Design and Evaluation of a Trackable Patient Model to train Ergonomic Patient Transfers in Virtual Reality

Bachelorarbeit

submitted by

Simon Röhrle

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Universität Konstanz

Department of Computer and Information Science

Human-Computer Interaction

1.Gutachter: Prof. Dr. Harald Reiterer
2.Gutachter: Prof. Dr. Oliver Deussen

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Abstract

Injuries in the field of care are not uncommon. One area where these injuries occur is in the field of patient transfers. Physically demanding tasks, especially when under time constraints, can quickly result in injuries for both the caregiver and the cared-for if performed incorrectly. The kinaesthetics care conception is a movement system that supports the ergonomic transfer of patients and therefore minimizes the physical strain on both the patient and the nurse. Programs in which trainee nurses learn how to transfer patients based on the kinaesthetics care concept are already being offered at many government-supported schools in Germany. However, these programs are very limited and usually only consist of three lectures.

As part of this thesis, the Virtual Reality training application VRPatient was developed to support the training of ergonomic patient transfers. With this application, it is possible to practice a patient transfer without the need of an instructor or training partner.

First, related work is presented and explained to what extent it differs from the content of this thesis. Then, the requirements of the system were discussed and drawn up, based on which a tracking system was selected for the prototype. Afterwards the implementation of a prototype and its functions will be shown. To evaluate the implemented prototypes, a usability study was carried out with twelve participants. This study was guided by three research questions concerning user experience, immersiveness, and the possibility of the trackable patient model replacing a human as an exercise partner. While the feedback on the user experience and immersiveness was good, the study also showed that the trackable patient model still has some limitations compared to a human. The results of the study were discussed, and suggestions for improvement were made. Finally, potential future work for the extension of VRPatient was presented.

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1. Introduction

The situation of care in Germany is currently being discussed a lot in the media. The presence of nursing in the headlines is steadily increasing, and most of them report on the mental and physical stress on nurses. Due to the age pyramid in western societies, this shortage of skilled workers is forecast to be even greater in the future [1, 2]. The current situation shows that the understaffed staff even lacks sufficient training. In particular, the transfer of patients is stressful to the lower back and can lead to musculoskeletal disorders [3, 4]. Well-trained staff in the already busy system is therefore essential to guarantee the health of both the caregivers and those being cared for. One approach to addressing the problem is to conduct training transfers based on the kinaesthetics care conception. *"Kinaesthetics is the learning of movements that an individual commonly performs. The individual must repeat the motions that they are trying to learn and perfect many times for this to happen. While kinesthesis may be described as "muscle memory", muscles do not store memory; rather, it is the proprioceptors that give the information from muscles to brain"* [5] In Germany, the concept of kinaesthetics is currently taught once as a workshop, split into three days, and has gained popularity in the last 10-20 years [6]. Physically demanding tasks, as shown in figure 1.1, can quickly result in injury to both the nurse and the patient [3, 4]. The concept of kinaesthetics is supposed to help reduce the physical strain on patients as well as nurses. By creating an awareness of one's own body movements, the patient transfer should be made as safe as possible.

Figure 1.1.: Daily transfer of a nurse. The nurse has to transfer the patient from a lying to a sitting position and afterwards into the wheelchair.

Current support to train the ergonomic transfer of patients is very limited [7]. The SARS-CoV-2-pandemic in particular has shown that the overloading of nursing staff results in them increasingly quitting their jobs, since both the physical and psychological stress are getting too high [8]. While better training cannot completely solve the problem of skills shortages, it can help existing staff to work more efficiently and safely. This would also lead to fewer absences due to injuries, especially in the area of patient transfers. In the bachelor's project, a prototype VRPatient was developed to train the ergonomic transfer of patients (see figure 1.2). In this system, the users do not have a training partner (as patient transfers are usually practiced) but a training dummy (physical model) with which to carry out the transfer. This physical model is displayed to the trainee as a virtual patient. In order to match the position of the virtual patient with the position of the physical model, the physical model has to be tracked. The method used to track the physical model was discussed in the bachelor's seminar. In the bachelor's project, VRPatient was implemented with the selected tracking system. In this thesis, the design and execution of a usability study evaluating the trackable patient model will be presented. VRPatient was supplemented with further details for the study. The implementation of everything that was changed on the prototype for the study will be justified and discussed in detail in chapter 3.

Figure 1.2.: Prototype VRPatient: A Virtual Reality application to train the ergonomic transfer of patients.

The goal of this thesis is to evaluate the implementation of a trackable patient model that is used to train the ergonomic transfer of patients. The evaluation should provide information about whether or not patient transfers with a trackable patient model instead of a person would be accepted and therefore worth further research. The system should not only be evaluated on its usability. But also, for example, the emotions of the user that he has when using the system have to be considered. If the users of this system hate it or feel uncomfortable using it, they will not use it. An alternative VR training method will only be used if the user has a good user experience and likes using the system. Evaluating the system may reveal which aspects are still problematic and result in negative user experiences and which aspects are enjoyable and valuable for the user. The study results should also clarify to what extent it was successful to implement an immersive system and how it influenced participants in completing the task. It is to be investigated to what extent the trackable patient model is a good substitute for a real human. Are there significant differences between the trackable patient model and a human that impede meaningful simulation? Or can the trackable patient model completely replace the human as a training partner in certain areas, and if so, in which ones?

To make the goals operational, clearly articulated questions have to be set up so that they can be answered in the evaluation. To accomplish that, the three research questions below have been chosen:

RQ1: *Does the training of patient transfer with VRPatient provide a good user experience?*

RQ2: *Does the system deliver an immersive experience?*

RQ3: *To what extent is the simulated human patient in VRPatient a good surogate for a real human for the purpose of the training of patient transfers?*

At the beginning of this thesis, related work is presented in chapter 2 and shown how it differs from the content of this thesis. Afterwards, the design of the prototype VRPatient will be presented. Insights and decisions from the bachelor's seminar as well as the bachelor's project will be summarized in chapter 3. The selection of the tracking system was explained, which was the content of the seminar. After that, the design and implementation of the prototype will be presented. The purpose of chapter 4 is to evaluate VRPatient based on the research questions. The study design will be discussed in detail, and the results will be presented. These results will be discussed afterwards with regard to the research questions. Lastly, in chapter 5 conclusions are drawn and potential future work is shown as to how the prototype VRPatient could be further improved.

2. Related work

The following chapter examines related work to determine the similarities and how differences from the work of this thesis. While there are many works that investigate systems supporting the self-learning of movements, the number of works which address the self-learning of ergonomic patient transfers are very limited. In the following, works that support the self-learning of ergonomic patient transfers are presented.

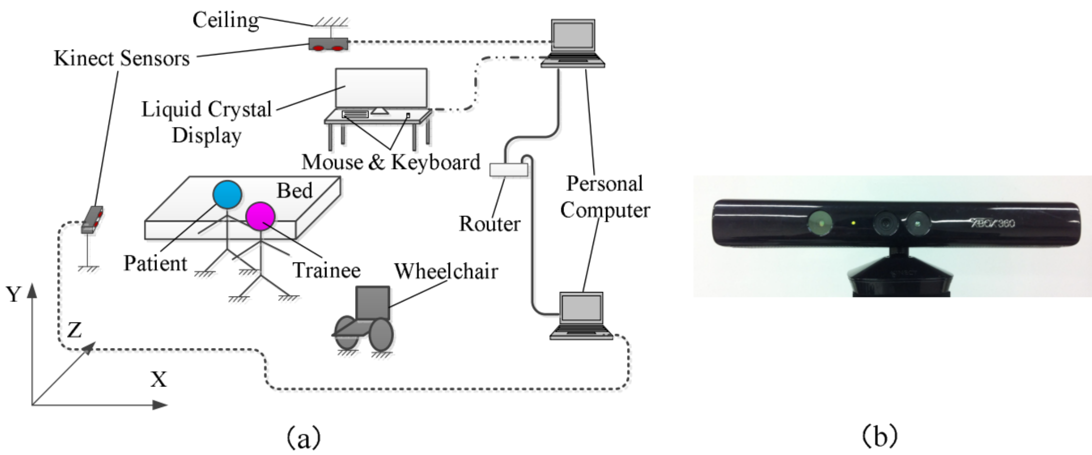

Figure 2.1.: (a) System architecture proposed by Huang et al.[9]; (b) Kinect sensor

Huang et al. presented a self-training system to assist nursing students in learning nursing skills.[9] The system architecture can be seen in figure (see figure 2.1 (a)). Their system uses two Kinect sensors (see figure 2.1 (b)) to track the posture of both the patient and the caregiver. The person practicing in the role of the caregiver has to transfer the person being cared for (simulated by a practice partner) from the bed to a wheelchair. Based on the tracking data, the trainees receive automatic feedback from the system. The feedback is shown to the trainees in the form of a checklist. In this list, the trainees can see which parts of the tasks they have performed correctly and which they have performed incorrectly. A control test was carried out to evaluate whether the use of the system with the additional feedback offers advantages over learning with textbooks and demonstration videos. For this test, ten apprentice nursing students who were at the beginning of their education were recruited. Five of the participants trained with the system, and five trained with a textbook and video instruction as a control group. A 160-cm-tall woman was brought in to simulate the patient. The experiment was divided into four sections. The first section was the learning period. Here, both groups were given seven minutes to learn the basics of the transfer and watch the demonstration video at least twice. After that, the participants of both groups completed a pretest to record their skills. After that, the participants of both groups had 20 minutes to carry out the patient transfer. The group that used the system received automatically generated feedback, while the control group was only allowed to use the textbook and demonstration video. A nursing teacher evaluated the participants' pre-test and post-test using the same checklist, that the participants get as a feedback. One point is given for each task on the checklist that the participants have completed correctly. No point for every task that they did not complete correctly. The points generated by the participants in the pre-test were then compared to the points generated in the post-test to see how much the participants could improve. The group that trained with the system and received feedback improved by an average of 79%, while the control group only improved by 48%.

Nakamura et al. investigated the effects of using a robot patient instead of a human in a wheelchair transfer.[10] The robot used was 160 cm tall and weighed 40 kg (see figure 2.2). The robot was equipped with motors in the shoulder and elbow joints. A thermobrake was installed in both knee joints. The thermobrake and motors can be controlled to simulate the paralysis of different parts of the body. Through the audio output, the robot can express pain. In their research, they wanted to clarify two points. First to *"Clarify the effectiveness of self-study by nursing students by using our robot patient."* and second to *"Clarify the effect of more "patient-like" robot patient on the self-study of nursing students."*[10]

Figure 2.2.: The robot that was used by Nakamura et al. as a substitute for a human.[10]

To clarify the points mentioned, an experiment was carried out with twelve nursing students. These were more advanced in their education, with three in their fourth internship year and nine in their third. The study was divided into three steps. First, the participants had to watch a wheelchair transfer video created by nursing teachers. Next, the participants had to perform the wheelchair transfer six times with the robot. In this step, the participants were observed by a nursing teacher and evaluated using a checklist. Finally, the participants had to complete questionnaires related to the self-study with the robot. The results of the study showed that all twelve participants had a worse score in the first run of the transfer than in the last run. Nine out of twelve participants had their best score in the last run. This shows that the participants could improve by practicing with the robot. The opinions that the participants had about the robot were varied. Many participants shared positive feedback. It was said that some aspects can be better practiced with a robot than with friends. For example, friends would sometimes be too supportive of the trainee because they didn't want the task to be too strenuous for the other person. The robot does not give this help, and the transfer therefore feels more realistic. Some participants rated the participant's heavy weight positively. Still, others remarked that the robot was too heavy for them to lift. One participant commented that he was "rude" because the robot felt more like a thing than a real human.

Kopetz et al. designed and evaluated a smart glasses application for Google Glass that supports the trainee with instructions during the task.[11] The bed-to-wheelchair transfer was used again as an example training scenario. The evaluation was carried out with 29 nursing students (23 bachelor and six vocational students). The main three research questions were: *"acceptance by potential users, learning effects, and implications for further development"*.[11] In the results, the participants described both advantages and disadvantages of the system. Advantages included, for example, increased self-confidence through the reminder of the different steps. The participants also praised the clear structure that they got from the instructions. Disadvantages reported by the participants were, for example, distraction, more required time, and the fact that they needed one hand to interact with the device. Other effects reported by Kopetz et al. included lower error rates. The transfer of the participants was again evaluated by two nursing teachers. The participants' performance on the task with and without the glasses was compared. The results showed *"slightly lower error rates"*[11] in the transfers in which the AR application was used. One suggestion for improvement expressed by the participants was that the touch-based interaction would not be acceptable in terms of hygiene. Some participants would find it better if the system could be controlled by voice.

Kamachi et al. evaluated a system named 'Posture Coach'.[12] As the name suggests, the system gives feedback on posture based on a mobile tracking approach. Their goal was to assist caregivers who work from home with their system in order to reduce back injuries. The user of the system wears several inertial measurement units (IMUs) from XSens. (See figure 2.3) These are used to measure the flexion of the spine. If the flexion exceeds a certain value, auditory or vibratory feedback can be given. In the evaluation, only auditory feedback was used.

Figure 2.3.: The 'Posture Coach' system.[12]

To evaluate the system, a study was conducted with 20 participants (10 women and 10 men). Ten of the participants were assigned to an experimental group, and ten to a control group. A 25-year-old man, 175 cm tall and weighing 87 kg, simulated the patient in the study. The study was conducted on two consecutive days. On day one, each participant had to watch a 7-minute video on back injury prevention. Then the participants were asked to complete the first two training trials. The experimental group received auditory feedback every time they bent their spines further than the specified threshold. The control group received no feedback. On the second day, two more tasks were performed by the participants. The control group again received no feedback, and the experimental group only received feedback every other time they bent their spines further than the specified threshold. After two weeks and two months, the participants were again asked to carry out the tasks. Participants in both groups received no feedback. The results of the study indicate that training with 'Posture Coach' can be helpful for inexperienced caregivers. Using the system for two days at one hour intervals can have long-term effects lasting up to two months. It reduces the time during which the caregiver's spine is bent to a degree that is harmful to health in the long run.

The described work extended and tested the traditional transfer training. The goal of the systems, as well as the goal of VRPatient, is to use new ideas to make patient transfer learning more effective. The content of this thesis is distinguished from related work in the following ways:

The works described only measure the user experience superficially or not at all. Only Kopetz et al. used a standardized questionnaire to measure aspects of the user experience.[11]

The qualitative data obtained in the presented works is limited. Nakamura et al. used a free description in the questionnaire.[10] However, no interviews were conducted for any of the works, which could have provided additional insights.

None of the related work provides an immersive virtual reality system with a trackable patient model. There are immersive virtual reality systems that support the self-learning of movements, such as from Takala et al. a virtual reality system to train martial arts.[13] To my knowledge, however, there is no such immersive system with a trackable physical patient in the field of care. This assessment is consistent with the statement by Mäkinen et al., who state that: *"...only very few previous work made use of Virtual Reality HMDs to support the training of nursing-care students."*[14] Gutiérrez et al. compared knowledge acquisition between a group that used a fully immersed VR environment and another group that used a computer screen VR environment.[15] Both groups benefited from the VR training. However, it was found that the fully immersed group showed *"significantly higher gain"*.[15] An immersive system could therefore help the trainees to learn how to transfer a patient more effectively.

3. Prototype VRPatient

The system that was implemented (VRPatient) is a training system for trainee nurses to practice ergonomic patient transfer in Virtual Reality (VR). In this training scenario, the trainee wears a head-mounted display (HMD) and tracking gloves. In front of the trainee is a bed with a manikin (physical model) lying on it. In the virtual world, the trainee is located in a virtual hospital room. The physical model is visualized as a virtual patient in VR. The bed on which the physical model lies represents a virtual bed. The tracking gloves are used to visualize the trainee's hands in VR. A tracking system is needed to capture the position and orientation of the gloves, the physical model, and the HMD. The position and orientation of the gloves and the physical model are used to visualize them in the correct position in the virtual world. The position and orientation of the HMD have to be tracked as well, so that the person practicing is in the correct position and orientation in the room.

3.1. Choice of the Tracking System

3.1.1. Requirements

The goal of the seminar paper was to compare different tracking systems and select one that is going to be used to develop a prototype in the Bachelor Project. To decide which tracking system would be suitable for the prototype, six requirements were set. These requirements have to be fulfilled to get an accurate simulation of a patient transfer in the virtual world. Based on these requirements, different tracking systems were compared and the most interesting systems are presented in section 3.1.2.

Summary of Requirements

- **Real time tracking and mapping**: Keeping the latency as low as possible
- **Full body tracking**: Full body of the physical model needs to be tracked
- **Occlusion-stable tracking**: Physical model should be accurately tracked, even if occlusion occurs
- **Precise mapping**: The position of the virtual body has to precisely be mapped on the position of the physical
- **Free movement of physical model**: The tools that are used to track the physical body should not negatively influence the movement
- **Affordability**: The costs and the setup effort of the system should be as low as possible

In the following, the reasoning for the requirements will be explained briefly:
The latency of the system should be as short as possible. This is important to ensure that the new skills the participant learns can be applied to the real world. If trainees move the physical body and they see the movement in VR with a great delay, then proper practice is not possible and it would not help to train with such a system. Patient transfers usually involve most of the person's body and, many times, even the whole body. I.e., helping a patient from a lying position to a sitting position. This is why the full body of the physical model needs to be tracked. Nurses are also often in close physical contact with the patients or, for example, leaning over them, so it is important to ensure that the tracking stays stable for the whole time, no matter in what position the nurses need to interact with the patients and even if occlusion occurs. The mapping of the virtual patient on top of the physical one should also be as precise as possible. The greater the tracking and the mapping work, the smaller the offset of the virtual and physical body will be, which will then lead to a better user experience. Tracking the patient with a system that negatively influences the movement of the physical model is also something that should be avoided, because only if the physical model can move freely it can be ensured that every procedure is possible to train with the system. The system should also be affordable, so that in the bachelor project and its later use for patient transfer practice is possible.
Based on these requirements, different tracking approaches from related work were presented and compared to each other. The most promising ones are shown below.

3.1.2. Tracking Systems

Azure Kinect DK

Table 3.1.: Overview of the matched requirements for Azure Kinect

Requirements	
Real time tracking and mapping	Low latency [16]
Full body tracking	Capable of tracking the full body [17]
Occlusion-stable tracking	Occlusion problems [18, 19]
Precise mapping	Problems with fine movements [20]
Free movement of physical model	Perfect, since nothing is attached to the body
Affordability	Only 1 Azure Kinect DK is needed and with 400 Euros, it is relatively cheap, compared to the other systems

Figure 3.1.: Azure Kinect Device

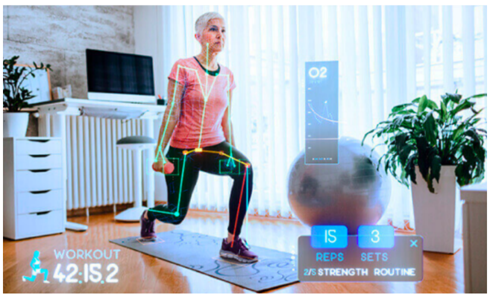

Figure 3.2.: Full body tracking using Azure Kinect DK

M. Tölgyessy et al. [21] evaluated the skeleton tracking abilities of the Azure Kinect. Microsoft´s Azure Kinect is a depth camera, and it has progressive functions for machine vision and AI-Sensors [17]. It is like its predecessor, the Microsoft Kinect, a markerless motion capture system. Due to the Azure Kinect being a markerless motion capture system, there is no need for additional markers to be attached to the body. Therefore, the setup is very simple and inexpensive since you only need the Azure Kinect to track the full body. M. Tölgyessy et al. [21] compared the Azure Kinect with the Kinect v1 and the Kinect v2 and wrote in his results that the Azure Kinect "surpasses its discontinued predecessors, both in accuracy and precision". However, there are some problems that markerless motion capture systems like the Azure Kinect have. Research publications often report problems when a person is partially occluded [22, 19]. Also, the tracking of fine movements is not well recognized by the Azure Kinect [20].

Optitrack

Table 3.2.: Overview of the matched requirements for Optitrack

Requirements	
Real time tracking and mapping	Low latency [23]
Full body tracking	Capable of tracking the full body
Occlusion-stable tracking	Multiple cameras lead to less occlusions, multiple markers lead to stable tracking, even if few markers are occluded.
Precise mapping	Very accurate [24]
Free movement of physical model	Due to the markers being very small, they only effect the movement minimally
Affordability	At least 10.000 Euro and a complex setup is far more expensive than the other systems.

Figure 3.3.: Optitrack suit with marker

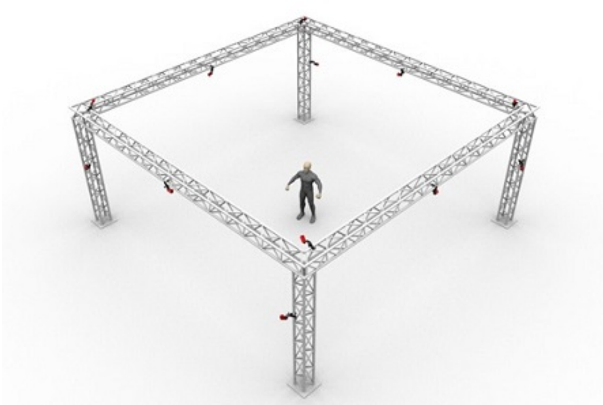

Figure 3.4.: Optitrack setup

T. Ameler et al. [25] wrote a comparative evaluation of the low-cost Swept Angle Laser Tracking system, Steam VR Tracking, and the OptiTrack System for Medical Device Tracking. In the expiration, the tracking errors are evaluated and common issues like occlusion or reflection also occur. Optitrack is a marker-based motion capture system. As shown in Figure 3.3, the person to be tracked has multiple markers on their body. These markers are being tracked by multiple cameras around the person, as shown in figure 3.4. The number of cameras is flexible, but if you want to buy a system directly from Optitrack, it includes at least six and even up to 24 cameras. Due to the large number of markers and cameras used in this system, the tracking is very accurate [24]. The person that is tracked usually wears a tight suit, which is used to attach the markers to it. These suits are reported to be uncomfortable because they need to be tight to not move. However, this would not be a problem for the system because the physical model wears the suit. Marker-based tracking systems, especially Optitrack, also have a low latency [23] and they are more stable when occlusion occurs than markerless tracking systems [26]. One problem the system has is its cost and its complicated setup. New optitrack systems that would support all the requirements start at around 10.000 euros.

Vive Trackers

Table 3.3.: Overview of the matched requirements for Vive Tracker

Requirements	
Real time tracking and mapping	The tracking and mapping time needed is low, due to marker-based systems generally having a low latency [27], if the inverse kinematics solver that is used is fast.
Full body tracking	There are 6 Tracker needed at the hands, feets, the hip, and one the head. Tracking these 6 Tracker at once is possible.
Occlusion-stable tracking	In most of the works, close physical contact does not happen, but other work shows, that the marker-based systems are very robust. [28] However completely covering multiple Tracker would lead to a loss of information.
Precise mapping	With the help of inverse kinematics, it is possible to estimate the full-body motions and map the virtual model on top.
Free movement of physical model	The movement is slightly influenced, because of the size of the Vive Tracker. However pretty much every movement used in nursing is still possible and new models are becoming smaller.
Affordability	The system used would cost atleast 2 thousand euros, depending on the way the hands of the trainee are tracked. That makes it more expensive than most markerless systems i.e. Microsoft Kinect , but also cheaper than other modern marker-based systems i.e. Optitrack.

Figure 3.5.: Vive tracker 2.0

Figure 3.6.: Vive tracker setup

P. Caserman et al. [28] reconstructed a full-body avatar by tracking the position and orientation of the head, hands, feet, and hips. The user held an HTC-Vive controller on every hand and, additionally, a Vive-Tracker was bound on the feet and the hip. To estimate the full body pose, they applied one of the most popular inverse

kinematic methods. Their research goal was to find out which IK-method was the most accurate and fastest at solving the IK-Problem.
Vive Trackers can be attached to certain parts of the body. However, when these trackers are attached like in figure 3.5, methods like inverse kinematics have to be used to estimate the full body-motions [29]. Attaching one Vive Tracker to each foot, one to each hand, one to the hip, and one to the head is enough to track and display the full body with inverse kinematics [29]. The size of the Vive Tracker (2018) is ø 99.65mm * 42.27mm (height) and 89g in weight. That makes the markers larger than the ones that are used for other systems, i.e., Optitrack. However, due to the low number of trackers that are needed, the movement does not get influenced as much and there are new products like the Vive Tracker 3.0 or the Tundra Tracker, which had their kickstarter campaign in 2021. So, even if a system is designed for the Vive Tracker 2.0, a Vive Tracker 3.0 or a Tundra Tracker could be easily added to the system. This could be helpful because the size of the Tundra Tracker is much smaller and therefore the movement is less influenced.

3.1.3. Summary

The different tracking approaches presented have different advantages and disadvantages. However, one very important point is the stability of the tracking. To guarantee good training, the offset between the virtual and physical patient has to be as low as possible. Otherwise, the training will not feel natural and the training will most likely not be useful for the situation of a real patient transfer.
Systems like the Azure Kinect DK which do not use attached markers, are handy to use and easy to set up. However, the tracking of body movement does not work well for fine movements. Also, when occlusion occurs, the tracking does not stay stable. This is critical because, in a patient transfer, occlusion of certain body parts will happen with certainty. Tracking systems with trackers on the physical patient are more precise and more robust at tracking when occlusion occurs. The 2 most interesting systems that are also mentioned in section 3.1.2 are the Optitrack system (see figure 3.4) and the system with the Vive trackers (see figure 3.6). The difference between the two and the decision that had to be made in the selection was to weigh out the quality of tracking against the affordability. New Optitrack systems deliver a more precise tracking than the system with Vive Trackers. Due to the high number of cameras and markers on the body, the Optitack system is still tracking accurately, even if some markers are occluded. The Vive tracker system, on the other hand, would be far less expensive. For a functioning full body track of the physical patient, only six Vive trackers would be needed. Two trackers would be placed on the feet, two on the hands, one on the head and one on the belly of the physical model. A method called inverse kinematics is used to create a full body in the virtual world out of these six tracking points. With inverse kinematics, it is possible to calculate the position and rotation of, say, the elbow or the knee using only the position and rotation of the six trackers. Although this method leads to accurate tracking, the Optitrack system is still unmatched in terms of tracking and mapping quality. In the conclusion of the seminar paper, the Vive Tracker system prevailed against the Optitrack system. This later turned out to be a misjudgment. In section 3.2, problems with implementing the system with the Vive trackers will be shown. The main reason for the decision in the seminar paper was the affordability of the Optitrack setup. If a system with accurate tracking could be implemented with the Vive trackers, there would be no reason to use the far more expensive Optitrack system. The first prototype was therefore developed with the Vive Trackers.

3.2. Implementing a System with a Trackable Patient

This section first shows the steps of the implementation of the Vive trackers and the reason why they were not used in the end and instead the Optitrack system. Then it is explained why the conclusion of the seminar was reconsidered. At the end, the final Optitrack implementation is described.
The goal of the bachelor project was to implement and add a trackable patient model to a Unity project, that

was created in an earlier master thesis by Daniel Schweitzer with the title: "VITT — Virtual Transfer Trainer: Design and Evaluation of a Virtual Reality System to Support the Self-directed Training of Ergonomic Patient Transfers".[30]
He implemented a VR system in which nursing students are able to train patient transfers without the need for instructors or training partners. In his implementation, the trainee also wears trackable gloves that get displayed as gloves in the virtual world (see figure3.7). The magenta highlight is a translucent version of the patient in the position that the patient has to be moved to complete the next transfer step. The different transfer steps are on the instruction panel on the right side of the bed. Behind the bed is a video tutorial that shows how the next step is performed. The virtual patient can be moved by the virtual glove, interacting with the patient. The trainee does not interact with a patient in the real world. In my bachelor project, a physical model in the real world was added, that the trainee is able to touch and interact with.

Figure 3.7.: Implementation of Daniel Schweitzer [30]

First, a manikin that serves as the physical model was needed. To create an immersive system, it is important that moving the physical model feels like moving a human body. In the end, the BUIYY patient care doll [31] was selected. The physical model is 170 cm tall and has a weight of 15 kg. Moving this model feels close to moving a human, because it is only possible to bend the body parts at the joints. The height is also ordinary. The weight does not correspond to that of a human, but for the study there could be weight attached to the model if necessary.

3.2.1. Vive Tracker System

The main setup with the Vive tracker approach is to have 6 Vive trackers that are fixed with straps to the physical model at both feet, both hands, the hip, and the head. The trackers are being tracked by two base stations from

different angles. The physical model lies on a table with a mattress on it, which represents the bed in the virtual world. The trainee is able to freely move around the table and wears the HMD together with the MANUS gloves to track the position of the head and the hands. The MANUS gloves are also capable of tracking finger movements, which helps to make the training feel more immersive.
With the purchase of the MANUS gloves, it is possible to get access to MANUS Polygon (see figure 3.8). MANUS Polygon is a motion capture software that is able to stream body data into Unity. From the 6 trackers, a full body can be created with the inverse kinematics (IK) solver that MANUS Polygon provides. For that to work, a series of calibration steps have to be completed. With this system, the full body of the physical model is tracked and can be displayed in Unity as a virtual patient (see figure 3.9). However, there are still several limitations to this approach, especially with regard to the study. The first problem is that it is difficult to get the calibration accurate with the physical model. There are a lot of body poses for which at least three or more people are needed to accurately hold the physical model in the desired position. After testing the system, the results of the mapping were not satisfactory. This can be attributed to two problems. The first one is that in the complex calibration, body poses have to be performed. As a human, they are easy to execute. However, it is difficult to place the manikin in the correct position because several parts of the body must be properly angled. Due to the complexity of the body poses and the high quantity of calibration steps, the calibration of the physical model will not be as accurate as calibrating with a human. The second problem might be that the trackers can not be detected from every angle if two people are standing close to the model to hold it for the calibration. Although this problem could be solved by calibrating until a sufficient quality is achieved. MANUS Polygon saves the information for the calibration. However, a tracker only has to be slightly twisted or slipped to worsen the mapping. In regards to the study, some participants may touch the trackers, which would result in the need to calibrate the physical model again.
The next limitation is the tracking and mapping quality. To get an idea of the quality of the Vive tracker approach, there is a link to a short demo in the sources.[32] In the first part, the calibration was carried out with a human to show how the tracking could work with a proper calibration. In the second part, when carried out with the physical model, there is already a greater offset between the virtual and the physical model. This is particularly visible when the hand of the model is put on its stomach. Although the offset is small when the calibration is carried out properly, this approach can not handle occlusion of the trackers. If one tracker on the feet or hands is occluded, it will lead to a complete loss of information about the corresponding leg or arm. This problem could only be solved by putting more trackers on the physical model. However, this would negatively influence the free movement of the physical model due to the size of the Vive trackers.

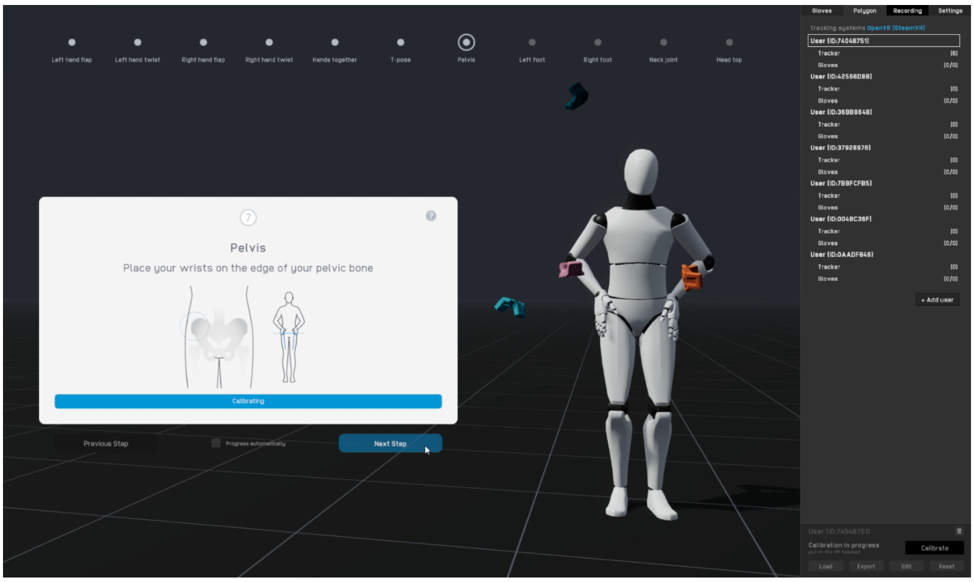

Figure 3.8.: MANUS Polygon

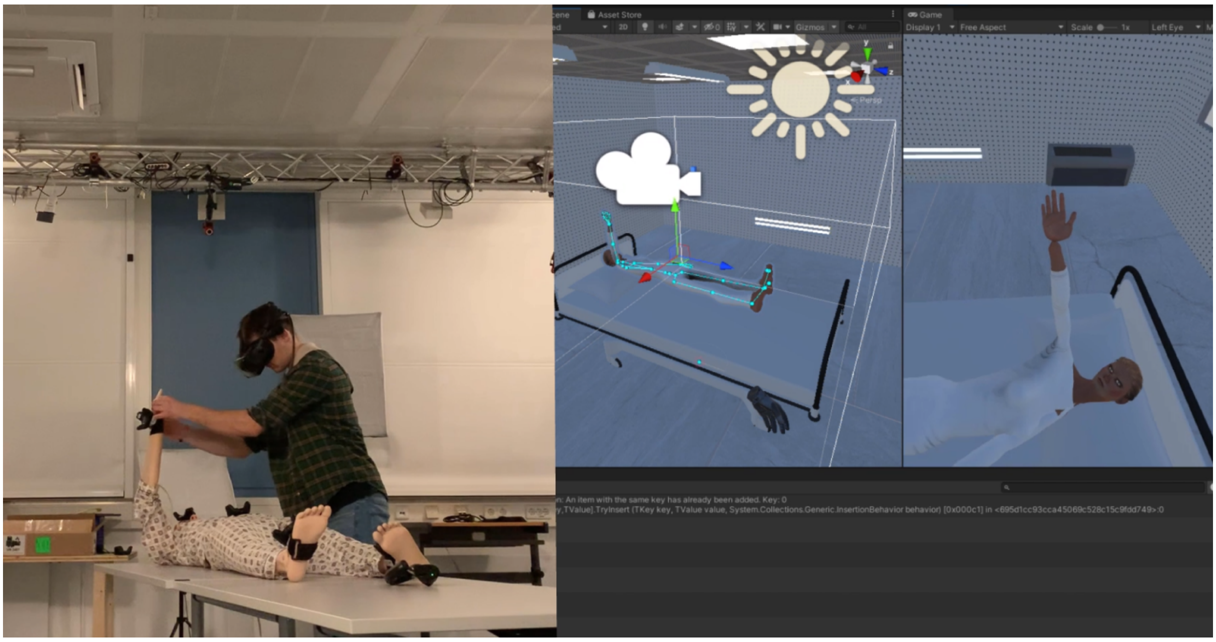

Figure 3.9.: Tracking physical model with Vive trackers

3.2.2. Optitrack System

Due to the many problems that would come with the Vive tracker approach, especially in regard to the study, the decision in the seminar conclusion was reconsidered and a second prototype with the Optitrack system was implemented. Early tests with the system were already convincing, with accurate tracking quality.
In the Optitrack system, the physical model wears an Optitrack suit (see Fig. 3.10) on which several markers, in a pattern given by Motive, are attached. Motive is the software platform to control motion capture for this tracking application. The markers on the physical model are tracked by 20 cameras. These cameras are all in fixed positions on the ceiling in different locations and all point to the middle of the room. The MANUS gloves are still used to track the trainee's hands and fingers. Optitrack markers are attached to them to track their position. The Valve Index is the HMD, which is equipped with a Valve Index Clip from Optitrack to track the HMD with the Optitrack cameras. The physical model on the table represents the virtual model on the virtual bed. Before implementing the Optitrack generated tracking data into the project, the tracking quality was tested in Motive. To get an idea of the tracking quality, short demos are linked for each test. First, the skeleton tracking was tested (see Vid. [33]). For that, the body had to be calibrated. To calibrate the physical model, it must be set up in a T-pose. This is already a great advantage to the Vive Tracker approach. There, the calibration took several minutes with complicated poses. Next, the hand and finger tracking were tested (see Vid.[34]). The hand as well as the finger movements were tracked accurately. Unfortunately, Motive does not support streaming the movement of only the hands into Unity yet. This is why the position of the hands is streamed into Unity from Motive and the movement of the fingers from MANUS. MANUS depicts the fingers relatively accurately, but the finger movement is not actually tracked; only the bending angle of the fingers is measured. The Valve Index does not have any Optitrack markers attached to it. This is why a Valve Index Clip was attached to it and also tested at last (see Vid.[35]). The tracking results were all very accurate and fulfilled the requirements discussed in the seminar recap, except for affordability, which has to suffer as a result. The Optitrack system is superior in two of the seminar requirements due to the number of cameras and markers. The first one is the precise mapping, which is better in the Optitrack system, as can be seen in the demo videos. The occlusion stable tracking is the second. A loss of one tracker results in a loss of information about certain body parts in the Vive tracker system.

On the other hand, the Optitrack system can handle occlusion of body parts better, as can be seen in the videos. This is why the finished implemented system uses Optitrack instead of Vive trackers, even if the affordability of the system has to suffer.

Figure 3.10.: Physical model with Optitrack suit

3.2.3. Creating the Virtual Model

The following section shows how the virtual model was created. The software that was used to create a character with bone structure was Character Creator 3 (CC3). In the first attempt, a character created by Daniel Schweitzer, recently created for his master's thesis [30], was used as the patient model for this project. The size of this character had to be matched with the size of the physical model that is used in the project.

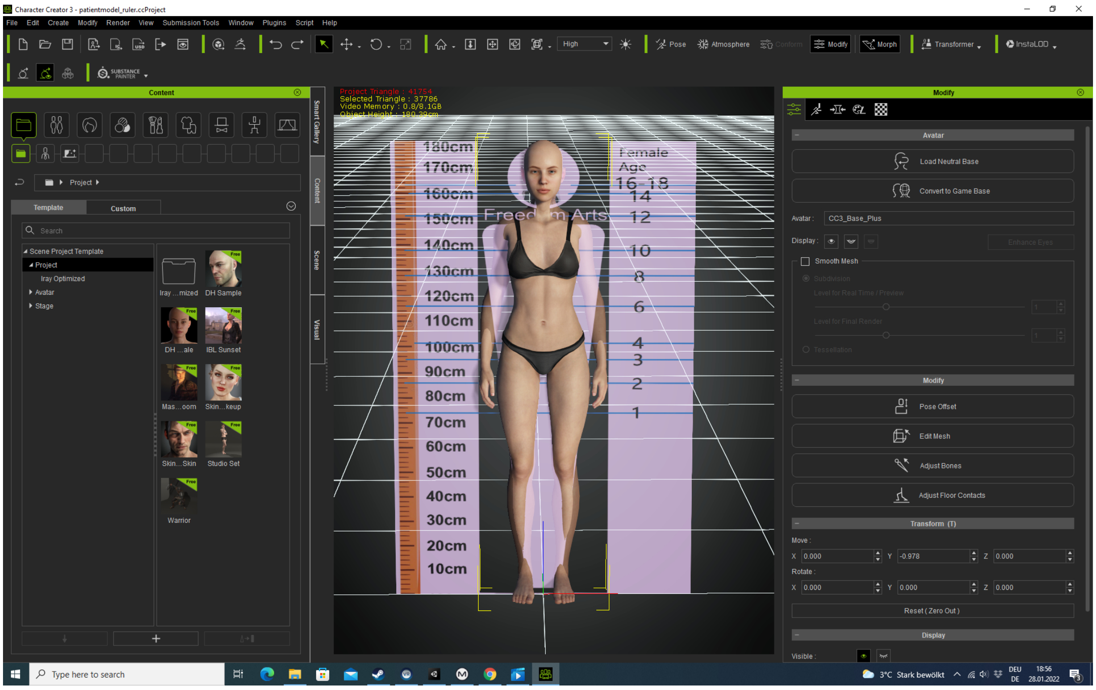

Figure 3.11.: Character Creator 3

The main screen of CC3 is depicted in Figure 3.11. On this screen, it is possible to make adjustments for the character like the size of the different body parts, stature, and clothing. The ruler in the background was imported to measure the different body measurements of the model. The lengths of the different body parts of the physical model were measured. The virtual model was adjusted by changing the length and proportions of the model. This character was then imported into Unity (see fig.3.12) as a High Definition Render Pipeline (HDRP) model, because the project of Daniel Schweitzer is a HDRP project.

Figure 3.12.: Virtual model in Unity

After the basic functions of the system were implemented, it turned out that there was still an offset between the virtual and the physical patient. This was traced back to the measurements of the virtual model not matching those of the physical one in every part of the body. Although the height and length of the body parts of the physical body were measured, the circumference of the limbs of the virtual model was not completely accurate. Another method, other than measuring the physical model and changing the size manually, was to scan the physical model and import the scanned model into CC3. A 3D scanner called "EinScan H" [36] with hybrid (LEDinfrared) light source was used to create a 3D scan of the physical model.

Figure 3.13.: EinScan H 3D Scanner

The physical model was scanned both with, and without clothes. In this system, the physical model has to wear its suit to fix the markers on it. The suit is thin, and because the scan without the suit was more precise, the scan without the clothes was used. The reason for the scan without the clothes being better is that the camera has more clues if the model is not in one uniform color. The 3D model scan of the physical patient without clothes was then imported into CC3.

4. Evaluation

This chapter is about the evaluation of the prototype VRPatient. A usability study was carried out to evaluate different aspects of the system. First, the design of the study will be presented. After that, the execution and the results of the study are shown and discussed. The study was designed with the help of the DECIDE framework of Rogers, Preece, and Sharp [37]. This framework provides a checklist to help plan an evaluation study. The DECIDE framework consists of the following 6 items:

i **D**etermine the goals

ii **E**xplore the questions

iii **C**hoose the evaluation methods

iv **I**dentify the practical issues

v **D**ecide how to deal with the ethical issues

vi **E**valuate, analyze, interpret, and present the data

It is important to note that dealing with the items takes place iteratively. When deciding on some items, others are changed in turn. Jenny Preece et al. also state that *"when working with the DECIDE framework, it is common to think about and deal with items iteratively, moving backwards and forwards between them after taking the first pass through each one."*. In the following, the different items will be discussed.

4.1. **D**etermine the Goals

The goal of this thesis is to evaluate the implementation of a trackable patient model that is used to train the ergonomic transfer of patients. The evaluation should provide information about whether or not patient transfers with a trackable patient model instead of a person would be accepted and are therefore worth further research. The general goal correlates with the first research question about the user experience. The system should not only be evaluated on its usability. Other aspects, such as the emotions that the user has while using the system, have to be considered as well. If the users of this system hate it or feel uncomfortable using it, they will not use it. An alternative VR training method will only be used if the user has a good user experience and likes using the system. Also, the aspect of cyber sickness [1] has to be considered in this system. Physical activities in combination with VR, especially with users that might have their first touchpoint with VR, could lead to users getting cyber sick. That would in turn mean a bad user experience. Evaluating the system may reveal which aspects are still problematic and result in negative user experiences and which aspects are enjoyable and valuable for the user. One goal is to find out to what extent it was successful to implement an immersive system and how it influenced

[1] "[]... VR sickness occurs when exposure to a virtual environment causes symptoms that are similar to motion sickness symptoms." [38]

participants in completing the task. With an immersive system, it would be possible to influence the trainee. Stress could be generated by making the virtual world hectic, and a realistic training scenario could be played through. This goal is achieved by answering the second research question. The purpose of the trackable patient model is to create an alternative to the exercise partner. Another goal is to find out to what extent the trackable patient model is a good substitute for a real human. Are there significant differences between the trackable patient model and a human that impede meaningful simulation? Or can the trackable patient model completely replace the human as a training partner in certain areas, and if so, in which ones? It is the goal to create clarity about the points just mentioned with the results of the study.

4.2. Explore the Questions

To make the goals operational, clearly articulated questions have to be set up so that they can be answered in the evaluation. To accomplish that, the three research questions below have been chosen. RQ1 is about the whole user experience, including usability, when using the system. RQ2 is about the system delivering an immersive experience, while RQ3 is more specific and only about the trackable patient model as a surrogate for a human.

RQ1: *Does the training of patient transfer with VRPatient provide a good user experience?*

RQ1 asks about the user experience that VRPatient provides. If the system has a high user experience, the will of the user to use it again should increase. The study should show whether using the system offers a high user experience, which aspects contribute to this, and which aspects prevent it.

RQ2: *Does the system deliver an immersive experience?*

RQ2 asks whether VRPatient has managed to create an immersive experience. The user's feeling of presence and the influence that comes with it should be investigated. The study should show if interacting with the patient in the training scenario feels like diving into a real (virtual) world.

RQ3: *To what extent is the simulated human patient in VRPatient a good surrogate for a real human for the purpose of the training of patient transfers?*

Patient transfers are currently practiced in such a way that one person is practicing and the exercise partner is representing the patient. RQ3 questions to what extent is the simulated human patient a good surrogate for a real human or an exercise partner. What differences might there still be between a real person and a simulated human patient when it comes to practicing patient transfers? And to what extent is patient transfer training possible with the simulated human patient?

4.3. Choose the Evaluation Methods

In the following section, the participants will first be discussed. Next, the apparatus is described, giving details about the design of the study and the hardware and software used. After that, the tasks that the participants had to perform in the study are described. Next, procedure of the study will be presented in detail. Finally, the questionnaires used and the data obtained from them are presented.

To evaluate the system, a usability study was carried out. The participants had to perform a predetermined set of tasks with VRPatient. Different questionnaires as well as a semi-structured interview about the tasks executed by the participants were designed to answer the research questions from different perspectives.

4.3.1. Participants

The study was conducted with 12 participants (plus 1 pilot study participant). Initially, it was considered appropriate to only choose participants who work in care. However, this is difficult due to the limited time window, as it has turned out to be way more difficult to recruit people from nursing for the study than students. Unfortunately, it was not possible to collect enough quantitative data from participants who have experience in nursing to conduct statistical tests. However, it was still possible to recruit one person who works in care. This could be helpful because the person might deliver interesting qualitative data due to their professional insights.

4.3.2. Apparatus

The study was conducted in a laboratory room (see Fig. 4.1). Since the Optitrack approach has been chosen for the study, a room with Optitrack cameras is needed to track the movement of the physical patient. The mattress is in the center of the room, on top of a structure made up of two height-adjustable tables. Height-adjustable tables have been selected for the study, because different participants of different sizes should have the same ability to use the system. On top of the mattress is the physical patient, with whom the participants interact with the HMD and the tracking gloves that they are wearing while doing so. Two cameras on the ceiling record the study. One camera can be seen in Fig. 4.1. The other camera is right where the photo was taken from. These cameras are aligned towards the middle of the room, so that the study is always recorded from 2 angles, no matter the position of the participant. The place of the head of study is on the left side. From here, starting the system and recording the data occurred. Also, the semi-structured interview at the end of the study took place there. The blue glowing cameras at the top are the Optitrack cameras, and there are a total of 20 pieces.
The system was implemented with Unity[39] in version 2019.4. Motive 3.0[40] was used to stream the data with the positions of the hands, the HMD and the physical patient into Unity. The MANUS Core[41] version 1.9 was used to detect the finger movement of the MANUS gloves. To integrate the HMD into the system, SteamVR[42] version 1.23 was used.

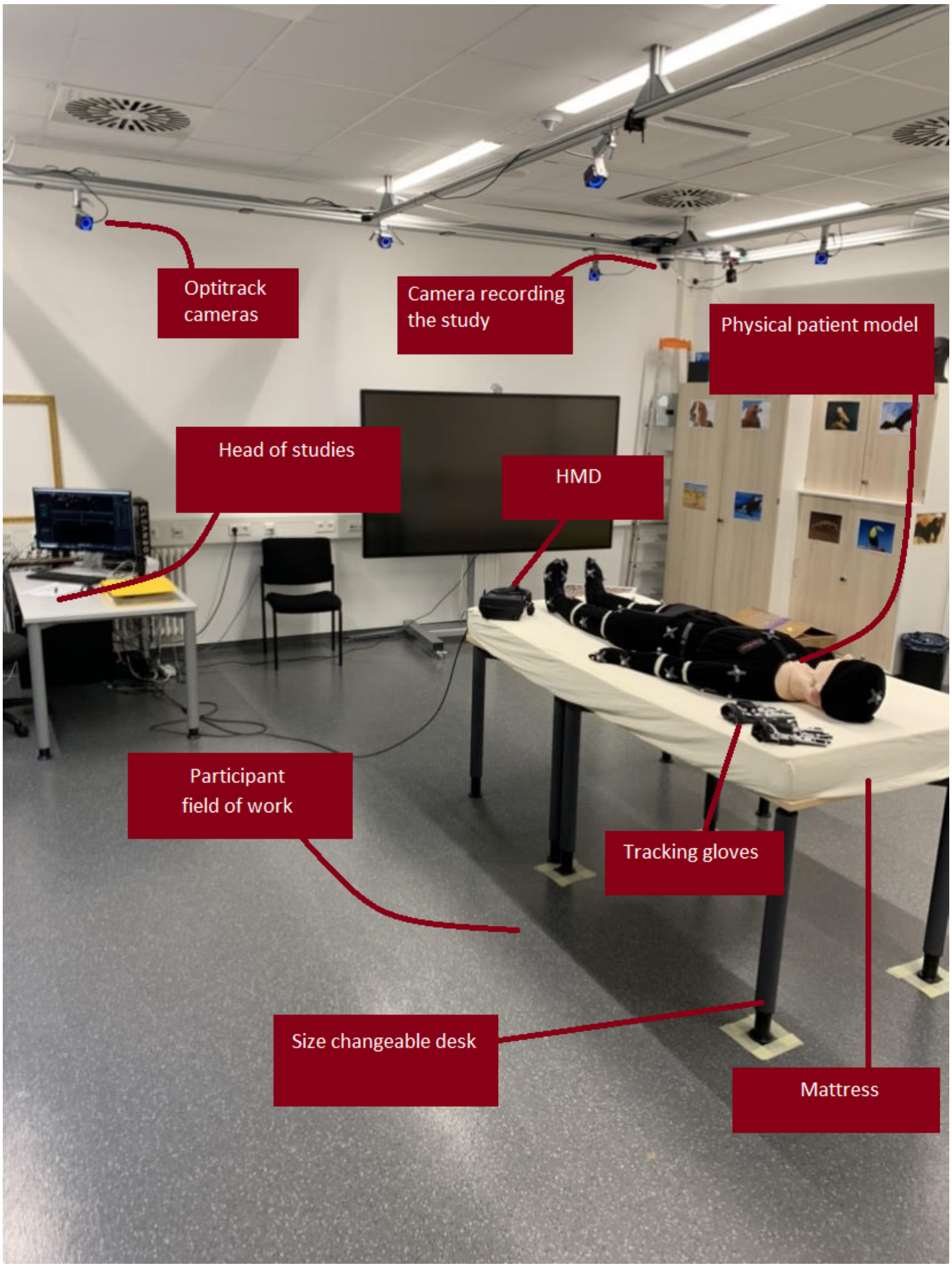

Figure 4.1.: The experimental setup of the course. The participants took a seat at a table, which is where the picture was taken from, to fill out the questionnaires. While performing the task, the participants were able to walk freely from one side of the "bed" to the other. Markings on the floor were there to ensure the correct position of the table. The participants were recorded from two angles by the two cameras, which were aligned towards the center of the room, where the study task was performed. The semi-structured interview took place at the table of the head of study.

4.3.3. Tasks

For the participants to get used to the system, they have to execute a tutorial task first, before going to the main task. Some participants may never have used VR or AR glasses, so they have to get used to them first before performing tasks. Also, when performing easy tutorial tasks, the participants get acclimatized and see how their actions affect the system.
For the used tutorial task, the participants are prompted to walk towards the virtual bed. Here they should touch the patient at different parts of the body in order to get used to the physical contact with the patient. Then they are prompted to angle each leg and raise the feet of the patient afterwards. Next, they are asked to do the same with their arms and hands. After they are comfortable with interacting with the patient, they can press a button on the right side of them. When pressing the button, a video of a patient being transferred will play on the video panel behind the bed. Every time the participants press the right button, the next step of the transfer will be played on the video panel. Every time the participants press the left button, the step that was just played will be played again. There are a total of five steps in this patient transfer. After the participants feel ready to execute the transfer, they can start with the main task.
In the main task, the participants have to execute the patient transfer that they see on the video panel in front of them. This transfer is divided into five different steps. The participants have to execute one step after another. If the participants do not remember what to do next, they can always watch the step that they have to do next. After all five steps are completed, the patient will be moved to the starting position by the head of study. This transfer is completed three times in total by the participants.

Figure 4.2.: View of the participant in Virtual Reality.

Figure 4.2 shows the VR view of the participant in the study. The two extensions added to the system for the study can also be seen here. Figure 4.3 shows the two buttons that the participant is able to press. By pressing the right button (see figure 4.4), the participant is able to see the next part of the patient transfer (see figure 4.5). After step one, it shows step two, and after step two, step three, etc. If the right button is pressed again after the last clip of the video is finished, the first video clip will be played. Holding the right button will skip the video clips until the button is released again. This was helpful for the participants if they quickly wanted to skip steps to play the desired one.

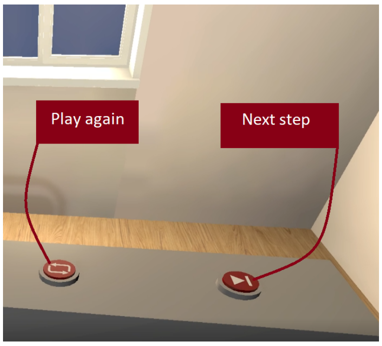

Figure 4.3.: The play again button and the play next button.

Figure 4.4.: The right button being pressed.

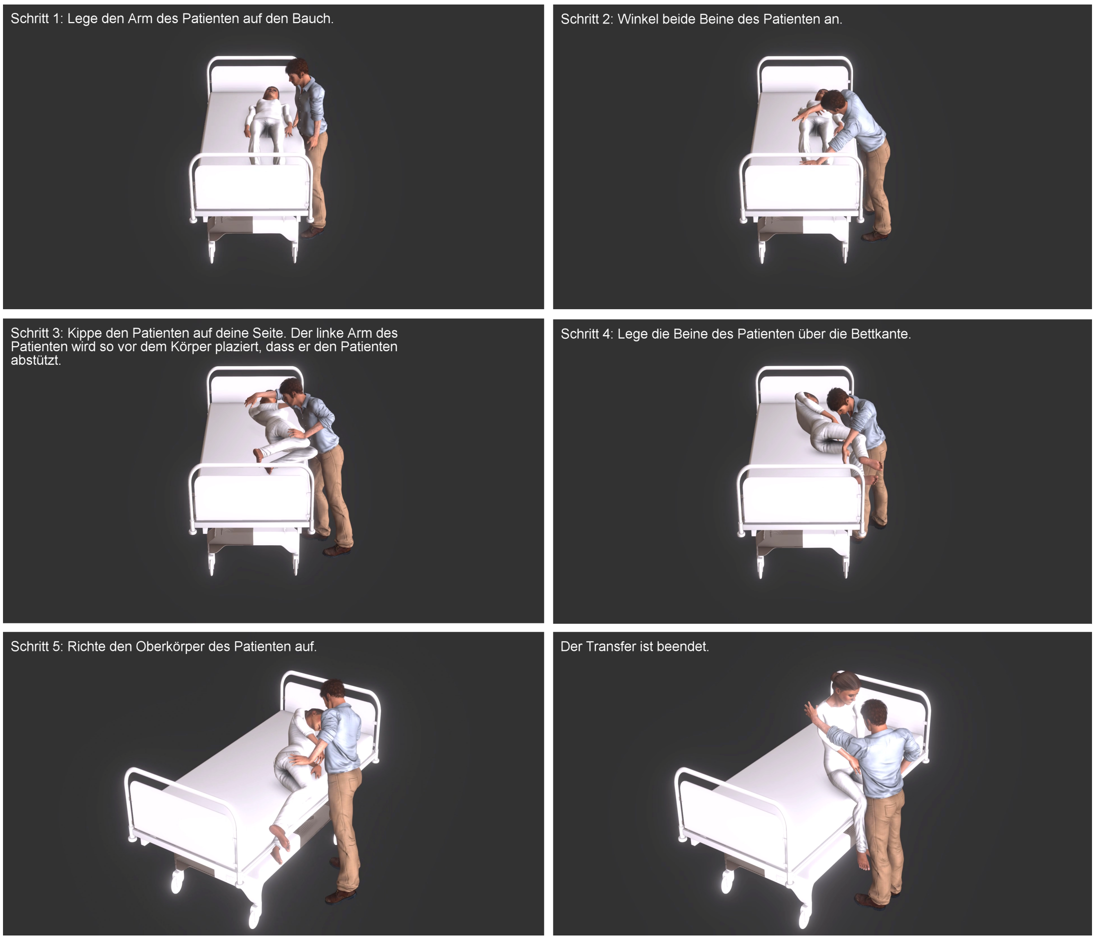

Figure 4.5.: Frames of each of the 5 video steps that were carried out in the study. The last image is displayed when all videos before it have been played.

4.3.4. Procedure

In the following, the execution of the study is described in detail. The 12 participants (+ 1 pilot study participant) were asked to participate one after the other. Each participant was greeted and received a welcome letter. (All documents that will be talked about in the following are attached to this work, including the welcome letter.) Before the participants took their seats, their waist height was measured. The reason for that is that the height of the bed was adjusted depending on the height of the participant. After reading the welcome letter, the participant had to sign the letter of acceptance and fill out the demographic questionnaire. After that, every participant filled out a standardized Simulator Sickness Questionnaire (SSQ) [43] before the task. The reason for that is that if participants are already feeling unwell before the task starts, they will also feel unwell after completing the task since it is only a short time frame. So, if complaints have already occurred before, the questionnaires before and after the study can be compared to evaluate if the system specifically had an impact on the well-being of the participants. While the participant was reading and filling out the first documents, the head of study was adjusting the height of the desks with the mattress on top, to adapt the "bed" to the size of the participant. The height of the virtual bed was adjusted by the head of study afterwards, to match it again with the height of the "bed" in the real world. The shutters in the room were lowered and the light in the room was switched on. This was done to avoid tracking errors caused by sunlight and to create the same conditions for every participant. After finishing the first documents, the participant was asked to disinfect their hands. Following that, each participant put on the HMD and adjusted the size to fit their head. The distance between the lenses of the HMD was adjusted to the eye distance of the participant. To make sure that the participant set the correct distance, he was asked to read out a text in the virtual world. The participant was also able to adjust the distance of the lenses if the text became sharper as a result. As a next step, the participant had to take off the HMD again and put on the tracking gloves. It was taken care to ensure that the velcro fastener of the gloves were closed properly so that it would not later get caught on the suit of the physical model. Next, the gloves of the participants were calibrated for them in the MANUS Core software. For that, the participant had to make three gestures with their hands. The first gesture is a fist; the second is a flat hand with an angled thumb. The third step is a so-called "pistol," in which the thumb and forefinger are stretched out and the other fingers remain bent. If a calibration was unsatisfactory, it was repeated. After the correct calibration, the head of study starts the recording of the cameras, which film the participant during the task. The participant put the HMD on again and received an easy tutorial task to get acclimated to the system. After that, the participant must perform the main task, which includes a patient transfer. After the main task was completed, 4 different questionnaires had to be filled out. The first is the Simulator Sickness Questionnaire (SSQ) to get a direct comparison of the participant before and after the task. The custom questionnaire contains questions about three categories and target the research questions.(see 4.3.5) The User Experience Questionnaire (UEQ) [44] is the third one and targets RQ1. The last document to fill out is the IGROUP Presence Questionnaire (IPQ) [45]. The IPQ is a "*is a scale for measuring the sense of presence experienced in a virtual environment*" [45]. Finally, the participant is interviewed by the study director using a semi-structured interview. This interview was recorded and automatically transcribed on a smartphone. In addition, the head of study takes notes of the answers of the participant. At the end, the participant was thanked and received 12 euros in compensation. The duration of the study was about one hour.

Course of action: These are the study's parts. They are listed in the order in which they were executed. It must be said that step 3 of the preparation took place while the participant was busy with the documents in step 2.

1 Welcome participants

1.1 Greet participants

1.2 Brief summary of the study

1.3 Measure height of the participant

1.4 Welcome letter, letter of acceptance

2 Filling of pre-study documents

2.1 Demographic questionnaire

2.2 Simulator sickness questionnaire

3 Preparation

3.1 Adjust height of the desks

3.2 Adjust height of the virtual bed

3.3 Adjust lighting conditions

4 Calibrating VR setup

4.1 Participant disinfects hands

4.2 Explain hardware to participant

4.3 Participant puts on HMD and tracking gloves

4.4 Adjust size and eye distance of HMD

4.5 Calibrate tracking gloves for participant

5 Tasks

5.1 Participant receives a tutorial task

5.2 Participant watches transfer video in VR

5.3 Participant starts with the transfer

6 Questionnaires and Interview

6.1 Simulator sickness questionnaire [43]

6.2 Custom questionnaire

6.3 User experience questionnaire [44]

6.4 IGROUP presence questionnaire [45]

6.5 Semi-structured interview

7 Discharge, Transfer of compensation, Thank you for participation

At the end of each study, the HMD as well as the tracking gloves were put into a cleanbox to keep everyone involved in the study as safe as possible. Furthermore, in the beginning, each participant was asked whether he or she wanted to put on a kind of disposable mask so as not to come into direct contact with the HMD on their face.

4.3.5. Questionnaires and Interviews

One part of the questionnaires is completed before performing the task and one after. The first group of questionnaires consists of only the demographic questionnaire and the Simulator Sickness Questionnaire (SSQ). In addition to gender and age, the demographic questionnaire also consists of questions about eyesight, previous experience with Virtual Reality, and previous experience in care. The SSQ is a questionnaire to quantify simulator sickness [43]. This questionnaire is filled out by the participants before and right after the task. The questionnaires which are filled out after the study task, consist out of the SSQ again first, then the custom questionnaire, after that the User Experience Questionnaire (UEQ) [44], and finally the IGROUP Presence Questionnaire (IPQ) [45]. The SSQ, as previously stated, is used to quantify simulator sickness. Getting cyber sick obviously has an impact on the user experience, which is why it is measured in the study. The custom questionnaire is divided into 3 sections: Questions about the physical mode, questions about the virtual model and questions about the task itself. The well known UEQ was used to measure the user experience of the system. *"The user experience is understood as a subjective impression that of the user in relation to the product has developed."* [46]. The last questionnaire, the IPQ was used to quantify the feeling of presence that the participants have, while they are in the virtual world.
After the participants filled out all four questionnaires, a semi structured interview was conducted with them. This interview consist of 15 questions, which are thematically similar to the questionnaires. Due to the semi-structured character of the interview, the participants are able to freely speak about their perception of the system. That way they can also add important information to aspects that might not have been asked about in the questionnaires.

A summary of the collected data:

a Qualitative data

  i Custom questionnaire answers of the participants to open questions (subjective)

  ii Answers of the semi structured interview (subjective)

  iii Observation of the head of study (subjective)

b Quantitative data

  i Demographic questionnaire (objective/subjective)

  ii Simulator sickness questionnaire (subjective)

  iii User experience questionnaire (subjective)

  iv IGROUP presence questionnaire (subjective)

  v Custom questionnaire answers of the participants on Likert scales (subjective)

4.4. Identify the Practical Issues

Since the implemented system uses Optitrack cameras, the study could only take place in a room with Optitrack cameras. The university made it possible for me to reserve room ZT 701 for two weeks to carry out my studies there. The participants, who were either studying or working themselves, could choose a date that suited them best. This made it possible to process all participants in two weeks.
There were a few things that had to be considered about the study itself. The study environment should create the same initial conditions for each participant. One problem that had to be solved right from the start was the different sizes of the participants. To address this problem, height-adjustable desks were placed in the room. As already explained in (4.3.2), these function together with the mattress as a bed replacement. Another issue was using the tracking gloves. The MANUS tracking gloves recognize the flexing of the individual fingers with the help of a magnetic strip. Depending on the hand size with which the gloves were calibrated, the degree of angulation of each finger is calculated. A bigger difference between the size of the hands of the participants will inevitably lead to a greater inaccuracy in finger tracking. To solve this problem and to create the same conditions for everyone, each participant's gloves were recalibrated before the task was performed.
To prevent any differences in lighting conditions and thus possible differences in tracking, the blinds were always lowered and the lights turned on.
The cameras recording the study were hung on the ceiling of the room and could be controlled from the computer. The viewing angles of the cameras did not have to be changed because the participants only had to move in a small field in the middle of the room.
To ensure the safety of the participants, the study leader always stood close to the participants and made sure that no one could stumble over the cable of the HMD or otherwise injure themselves.
A pilot study was conducted to ensure that no practical issue was overlooked or forgotten. In the pilot study, almost everything went as planned. However, an unexpected complication arose, which was resolved for further studies. The pilot study participant stated that his/her hand size in the virtual world does not match his/her hand size in the real world. This difference in size was perceived as disturbing by the participant. In the other studies, after the calibration of the tracking gloves, the size of the virtual hands was adjusted to the participants. The procedure was such that the hand size was reduced or increased by 10 percent, depending on whether the participant felt the hands were too big or too small. This process was repeated until the hands were the right size for the participants. The 10 percent were always based on the initial value.

4.5. Decide How to Deal With the Ethical Issues

Communication with the participant is essential in order to avoid ethical problems and to make participation pleasant for the participant. Participants were informed of the objectives and what exactly they needed to do in the study if they agreed to take part. The expected time and the compensation were clearly communicated. The participants were also informed about what kind of data was collected and that it would be treated pseudonymously in further work. It is therefore not possible to draw any conclusions about the identity of the person. Each person is referred to as Participant 1, Participant 2, etc., and has an ID. A coding system is used to record each participant's data. If, after some time, a participant does not want their data to be used, it can still be deleted. It is stated to the participants, orally and on the documents, that they can, of course, stop the study at any time without the need to name specific reasons. Before starting the semi-structured interview, the participants were also asked if it would be okay for them to be recorded and logged while being interviewed to quote them. The participants were also offered the chance to get a draft of the final report and were invited to give feedback.

4.6. Evaluate, Analyze, Interpret, and Present the Data

This chapter presents the results obtained in the study. All questions were asked of the participants in German. If specific questions are discussed below, they will be translated into English. The originally formulated questions in German are attached to this document. Section 4.6.1 introduces the participants' demographics and their basic knowledge of Virtual Reality and nursing. Section 4.6.2 shows the results of the Simulator Sickness Questionnaire. Section 4.6.3 presents the results of the custom-made questionnaire. Section 4.6.4 is about the results of the User Experience Questionnaire, and section 4.6.5 shows the results of the IGROUP Presence Questionnaire. Section 4.6.6 summarizes the results of the semi-structured interview and addresses comments made by the participants in the study.

4.6.1. Demography

Twelve participants in the age range of 19–24 years took part in the study. The exact distribution can be seen in figure 4.6. The average age was 22.3 years. Nine of the twelve participants were male, and three were female. (see fig. 4.7) The participants were also asked to give a self-assessment about their familiarity with Virtual Reality. Respectively, 3 participants rated themselves as "familiar", "a bit familiar", "rather unfamiliar", and "not familiar at all". None rated themselves as very familiar with Virtual Reality. (see fig. 4.8) Self-assessment about their previous experience in nursing revealed that only one person answered "yes" and one "rather no". According to their self-assessment, all others have no experience in care. (see fig. 4.9)

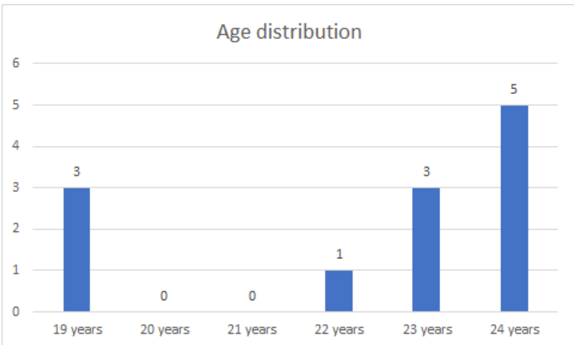

Figure 4.6.: Age distribution of the participants.

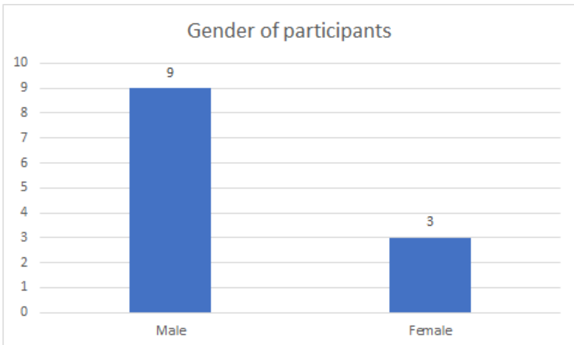

Figure 4.7.: Gender distribution of the participants.

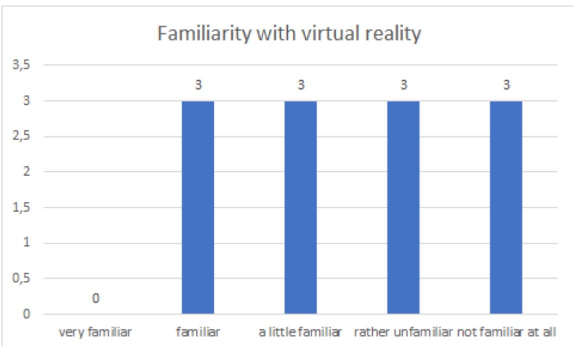

Figure 4.8.: Experience of participants with VR.

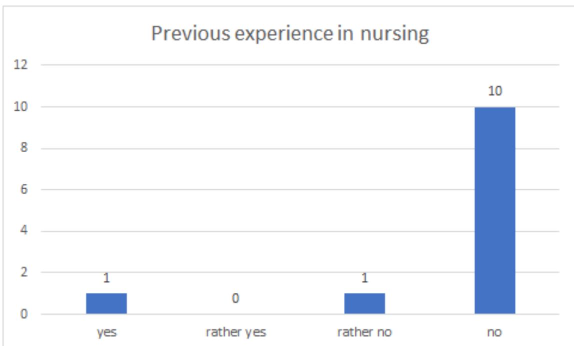

Figure 4.9.: Experience of participants with nursing.

4.6.2. Simulator Sickness Questionnaire

Table 4.1 shows how the different values for "nausea", "oculomotor disturbance", "disorientation" and "total simulator sickness score" are calculated, as introduced by Kennedy et al. [47]. The participants can rate how much each of the 16 symptoms applies to them on a scale from 0 (not at all) to 3 (strongly). The total simulator score can reach from 0 to a maximum of 235.62.

	Weight		
SSQ Symptom	N	O	D
General discomfort	1	1	
Fatigue		1	
Headache		1	
Eyestrain		1	
Difficulty focusing		1	1
Increased salivation	1		
Sweating	1		
Nausea	1		1
Difficulty concentrating	1	1	
Fullness of head			1
Blurred vision		1	1
Dizzy (eyes open)			1
Dizzy (eyes closed)			1
Vertigo			1
Stomach awareness	1		
Burping	1		
Total	[1]	[2]	[3]

$$N = [1] \times 9.54$$
$$O = [2] \times 7.58$$
$$D = [3] \times 13.92$$
$$TS = ([1] + [2] + [3]) \times 3.74$$

Table 4.1.: Calculation of nausea (N), oculomotor disturbance (O), disorientation (D), and total simulator sickness (TS) as introduced by Kennedy et al. [47]. The red brackets are not in the original formula. They were added by Bimberg et al. [48] to clarify that all three values are first added and then multiplied by 3.74.

K. M. Stanney et al. [49] state based on a large amount of data from military pilots, that scores (<5) are considered negligible, (5 − 10) minimal, (10 − 15) significant, and (15 − 20) concerning symptoms. They report that a score above 20 is considered to be bad. One problem with evaluating the results of the SSQ is that it assumes the participant is completely healthy before participating in the study. If, for example, a student is still taking part in the study after a long day at university, he will potentially already start out tired or with a headache. To prevent this problem, as already explained, one questionnaire was answered by the participants before and one after the task was carried out (see figure 4.10). In order to be able to better see what proportion the execution of the task made, the difference before and after the execution of the task is shown in figure 4.11. This figure shows that for 8 participants, the execution of the task had only a minimal effect, if any. Participant six felt better after completing the task than before. This may be due to the fact that when performing physical tasks, participants become less tired, which is one of the symptoms. Participant 6 and 12 reached a significant, and participant 2 a concerning, increase in the score.

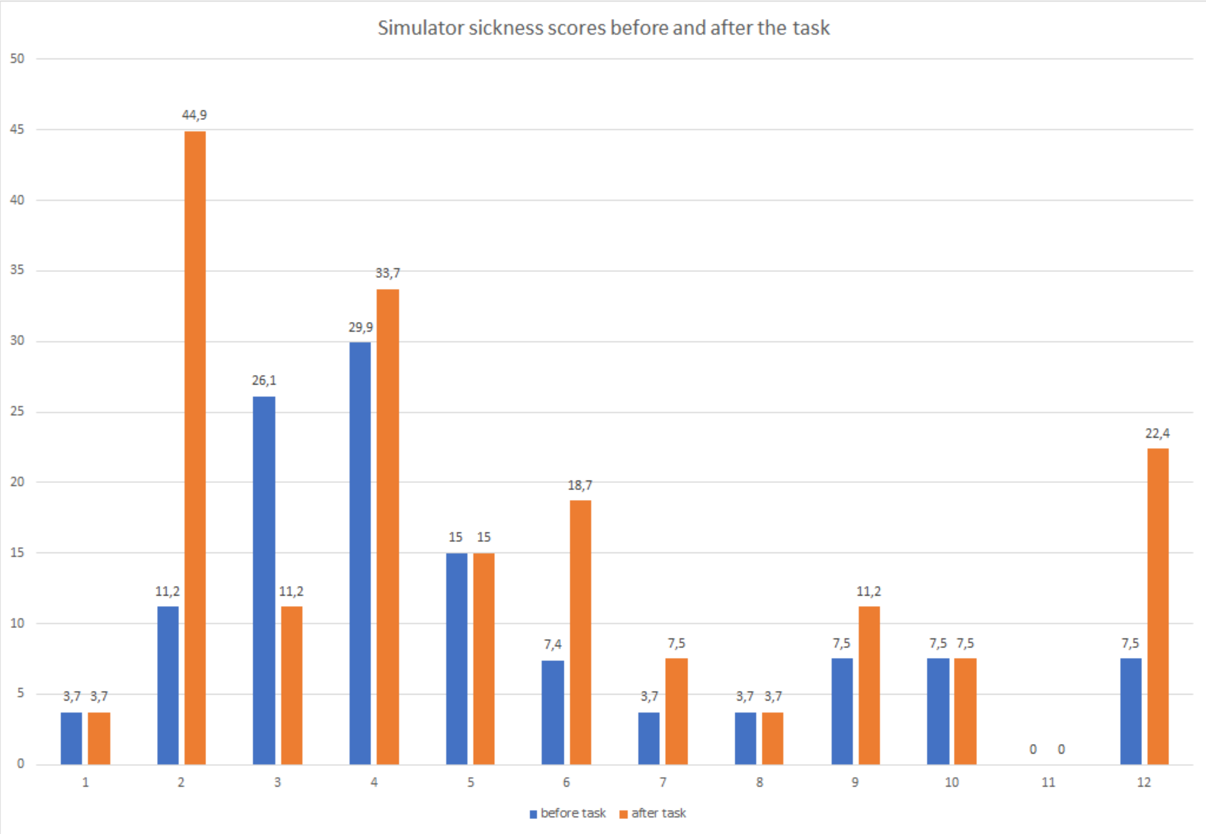

Figure 4.10.: The sickness score. The blue bar represents the score that they received at the beginning of the study. The orange bar represents the score that they received right after the execution of the task. The maximum value that can be reached is 235.62 and the lowest possible value is 0. The higher the value, the worse the participants feel.

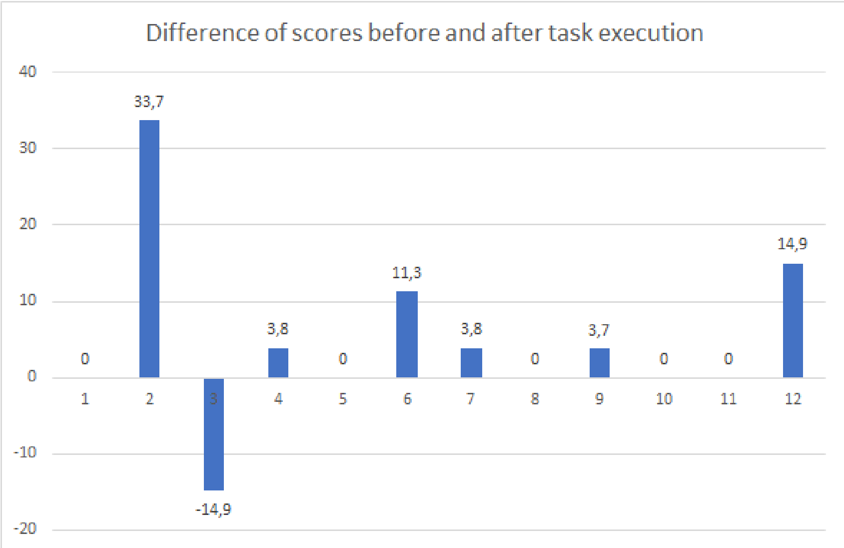

Figure 4.11.: The sickness score difference. So the value for each participant is calculated as follows: $value = TS_{afterthetask} - TS_{beforethetask}$. The negative score of participant 3 is due to the fact that he had a higher score before the task than after the task.

4.6.3. Custom Questionnaire

The custom questionnaire was designed to specifically answer different aspects of the research questions. The participants were asked different questions, and they could indicate how much they agreed with the statement on a 5 point likert scale. In the questionnaire, the alignment of "I totally agree" (5) and "I totally disagree" (1) was reversed after each question. The reason for this is that the participants do not tend to tick the same answer over and over again. However, in the following, to improve readability, a rating of 5 means a positive response from the participants in relation to the prototype, and a rating of 1 means a negative one. The questions were put to the participants in German. In the following, they will be translated into English. The original German questions can be looked up in the attachment. The questions were divided into three categories: questions about the physical model, questions about the virtual model, and questions about the task itself. In the following, the arithmetic mean (M), the median (Md), and the standard deviation (SD) are presented for the questions. Specific comments made by participants on individual statements in the semi-structured interview are also briefly described. Due to the number of questions, only the most important ones are visualized. The rest will be briefly summarized afterwards.

Questions about the Physical Model

"How realistic did the physical model ***feel*** *compared to a human?"*

The answer options ranged from "very unrealistic" (1) to "very realistic" (5). The assessment of the participants was neutral. The participants that were rating the realism of the feel of the physical model with lower numbers reported three problems. In the interview, four participants said that the physical model has too little weight. Three criticized that the texture of the physical model was too tough and did not feel like touching a human muscle. One participant also said that the surface of the physical model was "slippery". Two participants positively mentioned the weight and size of the physical patient.

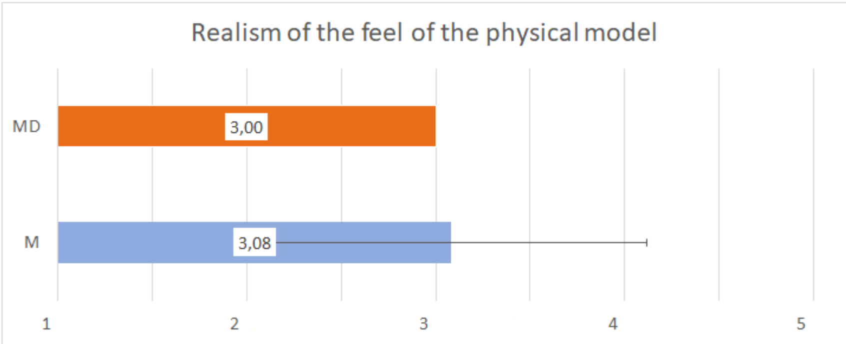

Figure 4.12.: Result of realism of the feel of the physical model question. The arithmetic mean (M) with the associated standard deviation (SD) and the median (Md)

*"How did body parts and joints of the physical model **move** compared to those of a human?"*

The answer options ranged from "very bad" (1) to "very good" (5). The result is between neutral and rather good. In the interview, three participants described the physical patient's joints as stiff. All three also mentioned, that human joints would be more flexible. Five said that they think it's good that the body can only be moved at the joints.

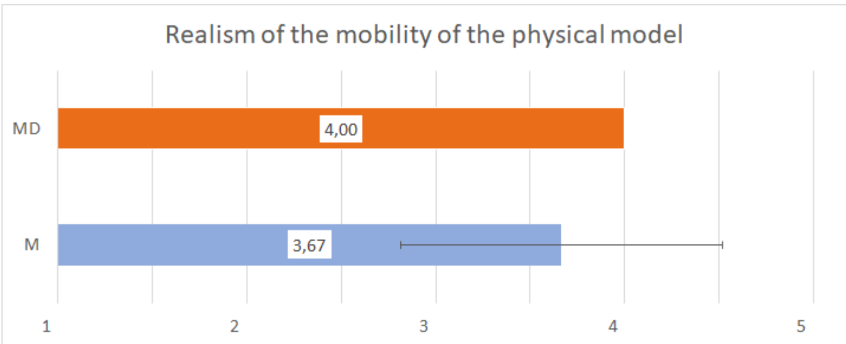

Figure 4.13.: Result of the realism of the mobility of the physical model question. The arithmetic mean (M) with the associated standard deviation (SD) and the median (Md)

*"What **influence** did the **markers** of the physical model have on the execution of the task?"*

The answer options ranged from "very disturbing" (1) to "not disturbing at all" (5). The result is unambiguously. One person found the markers "rather not disturbing" (4) and everyone else "not disturbing at all" (5).

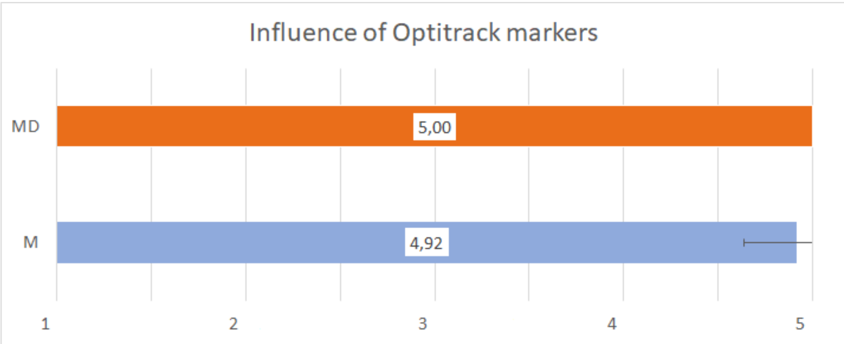

Figure 4.14.: Result of Influence of the Optitrack markers question. The arithmetic mean (M) with the associated standard deviation (SD) and the median (Md)

*"Did you have the feeling that you could handle the tasks just as well as if a **motionless person** had been lying there instead of **the physical model**?"*

The answer options were "no" (1), "rather no" (2), "neither nor" (3), "rather yes" (4), and "yes" (5). The result is a little worse than neutral. As already mentioned, the weight as well as the stiff joints were mentioned negatively. In the interview, three participants also reported that they had fewer inhibitions with the physical model than they would have had with a human. With a human, they would have been afraid of hurting them. They would have proceeded more carefully with a human being, as they would then have been afraid of injuring them.

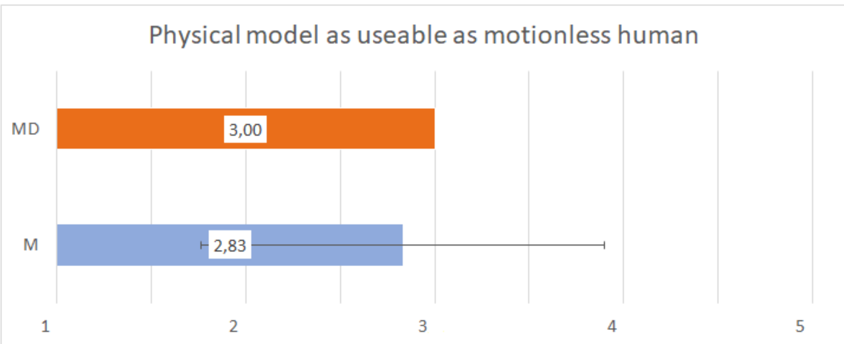

Figure 4.15.: Result of the physical model as useable as motionless human question. The arithmetic mean (M) with the associated standard deviation (SD) and the median (Md)

Questions about the Virtual Model

*"How **realistic** was the appearance of the virtual model?"*

The answer options ranged from "very unrealistic" (1) to "very realistic" (5). The result is between neutral and rather realistic. In the interview, four participants mentioned that they did not remember how the virtual model looked after completing the task because it was not important to them while transferring the patient.

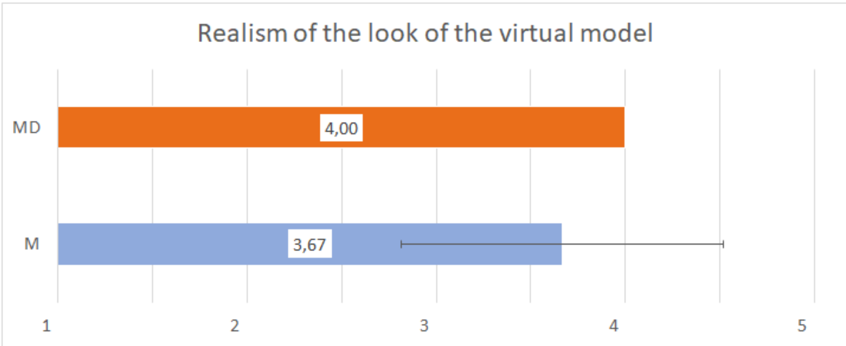

Figure 4.16.: Result of the realism of the look of the virtual model question. The arithmetic mean (M) with the associated standard deviation (SD) and the median (Md)

*"Did the **size** of the virtual model match the size of the physical model?"*

The answer options were "no" (1), "rather no" (2), "neither nor" (3), "rather yes" (4), and "yes" (5). The results were consistently positive. In the interview, six of the participants answered with yes and six with rather yes.

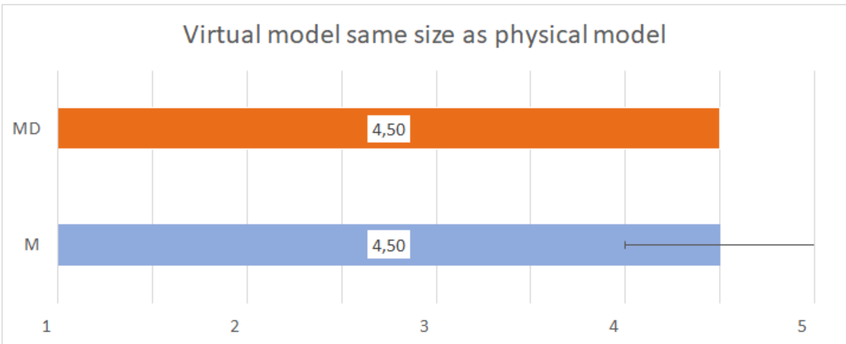

Figure 4.17.: Result of the virtual model being the same size as physical model question. The arithmetic mean (M) with the associated standard deviation (SD) and the median (Md)

*"Did the **position** of the virtual model match the position of the physical model?"*

The answer options were "no" (1), "rather no" (2), "neither nor" (3), "rather yes" (4), and "yes" (5). On average, the participants agree with this question with a "rather yes". However, in the interview, four participants still mentioned that the arms of the virtual model sometimes went through the body. Six participants mentioned that in some positions, the arms of the virtual model showed an offset. Nine of them said, that most of the time the mapping was correct.

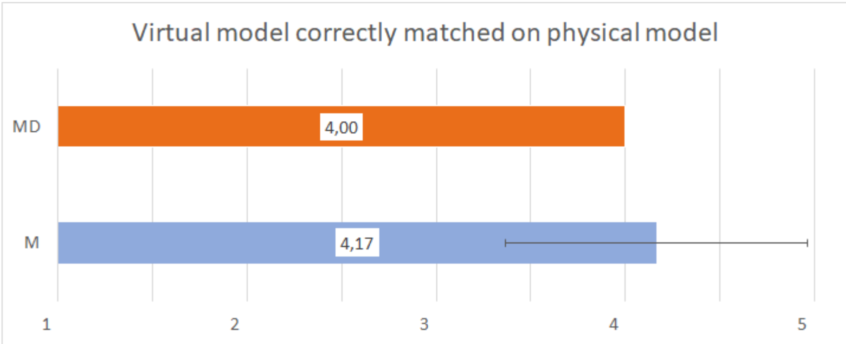

Figure 4.18.: Result of the virtual model correctly matched on the physical model question. The arithmetic mean (M) with the associated standard deviation (SD) and the median (Md)

Questions about the Task

*"What was the impact on the task if the **size** of the virtual model did not match the size of the physical model?"*

The answer options ranged from "very disturbing" (1) to "not disturbing at all" (5). In the interview, two participants mentioned, they had the impression that the shoulder height of the virtual model was lower than that of the physical model as soon as he stood it up. That was disruptive if they wanted to touch the patient's shoulder at that moment. This impact is reduced, though, due to the fact that most participants did not notice any difference in terms of the sizes of the two models (see figure 4.17).

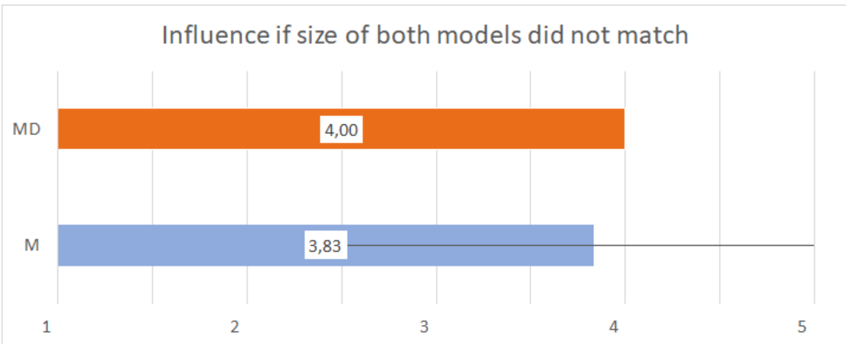

Figure 4.19.: Result of influence if size of both models did not match question. The arithmetic mean (M) with the associated standard deviation (SD) and the median (Md)

*"What was the impact on the task if the **position** of the virtual model did not match the position of the physical model?"*

The answer options ranged from "very disturbing" (1) to "not disturbing at all" (5). For participants, incorrect mapping had the most negative impact on task performance. In the interview, six participants mentioned, that in situations in which the arm of the virtual model is not mapped correctly, they sometimes reached past the arm and therefore could not grab the patient directly. Four participants also stated that it did not affect them, since they could always feel the patient since the offset was small.

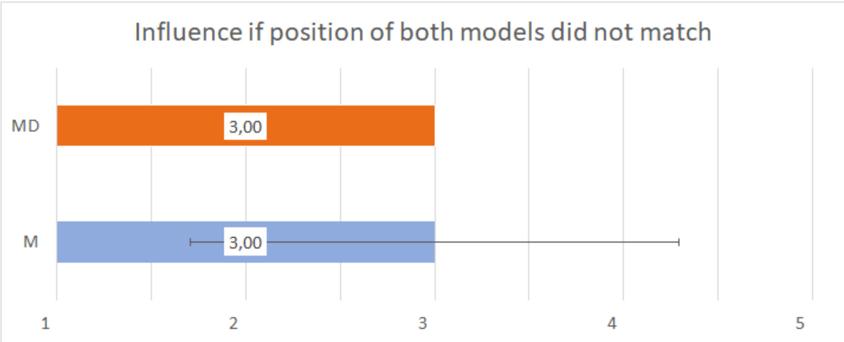

Figure 4.20.: Result of the influence if position of both models did not match question. The arithmetic mean (M) with the associated standard deviation (SD) and the median (Md)

*"Did the **hands** feel **realistic** in the virtual world?"*

The answer options were "no" (1), "rather no" (2), "neither nor" (3), "rather yes" (4), and "yes" (5). One participant mentioned, that sometimes some fingers stood away to the side.

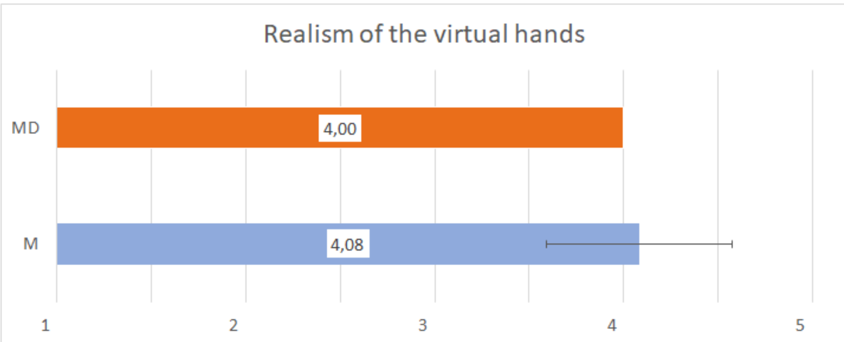

Figure 4.21.: Result of realism of the virtual hands question. The arithmetic mean (M) with the associated standard deviation (SD) and the median (Md)

Some questions about the task are not shown as a diagram but are briefly summarized here.
The first two questions of the part "Questions about the Task" were: *"Was it immediately understandable how to interact with the patient?"* and *"Were the tasks that had to be done explained clearly?"*. These two questions were aimed more at ensuring that the study data were not skewed because the participants did not understand the task. In the first question, everyone answered "yes" (5), and in the second question, eleven answered "yes" (5),

and one participant answered "rather yes" (4). The results made it clear that the participants were not confused when performing the task.

The fifth question of the part "Questions about the task" was: *"What was the impact on the task if the response time of the system was too slow or stopped completely for a short time?"* This question was aimed at the fact that if the HMD loses tracking, then the participant experiences a short, freeze frame until it is tracked again. This does not occur often, which is why seven participants said "not disturbing at all" (5), four said "rather not disturbing" (4), and only one said "rather disturbing" (2).

The sixth question of the part "Questions about the Task" was: *"Was it fun to complete the Task?".* Here, the answers were pretty clear, with six participants answering "yes" (5) and six with "rather yes" (4).

The seventh question of the part "Questions about the task" was: *" "Did you feel during the task that you needed a break because using the system was tiring or nauseous?"* Only one participant answered with "rather yes" (2), and everyone else answered with "no" (5). Due to the task only taking about 10-15 minutes, all eleven participants had no problem using it. However, they all stated that after using it for more than 30 to 60 minutes, they could imagine that they would need a short break.

4.6.4. User Experience Questionnaire

The User Experience Questionnaire (UEQ) [44] was selected to measure the user experience. The questionnaire consists of 26 questions with bipolar statements, which must be answered on a 7-point Lickert scale. The answers of the participants are then converted into values between (-3) and (+3). The most positive answer is converted to +3 and the most negative to -3, while 0 is neutral. Each of the word pairs contributes to one of the 6 categories listed below. This increases the measurement accuracy (reliability) and robustness of the answers if, for example, a participant did not understand a question or accidentally ticked it wrong.[46] The UEQ was evaluated using an Excel tool provided by the UEQ website.[44] The results obtained from the questionnaires are automatically evaluated and visualized.

- **Attractiveness**
  - annoying/enjoyable
  - good/bad
  - unlikable/pleasing
  - unpleasant/pleasant
  - attractive/unattractive
  - friendly/unfriendly
- **Perspicuity**
  - not understandable/understandable
  - easy to learn/difficult to learn

  - complicated/easy
  - clear/confusing
- **Efficiency**
  - fast/slow
  - inefficient/efficient
  - impractical/practical
  - organized/cluttered
- **Dependability**
  - unpredictable/predictable
  - obstructive/supportive
  - secure/not secure
  - meets expectations/does not meet expectations
- **Stimulation**
  - valuable/inferior
  - boring/exciting
  - not interesting/interesting
  - motivating/demotivating
- **Novelty**
  - creative/dull
  - inventive/conventional
  - usual/leading edge
  - conservative/innovative

Figure 4.22 shows the results of the UEQ. The colors in the background indicate whether the corresponding value is positive or negative. If the bar ends in the green color, the value is interpreted as positive, the yellow as neutral and the red as negative. Dependability received the lowest rating, while perspicuity received the highest.

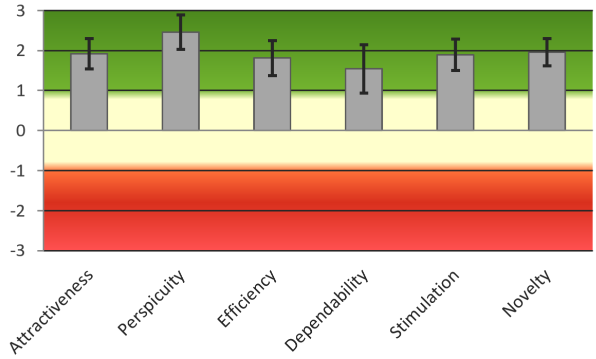

Figure 4.22.: The results of the UEQ. The confidence interval is also included for each bar.

Table 4.2 shows the concrete results in numbers. The first column shows how much the value is above or below the neutral value 0. The second column shows the variance.

UEQ Scales (Mean and Variance)		
Attractiveness	1,917	0,44
Perspicuity	2,458	0,57
Efficiency	1,813	0,60
Dependability	1,542	1,12
Stimulation	1,896	0,47
Novelty	1,958	0,36

Table 4.2.: The concrete results in numbers of the UEQ.

The official website of the UEQ offers a benchmark to compare results to. *"This data set contains data from 21175 persons from 468 studies concerning different products (business software, web pages, web shops, social networks)."* [44]. Figure 4.23 shows how the results of the UEQ are compared to their benchmark. Dependability and efficiency are "good" compared to the benchmark, which means that 10% of the results from the benchmark are better and 75% of the results are worse. Attractiveness, perspicuity, stimulation, and novelty even get the value "excellent" because they are in the top 10% of the results.

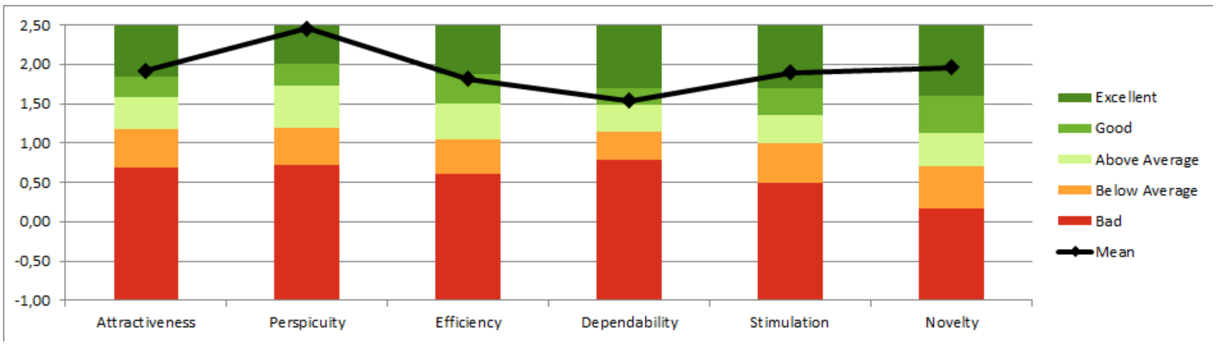

Figure 4.23.: Results of UEQ compared to the benchmark data from the UEQ website. [44]

Scale	Mean	Comparisson to benchmark	Interpretation
Attractiveness	1,92	**Excellent**	In the range of the 10% best results
Perspicuity	2,46	**Excellent**	In the range of the 10% best results
Efficiency	1,81	**Good**	10% of results better, 75% of results worse
Dependability	1,54	**Good**	10% of results better, 75% of results worse
Stimulation	1,90	**Excellent**	In the range of the 10% best results
Novelty	1,96	**Excellent**	In the range of the 10% best results

Table 4.3.: Evaluation assigned to each value and specified how this is to be interpreted.

Cronbachs α-Coefficient is a measure for the consistency of a scale. The value can be between $-\infty$ and 1, where 1 is the best possible value. The concrete values of the study results are shown in figure 4.24. Many authors consider a value of > 0.7 to be sufficiently consistent. Values below 0.7 should be used with great caution. Values below 0.5 are considered unacceptable. However, there are no statistical facts to prove these suggestions; they are more like *"rules of thumb"*[50]. In addition, it has to be said, that low values of Cronbachs α-Coefficient can result, if the number of participants is too small. In the UEQ excel table, they mention fewer than 50 participants as an example.[44] Since the study only had twelve participants, Cronbachs α is taken into account, but the weight should not be too high.

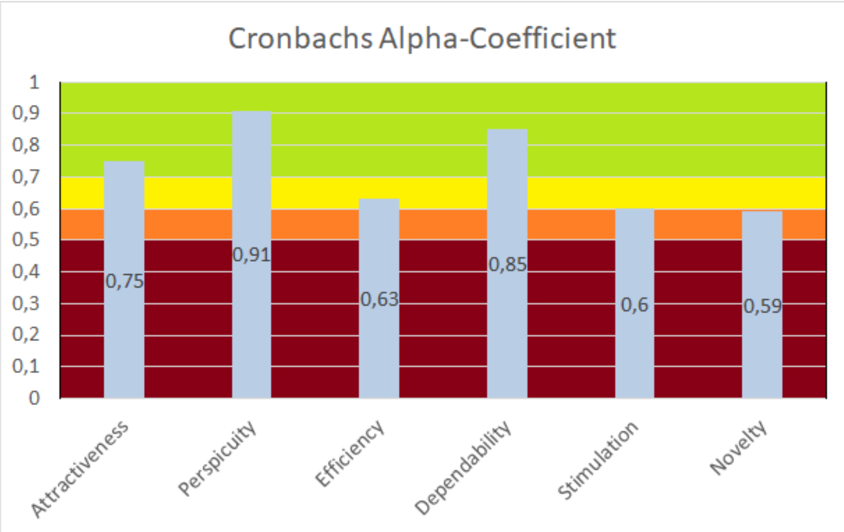

Figure 4.24.: Cronbachs α for each of the different categories of the UEQ.

4.6.5. IGROUP Presence Questionnaire

The IGROUP Presence Questionnaire (IPQ) [45] was selected to measure the presence of the participants. This questionnaire tackles **RQ2** *"Does the system deliver an immersive experience?"* Since the questionnaire measures presence and the research question talks about immersion, the differences have to be briefly explained. James et al. investigated the correlation between presence and immersion and defined *" [...] immersion as a technological quality of media—and presence as the psychological experience of "being there.""*.[51] Presence affects immersion, but immersion also depends on it. Slater states that *"Immersion provides the boundaries within which PI can occur."*[52]. Slater et al. designate 'presence' as 'place illusion' (PI). The IPQ can be used to determine whether

participants experience presence or place illusion and thus whether the system they are using is immersive.
In the following, the 14 different questions are translated into English together with their associated anchors. The IPQ delivers results in four different categories. These are: "General", "Spatial Presence", "Involvement" and "Realism". In Table 4.4 the "IPQ item name" indicates which category the question is targeting. So for example, REAL1, REAL2, REAL3, and REAL4 influence the category "Realism".

IPQquestions			
Number	IPQ item name	Question	English anchors
1	G1	In the computer generated world I had a sense of "being there"	not at all–very much
2	SP1	Somehow I felt that the virtual world surrounded me.	fully disagree–fully agree
3	SP2	I felt like I was just perceiving pictures.	fully disagree–fully agree
4	SP3	I did not feel present in the virtual space.	did not feel–felt present
5	SP4	I had a sense of acting in the virtual space, rather than operating something from outside.	fully disagree–fully agree
6	SP5	I felt present in the virtual space.	fully disagree–fully agree
7	INV1	How aware were you of the real world surrounding while navigating in the virtual world? (i.e. sounds, room temperature, other people, etc.)?	extremely aware-moderately aware-not aware at all
8	INV2	I was not aware of my real environment	fully disagree–fully agree
9	INV3	I still paid attention to the real environment.	fully disagree–fully agree
10	INV4	I was completely captivated by the virtual world.	fully disagree–fully agree
11	REAL1	How real did the virtual world seem to you?	completely real–not real at all
12	REAL2	How much did your experience in the virtual environment seem consistent with your real world experience ?	not consistent-moderately consistent-very consistent
13	REAL3	How real did the virtual world seem to you?	about as real as an imagined world–indistinguishable from the real world
14	REAL4	The virtual world seemed more realistic than the real world.	fully disagree–fully agree

Table 4.4.: The Questions of the IPQ together with their associated IPQ item names and anchors.

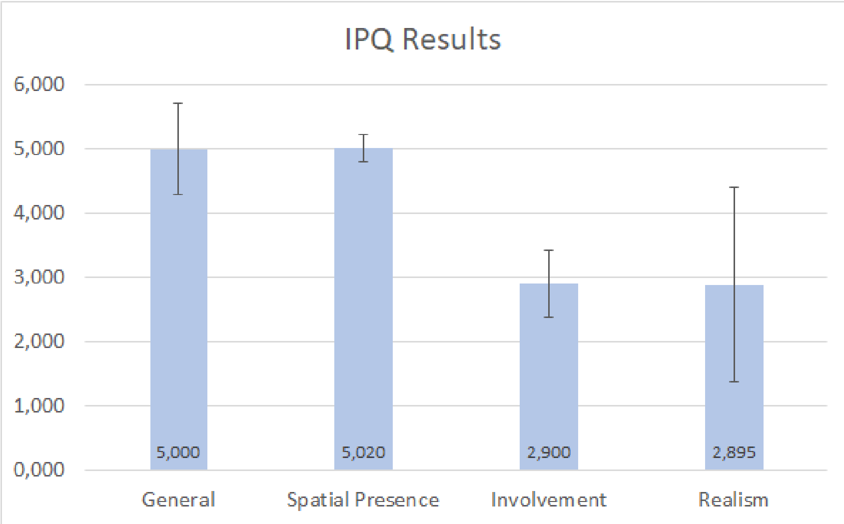

Table 4.5.: The results of the IPQ. 6 is the best possible result and 0 is the worst possible. The associated standard deviation is also shown for each category.

4.6.6. Interview

As the final part of the study, a semi-structured interview was conducted. A conversation was held with the participants in which they were able to answer questions about the task and suggestions for improvement about the system in detail. The conversation was recorded using a smartphone and automatically logged. In addition, the head of the study took notes on the feedback of the participants. The data was evaluated after all interviews were completed. The opinions and views of the participants in the interview led to qualitative results, which are summarized below.

Physical Model

- **Weight**
  A problem with the physical model, which was often noted, was that it weighed too little compared to a human. Five participants noted that if the physical model is to act as a surrogate for a human, then it needs more weight. More weight would make the task harder and, therefore, more realistic in their opinion.
- **Agility**
  Five participants mentioned that the joints of the physical model felt stiff. In particular, the arms were described as being inflexible and also interfering with the execution of tasks. This was particularly the case when the arms could not be placed on the stomach due to their inflexibility.
- **Surface area**
  Six participants noted that the surface of the physical model felt too hard. As an alternative, soft plastic was mentioned instead of hard plastic, as this would feel more like skin and would therefore be more realistic.
- **Human alternative**
  Three participants mentioned that they feel more comfortable interacting with a physical model than with a human for two reasons. The first is that for them, it would be strange to get into close contact with a real person they do not know well. The second reason is that they would be afraid of hurting that person if they did something wrong in the transfer.

VR Setup

- **Cable**
  The only criticism of the VR setup was that four participants described the cable as annoying or slightly annoying. They felt restricted in their movement. A wireless HMD or one where the cable comes from the ceiling was suggested.

Cyber Sickness

- **Duration of use**
  The participants were asked if they were able to use the system for a longer period of time or if there would be reasons that they needed a break in between. All twelve said that they would be able to use it over a longer period of time. Five participants specified their statement as lasting more than one hour, and three said it lasted more than half an hour. All of them mentioned that if there were no breaks for multiple hours, they could imagine that cyber sickness would occur to them. Only one participant answered "very weak yes" when asked if he felt nausea while performing the task. Everyone else said "no".

Immersive Experience

- **Room**
  Nine participants said that the room looks more like a training room and less like a real hospital room. The lack of hospital equipment combined with the video panel and buttons meant that participants did not feel like they were in a hospital room.
- **Physical button**
  Two participants would consider a physical button that gives haptic feedback more immersive.
- **Own avatar**
  One participant would have liked it if, in addition to the hands, the complete body had been shown as a separate avatar in the virtual world.

Virtual Model

- **Mapping**
  Six participants mentioned that the position of the arms was not always mapped correctly. This led to them grabbing the arm in the wrong place when mapping problems occurred. A more precise mapping of the hands of the virtual model would be important for trouble-free training of the transfer.
- **Missing feedback**
  Two participants said that they see it as a problem that the virtual patient does not give any feedback in the event of potential errors in the transfer. A person would speak up if you hurt him or her. Feedback from the patient on whether a movement performed causes any kind of pain would be helpful.

Missing Objects

- **Disturbing objects**
  One participant who works in care noted that items such as a bedside table or a pillow were missing. These would make the real transfer much more difficult and should therefore not be missing in a training scenario.
- **Presence button**
  The same participant also mentioned that when the nursing staff goes into a hospital room, they always have to press the presence button. This is important because if they need immediate support from other staff, they know where to go.

4.6.7. Discussion

In the following, the results obtained from the study are discussed to answer the formulated research questions.

RQ1 *Does the training of patient transfer with VRPatient provide a good user experience?*

This question can be answered with the results of the User Experience Questionnaire (UEQ) [44] and the participants' evaluations of the associated questions both in the custom questionnaire and in the interview. In addition to that, the occurrence of cyber sickness was examined more closely, as this can have a significant impact on the user experience.
The results of the UEQ turned out to be very positive. This is also confirmed by question six in the custom questionnaire for the task. Half of the participants rated the question whether it was fun to complete the task with "yes" and the other half with "rather yes". As can be seen in the demographic questionnaire, the majority of the participants have little previous experience with VR. (see fig. 4.8)
In the UEQ, all six categories received a rating > 1 which indicates that the value is to be interpreted as positive. This was also reflected when the results were compared with the existing values from the UEQ benchmark data set. Efficiency and dependability received the rating "good" in comparison to the benchmark. Attractiveness, perspicuity, stimulation, and novelty were even rated as excellent, which means that they are among the 10% best results of the benchmark data set.
Perspicuity received the best rating from the participants. The perspicuity was mentioned by the majority of participants in the interview. They liked that the system is limited to the bare essentials, that they are not distracted, and that they can fully focus on executing the transfer.
Dependability received the lowest rating from the participants. One problem with the dependability that the participants described was when the tracking of the gloves was lost. This occurred primarily when the participants reached under the patient with their hands, and all markers were therefore covered. Another problem with dependability that some participants mentioned was that the hands of the virtual patient were sometimes not mapped correctly when they were interacting with them.
The Simulator Sickness Questionnaire was used to determine if, in a potential training scenario, the trainees would be able to use the system for a longer period of time without becoming cybersick. The results of the first questionnaire before the start of the study were already surprisingly high, considering that a score above 20 is already classified as "bad".[49] In the second questionnaire for six participants, these scores were even higher. When comparing the second questionnaire after the task to the first questionnaire before the task, for most participants, only a slight change is noticeable. Eight participants had no or only a minimal increase in their score (> 5). One participant had a lower score after the task than before the task. With two participants, the score increased significantly (> 15). The participant for whom the score changed the most had an increase of (33.7), which is considered bad.
Without taking the first questionnaire into account, however, this result would be significantly worse. According to K. M. Stanney et al. [49] three participants have scores that are negligible. Two participants have a score that is considered to exhibit minimal symptoms; for another two, the value is significant; for another two, it is considered concerning. Three participants have bad results since their score is over 20, and the highest score is 44.9. However, these values should be compared with the values from the first SSQ. In addition to that, K. M. Stanney et al. stated that scores above 20 should not be automatically rated as bad since the threshold values are very strictly chosen due to the fact that they are adapted for aviators.[49] Additionally, all of the participants stated that they would be able to use the system for a longer period of time. The shortest time that was mentioned was half an hour, before a break would be needed.
The general user experience was rated positively by the participants. Individual aspects such as mapping can be improved, but according to the participants they did not disturb them in their task. Based on their self-assessment, the aspect of cybersickness will only potentially arise among the participants after longer use. The SSQ confirmed this self-assessment, with the exception of one participant. According to the SSQ, this participant could experience problems with the system in relation to cybersickness. Overall **RQ1** if the system provides a good user experience can be answered with "yes".

RQ2 *Does the system deliver an immersive experience?*

This question can be answered with the results of the IGROUP Presence Questionnaire (IPQ) [45] and the participants' evaluations of the associated questions both in the custom questionnaire and in the interview.
The results of the IPQ in the categories "general" and "spatial presence" received a good rating of 5 and 5.02 out of 6. The participants had the feeling of being physically present in the computer-generated world. With a score of 2.9 out of 6 and 2.895 out of 6, the categories of involvement and realism performed slightly below average. In the realism category, question 14, "The virtual world seemed more realistic than the real world." performed significantly worse than the others. Most participants fully disagreed with the statement, with nine participants ticking "0", two ticking "1", and one ticking "2". This results in an arithmetic mean of 0.33 for this question. This is the reason why the standard deviation in the fourth category is disproportionately high. In the involvement category, the results deviated significantly less from the mean value.
The reason the involvement category didn't do as well as the first two was that the participants mentioned they were still more or less aware of the real world. There were mainly two reasons for that. First, the majority of the participants mentioned that they still felt the cable of the HMD and felt like they had to make sure it didn't get in the way. This problem was addressed by having the study leader hold the cable next to them so that they did not trip or become entangled. Despite this, the participants still felt the cable. This problem could be solved by using a wireless HMD. Another approach would be to reroute the cable so that it hangs from the ceiling and thus does not attract the attention of the participant and does not restrict him. The participants' second reason was that they were aware of the presence of the head of study when communicating with him. When a transfer was finished, for example, the head of the study put the patient back in the starting position and also informed the participants of this so as not to unsettle them. Also, if the participants had questions during the task, they could still communicate with the head of study. However, this problem would disappear once the participants were familiar with the system and could use it independently.
One point raised by the majority of participants that could improve realism would be the hospital room. More devices could be placed next to the bed, as is usually the case in a normal hospital room. According to the participants, this would lead to them feeling more like they were in a realistic transfer scenario. Another point that some participants mentioned was that, due to the buttons and the video panel, the room looked more like an abstract training room. The video panel is essential for users to be able to see the transfers they need to make; therefore, it cannot be left out. However, it could be designed to look more like a realistic canvas on which, for example, a video is played with a projector. Some participants also mentioned that the graphics in the virtual world are not good enough so that the virtual world could look as realistic as the real one.
In the custom questionnaire, the realism of the hands the realism of the look of the virtual model and the realism of the feel of the physical model were rated by the participants. In all three ratings, 1 is the worst possible result, and 5 is the best possible result. The question of whether the physical model feels like a human was rated with (3.08/5). It was criticized that the texture of the physical model was too tough and did not feel like touching a real human. The joints in particular were different from those of a human being. This problem could be solved by using a different physical model. However, high-quality care dolls are associated with high costs. The realism of the trainee's virtual hands was rated 4.08 out of 5 by the participants. Only the finger tracking was described as not being perfectly accurate by a few participants. The virtual model's realism received a slightly lower rating (3.67 out of 5). Some participants mentioned that the patient's resolution could be better. Another point of criticism was the constant facial expressions without feedback. Including feedback from the virtual patient on whether a movement performed could lead to pain would also lead to more realism.
The participants felt physically present in the virtual room. This is confirmed by the reactions of the participants, their statements in the interview, and the results of the questionnaires, both the IPQ and the custom questionnaire. However, there is still room for improvement, especially in terms of realism. A hospital room with more details, haptic feedback when interacting with buttons, and a virtual model with facial feedback would make the system even more immersive. Objects like the HMD or the table base that draw the user's attention to the real world can be minimized. Thus, the user's full concentration can focus on the virtual world. Overall, **RQ2** of whether the system delivers an immersive experience can be answered with "yes, but there are still aspects of the system that can be adjusted to improve the immersiveness of the system".

RQ3 *To what extent is the simulated human patient in VRPatient a good surogate for a real human for the purpose of the training of patient transfers?*

This question will be answered with the results of the custom questionnaire and the statements from the interview. When talking about the "simulated human patient," it means both the physical and the virtual patient. In this project, the focus is more on the virtual model since the physical model can easily be substituted by putting the tracking suit on another physical model. However, the participants should still be asked about the physical model. Because if there are difficulties in interacting with the patient, it should be clearly differentiated whether the problem is related to the physical or virtual model.
The participants' ratings of the physical model were moderate. Especially with regard to the question of whether the task could be performed just as well with the physical model as with a motionless person. The question was rated rather negatively, with 2.8 out of 5 possible points (where 1 is the worst and 5 is the best possible result). In particular, the rigidity of the physical model was criticized here.
The markers on the patient's suit were rated positively respectively as not disturbing, with eleven stating "not disturbing at all" and one stating "rather not disturbing". This is good for the system because if the physical model were swapped out for a different one, the markers on the new model wouldn't bother either.
The low weight was also one aspect of the physical model that was criticized by some participants. For a future training scenario, weights could be placed under the physical model's suit.
Some participants even spoke of a preferred alternative, as they have fewer inhibitions when interacting with a puppet than when interacting with a human being.
For the questions about the virtual model, suitable mapping was rated 4.2 and suitable size 4.5 out of 5. The majority of participants rated the matching as largely correct. However, the majority of participants indicated that correct matching is very important to them in order to complete the task. As a result, it is disturbing if the mapping is not accurate. It was reported by most participants that if there were inaccuracies, they were mostly on the arms.
With regard to the research question, the simulated human patient has natural limitations compared to an exercise partner. The simulated patient cannot support the trainee during transfers. Some transfers are not even possible to play through because the simulated patient would overturn in some positions. So, it only makes sense to compare the simulated patient with a patient who is unable to move and therefore not able to support the nurse.
The main differences that the practitioner feels are the weight, the mobility, and the surface of the physical patient. The weight could be modified even on the current model. The mobility and surface will be better depending on the quality of the physical model.
The main difference in the virtual world is when certain body parts of the patient are not mapped accurately. Depending on the size of the offset, it is then difficult for the trainee to carry out the tasks precisely. This issue could be mitigated by firmly attaching the markers to the patient, preventing them from slipping. Optimizations of the implementation could also reduce the offset.
In relation to a transfer, the simulated human patient in VRPatient has limitations that clearly distinguish him from a real human. Missing feedback from the exercise partner as well as the points just mentioned restrict its usability. To practice a precise and completely realistic transfer, too many parameters are different and would have to be changed. In some areas, however, the simulated human patient could replace the training partner, such as when training the basic motion sequences of a patient transfer.

5. Future Work and Conclusion

The last chapter is about potential extensions of VRPatient and the conclusion. The prototype focuses on training a specific patient transfer and can be extended in several ways. Before the process and the result of the thesis are summarized in the conclusion, some of these extensions are briefly described.

5.0.1. Future Work

Feedback on the interaction with the patient

At the moment, the trainees do not get any feedback as to whether their actions with the patient were correct or incorrect. Instructions such as "do not reach behind the patient's knees" are given but not checked. Real transfers can cause pain for the patients if they are not moved correctly. It would therefore be helpful if the trainees received feedback in the simulation as to whether this movement would lead to pain in the real transfer. The virtual model could use the facial expression to indicate when a mistake has been made by the trainee. The system would have to recognize the areas where the person exercising is not allowed to touch the patient. And if this happens, give appropriate feedback.

More Variety in the Scenarios

At the moment, there is only one transfer training scenario that can be trained with VRPatient. In addition to this scenario, VRPatient could offer the possibility of offering different transfers, which could then be divided into different levels of difficulty. Of course, the transfers must be chosen in such a way that they can be performed with a patient who is unable to move. In addition to the various transfers, the patient's attributes could be altered. Weight or injuries such as a broken arm could be simulated. In the event of injuries, the trainees were then no longer allowed to touch the patient in certain areas. The facial expression of the virtual model could then give feedback again if this happens.

Feedback on the Posture of the Trainee

VRPatient focuses on the trackable patient model to train ergonomic patient transfers. However, the trainees do not get any feedback on their posture. According to Dürr et al., the three essential components that teachers follow are: instruction, practice, and feedback.[7] With VRPatient, it is possible to see the instructions and practice the transfer, but the component feedback is completely missing. For this purpose, the trainee's movements could be recorded in order to give him feedback afterwards. It could analyze his posture and point out possible mistakes that could lead to injuries in the long run.

5.0.2. Conclusion

In this thesis, the design of a trackable patient model, which can be used to train ergonomic transfers, was introduced. First, different tracking systems were compared and selected based on several requirements. After the final selection of the tracking system, the prototype VRPatient was implemented. Related work was presented to demonstrate the similarities and differences with VRPatient. To evaluate this prototype, a usability study was carried out with twelve participants. Information from the participants was obtained through several questionnaires and a subsequent interview.
The results of the study showed that the trackable patient model in VRPatient can only replace humans as training partners to a limited extent. The trackable patient model can only simulate a motionless patient since it cannot speak or help with the transfer. The difference in mobility between the physical model and that of a human is

still disturbing in some parts of the body. The precision of the mapping could also be improved in some areas so that the transfers can be carried out more precisely. However, the movement sequences of specific patient transfers can be efficiently trained with VRPatient, even if certain parts of the system still differ from a conventional transfer. In terms of user experience and immersion, the prototype performed very well. The participants had a high user experience, enjoyed using the system, and had immersive experiences for the most part.
The prototype VRPatient still has weaknesses and potential for improvement. However, it shows that a trackable patient model in a VR training scenario has potential and can be expanded in a promising way.

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A. Welcome letter

Herzlich willkommen!

Herzlichen Dank, dass Sie unsere Arbeit unterstützen indem Sie an der Studie teilnehmen. Zunächst möchten wir Ihnen kurz den Ablauf der Studie erklären und Ihnen mitteilen, was genau Sie dabei machen werden.

Ziel und Ablauf der Studie:

In der Studie geht es darum, Patiententransfers in virtueller Realität zu untersuchen, um in Zukunft mögliche Training Szenarios für die Pflege zu etablieren. Hierbei werden Sie mit einem physischen Model in Form einer Trainingspuppe verschiedene Aufgaben bekommen.

Zunächst müssen Sie die Einwilligungserklärung unterschreiben. Dann werden Sie gebeten einen Fragebogen auszufüllen, in dem Fragen zu Ihrer Person gestellt werden.

Als nächstes werden Sie gebeten Tracking Handschuhe anzuziehen, welche für Sie kalibriert werden müssen. Dann setzen Sie die VR Brille auf und bekommen eine kurze Übungsaufgabe um mit dem System und der virtuellen Welt vertraut zu werden. Danach werden Sie gebeten, sich ein Video in der virtuellen Welt anzuschauen, in welcher ein Patiententransfer zu sehen sein wird. Dieses Video können Sie sich mehrmals anschauen, bis Sie den Eindruck haben, dass Sie bereit sind den Transfer selbst durchzuführen. Beim Durchführen des Transfers können Sie die einzelnen Schritte erneut anschauen, um fest zu stellen was genau Sie als nächstes tun müssen.

Bei der Durchführung der Aufgaben werden Sie nicht bewertet, es geh uns nur darum die Tauglichkeit des Systems zu testen. Nachdem Sie den Transfer abgeschlossen haben, werden Sie gebeten ein weiteren Fragebogen zum System auszufüllen. Danach werden Ihnen noch Interviewfragen gestellt, wovon die Antworten ebenfalls vom Studienleiter aufgeschrieben werden. All ihre Angaben werden pseudonymisiert gespeichert. Dafür haben wir eine Einverständniserklärung vorbereitet, welche sowohl vom Studienleiter als auch von Ihnen unterschrieben wird. Beim System wurde darauf geachtet, dass Sie sich nicht verletzen können. Ebenfalls wird der Studienleiter die ganze Dauer der Studie anwesend sein und alle Risiken minimieren. Sollte Ihnen jedoch trotzdem etwas passieren, möchten wir Sie darauf aufmerksam machen, dass der Studienleiter dafür keine Verantwortung übernimmt.

Für den Zeitrahmen der Studie ist ca. 1 Stunde angesehen. Falls Sie während der Studie sich unwohl fühlen oder aus anderen Gründen die Studie beenden möchten, ist dies selbstverständlich möglich auch ohne das Angeben von konkreten Gründen. Bitte geben Sie dann einfach dem Versuchsleiter Bescheid.
Nachdem die Studie durchgeführt wurde, erhalten Sie 12 Euro als Entlohnung für Ihre Hilfe. Wir bedanken uns schon im Vorhinein recht herzlich für Ihre Hilfe und wünschen Ihnen viel Spaß beim Durchführen der Studie!

B. Consent form

Einverständniserklärung ID: ID: ____

Informationen zur Studienleitung

Studienleiter: Simon Röhrle

Institution: Arbeitsgruppe Mensch-Computer Interaktion, Fachbereich Informatik und Informationswissenschaft, Universität Konstanz

Erklärung

Über das Ziel, den Inhalt und die Dauer der Studie wurde ich informiert. Im Rahmen dieser Studie werden in Fragebögen personenbezogene Daten erhoben. Zusätzlich wird die Studie auf Video aufgezeichnet, es werden Audioaufnahmen gemacht und Bewegungsdaten erfasst.

Hiermit bin ich darüber aufgeklärt, dass die personenbezogenen Daten vertraulich behandelt werden. Die Ergebnisse der Analyse der Video-, Audio- und Bewegungsdaten werden eventuell in späteren Publikationen pseudonymisiert veröffentlicht. Wir garantieren dabei absolute Diskretion. Es wird zu keinem Zeitpunkt Rückschluss auf Sie als Person möglich sein.

Optional (Bei Zustimmung bitte ankreuzen)

☐ Ich bin damit einverstanden, dass meine Videodaten zusätzlich zu internen Präsentationszwecken genutzt werden können.

Hiermit erkläre ich mich mit den unter „Erklärung" genannten Punkten und den angekreuzten optionalen Punkten einverstanden:

________________	________________	________________
(Name)	(Ort, Datum)	(Unterschrift)

Hiermit verpflichtet sich die Studienleitung, die Video- und Audioaufzeichnung sowie sämtliche sonstigen gewonnenen Daten lediglich zu Auswertungszwecken im Rahmen dieser Untersuchung zu verwenden:

________________	________________	________________
(Name)	(Ort, Datum)	(Unterschrift)

C. Demographic Questionnaire

Demographischer Fragebogen

1. Personenbezogene Daten

1.Personenbezogene Daten Alter: ______ Jahre

Körpergröße:______

Geschlecht: [ ] männlich [ ] weiblich [ ] divers

Bist du Student*in? [ ] ja [ ] nein

Falls ja, was studierst du und in welchem Semester?

____

Falls nein, was ist deine momentane Tätigkeit/ Beruf?

____

Benutzt du eine Sehhilfe? [ ] ja [ ] nein

Falls ja, trägst du überwiegend… [ ] eine Brille [ ] Kontaktlinsen [ ] beides

Falls ja, welche Art von Sehschwäche hast du?

[ ] Kurzsichtigkeit – wie stark? ______________

[ ] Weitsichtigkeit – wie stark? ______________

[ ] Sonstiges: ____________________________

Hast du bereits in der Pflege gearbeitet? [ ] ja [ ] nein

Falls ja, wie lange?

____

Hast du andere Vorerfahrungen mit Transfers bei der Pflege von anderen Personen?

[ ] ja [ ] eher ja [ ] weder noch [ ] eher nein [ ] nein

2. Vorerfahrung – Virtual Reality

Hast du schon mal eine Virtual Reality Brille verwendet? [ ] ja [ ] nein

Hast du bereits Erfahrung mit Virtual Reality Anwendungen? [ ] ja [ ] nein

Wie vertraut bist du mit der Verwendung von Virtual Reality?

[ ] sehr vertraut

[ ] vertraut

[ ] etwas vertraut

[ ] eher nicht vertraut

[ ] überhaupt nicht vertraut

Mit welchen Augmented Reality Anwendungen konntest du bisher Erfahrungen sammeln?

[ ] Smartphone AR

[ ] Tablet AR

[ ] Head-Mounted-Displays (AR Brillen)

[ ] andere: ____

D. User Experience Questionnaire

Bitte geben Sie Ihre Beurteilung ab.

Um das Produkt zu bewerten, füllen Sie bitte den nachfolgenden Fragebogen aus. Er besteht aus Gegensatzpaaren von Eigenschaften, die das Produkt haben kann. Abstufungen zwischen den Gegensätzen sind durch Kreise dargestellt. Durch Ankreuzen eines dieser Kreise können Sie Ihre Zustimmung zu einem Begriff äußern.

Beispiel:

attraktiv	○	⊗	○	○	○	○	○	unattraktiv

Mit dieser Beurteilung sagen Sie aus, dass Sie das Produkt eher attraktiv als unattraktiv einschätzen.

Entscheiden Sie möglichst spontan. Es ist wichtig, dass Sie nicht lange über die Begriffe nachdenken, damit Ihre unmittelbare Einschätzung zum Tragen kommt.

Bitte kreuzen Sie immer eine Antwort an, auch wenn Sie bei der Einschätzung zu einem Begriffspaar unsicher sind oder finden, dass es nicht so gut zum Produkt passt.

Es gibt keine „richtige“ oder „falsche“ Antwort. Ihre persönliche Meinung zählt!

Bitte geben Sie nun Ihre Einschätzung des Produkts ab. Kreuzen Sie bitte nur einen Kreis pro Zeile an.

	1	2	3	4	5	6	7		
unerfreulich	○	○	○	○	○	○	○	erfreulich	1
unverständlich	○	○	○	○	○	○	○	verständlich	2
kreativ	○	○	○	○	○	○	○	phantasielos	3
leicht zu lernen	○	○	○	○	○	○	○	schwer zu lernen	4
wertvoll	○	○	○	○	○	○	○	minderwertig	5
langweilig	○	○	○	○	○	○	○	spannend	6
uninteressant	○	○	○	○	○	○	○	interessant	7
unberechenbar	○	○	○	○	○	○	○	voraussagbar	8
schnell	○	○	○	○	○	○	○	langsam	9
originell	○	○	○	○	○	○	○	konventionell	10
behindernd	○	○	○	○	○	○	○	unterstützend	11
gut	○	○	○	○	○	○	○	schlecht	12
kompliziert	○	○	○	○	○	○	○	einfach	13
abstoßend	○	○	○	○	○	○	○	anziehend	14
herkömmlich	○	○	○	○	○	○	○	neuartig	15
unangenehm	○	○	○	○	○	○	○	angenehm	16
sicher	○	○	○	○	○	○	○	unsicher	17
aktivierend	○	○	○	○	○	○	○	einschläfernd	18
erwartungskonform	○	○	○	○	○	○	○	nicht erwartungskonform	19
ineffizient	○	○	○	○	○	○	○	effizient	20
übersichtlich	○	○	○	○	○	○	○	verwirrend	21
unpragmatisch	○	○	○	○	○	○	○	pragmatisch	22
aufgeräumt	○	○	○	○	○	○	○	überladen	23
attraktiv	○	○	○	○	○	○	○	unattraktiv	24
sympathisch	○	○	○	○	○	○	○	unsympathisch	25
konservativ	○	○	○	○	○	○	○	innovativ	26

UEQ_german.doc

E. IGROUP Presence Questionnaire

IGROUP PRESENCE QUESTIONNAIRE

In der Computer erzeugten Welt hatte ich den Eindruck, dort gewesen zu sein…

überhaupt nicht						sehr stark
O	O	O	O	O	O	O

Ich hatte das Gefühl, dass die virtuelle Umgebung hinter mir weitergeht.

trifft gar nicht zu						trifft völlig zu
O	O	O	O	O	O	O

Ich hatte das Gefühl, nur Bilder zu sehen.

trifft gar nicht zu						trifft völlig zu
O	O	O	O	O	O	O

Ich hatte nicht das Gefühl, in dem virtuellen Raum zu sein.

hatte nicht das Gefühl						hatte das Gefühl
O	O	O	O	O	O	O

Ich hatte das Gefühl, in dem virtuellen Raum zu handeln statt etwas von außen zu bedienen.

trifft gar nicht zu						trifft völlig zu
O	O	O	O	O	O	O

Ich fühlte mich im virtuellen Raum anwesend.

trifft gar nicht zu						trifft völlig zu
O	O	O	O	O	O	O

Wie bewusst war Ihnen die reale Welt, während Sie sich durch die virtuelle Welt bewegten (z. B. Geräusche, Raumtemperatur, andere Personen etc.)?

extrem bewusst | mittelmäßig bewusst | unbewusst

O O O O O O O

Meine reale Umgebung war mir nicht mehr bewusst.

trifft gar nicht zu | trifft völlig zu

O O O O O O O

Ich achtete noch auf die reale Umgebung.

trifft gar nicht zu | trifft völlig zu

O O O O O O O

Meine Aufmerksamkeit war von der virtuellen Welt völlig in Bann gezogen.

trifft gar nicht zu | trifft völlig zu

O O O O O O O

Wie real erschien Ihnen die virtuelle Umgebung?

vollkommen real | weder noch | gar nicht real

O O O O O O O

Wie sehr glich Ihr Erleben der virtuellen Umgebung dem Erleben einer realen Umgebung?

überhaupt nicht | etwas | vollständig

O O O O O O O

Wie real erschien Ihnen die virtuelle Welt?

wie eine vorgestellte Welt | nicht zu unterscheiden von der realen Welt

O O O O O O O

Die virtuelle Welt erschien mir wirklicher als die reale Welt.

trifft gar nicht zu | trifft völlig zu

O O O O O O O

F. Simulator Sickness Questionnaire

The Simulator Sickness Questionnaire

Kreisen Sie ein, wie sehr jedes Symptom Sie jetzt beeinträchtigt.

0 = „überhaupt nicht“ 1 = „leicht“ 2 = „mäßig“ 3 = „stark“

1. Allgemeines Unwohlsein	0	1	2	3
2. Müdigkeit	0	1	2	3
3. Kopfschmerzen	0	1	2	3
4. Überanstrengung der Augen	0	1	2	3
5. Schwierigkeiten beim Fokussieren	0	1	2	3
6. Erhöhter Speichelfluss	0	1	2	3
7. Schwitzen	0	1	2	3
8. Übelkeit	0	1	2	3
9. Konzentrationsschwierigkeiten	0	1	2	3
10. Kopffülle	0	1	2	3
11. Verschwommenes Sehen	0	1	2	3
12. Schwindel (offene Augen)	0	1	2	3
13. Schwindel (geschlossene Augen)	0	1	2	3
14. Schwindel(Vertigo)*	0	1	2	3
15. Magenbewusstsein**	0	1	2	3
16. Rülpsen	0	1	2	3

*Vertigo wird als Orientierungsverlust in Bezug auf eine vertikale Senkrechte erlebt

**Magenbewusstsein wird normalerweise benutzt um ein Gefühl anzugeben, welches kurz vor dem Brechreiz ist

G. Custom Questionnaire

Fragen zum physischen Modell

1. Wie hat sich das physische Modell im Vergleich zu einem Menschen **angefühlt**?

[ ]sehr unrealistisch [ ]eher unrealistisch [ ]weder noch [ ]eher realistisch [ ]sehr realistisch

2. Wie haben sich Körperteile und Gelenke des physischen Modells im Vergleich mit denen eines Menschen **bewegen lassen**?

[ ] sehr gut [ ] eher gut [ ] weder noch [ ] eher schlecht [ ] sehr schlecht

3. Welchen **Einfluss** hatten die **Marker** (Silberne Kugeln) des physischen Modells auf die Ausführung der Aufgabe?

[ ] sehr störend [ ] eher störend [ ] weder noch [ ] eher nicht störend [ ] gar nicht störend

4. Hatten Sie das Gefühl, die Aufgaben gleich gut bewältigen zu können, wie wenn ein **regungsloser Mensch** statt des **physischen Modells** da gelegen wäre?

[ ] ja [ ] eher ja [ ] weder noch [ ] eher nein [ ] nein

Wenn (eher) nein: Was waren die Unterschiede? ________________________________

____

Fragen zum virtuellen Modell

1. Wie **realistisch** war das Aussehen des virtuellen Modells?

[ ]sehr unrealistisch [ ]eher unrealistisch [ ]weder noch [ ]eher realistisch [ ]sehr realistisch

2. Hat sich das virtuelle Modell immer so **bewegt** wie Sie es erwartet hätten wenn, wie Sie das physische Modell bewegt haben?

[ ] ja [ ] eher ja [ ] weder noch [ ] eher nein [ ] nein

3. War die **Größe** des virtuellen Modells mit der des physischen Modells übereinstimmend?

[ ] nein [ ] eher nein [ ] weder noch [ ] eher ja [ ] ja

4. War die **Position** des virtuellen Modells mit der des physischen Modells übereinstimmend?

[ ] ja [ ] eher ja [ ] weder noch [ ] eher nein [ ] nein

Fragen zur Aufgabe

1. War es direkt verständlich, wie man mit dem Patienten **interagieren** muss?

[ ] ja [ ] eher ja [ ] weder noch [ ] eher nein [ ] nein

2. Waren die Aufgaben die zu erledigen waren **verständlich** erklärt?

[ ] nein [ ] eher nein [ ] weder noch [ ] eher ja [ ] ja

3. Wie war der Einfluss auf die Aufgabe, wenn die **Größe** des virtuellen Modells nicht zu der des physischen Models zusammengepasst hat?

[ ] sehr störend [ ] eher störend [ ] weder noch [ ] eher nicht störend [ ] gar nicht störend

4. Wie war der Einfluss auf die Aufgabe, wenn die **Positionen** des virtuellen Modells nicht zu der des physischen Models zusammengepasst haben?

[ ] gar nicht störend [ ] eher nicht störend [ ] weder noch [ ] eher störend [ ] sehr störend

5. Wie war der Einfluss auf die Aufgabe, wenn die **Antwortzeit** des Systems zu langsam war, oder für kurze Zeit ganz abgebrochen ist?

[ ] sehr störend [ ] eher störend [ ] weder noch [ ] eher nicht störend [ ] gar nicht störend

6. Hat es **Spaß** gemacht, die Aufgaben zu erfüllen?

[ ] ja [ ] eher ja [ ] weder noch [ ] eher nein [ ] nein

Wenn (eher) nein: Was waren die Gründe? ______________________________________

____

7. Haben Sie während der Aufgabe das Gefühl gehabt, dass Sie eine Pause brauchen, weil die Benutzung des Systems **anstrengend** oder Ihnen übel war?

[ ] nein [ ] eher nein [ ] weder noch [ ] eher ja [ ] ja

8. Haben sich die **Hände** in der virtuellen Welt **realistisch** angefühlt?

[ ] ja [ ] eher ja [ ] weder noch [ ] eher nein [ ] nein

H. Semi-Structured Interview

Interviewfragen

1. War der Patient Ihrer Meinung nach ein guter Ersatz für einen Menschen?

2. Welche Einschränkungen hatte der Patient?

3. Konnten Sie die Bewegungen am Patienten immer so durchführen wie Sie es beabsichtigt haben, falls nein warum nicht / in welchem Fall nicht?

4. Haben Sie Vorschläge was am System geändert werden könnte, sodass sich der Patient mehr wie ein realer Mensch anfühlt?

5. Gab es Momente in denen dich das Equipment(VR Brille, Handschuhe) gestört haben?

6. Hatten Sie das Gefühl bei der Aufgabendurchführung in ihrer Bewegung eingeschränkt zu sein?

7. Wären Sie in der Lage das System über längere Zeit zu benutzen, oder gibt es Gründe, dass Sie zwischendurch eine Pause bräuchten?

8. War Ihnen während der Aufgabe unwohl oder haben Sie ein Gefühl von Übelkeit verspürt?

9. Was hast du an dem System als vorteilhaft/positiv und was als störend/negativ empfunden?

10. Hat das System ihre Erwartungen erfüllt?

11. Haben Sie sich Gefühlt, wie wenn Sie in einem realen Krankenhaus gewesen wären und dort den Transfer durchgeführt hätten?

12. Wie wichtig war Ihnen das Aussehen des virtuellen Patienten beim Ausführen der Aufgabe und wie bewerten Sie dieses?

13. Wie wichtig war Ihnen die Beweglichkeit des physischen Patienten beim Ausführen der Aufgabe und wie bewerten Sie diese?

14. Wie wichtig war Ihnen, dass die Position des virtuellen Modells übereinstimmend ist mit der Position des physischen Modells und wie gut hat es ihrer Meinung nach geklappt?

15. Haben Sie Vorschläge wie das System verbessert werden könnte, dass es sich noch realistischer anfühlt?

I. Payment Confirmation

Ich habe bei der Studie „Patiententransfers in virtueller Realität“ im Rahmen der Bachelorabschlussarbeit von Simon Röhrle an der Universität Konstanz (AG Reiterer/Informatik) teilgenommen und eine Kompensation in Höhe von 12 Euro erhalten:

Datum Name Unterschrift

Ich habe bei der Studie „Patiententransfers in virtueller Realität“ im Rahmen der Bachelorabschlussarbeit von Simon Röhrle an der Universität Konstanz (AG Reiterer/Informatik) teilgenommen und eine Kompensation in Höhe von 12 Euro erhalten:

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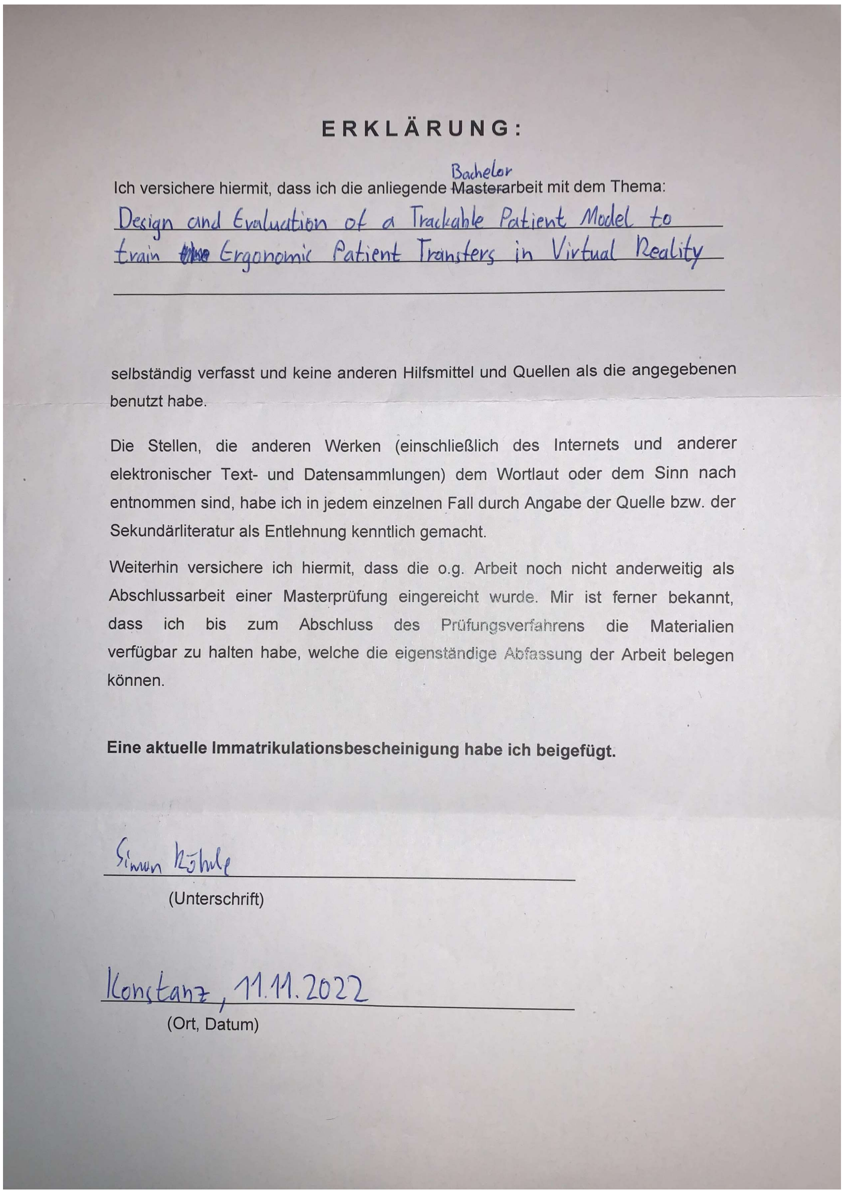
Datum Name Unterschrift

J. Declaration of Authorship



ERKLÄRUNG:

Ich versichere hiermit, dass ich die anliegende ~~Master~~ Bachelorarbeit mit dem Thema:

Design and Evaluation of a Trackable Patient Model to train ~~the~~ Ergonomic Patient Transfers in Virtual Reality

selbständig verfasst und keine anderen Hilfsmittel und Quellen als die angegebenen benutzt habe.

Die Stellen, die anderen Werken (einschließlich des Internets und anderer elektronischer Text- und Datensammlungen) dem Wortlaut oder dem Sinn nach entnommen sind, habe ich in jedem einzelnen Fall durch Angabe der Quelle bzw. der Sekundärliteratur als Entlehnung kenntlich gemacht.

Weiterhin versichere ich hiermit, dass die o.g. Arbeit noch nicht anderweitig als Abschlussarbeit einer Masterprüfung eingereicht wurde. Mir ist ferner bekannt, dass ich bis zum Abschluss des Prüfungsverfahrens die Materialien verfügbar zu halten habe, welche die eigenständige Abfassung der Arbeit belegen können.

Eine aktuelle Immatrikulationsbescheinigung habe ich beigefügt.

Simon Kühle

(Unterschrift)

Konstanz, 11.11.2022

(Ort, Datum)

K. Contents USB-Stick

The USB stick contains the following files:

- Bachelor´s thesis
- Bachelor´s project report
- Bachelor´s seminar report