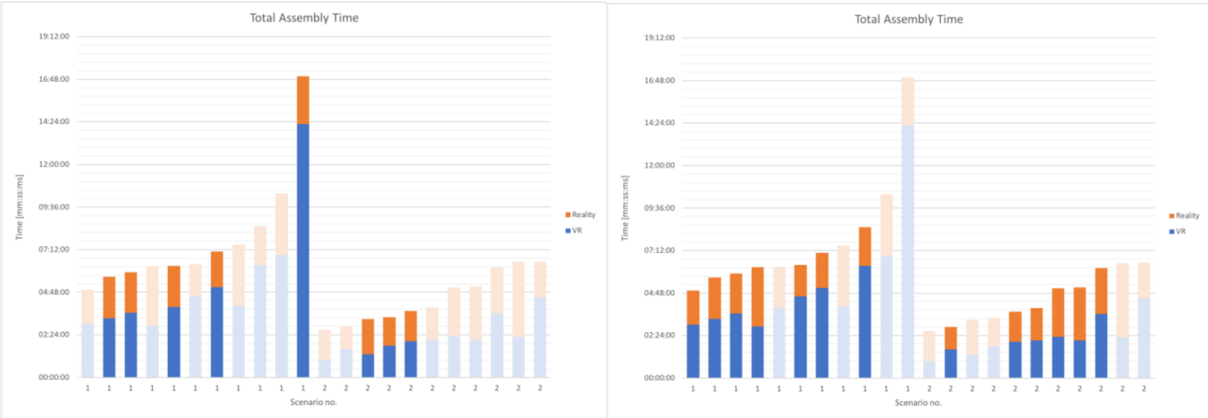


*Figure 6 (a).* Chart of the total assembly time. The highlighted columns represent participants with previous experience of assembly work. *Figure 6 (b).* Chart of total the assembly time. The highlighted columns represent participants with previous experience of VR.

The completion rate, in quantity of misplaced components, was the final data collected during the tests. The total number of misplacements is presented in Figure 7 where the blue part of the columns represents the number of misplacements during the assembly. The orange part represents the number of misplaced components and not completed assembly steps that were not corrected by the participant before the assembly was completed. The test does not imply any correlation between the type of scenario and number of misplaced components. As the results show, there were participants from both groups who finished the assembly without making any misplacements at all. However, the majority of the participants made at least one misplacement during the task.

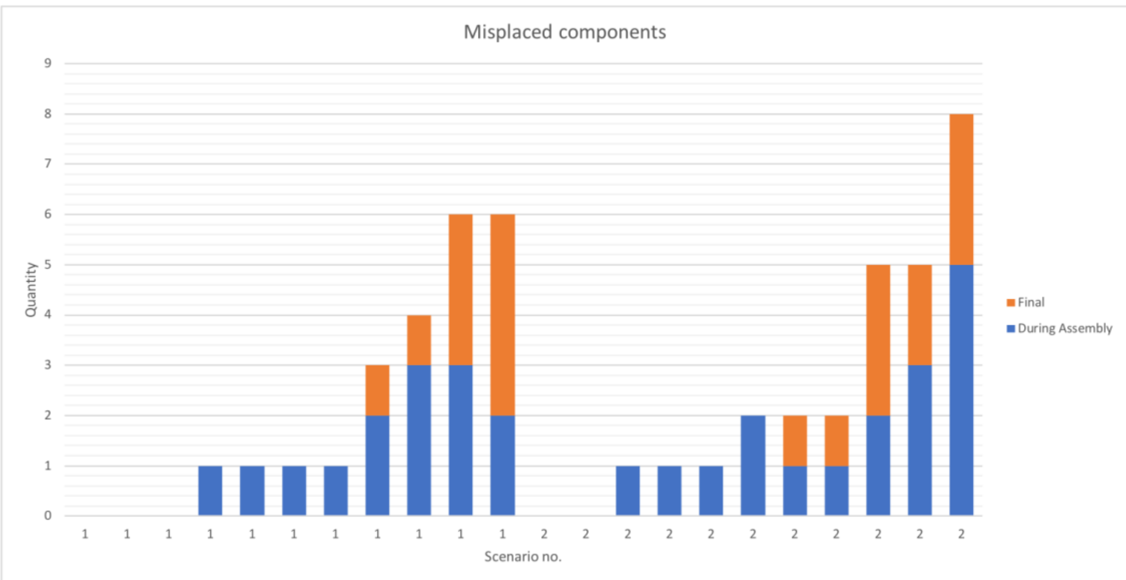


*Figure 7.* Chart of the number of misplacements during the assembly in reality. Blue columns represent misplacements during the assembly and orange the final misplacements that were not corrected during the assembly.

## 4.2 Qualitative results

The qualitative results were compiled from the user questionnaire, mainly focusing on comments and gradings on user experience. A compilation of all answers is presented in Appendix E. Participants were asked to grade their experience of similarities between virtual environment and the real assembly. The scale varied between 1 and 5, where 1 was identical and 5 was unrecognizable. The test results show no major difference in experienced similarities regardless of the tested scenario. The average grading for participants who tested the Scenario 1 was 2.36, slightly lower than for Scenario 2 where the average grading was 2.55.

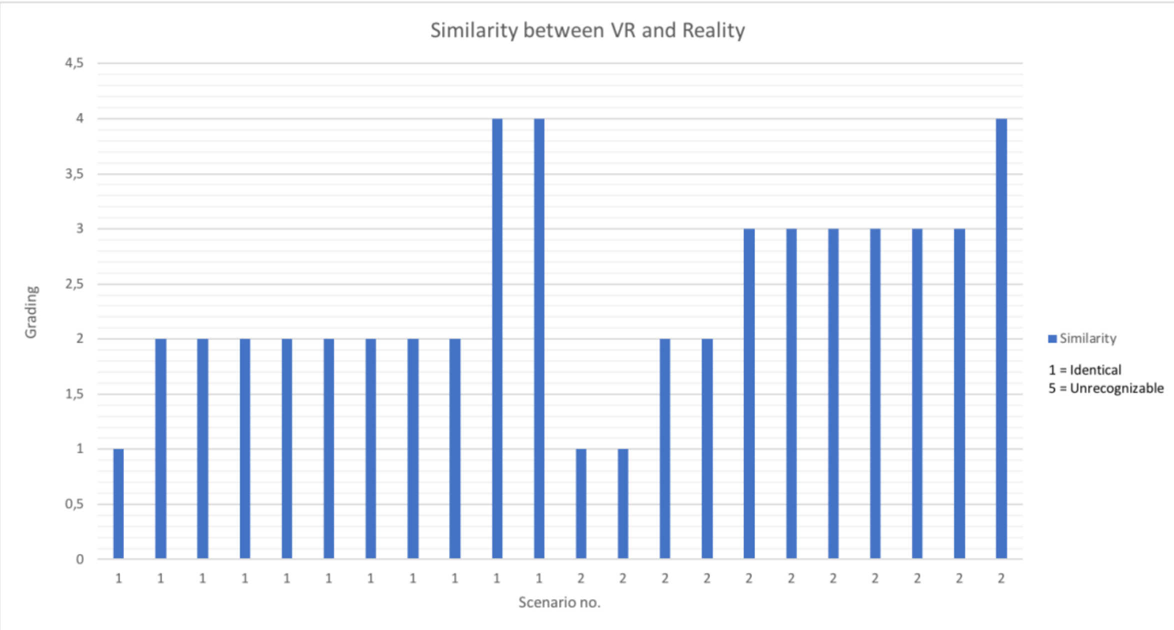


*Figure 8.* Chart of the experienced similarities between VR and reality. Higher columns represent less experienced similarities.

Another parameter of importance was how difficult it was for participants in the virtual environment. On average, participants who tested Scenario 2 found it easier to find components compared to participants who tested Scenario 1. According to the test results presented in Figure 9, only one participant found it hard to locate the correct components and the all the other participants reported it to be very easy or easy.

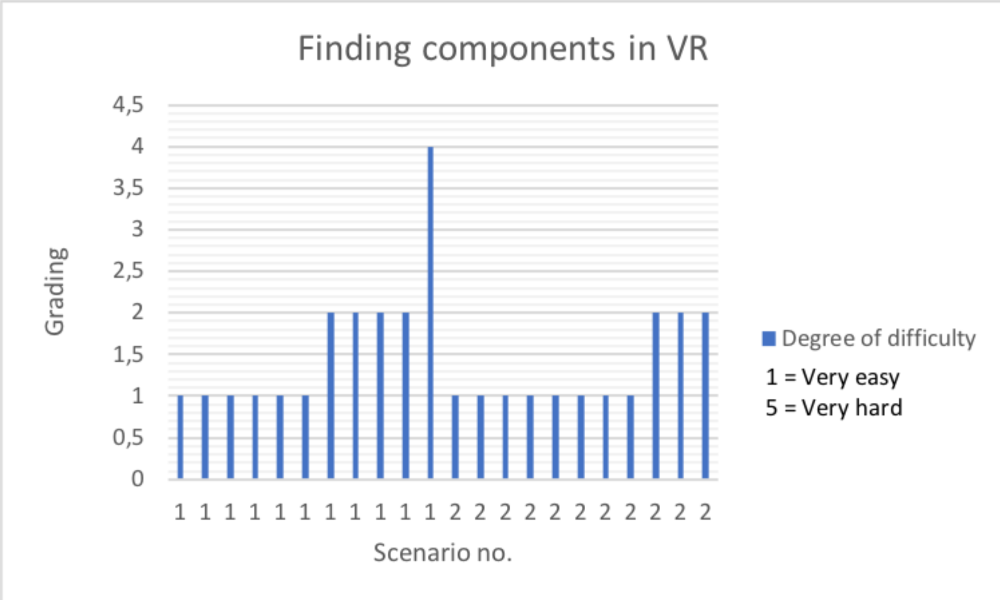


*Figure 9.* Chart of the level of difficulty in finding the right components in VR. Higher gradings represent greater level of difficulty.

As mentioned in Chapter 2 motion sickness is a possible side effect when using VR. In this thesis motion sickness was measured by experienced nausea, both during and after the test. The participants were asked to grade their experience on a scale between 0 and 5. The 0 represented no nausea, and the 5 was severe nausea. As presented in Figure 10 most participants did not experience any nausea at all neither during nor after the test. In total 6 out of 22 participants reported feeling nauseous with the lowest grades which were 1 and 2.

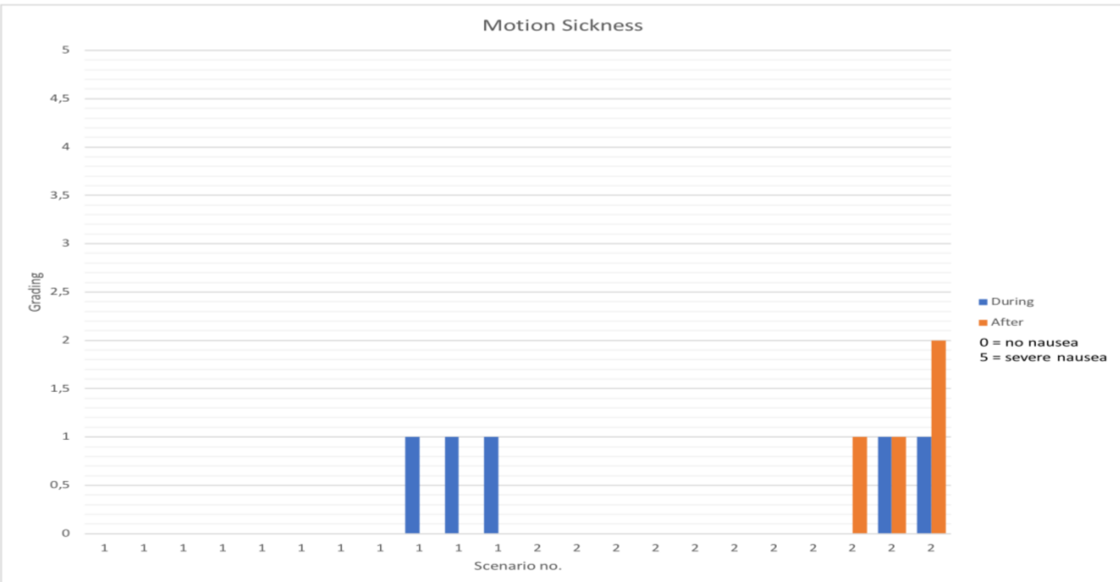


*Figure 10.* Chart of the experienced nausea during and after the VR test. The blue columns represent the experience of nausea during the use of VR and the orange columns represent the experience of nausea after testing VR.

## 4.3 Feedback

The representatives from the different companies gave the following feedback during the demonstration:

- As the real assembly test was held directly after the VR-test, it can be argued that only the short-term memory is tested. It could be a value to also perform the real assembly after a longer period of time to see if the scenarios have different impact on the long-term memory.
- The complexity of the chosen assembly task might not be high enough and therefore the test did not show big differences between the scenarios.
- It is important for the industry to use their recourses efficiently, therefore it would be necessary to be able to program the virtual environment in a short period of time.
- This type of virtual learning might be more suitable for ergonomic testing or for teaching the sequences of a standardized assembly task.
- Haptic or audible feedback could increase the recognition factor when going from the virtual environment to the real one.

# 5 Discussion

It is important to remember that the executed user tests were only testing the short-term memory as the participants' knowledge was assessed right after they were introduced to the assembly tasks in the virtual scenarios. The obtained results can only show an indication of how well the participants remember the assembly tasks for a short period of time after their VR training. Therefore, we cannot conclude how effective the scenarios are in terms of long-term memory.

Workstation 3 was not fully implemented. In total 6 sub-steps out of 14 were not included due to the time limit of the project. Most of the included steps were quite intuitive. For instance, one might easily guess where to assemble a cover and propellers on a drone. Therefore, the implemented steps of the assembly might have not been complex enough to obtain credible test results. The level of difficulty of the chosen steps was not assessed before the implementation phase. However, the supervisor of the thesis recommended Workstation 3 with the argument that it was the drone factory's most complex workstation. If a more complex assembly task was chosen or if all 14 steps of Workstation 3 were implemented, perhaps the results would have been different. A more promising approach would have been to test the complexity and difficulty of all the available workstations and choose one with the most suitable complexity in terms of assembly training. On another note, the complexity level depends on a person's knowledge. Therefore, verifying the level of complexity would have been hard to determine as it depends so much on personal knowledge and preferences.

A clear source of error is the small number of participants and the limited variation among participants. The total gender distribution was balanced whereas the age representation was limited. Most of the participants belonged to the age group of 18-25 years old. In addition, most of the participants had or were in the process of completing higher education. The majority had an education within the field of technology which might also be the reason why most of the participants completed the assembly task with ease. Therefore, one can argue that the sample of participants is not representative enough. On the other hand, this thesis is not focusing on assembly training for a specific company or type of users. Predicting traits, behaviours and preferences of a representative user group would have therefore not been possible to conduct during this thesis. To improve the representation, the sample size of participants could have been increased and more age groups could have been included.

By conducting the test, the impact of the deviations from the scenarios could be seen. As mentioned in Chapter 3, sets of screws and bolts that should be compatible with several drop zones were limited to a specific drop zone. This confused some participants when they tested Scenario 1, even though there were clear instructions that showed which component to pick up and where it should be assembled. For instance, some participants tried several times to assemble a screw on the correct spot, but they picked up the wrong of the four identical screws from the box. After a while, they realized that they had not followed the instruction.

In Scenario 2, since the timer function for correctly placed components did not work, an alternative solution was used. The deviation was that both the recently placed component and the next component were green, while the drop zone for the next component was not green. This led to hesitation for the participant, since they could not see the corresponding drop zone until they picked up the component. Also, the fact that the component and the drop zone was the same colour until the participant picked up the next component caused confusion since it visually looked like the component was already assembled. Although, most of the participants understood this after one or two assembly steps.

During the user tests total assembly time and number of misplaced components were measured. Both metrics help evaluate the task performance. However, one can argue that measuring the time, that the participators spent in the virtual environment, is not a reasonable metrics for assessing the efficiency of the design. The ability to process and to learn new information might vary on an individual level. Therefore, a low completion rate in the VR environment might not be beneficial if the participant is a slow learner. This indicates that measuring the total assembly time might not reveal anything about the efficiency and usability of the VR design because there are many different types of learners. Hence, the total assembly time of the drone performed in reality is more valuable when evaluating the design of the scenarios. On the other hand, there are many ways of measuring efficiency and task performance. During a manufacturing process, completion time is important and depends on the number of failures during an assembly. Therefore, we chose to define our efficiency according to the two parameters, assembly time and number of failures, that contributes to an efficient assembly line.

Based on the theory presented in Chapter 2 the VR design should be based on the real world. Previous research implies that RBI allows people to use their real-life experiences and thereby reducing the effort needed to interact within the virtual world. On the other hand, cognitive learning theory implies that the cognitive load experienced by the learner should be minimized. It can therefore be argued that the interaction design should be as simple as possible and only focus on the actual task. Although, memorisation building on past knowledge is an important step in cognitive learning supporting that the reality-based scenario should be most suitable for VR training. It can be argued that participants who tested Scenario 1 would pay more attention to the instructions and memorise the assembly step easier. It was therefore expected that participants who tested Scenario 1 would complete the assembly in reality in a shorter period of time and with fewer misplacements than participants who tested Scenario 2. As mentioned in Chapter 4, there was no significant difference in neither average assembly time, nor number of misplaced components between Scenario 1 and 2. Therefore the theory cannot be confirmed nor discarded by the test results. However, from the cognitive learning theory it can be argued that a simplified interaction design is enough to learn the sequences of an assembly task with similar complexity.

The implemented virtual environments did not require much movement and the time of the interaction with the two environments was on average 3.5 minutes. This implies that the occurrence of long-term injuries has a low expectation. Hence, the possibility of experiencing short term symptoms is also small. People who easily get nauseous may also experience motion sickness during or after interacting with a virtual world. Therefore, all participants were asked safety questions before the user tests including questions about motion sickness. None of the participants reported any symptoms after they interacted with the virtual environment. Based on those reports and the fact that the implemented scenarios did not require much movement and interaction with the virtual world, it can be concluded that the possibility of experiencing short-term symptoms is low for both scenarios. This also implies that our conducted user tests do not need to take any major ethical aspects into consideration.

# 6 Conclusion

Although the obtained results provide an insight that might be useful for answering the research questions, a conclusion cannot be fully drawn by the theoretical and empirical study. The participants scored noticeably similar in the real assembly test independently of scenario and none of the scenarios indicates remarkable discomfort. Therefore, based on the obtained results, we conclude that the virtual learning environment that requires the least number of resources is the most profitable. Hence, when creating a virtual learning environment, the resource efficiency, the implementation time and the efficiency of the training itself should be considered. In conclusion a simplified design inspired by reality trade-offs is preferred if the aim is to only learn the sequences of an assembly task.

# 7 Future Work

More user tests, similar to the one conducted for this thesis, are needed to conclude how efficient RBI design is for assembly training in VR. The created scenarios can be tested again and follow the same procedure for the user tests. we recommend increasing the number of participants and if possible, increase the representativeness of the sample. Another suggestion is to include participants of different age groups and with different levels of education. Furthermore, the complexity of the assembly task can be increased. An interesting follow-up investigation to this thesis could be to implement the total number of steps included in the drone assembly.

In this thesis the implemented scenarios have not been designed according to a specific user group. To evaluate the usability and effectivity of a virtual environment for assembly training, the evaluation should include a more niched sample of users. With a more niched user sample, it might be easier to conclude what design decisions are preferable. The type of input device also affects the user experience. Our user tests included only one type of input device and the results might have been different if other devices were used. To investigate what type of input devices are preferred for assembly training in VR, user tests can be conducted where different input devices are tested for the same assembly task.

The assembly in the two scenarios did not require any specific rotations or directions of the components. When sufficiently close to the correct zone on the drone, the component will snap to the zone when the user drops it. During the snap, the component will automatically adjust itself to match the position and rotation of the zone. This is a huge simplification compared to the reality. To teach the exact assembly process, a VR assembly can be implemented where the users must rotate the components correctly by themselves. This would also increase the complexity of the test. Finally, another recommendation is to conduct user tests that evaluate long-term memory. To analyse how VR can be effectively used for training purposes, it is crucial to study how long and how well the users remember the information that they learned by the virtual assembly training.

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# APPENDIX A

Workstation 3

| Operations | Parts | Steps | Sub-steps |
|---|---|---|---|
| 0100, Asm_Control_Unit_0100, A.2 (Manufacturing), 0000000058 | | 1 | |
| | 0000000023, Bolt_M5x70mm_AK, A.2 (Design) | | 4 |
| | 0000000023, Bolt_M5x70mm_AK, A.2 (Design) | | 4 |
| | 0000000033, Control_Unit, A.2 (Design) | | 2 |
| | 0000000039, Nut_M5, A.2 (Design) | | 5 |
| | 0000000039, Nut_M5, A.2 (Design) | | 5 |
| | 0000000040, Holder_Control_Unit, A.2 (Design) | | 3 |
| | 0000000046, Frame_Control_Unit, A.2 (Design) | | 1 |
| 0110, Place_Battery_0110, A.2 (Manufacturing), 0000000051 | | 2 | |
| | 0000000037, Battery_1350_14_8V, A.2 (Design) | | 1 |
| 0120, Place_Radio_Control_Receiver_0120, A.2 (Manufacturing), 0000000046 | | 3 | |
| | 0000000036, Radio_Control_Receiver, A.2 (Design) | | 1 |
| 0130, Clamp_Battery_0130, A.2 (Manufacturing), 0000000052 | | 4 | |
| | 0000000032, Clamp_Battery, A.2 (Design) | | 1 |
| | 0000000044, Bolt_M6x12mm_AK, A.2 (Design) | | 2 |
| 0140, Asm_Cover_0140, A.2 (Manufacturing), 0000000059 | | 5 | |
| | 0000000084, Cover, A.2 (Design) | | 1 |
| | 0000000122, Cap_Nut_M5, A.2 (Design | | 2 |

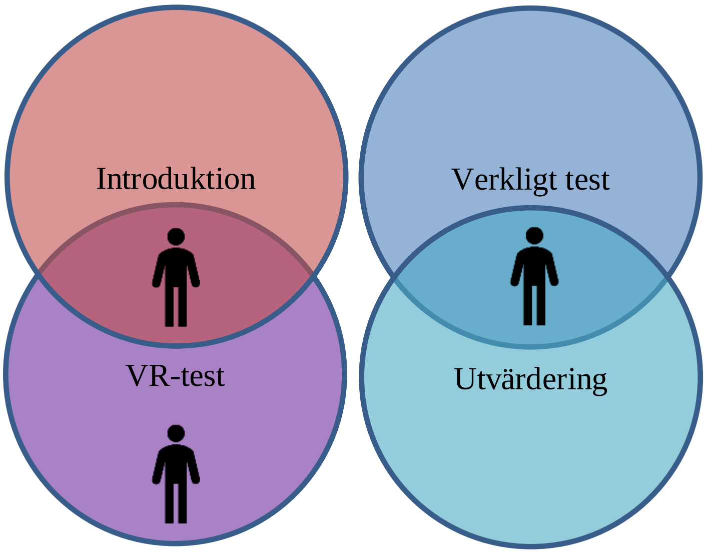
| | | | |
|---|---|---|---|
| | 0000000122, Cap_Nut_M5, A.2 (Design) | | 2 |
| | 0000000122, Cap_Nut_M5, A.2 (Design) | | 2 |
| | 0000000122, Cap_Nut_M5, A.2 (Design) | | 2 |
| 0150, Asm_Propellers_0150, A.2 (Manufacturing), 0000000054 | | 6 | |
| | 0000000022, Propeller_5045_CW, A.2 (Design) | | 1 |
| | 0000000022, Propeller_5045_CW, A.2 (Design) | | 1 |
| | 0000000025, Nut_Propeller, A.2 (Design) | | 3 |
| | 0000000025, Nut_Propeller, A.2 (Design) | | 3 |
| | 0000000025, Nut_Propeller, A.2 (Design) | | 3 |
| | 0000000025, Nut_Propeller, A.2 (Design) | | 3 |
| | 0000000141, Propeller_5045_CCW, A.2 (Design) | | 2 |
| | 0000000141, Propeller_5045_CCW, A.2 (Design) | | 2 |

# APPENDIX B

## Test manuscript

Test setup in SII-Lab:

1. Introduction
2. VR-test
3. Real assembly test
4. Evaluation




| RANDOM ORDER OF SCENARIOS: | |
|---|---|
| **Test no.** | **Scenario no.** |
| 1 | 2 |
| 2 | 1 |
| 3 | 2 |
| 4 | 2 |
| 5 | 1 |
| 6 | 1 |
| 7 | 2 |
| 8 | 1 |
| 9 | 2 |
| 10 | 1 |
| 11 | 2 |
| 12 | 1 |
| 13 | 1 |
| 14 | 2 |
| 15 | 2 |
| 16 | 2 |
| 17 | 1 |
| 18 | 1 |
| 19 | 2 |
| 20 | 2 |
| 21 | 1 |
| 22 | 1 |

## Introduktion

*Person 1*

- *Lista på viket scenario som skall genomföras vid vilket test*
- *Beskrivning av bakgrund till test*
- *Genomgång av testet i sin helhet (1-4)*
- *”Hälsokoll” av testperson*

”Hej, kul att du kommit hit!

Vi gör ett kandidatarbete om hur man på det effektivaste sättet bör designa VR som metod för att lära sig en monteringsuppgift, då det idag inte finns några tydliga sådana riktlinjer.

Du kommer att få göra två tester nu, ett här i VR-miljö för att få lära dig en monteringsuppgift och sedan göra samma montering i verkligheten. Efter det ska du få svara på några frågor i en enkät. Du kommer vara helt anonym och test- och enkätsvaren kommer bara användas i detta kandidatarbete.

Gör testerna så gott du kan och säg bara till om något känns obehagligt eller om du av någon anledning vill avbryta.

För att minimera risken för obehagliga upplevelser skulle vi vilja att du svarar på tre frågor:

- Har du epilepsi?
- Har du tänkt köra bil inom 30 min efter VR-testet?
- Brukar du ha lätt för att bli åksjuk?

- *om nej på alla frågor* → skicka vidare till test
- *om ja på någon av de två första* → råd personen att avstå från test eller att vänta med bilkörandet
- *om ja på den sista* → beskriv att den kan uppleva åksjuka och att det bara är att avbryta testet om det blir obehagligt”

## VR-test

*Person 1* och *Person 2*

- *Tutorial av VR, olika beroende på scenario*
- *Sätt på testperson headsetet och ge kontrollerna*
- *Genomför VR-testet*
- *Fyll i protokoll*

”…nu kommer du få ett headset och två kontroller att hålla i vardera handen av mig. När du får på dig headsetet kommer du se en virtuell miljö av en monteringsstation. Du kommer inte att behöva röra dig så mycket i VR-världen men vi kommer att hålla koll på dig så du inte går in i något om du är nära en vägg här i den verkliga miljön.

**montera headset**

Känns det okej?

**ge kontroller**

Så, jag ska förklara hur du använder kontrollerna och sedan säger jag till när du får börja montera.

| *Om Scenario 1:* | *Om Scenario 2:* |
|---|---|
| Du har nu en arbetsbänk framför dig med en halvfärdig drönare och några komponenter i lådor bredvid.<br>Ovanför bänken ser du även en skärm och kollar du lite neråt ser du dina två kontroller du håller i.<br><br>För att teleportera dig i rummet pekar du med kontrollen dit du vill och klickar på den stora touch-knappen uppepå kontrollen. För att ta tag i en komponent pekar du på komponenten och klickar på knappen under kontrollen. När du vill släppa komponenten klickar du på knappen under kontrollen igen.<br><br>På skärmen kommer instruktioner på hur varje monteringssteg skall göras ses. | Du har nu en arbetsbänk framför dig med en halvfärdig drönare och en rund platta till höger.<br><br>Kollar du lite neråt ser du dina två kontroller du håller i.<br><br>För att teleportera dig i rummet pekar du med kontrollen dit du vill och klickar på den stora touch-knappen uppepå kontrollen. För att ta tag i en komponent pekar du på komponenten och klickar på knappen under kontrollen. När du vill släppa komponenten klickar du på knappen under kontrollen igen.<br><br>På plattan till höger kommer komponenter som skall monteras dyka upp. |

Är du redo att börja montera?

Varsågod att börja!

**Om personen frågar något: försök att upprepa det du sagt**

**fyll i protokoll (tidtagning och räkna moment)**

**koll håll på att testpersonen inte skadar sig/går in i möbler i verkliga världen**

Sådär, bra jobbat! Nu ska jag hjälpa dig av med utrustningen och så ska du få gå bort till den verkliga monteringsstationen.”

## Verkligt test

*Person 3*

- *Berätta vad som skall göras*
- *Ha en färdigmonterad drönare som enda instruktion under vägen*
- *Genomför verkliga testet*
- *För protokoll*

”Hej, nu ska du få montera drönaren i verkligheten. Framför dig har du den halvklara drönaren som skall monteras klart med komponenter och utrustning från lådorna bredvid. Till en av skruvarna kan man behöva använda en insexnyckel, denna användes inte i VR-världen.
**peka på den färdigmonterade**
Gör så gott du kan och säg till när du tycker att du är klar.
Är du redo att börja?
Varsågod att börja.
**fyll i protokoll (ta tid och räkna moment)**
Bra jobbat!
**räkna antal korrekt monterade komponenter m.m., fyll i protokoll*”*

## Utvärdering

*Person 3*

- *Onlineenkät*
- *Tacka för hjälpen*

”Nu ska du få fylla i en online-enkät, sedan är det klart!
Är det något du undrar är det bara att fråga. **ok att förklara frågorna**
**person fyller i och skickar in enkät**
Tack så jättemycket för att du hjälpt oss! Ta för dig av godis och kaffe. ☺ ”

**APPENDIX C**

Quantitative data form

Testdag:

Testpersons nr:

Scenario:

# Protokoll för VR-testet

| | | |
|---|---|---|
| Tid | | Svara med minut : sek |
| Fullföljde hela VR testet?<br>Om nej; varför? | | Ja/nej + kommentar |

# Protokoll för verklig montering

| | | |
|---|---|---|
| Tid | | Svara med minut: sek |
| Antal moment | | Dra streck/skriv antal |
| Antal rätt/fel/saknade på färdig montering | | Dra streck/skriv antal |
| Fullföljde hela monteringen? | | Ja/nej + kommentar |

**Vad innebär de olika delarna? Hur ska de räknas/mätas?**

**Tid:** Tiden startar när första komponenten berörs. Tiden slutar i VR världen när antigen sista komponenten är lagt rätt eller personen avbryter. Tiden slutar i verklig montering antigen när personen ger upp eller känner sig klar

**Antal moment**: Räkna under testet antal moment som sker, dvs att ta upp en komponent är ett moment, försök till att placera och placera är ett moment men lägga tillbaka komponenter/verktyg är EJ ett moment.

**Antal rätt/fel&saknade på färdig montering**: Räkna antal komponenter som är rätt respektive fel och saknas för att veta hur färdig monteringen är efter testpersonen är klar.

**Fullföljde**: Innebär om testpersonen genomförde hela testet eller om den avbröt. Kommentera gärna varför den avbröt.

**Testdag**: datum 2019-xx-yy, ifall det skulle skilja sig mellan dagarna

**Person och Scenario**: Skriv siffror på dessa platser för att identifiera och kontrollera att vi har all data

# APPENDIX D

Questionnaire

# Enkät

Nu efter att du har gjort våra test skulle vi gärna ha lite svar om vad du tyckte, upplevde och har för tidigare erfarenheter

*Obligatorisk

1. **Vilket test nummer har du? ***

2. **Vilken bild liknar den VR-världen du var i? ***
   Fråga någon av oss om du inte minns vilket scenario du var i.



- Världen hade väggar, möbler osv
- Världen hade enbart bord

# Bakgrundsfrågor

För att kunna ge en rättvisare bild av data vi har samlat ihop skulle vi behöva lite bakgrundsinformation om dig.

3. **Vad identifierar du dig som? ***
   - Man
   - Kvinna
   - Annat alternativ
   - Vill ej uppge

4. **Har du arbetat med montering tidigare? ***
   - Ja
   - Nej

5. **Hur gammal är du? ***

- 0-18 år
- 19-25 år
- 26-35 år
- 36-45 år
- 46-55 år
- över 55 år

6. **Hur många gånger har du använt/testat VR innan detta test? ***

- 0
- 1
- 2
- 3-10
- >10 ggr

# Om dagens test

7. **Upplevde du illamående, huvudvärk, etc under användningen av VR? ***

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Inget | | | | | | Mycket |

8. **Upplevde du illamående, huvudvärk, etc efter användningen av VR? ***

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Inget | | | | | | Mycket |

# Om dagens test

9. **Hur upplevde du tiden det tog att arbeta i VR-världen? ***

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Väldigt långsam | | | | | | Väldigt snabb |

10. **Hur lätt var det i VR-världen att... ***

| | 1: Väldigt lätt | 2: Lätt | 3: Varken eller | 4: Svårt | 5: Väldigt svårt | Vet ej/upplevde aldrig |
|---|---|---|---|---|---|---|
| förstå om komponenten placerats rätt? | | | | | | |
| förstå om komponenten placerats fel? | | | | | | |
| förstå när du kunde gå vidare till nästa steg? | | | | | | |
| förstå vad som skulle göras i varje steg? | | | | | | |
| hitta rätt komponent? | | | | | | |
| sätta komponenten på rätt ställe? | | | | | | |
| orientera sig? | | | | | | |
| interagera (greppa, flytta, placera…) med objekt (material och verktyg)? | | | | | | |

11. **Hur lik var den verkliga monteringen VR-testet? ***

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Identisk | | | | | | Mycket olik |

12. **Upplevde du att du hade tillräckliga kunskaper för att göra den verkliga monteringen efter VRtestet och med dina tidigare erfarenheter? ***

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| Nej, det var väldigt svårt att göra det verkliga testet | | | | | | Ja, det var väldigt lätt att göra det verkliga testet |

# Kommentarer

13. **Skriv kortfattat, vad du tyckte om VR-testet och det verkliga testet generellt. ***

Google Forms

# APPEDIX E

## Questionnaire answers

| Test nummer | Scenario | Kön | Ålder | Montering innan? | VR innan | Tid VR | Tid Verklighet | Verkl./VR | Antal moment fel | Antal slutfel i verkligheten, felmontering eller saknad komp. | Total fel |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | Man | 18-25 år | Ja | 2 | 02:03:00 | 01:42:00 | 83% | 1 | 0 | 1 |
| 2 | 1 | Kvinna | 18-25 år | Nej | 0 | 06:53:00 | 03:30:00 | 51% | 2 | 4 | 6 |
| 3 | 2 | Man | 18-25 år | Ja | 0 | 01:47:00 | 01:37:00 | 91% | 2 | 3 | 5 |
| 4 | 2 | Kvinna | 18-25 år | Nej | 2 | 02:07:00 | 03:00:00 | 142% | 1 | 1 | 2 |
| 5 | 1 | Kvinna | 25-35 år | Ja | 6 | 03:21:00 | 02:20:00 | 70% | 1 | 0 | 1 |
| 6 | 1 | Man | 25-35 år | Nej | 1 | 02:55:00 | 03:20:00 | 114% | 2 | 1 | 3 |
| 7 | 2 | Man | 25-35 år | Nej | 6 | 01:37:00 | 01:16:00 | 78% | 0 | 0 | 0 |
| 8 | 1 | Kvinna | 18-25 år | Nej | 1 | 06:20:00 | 02:11:00 | 34% | 1 | 0 | 1 |
| 9 | 2 | Man | 18-25 år | Nej | 1 | 02:07:00 | 01:50:00 | 87% | 0 | 0 | 0 |
| 10 | 1 | Man | 18-25 år | Ja | 2 | 03:38:00 | 02:17:00 | 63% | 3 | 3 | 6 |
| 11 | 2 | Kvinna | 18-25 år | Nej | 0 | 02:18:00 | 04:12:00 | 183% | 5 | 3 | 8 |
| 12 | 1 | Kvinna | 18-25 år | Nej | 0 | 04:03:00 | 03:26:00 | 85% | 3 | 1 | 4 |
| 13 | 1 | Man | 25-35 år | Ja | 0 | 03:58:00 | 02:19:00 | 58% | 1 | 0 | 1 |
| 14 | 2 | Man | 18-25 år | Nej | 1 | 02:19:00 | 02:45:00 | 119% | 1 | 0 | 1 |
| 15 | 2 | Man | 18-25 år | Ja | 0 | 01:19:00 | 01:59:00 | 151% | 0 | 0 | 0 |
| 16 | 2 | Kvinna | 25-35 år | Nej | 1 | 03:37:00 | 02:36:00 | 72% | 1 | 1 | 2 |
| 17 | 1 | Man | 25-35 år | Nej | 1 | 03:01:00 | 01:55:00 | 64% | 1 | 0 | 1 |
| 18 | 1 | Kvinna | 18-25 år | Nej | 1 | 04:36:00 | 01:47:00 | 39% | 0 | 0 | 0 |
| 19 | 2 | Man | 18-25 år | Nej | 0 | 00:58:00 | 01:42:00 | 176% | 1 | 0 | 1 |
| 20 | 2 | Kvinna | 18-25 år | Nej | 0 | 04:30:00 | 02:01:00 | 45% | 3 | 2 | 5 |
| 21 | 1 | Kvinna | 18-25 år | Ja | 1 | 05:06:00 | 01:59:00 | 39% | 2 | 0 | 2 |
| 22 | 1 | Man | 35-45 år | Ja | 0 | 14:17:00 | 02:41:00 | 19% | 0 | 0 | 0 |

| Test nummer | Scenario | Upplevelse av tillräcklig kunskap för testet | Upplevelse av illamående under användningen av VR | Upplevelse av illamående efter användningen | Upplevelse av VR-tid | Hur lik var den verkliga monteringen VR-testet? |
|---|---|---|---|---|---|---|
| 1 | 2 | 5: Ja | 1: Inget | 1: Inget | 3: Normal | 2: Lik |
| 2 | 1 | 4: Delvis ja | 1: Inget | 1: Inget | 4: Snabb | 4: Olik |
| 3 | 2 | 2, Delvis nej | 1: Inget | 1: Inget | 3: Normal | 3: Varken eller |
| 4 | 2 | 4: Delvis ja | 1: Inget | 1: Inget | 4: Snabb | 3: Varken eller |
| 5 | 1 | 4: Delvis ja | 2: Lite | 1: Inget | 3: Normal | 4: Olik |
| 6 | 1 | 4: Delvis ja | 1: Inget | 1: Inget | 3: Normal | 2: Lik |
| 7 | 2 | 5: Ja | 1: Inget | 1: Inget | 4: Snabb | 1: Identisk |
| 8 | 1 | 5: Ja | 1: Inget | 1: Inget | 4: Snabb | 2: Lik |
| 9 | 2 | 5: Ja | 1: Inget | 1: Inget | 4: Snabb | 2: Lik |
| 10 | 1 | 5: Ja | 1: Inget | 1: Inget | 2: Långsam | 2: Lik |
| 11 | 2 | 3: Varken eller | 1: Inget | 1: Inget | 5: Väldigt snabb | 1: Identisk |
| 12 | 1 | 2: Delvis nej | 2: Lite | 1: Inget | 2: Långsam | 1: Identisk |
| 13 | 1 | 5: Ja | 1: Inget | 1: Inget | 3: Normal | 2: Lik |
| 14 | 2 | 4: Delvis ja | 2: Lite | 2: Lite | 4: Snabb | 3: Varken eller |
| 15 | 2 | 4: Delvis ja | 1: Inget | 2: Lite | 4: Snabb | 2: Lik |
| 16 | 2 | 4: Delvis ja | 2: Lite | 3: Medel | 3: Normal | 3: Varken eller |
| 17 | 1 | 5: Ja | 1: Inget | 1: Inget | 4: Snabb | 2: Lik |
| 18 | 1 | 5: Ja | 2: Lite | 1: Inget | 5: Väldigt snabb | 2: Lik |
| 19 | 2 | 4: Delvis ja | 1: Inget | 1: Inget | 4: Snabb | 3: Varken eller |
| 20 | 2 | 3: Varken eller | 1: Inget | 1: Inget | 3: Normal | 3: Varken eller |
| 21 | 1 | 4: Delvis ja | 1: Inget | 1: Inget | 3: Normal | 4: Olik |
| 22 | 1 | 5: Ja | 1: Inget | 1: Inget | 3: Normal | 2: Lik |

| | | Hur lätt var det i VR-världen att… | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Test nummer | Scenario | förstå om komponenten placerats rätt? | förstå om komponenten placerats fel? | förstå när du kunde gå vidare till nästa steg? | förstå vad som skulle göras i varje steg? | hitta rätt komponent? | sätta komponenten på rätt ställe? | orientera sig? | interagera med objekt? |
| 1 | 2 | 2: Lätt | Vet ej/upplevde ald | 1: Väldigt lätt | 1: Väldigt lätt | 1: Väldigt lätt | 2: Lätt | 1: Väldigt lätt | 1: Väldigt lätt |
| 2 | 1 | 1: Väldigt lätt | 2: Lätt | 2: Lätt | 1: Väldigt lätt | 1: Väldigt lätt | 2: Lätt | 4: Svårt | 2: Lätt |
| 3 | 2 | 2: Lätt | 5: Väldigt svårt | 2: Lätt | 2: Lätt | 2: Lätt | 1: Väldigt lätt | 2: Lätt | 3: Varken eller |
| 4 | 2 | 1: Väldigt lätt | 2: Lätt | 1: Väldigt lätt | 2: Lätt | 2: Lätt | 1: Väldigt lätt | 2: Lätt | 2: Lätt |
| 5 | 1 | 2: Lätt | 4: Svårt | 2: Lätt | 2: Lätt | 2: Lätt | 3: Varken eller | 2: Lätt | 2: Lätt |
| 6 | 1 | 1: Väldigt lätt | 2: Lätt | 2: Lätt | 2: Lätt | 2: Lätt | 2: Lätt | 4: Svårt | 3: Varken eller |
| 7 | 2 | 1: Väldigt lätt | 3: Varken eller | 3: Varken eller | 2: Lätt | 1: Väldigt lätt | 2: Lätt | 1: Väldigt lätt | 2: Lätt |
| 8 | 1 | 1: Väldigt lätt | 4: Svårt | 2: Lätt | 1: Väldigt lätt | 4: Svårt | 1: Väldigt lätt | 3: Varken eller | 3: Varken eller |
| 9 | 2 | 2: Lätt | 3: Varken eller | 1: Väldigt lätt | 2: Lätt | 1: Väldigt lätt | 2: Lätt | 1: Väldigt lätt | 2: Lätt |
| 10 | 1 | 1: Väldigt lätt | 1: Väldigt lätt | 1: Väldigt lätt | 2: Lätt | 1: Väldigt lätt | 2: Lätt | 1: Väldigt lätt | 2: Lätt |
| 11 | 2 | 2: Lätt | 4: Svårt | 1: Väldigt lätt | 2: Lätt | 1: Väldigt lätt | 1: Väldigt lätt | 2: Lätt | 3: Varken eller |
| 12 | 1 | 1: Väldigt lätt | 1: Väldigt lätt | 1: Väldigt lätt | 1: Väldigt lätt | 1: Väldigt lätt | 1: Väldigt lätt | 3: Varken eller | 2: Lätt |
| 13 | 1 | 2: Lätt | 2: Lätt | 2: Lätt | 1: Väldigt lätt | 2: Lätt | 2: Lätt | 3: Varken eller | 3: Varken eller |
| 14 | 2 | 4: Svårt | 5: Väldigt svårt | 4: Svårt | 4: Svårt | 1: Väldigt lätt | 4: Svårt | 2: Lätt | 2: Lätt |
| 15 | 2 | 3: Varken eller | 2: Lätt | 1: Väldigt lätt | 2: Lätt | 2: Lätt | 2: Lätt | 2: Lätt | 2: Lätt |
| 16 | 2 | 4: Svårt | 4: Svårt | 4: Svårt | 4: Svårt | 1: Väldigt lätt | 4: Svårt | 4: Svårt | 4: Svårt |
| 17 | 1 | 1: Väldigt lätt | 1: Väldigt lätt | 1: Väldigt lätt | 2: Lätt | 1: Väldigt lätt | 1: Väldigt lätt | 1: Väldigt lätt | 2: Lätt |
| 18 | 1 | 1: Väldigt lätt | 3: Varken eller | 2: Lätt | 1: Väldigt lätt | 1: Väldigt lätt | 3: Varken eller | 2: Lätt | 4: Svårt |
| 19 | 2 | 1: Väldigt lätt | 1: Väldigt lätt | 2: Lätt | 2: Lätt | 1: Väldigt lätt | 1: Väldigt lätt | 1: Väldigt lätt | 2: Lätt |
| 20 | 2 | 2: Lätt | 2: Lätt | 1: Väldigt lätt | 1: Väldigt lätt | 1: Väldigt lätt | 1: Väldigt lätt | 2: Lätt | 4: Svårt |
| 21 | 1 | 2: Lätt | 2: Lätt | 3: Varken eller | 1: Väldigt lätt | 1: Väldigt lätt | 4: Svårt | 2: Lätt | 1: Väldigt lätt |
| 22 | 1 | 2: Lätt | 4: Svårt | 2: Lätt | 4: Svårt | 2: Lätt | 4: Svårt | 2: Lätt | 3: Varken eller |

| Test nummer | Scenario | Skriv kortfattat, vad du tyckte om VR-testet och det verkliga testet generellt. |
|---|---|---|
| 1 | 2 | Roligt och intressant. Skulle vart kul att få monter ihop hela drönaren :) |
| 2 | 1 | VR-testet var väldigt bra, det fanns tydliga instruktioner som man lätt kunde följa däremot var det lite svårt att placera sig rätt/teleportera sig, för mig iallafall. Det verkliga testet var också bra men man visste inte om man skulle göra det snabbt eller ta sin tid så jag blev lite osäker och försökte göra det så snabbt som möjligt. |
| 3 | 2 | kul och bra sätt att lära sig på. behövdes dock inte så mycket precision i vr-världen vilket gjorde det svår vid den verkliga monteringen sen. |
| 4 | 2 | Bra sätt att snabbt lära sig en monterings ordning, men kändes inte som om VR-testet tog hänsyn till hur man höll objektet eller ifall det placerades snett etc. vilket spelar roll när man monterade den i verkligheten. |
| 5 | 1 | Vissa mindre delar var det svårare att se var eller hur man skulle placera dem i VR modellen vilket märktes att jag inte riktigt hade förstått när jag gjorde monteringen i verkligheten. |
| 6 | 1 | Svårt att läsa/se texten på skärmen och lådorna samtidigt, väldigt suddigt i VR miljön gjorde det svårt att läsa hela instruktionstexten och se på lådorna/orientera sig om rätt komponent samtidigt. |
| 7 | 2 | VR: Jag har för mig att efter du av avklarat en del så är den fortfarande grön, kanske borde varit en annan färg som indikerar att den är klar. |
| 8 | 1 | Jag tyckte det var klurigt att i VR-världen när jag hade identiska grejer som skulle monteras. I verkligheten kan man välja vilken plats man ska sätta första av fyra skruvar medan i VR-världen va de lite märkligt att inte kunna välja själv vilken av skruvarna/propellerbladen jag började med. |
| 9 | 2 | vr-testet var tydligt, lätt att anpassa sig, man såg lätt vart man skulle placera komponenter med att de skiftade färg, det verkliga testet var också trevligt, vissa komponenter såsom propeller och motor hade detaljer som var svåra att urskilja i vr såsom färg och former som man såg begränsat i vr |
| 10 | 1 | Det var ett pedagogiskt sätt att lära sig montera. Var intuitivt och tydligt. Det var bra att det lös grönt när man placerat rätt så att man inte lär in fel. Hade velat kunna rotera och se från flera vinklar då det är viktigt med vinklar för att kunna montera effektivt och utan att skada komponenter i verkligheten. |
| 11 | 2 | Väldigt bra! Pedagogiskt i VR-miljön och enkelt att följa. Det svåra var att komma ihåg hur delarna skulle sitta. Bra val av montering! |
| 12 | 1 | VR testet var enkelt att följa men mindes inte vad som skulle göras vid det generella testet |
| 13 | 1 | VR-tested var mycket bra för att få mig att förstå i vilken ordning som komponenterna skulle monteras i det verkliga testet. Drönaren var en lämpligt/tillräckligt komplex produkt. |
| 14 | 2 | VR-test: bra överblick vilken komponent som skulle på i vilken ordning samt på ett ungefär var den skulle placeras på drönar-plattformen. Proportionerna på testet stämde bra överens med verkligheten. Svårt att förstå vilken orientering komponenten skulle ha vid montering, man släppte komponenten och så vred den sig rätt. Svårt att förstå hur man skulle starta med enbart grön markering av komponent och ingen text.<br><br>Verkligheten: Gick bra att utföra efter VR-miljön med de komponenter som skulle monteras. Det svåraste var hur orienteringen på komponenterna skulle vara samt de moment som inte framgick i VR-miljö (typ skruva med insektsnyckel eller händerna) samt om det var viktigt att memorera vilken propeller som skulle sitta på vilken plats |
| 15 | 2 | Jag tyckte det var en bra genomgång för att lära sig att montera. På de industrier jag har monterat på har man fått monteringsanvisningar på papper och då var detta mycket bättre för då fick man en 3D känsla istället för bara 2D på papper. Det jag saknade lite med VR var att man kunde inte lägga biten fel som att det spelade ingen roll åt vilket håll delan sitter åt, bara den är på rätt ställe. Jag saknade också känslan av att montera något som att skruva på skruven som man gör i verkligheten men det saknar ju man på papper med. Så jag tyckte detta var en bra grundläggande genomgång men man behöver även känna på delarna i verkligheten innan man kan säga att man kan montera delen. |
| 16 | 2 | I början av VR-testet förstod jag inte alls hur jag skulle göra. Jag råkade trycka på teleporteringknappen och var tvungen att starta om då jag hamnade långt bort från där jag skulle vara. Jag hade även problem med bordet. När jag lutade mig över för att kunna se så hamnade jag på nåt vis "på bordet". Men efter ett par minuter så förstod jag att de gröna delarna skulle matchas och då blev det mycket enklare och mot slutet gick det riktigt fort. Det var även ett problem att jag kunde "gå igenom" komponenterna med min hand så att upplevelsen inte blev helt identisk med att faktiskt göra monteringen i verkligheten. I VR-världen var drönaren placerad åt andra hållet än i verkligheten, vilket förvirrade mig när jag skulle göra den verkliga monteringen. Vissa delar var inte heller identiska, tex så fanns det små hål på den stora fyrkantiga saken som inte fanns i VR. Overall tyckte jag att det var ett spännande test och med tanke på att jag innan aldrig testat att montera saker och bara testat VR en kort stund en gång tidigare så tyckte jag att jag lärde mig uppgiften på ett bra och snabbt sätt. Jag kan lätt se att det här skulle kunna hjälpa mycket i industrin. |
| 17 | 1 | Det var väldigt smidigt att först få testa på en simulering där man kunde göra fel utan att något kan gå sönder eller så, det kändes som att jag hade koll på vart allt skulle när jag kom till den verkliga monteringen. |
| 18 | 1 | Jag tyckte att VR-testet var roligt men då jag har lite små dålig syn så tyckte jag att det ibland var svårt att läsa vissa saker. Dock ändrades detta väldigt snabbt genom att bland annat vrida huvudet så att texten syntes direkt. Det verkliga testet var bra. Dock var inte drönaren i verkligheten placerad samma som i VR miljön vilket kanske är förvirrande för vissa men jag tyckte testet var enkelt och roligt. Och jag hade gärna gjort detta igen. |
| 19 | 2 | bra genomgång och enkelt att förstå |
| 20 | 2 | Väldigt kul att prova! Var svårt att när man väl greppat en komponent att vrida den så den skulle komma i rätt vinkel, man behövde släppa komponenten och ta upp den igen för att det skulle funka vissa gånger. Kändes konstigt att vara i en helt tom miljö med endast ett bord. |
| 21 | 1 | Det var cool att man faktiskt kunde bygga i verkligheten när man enbart gjort det i VR innan. |
| 22 | 1 | Svårt att se markeringen för placering om man inte stod vinkelrätt mot instruktionstavlan. Bilden blev suddigare efter en stunds användning. För att gör det mer likt borde det kunna gå att vrida modell så de står på samma sätt, i både VR och montering. Lite oklart om ordning av muttrar t.ex. spelade nån roll i verklig montering som den gjorde i VR. Placeringen av nästa monteringsobjekt i VR modellen bör bli tydligare. |