Hands-free Interactions with Augmented Reality Glasses during the Training of Ergonomic Patient Transfers

Bachelor Thesis

submitted by

Anna-Maria Fritschle

at the

Universität Konstanz

Human-Computer Interaction Group

Department of Computer and Information Science

1. Reviewer: Prof. Dr. Harald Reiterer

2. Reviewer: Prof. Dr. Michael Grossniklaus

Konstanz, 2022

Abstract

Nursing is a physically demanding profession and many caregivers have to leave this profession due to work-related back pain and injuries. The injuries are mainly caused by over-exertion during patient transfers. Care concepts like Kinaesthetics can help avoid such injuries. In Germany, three-day-long courses are offered for nursing students to learn and practice Kinaesthetics. But aside the courses, there is a lack of support for the training of kinaesthetics transfers. A modern approach to support the self-training of ergonomic patient transfers outside of training courses is to use AR glasses, which display step-by-step instructions. The interaction with the AR glasses has to be hands-free, since both hands are needed to conduct a patient transfer. Even though systems to support the training already exist, there is currently still a lack of research on hands-free interactions with AR glasses in the patient transfer training context. In this bachelor thesis, a design concept and the implementation of an AR application that supports the patient transfer training and enables hands-free interaction via (i) eye gaze and voice and (ii) head gestures are presented. Furthermore, the design and results of a comparative study with both hands-free interaction techniques are presented. The results of the study indicate that the interaction techniques have many benefits to support the training of ergonomic patient transfers, but they need further investigation. Two main difficulties were encountered with them, which should be improved in the future.

Contents

List of Figures

List of Tables

1 Introduction

The increasing shortage of nurses in Germany has been a problem for years [1]. Still, many nurses have to leave their job due to work-related back injuries [2]. Nursing is a physically demanding profession and the risk of back injuries is high. Compared with other occupations, it is reportedly six times higher [3]. A study found that a major risk factor for these back injuries is the transfer of patients from one position to another when conducted on a daily basis [4]. Patient transfers generally require a lot of physical effort and pose the risk of over-exertion [2]. Care concepts like kinaesthetics can help avoid back injuries by applying ergonomics to patient transfers. The central aspect of kinaesthetics is the perception of movement [5]. Applied in practice, it avoids unnecessary effort for nurses and promotes the patients' movement abilities [6]. In Germany, kinaesthetics can be learned and practiced in three-day courses [7]. Nursing training normally includes attending one kinaesthetics course [7]. After attending just one course, nursing students are often not practiced enough to apply kinaesthetics at work and still need more practice [7]. Apart from these courses, there is, however, a lack of support for the training of kinaesthetics transfers as teachers to support the training are not available [7].

Technical systems can help enable nursing students to self-train ergonomic patient transfers outside training courses without the help of a teacher. Various technical solutions to support nursing students during the self-training exist so far. Previous work has, for example, introduced a robot patient [8] or a feedback system [9] to support the self-training of patient transfers. Another example is the tablet-based KiTT application, which provides step-by-step instructions for the training of patient transfers [10]. Over the last years, Augmented Reality (AR) glasses found their way into nursing training. Augmented Reality is defined by Azuma [11] as the complementation of the real world with virtual objects. With AR glasses, virtual instructions for the patient transfer training can be directly displayed in the nursing students' field of view. This is advantageous because it is not required to turn the gaze away from the patient to see the instructions, unlike with monitor-based systems [11]. Previous work showed how promising this approach is. Kopetz et al. [12] evaluated AR glasses that provide step-by-step instructions for the training of patient transfers and found numerous benefits, such as a facilitated training procedure or a reduced error rate. However, they found that a downside was the touch-based interaction with the glasses, which required a tap on the glasses with one hand to navigate between the different instructions. The authors concluded that touch-based interaction is not favorable and that hands-free interaction with AR glasses is required for the patient transfer training context.
As one can imagine, both hands are already busy with the conduct of the patient transfer and can not be used for the interaction with the instructions.

With modern AR glasses like the Microsoft HoloLens 2, it is no longer necessary to use the hands for the interaction with the system, they already allow users to interact hands-free [13]. Previous work has introduced various interesting and innovative techniques for hands-free interaction with AR glasses. Input modalities like voice [14], eyes [15], head [16] or feet [17] can be used for hands-free interaction. Furthermore, different input modalities can also be combined. For example, eye gaze can be combined with voice [18] or foot [17] as a second input modality. These are just a few examples to show how diverse this hands-free approach is. Many of these approaches showed to be promising solutions. However, not all existing techniques are equally suitable to support the training of ergonomic patient transfers. The patient transfer training context has certain requirements that have to be fulfilled by an interaction technique to support the training efficiently. Otherwise, the overall training quality and experience might be affected. From related work, two potentially suitable hands-free interaction techniques were found to be (i) eye gaze and voice and (ii) head gestures.

Currently, the approach of hands-free interactions with AR glasses to support the training of ergonomic patient transfers is still unexplored. Existing systems that support the training, including the systems that were briefly mentioned before, do mostly not use AR glasses and do not support hands-free interaction. Therefore, systems that were evaluated in the patient transfer training context were mostly touch-based. In contrast to that, existing hands-free interaction techniques with AR glasses were never evaluated in the patient transfer training context, only in other contexts. There is still a lack of research on hands-free interactions in this context. To my knowledge, no empirical data about the two hands-free interaction techniques (i) eye gaze and voice and (ii) head gestures in the patient transfer training context exists. Therefore, this bachelor thesis presents a design concept and an implementation approach for an AR application that supports the self-training of ergonomic patient transfers and enables hands-free interaction via the two techniques (i) eye gaze and voice and (ii) head gestures. Furthermore, it presents a comparative empirical study that was conducted with both interaction techniques with the goal to find the benefits and downsides of (i) eye gaze and voice and (ii) head gestures to support the training of ergonomic patient transfers.

Chapter 2 analyzes the patient transfer training context by further investigating the kinaesthetics care concept and kinaesthetics courses. From the context analysis of the kinaesthetics courses, the requirements the context has on a hands-free interaction technique are derived. Chapter 3 provides an overview of existing systems to support the training of patient transfers and an analysis of different hands-free interaction techniques. The hands-free interaction techniques are compared with the context requirements to find out to what extent they are fulfilled and which techniques are potentially suitable to support the training, and the results are discussed. Here, it is explained why (i) eye gaze and voice and (ii) head gestures turned out to be potentially suitable. Chapter 2 and 3 are based on the bachelor seminar, where the goal was to identify suitable hands-free interaction techniques to implement them in the bachelor project. Chapter 4 proposes a design concept for the application. The steps from basic paper sketches to an iteratively improved design are described. Furthermore, the implementation of the user interface and the two hands-free interaction techniques is described. This Chapter is based on the bachelor project but goes beyond the bachelor project as the hands-free interaction technique head gestures was implemented in the course of the thesis. Chapter 5 describes the design and conduct of the comparative study. After that, the study results are presented and discussed. Lastly, Chapter 7 provides a conclusion and implications for future work.

2 Analysis of Application Context and Requirements

This chapter analyzes the context of the application. Before developing an application, it is important to gain more knowledge about the context it is developed for to ensure it meets the requirements of the context. Therefore, Section 2.1 goes more into detail about the kinaesthetics care concept. It briefly explains kinaesthetics the central aspects of kinaesthetics and then describes an exemplary kinaesthetics transfer to better understand how such a transfer is conducted. In Section 2.2, the state-of-the-art of the kinaesthetics course training is described. From the context, requirements are derived and presented in Section 2.3.

2.1 Kinaesthetics Care Concept

Definition and Concepts

Roier [6] described that caregivers often provide more support during caring tasks than necessary and let patients play a passive role instead of letting them make use of their own abilities. This leads to unnecessary effort for the caregivers and muscle loss for the patient. Instead, the caregiver and patient should be jointly involved in the caring process. Kinaesthetics is a care concept that supports the active role of the patient to avoid overexertion of the nurse and promote the patient's movement abilities, as Roier further explained. It helps assess the patient's abilities, adjust the support accordingly so that the patient is neither overstrained nor under-challenged, and allow the patient's self-activity.

Kinaesthetics consists of the following six concepts:

1. **Interaction** The interaction between caregiver and patient can be either mutual (e.g., performing a movement together to guide the patient), stepwise (e.g. instructing a movement), or unilateral (either caregiver or patient perform a movement alone) [6].

2. **Functional anatomy** Kinaesthetics divides the human body into masses, which are the head, rib cage, limbs and pelvis, and spaces, which are the neck, armpits, waist, and groin [6]. Only masses should be touched and the spaces should be avoided because they are vulnerable [6].

3. **Human movement** Kinaesthetics distinguishes between postural movements, where weight is shifted between masses, and transport movements, where the masses are moved in space [6]. Movements should be asymmetrical and spiral because they require less effort [6].

4. **Exertion** Kinaesthetics helps reduce exertion by applying pushing and pulling techniques [6].

5. **Human function** Positions are an important component of kinaesthetics, one should be mobile in a position but also able to hold the position [6].

6. **Environment** The environment (e.g., furniture and bed) must be adjusted so that there is enough space to perform the movements and if necessary, holding possibilities like chairs or transfer aids can be provided [6].

Kinaesthetics Transfer

In the following, an exemplary kinaesthetics transfer to sit up a patient to the bedside is described.

- The patient is in a supine position with the left arm placed on her stomach [19] (see Fig. 2.1 a).
- The caregiver bends the patient's legs one after the other and positions the feet in a standing position on the mattress [19] (see Fig. 2.1 b).
- The caregiver turns the patient onto her right side by first tilting the legs to the side and then moving the pelvis and upper body successively [19] (see Fig. 2.1 c).
- The caregiver pulls the patient's lower legs over the edge of the bed, while the thighs remain on the mattress [19] (see Fig. 2.1 d).
- The upper body is raised in a spiral movement over the thighs to the pelvis to avoid unnecessary effort [19] (see Fig. 2.1 e).

Figure 2.1: Kinaesthetics transfer to sit up a patient to the bedside. *Image from* [19]

2.2 Kinaesthetics Courses [7]

In the following, a paper by Dürr et al. [7], which describes the current state state-of-the-art of the course training for nursing students and shows the current limitations of the training outside of the courses, is analyzed to understand the patient transfer training context better.

Dürr et al. [7] investigated the state-of-the-art of kinaesthetics courses in Germany. The basic courses are three days long and consist of theoretical learning as well as practical training. Nursing students learn kinaesthetics transfers for different scenarios, e.g., transfer from bed to wheelchair, and for different movement capabilities of patients, e.g., mobile or immobile patients. The authors explained a transfer is learned in three phases, consisting of (i) Instruction, (ii) Practice, and (iii) Feedback. In the instruction phase, the teacher demonstrates the transfer and explains the underlying theory. In the practice phase, the nursing students practice the transfer by themselves. In the feedback phase, the teacher gives the students feedback on their performance.
The authors described that the practice is an especially important part of the course because it allows the students to learn by experience. For the practice, the nursing students are divided into groups of two to five students. In the groups, they practice the transfer in the roles of nurse and patient to simulate a patient transfer scenario, because the course training is not carried out with real patients. One student is in the role of the nurse and transfers another student, who is the simulated patient. An important aspect of the nurse role is the activation of the patient. The patient should be motivated to engage in the transfer procedure since the active role of the patient is a central aspect of kinaesthetics. During or after the practice, the students talk about their learning experiences in the groups. The teacher observes the practice and provides support to the groups, e.g., by demonstrating transfer movements.
Furthermore, Dürr et al. [7] stated that many nursing students who attended a kinaesthetics course would wish to continue practicing kinaesthetics after the course because they do not feel practiced enough to use the learned transfer movements at work. However, outside the courses, there is a lack of support for the training of kinaesthetics transfers. The authors explained that currently existing materials for the learning of kinaesthetics do not provide enough support and there are no teachers available to support the students during the practice outside of training courses.

2.3 Requirements

To support nursing students properly during the training, suitable hands-free interaction techniques have to be chosen. In general, the interaction technique should maintain the overall training quality and experience. It should match the context and fulfill the requirements of the context. These requirements can be derived from the context analysis which was described in Section 2.2 and from general human-computer interaction design principles.

Verbal communication
As the context analysis showed, verbal communication is an important aspect of the training scenario. The simulated patient has to be activated verbally during the training and the learning experience is discussed with the training partner [7]. Thus, the interaction with the system should not affect the verbal communication between the nursing students. They should be able to communicate verbally with each other without interruption, disturbance, or restriction. Furthermore, the interaction with the system should be distinguishable from verbal communication and not be mistaken for verbal communication. The simulated patient should not think that the training partner is talking to him or her when interacting with the system. This could lead to misunderstandings between the students and affect the training.

Non-verbal communication

Non-verbal communication is another important form of human communication in general and the nurse-patient interaction. Especially eye contact is important in the interaction with patients and should not be affected [20]. Therefore, eye contact and all other forms of non-verbal communication should be practicable during the training for a realistic training experience. The non-verbal communication between nursing students should not be interrupted, disturbed, or restricted by the interaction with the system. Nursing students should be able to communicate non-verbally, e.g., via eye contact or gestures. Moreover, the interaction with the system should be distinguishable from non-verbal communication to avoid misunderstandings.

In Section 2.1, it was described that body movements are often used to guide a patient [6]. Therefore, the non-verbal interaction between the nursing students via body movement should not be affected. The simulated nurse should be able to guide, instruct and support the simulated patient non-verbally with his or her own movements.

Visibility of interaction commands

Visibility is one of the six design principles by Donald Norman, which should help make the interaction with user interfaces easy and intuitive [21]. It states that "Users need to know what all the options are, and know straight away how to access them" [21]. Therefore, the available and executable commands for the interaction with the system should be visible to make the interaction easy. This might avoid that users have to memorize the commands or use the wrong commands.

Avoidance of Midas Touch

The patient transfer training context involves a lot of movement and talking. With interaction via voice commands or gestures, it could happen that commands are triggered unintentionally when saying a voice command during verbal communication with the training partner or performing a gesture during the movement flow. This problem is called the Midas Touch Problem [22]. The Midas Touch effect should be avoided by the interaction technique. Its occurrence might disturb or hinder the patient transfer conduct since the user repeatedly might have to reverse the action or effect caused by unintentionally triggered commands.

Social acceptability

The patient transfer training is a social situation that involves two people. Therefore, the interaction technique should be acceptable for this social context and not disturb it. Montero et al. [23] described that social acceptability is on the one hand about the user's feelings, whether he felt comfortable or awkward with the interaction and thinks it is appropriate for the context. On the other hand, the authors described that it considers the spectator's feelings, whether he finds the interaction weird or not and thinks it is appropriate. This means for the patient transfer training context that the nursing student who is interacting with the system should feel comfortable with the interaction and not awkward. At the same time, the training partner, who is observing the interaction, should not perceive it as weird. Both students should think it is appropriate for the training context.

Koelle et al. [24] stated that important factors, which contribute to a socially acceptable interaction, are subtlety and unobtrusiveness. Social acceptability has a broad spectrum of criteria, therefore it will be focused on these main criteria in the selection of suitable techniques. The interaction techniques should fulfill these criteria.

3 Analysis of Related Work

This chapter analyzes related work on systems that support the patient transfer training and related work on hands-free interaction techniques. Section 3.1 gives an overview of existing systems. Section 3.2 presents different hands-free interaction techniques and compares them with the requirements. The comparison of the techniques with the requirements should help determine which techniques are potentially suitable to support the patient transfer training. To be considered suitable, as many requirements as possible should be fulfilled by the technique. The results of the comparison are discussed afterward, and a conclusion is made about which techniques are potentially suitable. Furthermore, implications for the implementation of the selected techniques are derived from the findings.

3.1 Systems to Support the Training of Patient Transfers

Some systems to support the learning and training of patient transfers already exist.
Nakamura et al. [8] evaluated a robot patient that realistically simulates a patient for the self-training of wheelchair transfers. The authors conducted an experiment with 12 nursing students, who had to transfer the robot patient from bed to wheelchair multiple times. The participants' skills were measured through a score for each transfer conduct. The authors reported an increasing score, which indicated that the self-training with the robot patient was successful.
Dürr et al. [10] developed the tablet-based KiTT application, which enables two nursing students to learn and practice kinaesthetics transfers together outside of training courses. The learning with the system follows the same three-phase procedure that was applied by teachers in kinaesthetics courses to teach transfers and which consists of instruction, practice, and feedback. In the instruction phase, each step of the patient transfer is visualized as a 3d animation. In the training phase, short video and audio instructions support each transfer step. In the last phase, feedback is provided. The authors evaluated the application with 26 nursing students who had to conduct a patient transfer before and after using KiTT. Their results indicate that KiTT supports the learning and training of kinaesthetics transfers well.
Huang et al. [9] proposed a feedback system for the self-training of bed-wheelchair transfers. The system measures and evaluates the users' performance during the transfer conduct and provides feedback on a monitor. The authors evaluated the system with 10 nursing students. Half of the participants used the feedback system during the conduct of a wheelchair transfer, the other half did not use the feedback system. The authors reported an increased improvement in transfer skills through the use of the feedback system.

Only a few systems use AR glasses to support the self-training of patient transfers.
Kopetz et al. [14] developed an application for smart glasses to support the training of patient transfers. It provides instructions for each transfer step in form of short textual descriptions as well as pictures and videos to visualize the transfer movements. The application was evaluated with 29 nursing students. The authors assessed the participants' performances during the conduct of a bed-wheelchair transfer first without the application and then with it. They found that the use of the application led to an improved performance of the participants and concluded that it is promising to support the training of patient transfers.

The investigated related work introduced systems that provide instructions during the transfer or support the self-training in other ways. However, they mostly use forms of representation in which information is not displayed in the field of view, like monitors. Only few systems use AR glasses to display instructions in the field of view. These systems that use the approach with AR glasses do, however, not support hands-free interaction. To my knowledge, no previous work on systems that support the self-training with AR glasses and enable hands-free interaction exists.

3.2 Techniques for Hands-free Interactions

The application to be developed should provide instructions and interaction possibilities with these instructions similar to the systems that were discussed in Section 3.1, especially the KiTT application [10]. Furthermore, it should provide the corresponding buttons to interact with the instructions, e.g., a button to pause the video. This is further discussed in Section 4.1.1. An interaction task is performed by selecting the corresponding button, e.g., selecting the pause button to pause the video. This type of interaction tasks, where a 3D object is selected, is classified as a selection task [25]. In this case, the objects to be selected are buttons of a 3D user interface. Therefore, hands-free interaction techniques to perform selection tasks are needed.
Previous work introduced and compared different techniques for hands-free interaction with AR glasses to perform selection tasks. Various different input modalities can be used for hands-free interaction, like eyes (e.g. [26] [17], [15]), head [16] or voice [14]. Another approach is to combine different input modalities. Eye gaze can be combined with other modalities like voice (e.g. [27], [18]), foot [17] or elektromyografie (EMG) [15]. Head movements can also be combined with modalities like voice or foot [28].
In the following, the six most interesting and relevant related works are analyzed in detail, including the context they were evaluated in and essential study results. In Section 3.2.1, a table gives an overview of the comparison of the techniques with the requirements, which should help identify suitable techniques. The results of the comparison are discussed afterwards and implications are derived.

Prilla et al. [16]: Head Gestures

Prilla et al. [16] developed an AR system that supports caregivers during their work and enables hands-free interaction via head gestures. The set of used head gestures consists of nodding, shaking the head, tilting to the side, and turning to the side. The authors chose these specific gestures because they were considered natural, unobtrusive, and easy to learn as most people are familiar with them. The authors assigned the gestures to the different interaction tasks with the system in such a way that the user automatically associates the gesture with the task, e.g., nodding to select a button as nodding indicates agreement (see Fig. 3.1). The authors conducted a study to compare hands-free interaction via head gestures with hands-on interaction via handheld touch. The study was conducted with 24 caregivers in patient rooms but with a simulated patient. Each participant had to accomplish a pain management task with the handheld mechanism and the head gestures. They found that the participants encountered more difficulties with head gestures and produced more errors, which was most likely caused by the tilting gesture. The other head gestures worked better as they were easy to perform and intuitive. Furthermore, the authors found that the head gestures had no impact on the interaction with the patient. The participants talked less when interacting via head gestures compared to the handheld mechanism, but the authors traced this to the familiarity with the task. The participants also saw the natural gestures as advantageous for the interaction with the patient as they are not noticeable. Therefore, the authors suggested that head gestures are promising to support caregivers.

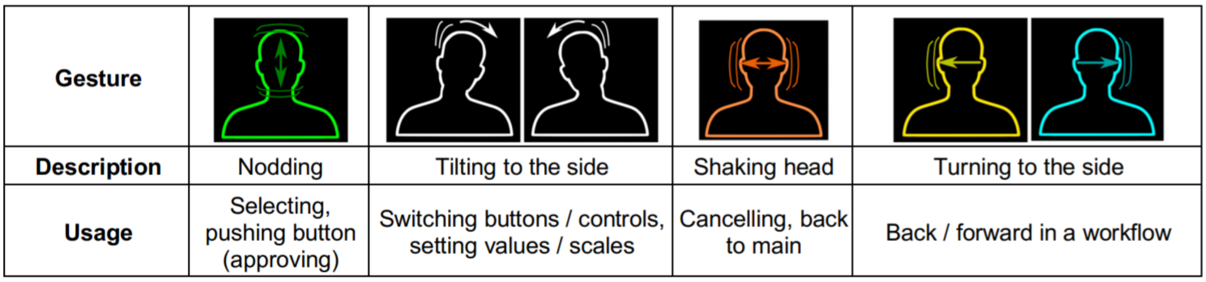

Figure 3.1: Assignment of the head gestures to the interaction tasks. *Image from* [16]

Kopetz et al. [14]: Voice Control

Kopetz et al. [14] used smart glasses to support the training of patient transfers with step-by-step instructions. Hands-free interaction should be enabled via voice control. For the different interaction tasks, different voice commands should be used, e.g., "back" to navigate to the previous transfer step. Through formative tests, the authors found that voice control with the AR glasses did not work properly due to device-related problems. The authors also expressed concerns over the interaction with the patient, which might be affected by the noticeable voice commands. Patients might mistake the interaction with the system for verbal communication. Therefore, the authors did not conduct a study with the voice control mechanism to enable hands-free interaction and only evaluated touch-based interaction.

Solovjova et al. [28]: Head and Voice

Solovjova et al. [28] combined head movement with the input modalities hand, foot, and speech to interact hands-free for different interaction tasks in a medical context. One of the investigated interaction tasks were confirmation tasks, which are selection tasks that require confirmation. The user first selects a target by moving a cursor to the target via head movement and then confirms the selection by either performing a gesture with the hand or foot or saying a voice command. A user study was conducted by the authors to examine head movement in combination with the three different input modalities. The study was conducted with 12 participants, who had to test two types of interaction tasks with all three techniques. The study results revealed that voice was the slowest technique and led to a higher frustration rate. Nevertheless, the authors reported that most participants preferred voice for confirmation tasks. A major benefit of the interaction via voice was that it did not require a lot of physical activity, unlike hand and foot, which was exhausting for arms and legs.

Hatscher et al. [17]: Eye Gaze and Dwell, Eye gaze and Foot

Hatscher et al. [17] introduced two hands-free interaction techniques for selection tasks in the operating room. The first technique is eye gaze and dwell, where the user first selects a target by pointing at it via eye gaze and then confirms the selection by dwelling with the gaze on the target for 1.5 seconds. With the second technique, eye gaze and foot, the target is also chosen by gaze pointing and confirmed by performing a triple-tap with the foot. In a pre-study, the authors already found that eye gaze and dwell was not practicable due to the Midas Touch effect, which occurred despite the relatively long dwell time of 1.5 seconds. Therefore, it was not evaluated in the real study. The authors conducted a study with eye gaze and foot and another approach, where only the foot is used for the interaction. The study was conducted with 13 participants, who had to test the interaction techniques for selection and manipulation tasks. The authors concluded that eye gaze is fast and suitable for pointing tasks, but it should only be used in combination with other input modalities for confirmation. Furthermore, they found that many participants encountered difficulties with eye gaze and foot as the foot had to be kept in a fixed position on a tactile floor (see Fig. 3.2). While the authors found that eye gaze and foot is a suitable technique in general, the fixed foot position is disadvantageous and not applicable for operation rooms.

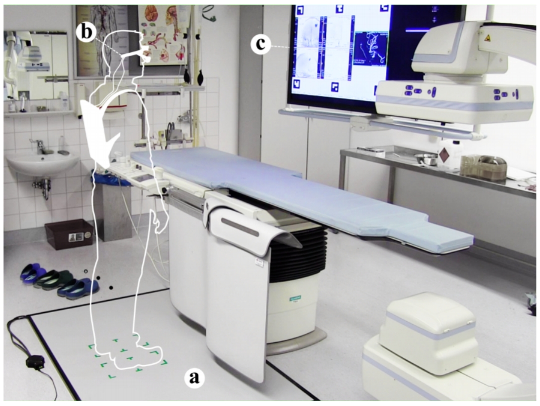

Figure 3.2: Setting of the study with a tactile floor. The feet have to be kept in a fixed position in the marked interaction spot on the tactilce floor. *Image from* [17]

Pai et al. [15]: Eye Gaze and Dwell, Eye Gaze and EMG

Pai et al. [15] examined eye gaze in combination with dwell and eye gaze in combination with Elektromyografie (EMG) for hands-free interaction in Virtual Reality. With eye gaze and dwell, the user first selects a target via eye gaze and then activates the selected target by dwelling on it with the eye gaze for 750 ms. With eye gaze and EMG, the target is also first selected via eye gaze and then activated by contracting the forearm muscle (see Fig. 3.3). The authors conducted a study with 16 participants to compare both techniques. The results showed that eye gaze combined with EMG outperformed eye gaze combined with dwell. Eye gaze and dwell led to a higher workload, and was tiring for the eyes due to the need to focus with the eyes on a target. The authors reported that some participants preferred eye gaze with EMG as it was fast and natural. However, EMG faces problems with the Midas Touch effect.

Figure 3.3: The muscle contractions are measured through sensors, which are placed on the forearm. *Image from* [15]

Klinker et al. [18]: Eye Gaze and Voice

Klinker et al. [18] proposed eye gaze in combination with voice as a hands-free interaction technique with AR glasses for wound management tasks. To interact via eye gaze and voice, the user first selects a target via eye gaze and then confirms it with the respective voice command. The authors used different voice commands for the different interaction tasks, e.g., "Click" to confirm the selection of a checkbox (see Fig. 3.4). Eye gaze and voice was evaluated with eye gaze and blinking as a second technique in an experiment by the authors. 45 healthcare workers participated in the experiment. The task was to document wounds without the application, and with the application and both interaction techniques. Both techniques turned out to be favorable and acceptable solutions. However, the interaction via blinking was significantly faster than via voice. The authors explained that the higher completion time for voice commands might have been caused by the need to look up the different voice commands. Some participants preferred voice commands over blinking due to the frequent blinking.

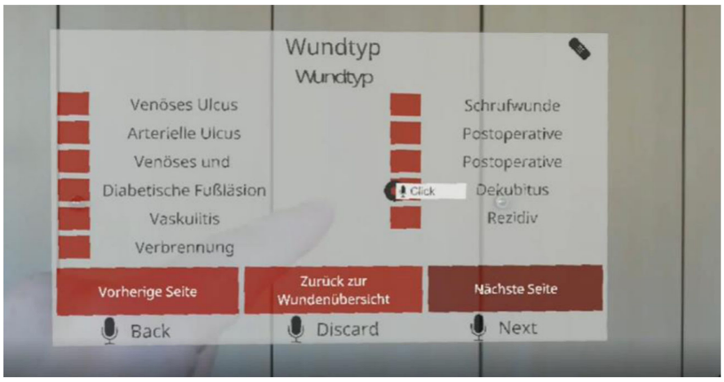

Figure 3.4: User interface of the application for wound management tasks. The eye gaze is indicated by a small circle and the respective voice command is displayed. *Image from* [18]

3.2.1 Comparison with Requirements

The following Table 3.1 gives an overview of the comparison of the interaction techniques with the requirements. The checkmarks indicate that a requirement is fulfilled and the crosses indicate that it is not fulfilled. The cells of the table that are highlighted in grey are conclusions based on statements or study results from the corresponding related work. The cells that are white are own assumptions that could be derived. Making own assumptions was necessary as many of the requirements have unfortunately not yet been evaluated with hands-free interaction techniques.
Comparing the techniques with the requirements of the context should help identify potentially suitable techniques for the patient transfer training context. A techniques is considered suitable if it fulfills many requirements.

Reference	Interaction Technique	Verbal Communication	Non-verbal Communication	Visibility of Commands	Avoidance of Midas Touch	Social Acceptability
Prilla et al. [16]	Head Gestures	✓ No differences in verbal communication; Interaction with system while talking with patient	✗ Head gestures might be mistaken for non-verbal communication; Restricted non-verbal communication	✓ Commands are visualized as icons on buttons	✓ Thresholds to discern simple head movements from gestures	✓ Unobtrusive, natural gestures; Not noticed by patients
Kopetz et al. [14]	Voice Control	✗ Patient might feel addressed by voice commands	✓ Interaction with system is verbal	✓ Commands are visualized as labels on buttons	✗ Commands might be triggered unintentionally during verbal communication	✗ Highly noticeable
Solovjova et al. [28]	Head and Voice	✗ Voice commands might be mistaken for verbal communication; Restricted verbal communication	✗ Head movements might be mistaken for non-verbal communication; Restricted non-verbal communication	-	✓ Selection requires confirmation; Unintentional selection less likely	✗ Voice commands are noisy; Head movements might seem weird and unnatural
Hatscher et al. [17]	Eye Gaze and Dwell	✓ Interaction with system is not verbal	✗ Eye contact might not be possible due to long dwelling	✓ Dwell time indicator indicates need to dwell for given time	✗ Midas Touch effect occurs with long dwell time of 1.5 s	✗ Excessive staring at one point due to long dwell time might seem weird
Hatscher et al. [17]	Eye Gaze and Foot	✓ Interaction with system is not verbal	✗ Upright stance with fixed, steady foot position; Restricted movement	-	✓ Triple taps to discern foot tap from normal movements	✓ Unobtrusive and subtle; Probably not noticeable
Pai et al. [15]	Eye gaze and Dwell	✓ Interaction with system is not verbal	✗ No sudden, large head movements due to eye calibration	-	✗ Might occur with shorter dwell time of 750 ms	✓ With shorter dwell time, dwelling might be less noticeable

Reference	Interaction Technique	Verbal Communication	Non-verbal Communication	Visibility of Commands	Avoidance of Midas Touch	Social Acceptability
Pai et al. [15]	Eye Gaze and EMG	✓ Interaction with system is not verbal	✗ No sudden, large head movements due to eye calibration	-	✗ Accidental activation through high muscle contractions	✓ Unobtrusive and subtle; Probably not noticeable
Klinker et al. [18]	Eye Gaze and Voice	✗ Voice commands might be mistaken for verbal communication; Restricted verbal communication	✓ Eye contact might be possible without dwell time	✓ Voice commands are visualized as labels	✓ Selection requires confirmation; Unintentional selection less likely	✗ Voice commands are noisy and obtrusive

Table 3.1: Comparison of hands-free interaction techniques with requirements.

Conclusion based on statements or study results
✓= Fulfilled
✗= Not fulfilled

3.2.2 Discussion

The results of the comparison of the hands-free interaction techniques with the requirements need further discussion as it does not directly emerge which techniques are potentially suitable. None of the investigated techniques fulfilled all requirements and many techniques fulfilled the same number of requirements. Therefore, the results are briefly discussed for each interaction technique to gain more insight before coming to a conclusion. The results are discussed in logical order. In the following, the three requirements verbal communication, non-verbal communication, and social acceptability are referred to as social requirements.

Eye gaze and dwell fulfilled only two requirements and is clearly unsuitable. It might be difficult to make eye contact due to the dwelling for an extended amount of time. Furthermore, the dwelling with longer dwell times might seem weird for spectators or even be inappropriate as spectators might feel stared at. This might not be favorable for a social context. The biggest problem with this technique is the Midas Touch effect, which occurs even with longer dwell times, as the related work by Hatscher et al. [17] showed.
Voice control has no potential to support the patient transfer training, either, as it also only fulfilled two requirements. The related work by Kopetz et al. [14] suggested that the interaction with the patient might be affected and that voice commands are highly noticeable. It has to be noted at this point that the authors did not evaluate voice control due to the problems they encountered with the AR glasses, so these assumptions were not supported by empirical data. Yet, it seems that voice control does not fulfill verbal communication and social acceptability. Furthermore, interaction commands might easily be triggered by accident if one of the nursing students says an interaction command unintentionally during their verbal communication. Therefore, the Midas Touch requirement is also not fulfilled.

The combination of head and voice seems very unfavorable for the patient transfer training context because head movements and voice commands are both highly noticeable and therefore probably not socially acceptable. In contrast to head gestures, random head movements might appear weird and unnatural for spectators. That combination of head movements and voice commands might also affect both the verbal and the non-verbal communication between the nursing students as the voice command might restrict the verbal communication and the head movements might limit the non-verbal communication. Therefore, it fulfilled none of the social requirements. However, the related work by Solovjova et al. [28] showed that voice is in general a favorable technique for confirmation tasks. Moreover, it can be assumed that the Midas Touch effect is avoided due to the combination of two techniques for selection and confirmation, where the user has to accomplish two subtasks. A target can not be selected directly, the selection has to be confirmed via voice command. The other way around, the voice command only leads to a target activation if the user has selected it previously. Otherwise, it has no effect. Therefore, an unintentional selection might be less likely compared to voice control, where a target is directly activated via voice command.

Eye gaze and EMG fulfilled most of the social requirements. It seems to be very unobtrusive and subtle and might therefore be socially acceptable. Furthermore, it might not affect verbal communication as this technique is not verbal, it involves no speech. The issue with this technique is also the Midas Touch effect. The related work by Pai et al. [15] suggested that it can occur through high muscle contractions. Muscle contractions might be triggered easily by accident in the patient transfer training context, where high muscle contractions occur, e.g., when supporting the training partner. Therefore, this interaction technique might not be applicable to the patient transfer training context.

Eye gaze and foot seemed to be a promising technique as well. It also fulfilled most social requirements as it involves no speech and seems to be subtle. A major drawback is the required steady and fixed foot position, which Hatscher et al. [17] found to be not applicable. The fixed foot position might lead to restricted freedom of movement. With such a restriction of movement, it might not be possible to conduct a patient transfer properly because a patient transfer involves a lot of movement. Furthermore, the feet carry the own bodyweight plus partially the bodyweight of the training partner during the transfer. Therefore, it might not be possible or too risky to perform a tap with the foot. Eye gaze and foot might not be applicable to the patient transfer training, either.

Nevertheless, the results from eye gaze with EMG and eye gaze with foot show that eye gaze works well when it is used for selection and combined with a second input modality for confirmation. Hatscher et al. [17] also confirmed eye gaze to be a suitable technique when it is used in combination with another input modality. Eye gaze seems to be subtle and unobtrusive, which is ideal for the patient transfer training context. Therefore, the idea is to combine eye gaze with another, more suitable input modality for confirmation tasks. Since voice turned out to be favorable for confirmation tasks as Solovjova et al. [28] showed, the obvious combination would be eye gaze and voice.

Compared with the requirements, eye gaze and voice fulfilled the majority of the requirements. The advantage of this combination over voice alone and eye gaze alone is the presumed prevention of the Midas Touch effect. As explained before, it is assumed that the combination of two techniques for selection and confirmation makes an unintentional activation less likely. A target can not directly be activated. It first has to be selected via gaze and then it has to be confirmed via voice command. Looking at the target without saying the voice command has no effect while saying the voice command without looking at the target has no effect, either. It might be highly unlikely that two subtasks are accomplished unintentionally. Thus, eye gaze and voice might be potentially suitable. It might only have difficulties with verbal communication and social acceptability due to the voice command.

The other potentially suitable technique is head gestures. Of all techniques, it fulfilled the most requirements, therefore, this is probably the most obvious choice. It fulfilled most of the social requirements. Verbal communication is not affected because the related work by Prilla et al. [16] found that it is possible to talk while executing the head gestures and the head gestures seem to be socially acceptable as they were described as unobtrusive and natural and not noticed by patients. The authors also stated that the false detection of head gestures can be avoided by pre-set thresholds. Therefore, the Midas Touch effect requirement is also fulfilled. It might only restrict non-verbal communication as it might not be possible to use head gestures as a form of non-verbal communication with the training partner. Furthermore, it might lead to confusion if the training partner mistakenly feels addressed by the head gestures.

Both techniques are not perfect as they could not fulfill all requirements. However, there seems to be no perfect solution. Each technique seems to have certain disadvantages. Of all techniques, (i) eye gaze and voice and (ii) head gestures were found to be the most promising techniques. Overall, they seem applicable for the patient transfer training context and the disadvantages of both techniques seemed to be the most tolerable.

3.2.3 Implications for Interaction Deign

Both potentially suitable hands-free interaction techniques have some weaknesses and difficulties as the related work analysis showed. The implications from related work should be considered for the implementation of the techniques to achieve possible improvements.
For eye gaze and voice, only one short voice command will be used instead of multiple commands like the related work did. Klinker et al. [18] assumed that the use of different commands slowed down the interaction during their evaluation as users had to look up the commands. Using only one voice command might be easier for the user in general and prevent that commands have to be looked up or are confused by the user. Furthermore, it might affect verbal communication less. If the voice command is short, interruptions in the verbal communication when saying the voice command might become shorter as well. The social acceptability could also be increased as a single, quickly executable might be less obtrusive. The training partner would probably also understand quickly that the voice command is used for the interaction with the system and might be able to distinguish it from verbal communication. Many well-known speech input systems use one standard voice command, e.g., "Hey Siri" or "Ok Google". Therefore, most people are presumably familiar with this concept.
Prilla et al. [16] found that the complex tilting head gesture led to problems and solely simple, intuitive gestures should be used. Therefore, only nodding, shaking the head, and turning the head to the side will be used. These might also be less noticeable, confusing, or weird looking for the training partner due to the familiarity with the gestures from everyday life. To make the interaction intuitive, the head gestures have to be used in a preferably meaningful way for the interaction tasks, as Prilla et al. [16] suggested. This should also be considered when assigning the head gestures to the interaction tasks with the application that is developed.

3.3 Contribution

As the related work analysis showed, many promising systems to support the self-training of patient transfers exist so far. Most systems do not use an approach with head-worn AR glasses to display instructions directly in the field of view. The systems that use AR glasses do, however, not support hands-free interaction. To my knowledge, no previous work about AR glasses that support the training of ergonomic patient transfers and enable hands-free interaction exists.
Furthermore, interesting hands-free interaction techniques were explored. The investigated related work examined hands-free interaction techniques mostly in different contexts than the patient transfer context. The two techniques (i) eye gaze and voice and (ii) head gestures turned out to be potentially suitable for the patient transfer training in theory, but it is unclear which benefits and downsides they have in practice. To my knowledge, no existing work has evaluated both hands-free interaction techniques in a patient transfer training context. Therefore, the question about the benefits and downsides of (i) eye gaze and voice and (ii) head gestures when used in a patient transfer training context to support the self-training of ergonomic patient transfers remains.

Therefore, this bachelor thesis proposes a design and implementation concept for the two hands-free interaction techniques (i) eye gaze and voice and (ii) head gestures to support the training of ergonomic patient transfers.

Furthermore, it describes the planning, conduct, and results of an empirical study to compare both techniques in a training context and find benefits and downsides.

4 Design and Implementation

This chapter presents a design and implementation concept for an application that supports the self-training of ergonomic patient transfers and enables hands-free interaction via (i) eye gaze and voice and (ii) head gestures. Section 4.1 describes the design process of the application. Section 4.2 explains the implementation process of the user interface and both interaction techniques. In Section 4.3, current limitations of the prototypes are outlined.

4.1 Design

This section focuses on the design of the application. The design process was oriented on the UX lifecycle model (see Fig. 4.1) that was described in the UX book 2 by Rex Hartson and Pardha Pyla [29]. The four steps of the model were passed accordingly and are discussed in order in this section. The first step to understand user needs was partially accomplished in Chapter 3 by analyzing the context and looking at existing systems that fulfill the user needs. Implications from existing systems were derived and applied to the design of a new system. In the next step, design solutions were created in form of sketches and wireframes. From the gathered design ideas, clickable prototypes were created in step three. In the last step, a cognitive walkthrough was conducted with the clickable prototypes to evaluate and refine the design. The methodical approach for the design process was iterative. Design ideas were iteratively improved.

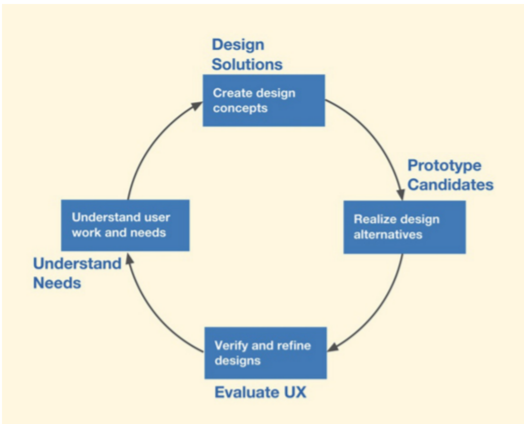

Figure 4.1: UX lifecycle model, which consists of four steps. The steps were followed iteratively during the design procedure. *Image from [29]*

4.1.1 Understand Needs

The context analysis in Section 2.2 showed that nursing students lack the support to practice ergonomic patient transfers outside of training courses when no teacher is available [7]. Therefore, an AR application should sup-

port the self-training with step-by-step instructions, similar to the KiTT application [10] that was described in Section 3.1. Unlike KiTT, the application that is developed should only support the training phase. It is assumed that the nursing students already have prior knowledge regarding kinaesthetics from visiting a kinaesthetics course and only need support during the training phase. The support the application should provide is based on the KiTT app as this system supports the training well [10].
A short video of the respective transfer movement should be displayed for each transfer step to instruct the nursing students visually. A video alone might not be sufficient as the students are still inexperienced and might need further support. Therefore, a short audio instruction explaining the transfer movement should be provided for each step in addition to the video instruction.
The combination of visual and auditory instructions might provide a good level of support. As explained in Section 2.2, teachers in the courses often demonstrate transfer movements again during the practice [7]. The teacher seems to visually instruct the students. Instructing the students through videos might be similar. Furthermore, audio instructions might be similar to a teacher giving verbal instructions. Given the patient transfer training context, audio instructions might be appropriate as it does not involve real patients. In front of real patients, audio instructions might be disturbing or confusing.

With these instructions, certain interaction possibilities should be provided. It should be possible to pause and play or replay the videos, as well as mute and unmute the audio instructions. Furthermore, the user should be able to navigate forward and backward between the transfer steps.

4.1.2 Design Solutions

This Section is divided into three components. First, the patient transfer training scenario is further explained to make the context of the interaction clearer. After that, the design of the interaction techniques is explained, e.g., which voice command is used and the assignment of the head gestures to the interaction tasks. Lastly, the user interface is designed.

Scenario

In Section 2.2, it was described how nursing students practice patient transfers in courses. The self-training context with AR glasses outside of training courses is similar. The training takes place in a training room with equipment like a bed and a wheelchair. Two nursing students can practice different transfers together in the roles of nurse and patient there. Figure 4.2 illustrates an exemplary training scenario, where two students want to practice the transfer to sit up a patient to the bedside with the support of the AR application. One student takes on the role of the nurse, the other student simulates the patient. The student who is in the role of the nurse wears the AR glasses and watches the instructions for each transfer step. The simulated nurse applies the given instructions by executing the instructed transfer movements for each step. Furthermore, the nurse interacts hands-free with the AR glasses, e.g., navigates to the next transfer step. After all five transfer steps have been completed and the training partner has been transferred accordingly, the training of this transfer is finished.

Interaction

In Section 3.2.3, implications from related work for the design of the interaction techniques were derived. For eye gaze and voice, it was decided to use only one short voice command. Therefore, 'Select' will be used as command. For head gestures, it was decided to use only a subset of the proposed head gestures, consisting of turning to the side, nodding and shaking the head. For the application that is developed, turning the head to the side will be

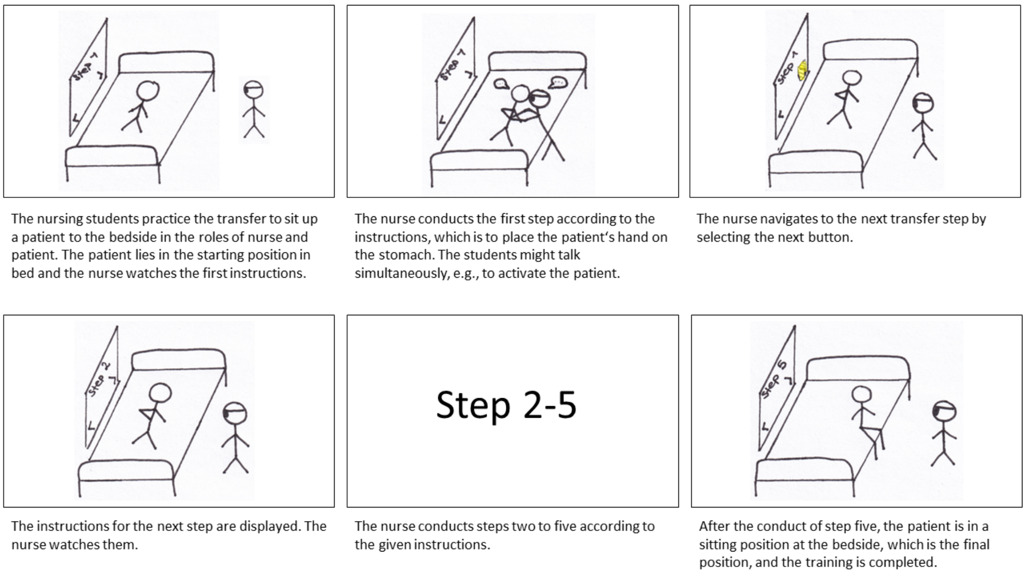

Figure 4.2: Storyboard of an exemplary transfer training scenario.

used to navigate between the steps (i.e. turning to the left to navigate backwards, turning to the right to navigate forward), nodding to pause and play the video, and shaking the head to mute and unmute the audio. An alternative would have been to use one head gesture to switch between buttons and nodding to select a button. This is what Prilla et al. [16] did with the tilting head gesture to switch between buttons. Using nodding to select something might have been more intuitive. However, this might have been more complicated or confusing for the user than using one head gesture for each interaction task. Therefore, the ease of use was found to be more important.

With eye gaze and voice, the user first has to look at a button with the eye gaze to select it. When the eye gaze meets a button, the button should be highlighted to provide visual feedback about the selection to the user. Furthermore, the voice command should be displayed to fulfill the visibility of interaction commands requirement which was specified in Section 2.3. Then, the user has to say the voice command to activate the selected button. In Figure 4.3 an, exemplary interaction via eye gaze and voice is illustrated. The user looks at the next button via eye gaze. The selected button is highlighted and the voice command is displayed. By saying the voice command 'Select', the next button is activated and the next transfer step is displayed accordingly.

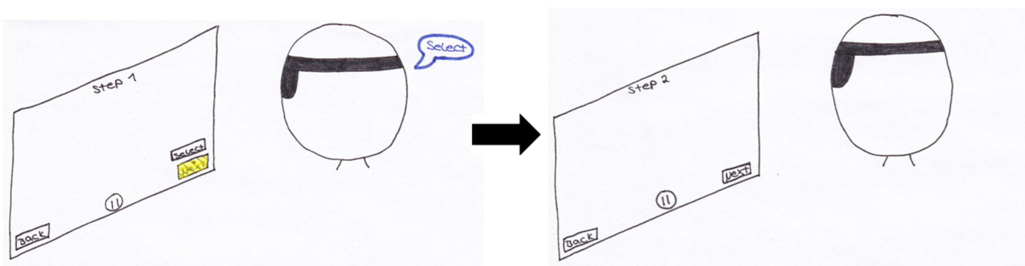

Figure 4.3: Exemplary interaction via eye gaze and voice.

With head gestures, one head gesture is used for each interaction task. In order to accomplish an interaction task, the respective head gesture has to be executed. In Figure 4.4 the user turns his head to the right. Since this head gesture is assigned to the interaction task to navigate forward, the according response is that the next step of the transfer is displayed.

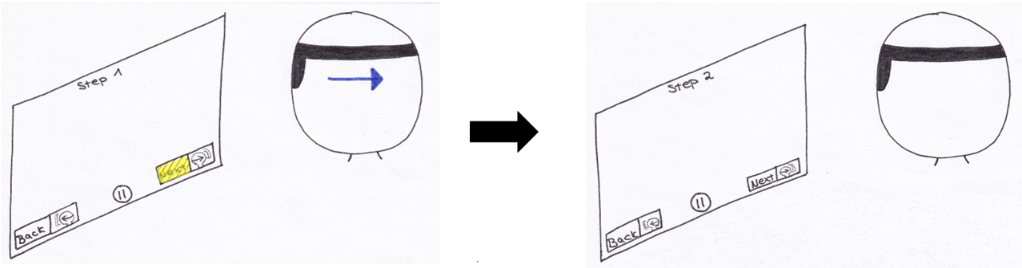

Figure 4.4: Exemplary interaction via head gestures.

UI Sketches and Wireframes

Design solutions for a user interfaces that provides the described instructions and the corresponding buttons to interact with the instructions were created, starting with basic paper sketches. Figure 4.5 shows a design solution for two user interfaces for eye gaze and voice on the left and head gestures on the right in form of paper sketches. The user interface for head gestures varies slightly from the user interface for eye gaze and voice. For the head gestures, additional icons next to the buttons should indicate the respective head gesture so that the interaction commands are visible in order to make the interaction easier. As explained before, the label with the voice command of eye gaze and voice should only appear when the gaze is pointing at the target.
Another important concerned the placement of the panel in the 3D context. There were two options for the placement: the panel could either be movable and move with the user's head movement or it could be in a fixed position in the room. The assumed advantage of a moving panel was that the panel would always be in the user's field of view, but it would cover the training partner. It might be difficult to apply the instructions when the training partner is not clearly visible and constantly covered. Therefore, it was decided to place the panel in a fixed position in relation to the bed to avoid that the training partner is covered (see Fig. 4.5). It should be parallel to the bed. That way, the instruction panel is directly in front if the user while conducting the transfer movements and the user might only have to look up and down between the training partner and the instructions.

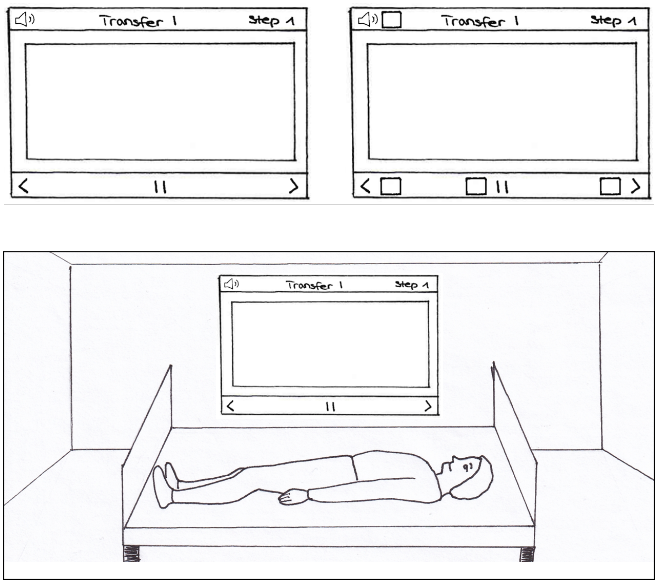

Figure 4.5: Paper sketches of user interfaces for (i) eye gaze and voice and (ii) head gestures. The panel with the instructions should be placed in a fixed position in relation to the bed.

Beyond the design for the interaction, the design for the emotional impact was also considered. The user interface should satisfy the emotions of users during the patient transfer training, which is an important according to the UX book 2 [29]. The design should be modern to match the modern approach of the training with AR glasses and it should be minimalist, clean and simple to support the user efficiently and not distract him or her unnecessarily. A style guide was created with bluish and greyish colour pallets, which complement this aesthetic (see Fig. 4.6).

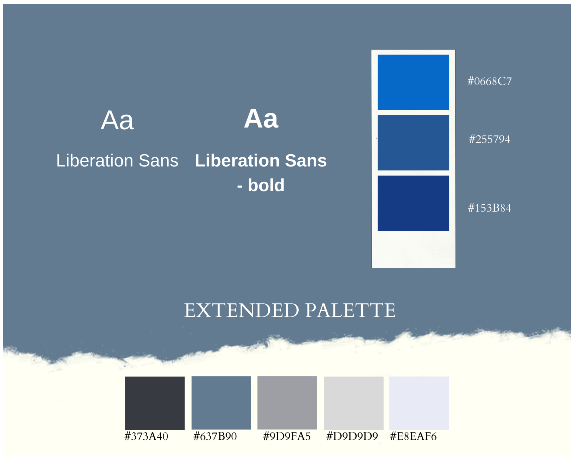

Figure 4.6: Style guide for the design of the user interface.

Based on the paper sketches and the style guide, wireframes for the user interfaces were created with the according color scheme (see Fig. 4.7).

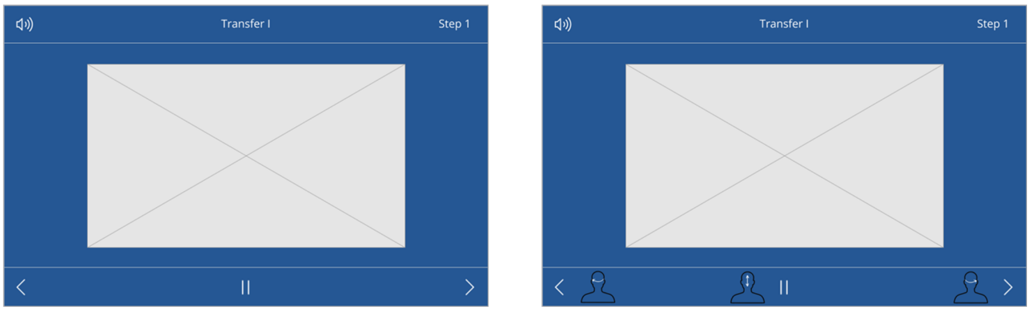

Figure 4.7: Wireframes of the user interface for eye gaze and voice on the left and head gestures on the right.

4.1.3 Prototype Candidates

In the next step, clickable prototypes were created. They were created for the exemplary transfer to sit up a patient to the bedside, which consists of five steps. The buttons of the prototypes are clickable and simulate an interaction. The prototype does not contain audio instructions and instead of a video, a picture of the corresponding transfer step was displayed. Figure 4.8 shows a part of the clickable prototype for eye gaze and voice. By clicking the next button, a picture of the next transfer step is displayed and on the timeline, the second step is indicated. This simulates the navigation to the next transfer step. Or by clicking the pause button, the button is replaced with a play button to simulate the pausing of the video. In that manner, all interaction possibilities for all five transfer step are simulated.
The prototype for head gestures had the same appearance and functionality, it only had the additional head gesture icons next to each button.

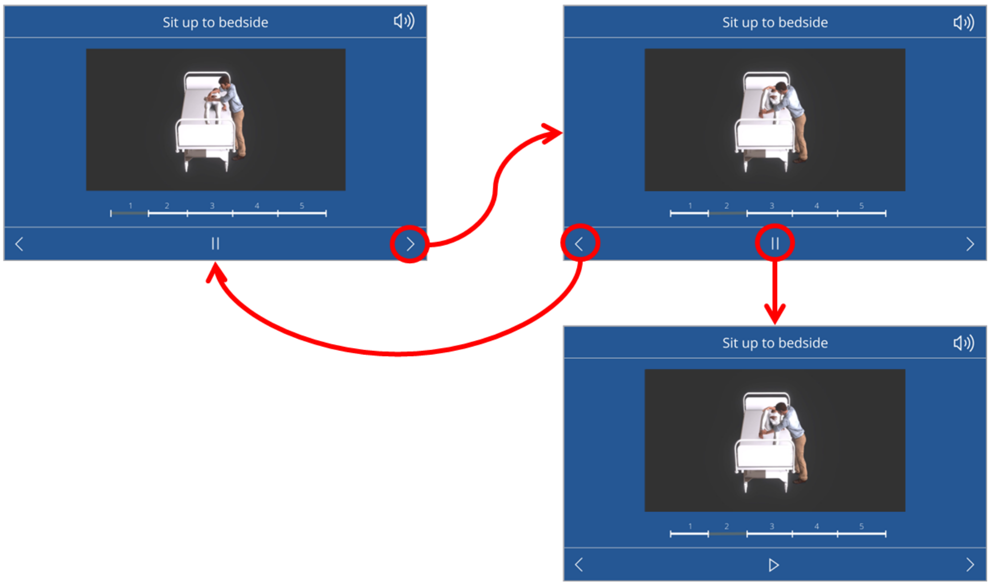

Figure 4.8: Exemplary interaction flow with the clickable prototype for eye gaze and voice.

4.1.4 Evaluate UX

Cognitive Walkthrough

A cognitive walkthrough was conducted with the clickable prototypes to evaluate the design and find possible improvements. It was conducted with one participant via Zoom due to Covid. The participants had access to the clickable prototypes and could click the buttons. The walkthrough started with the prototype for eye gaze and voice. After the interaction technique was briefly explained, the participant received the task to explain how he would transfer the patient in each step (e.g., "I would put the patient's hand on his stomach") and how he would interact with the instructions (e.g., "I would look at the pause button and say 'Select' to pause the video"). The interaction was simulated via a mouse click by the participant. Meanwhile, the participant's performance was observed to notice problems or errors. In that manner, all transfer steps and interaction tasks were passed. The same procedure was repeated with the prototype for head gestures. Here, the participant had to perform the head gestures for the respective interaction tasks (e.g., nod to pause the video).
The overall results were that the participant had no problem with both interaction techniques and made no errors, except for clicking besides a button one time. The participant found the design intuitive and simple, not overloaded, and appropriate. Moreover, he described that the head gestures were meaningful and easy to learn. The following findings for improvement were made:

1. Controls should always be in the field of view
   The participant expressed concerns over the fixed position of the panel. With eye gaze and voice, it is necessary to look at the target to select it. If the panel is in one fixed position, the user would always have to look at it to perform the interaction. That could be disadvantageous for the patient transfer training context as it involves movements where the user has to turn away from the bed. It might be better to have the controls constantly in the field of view so that the user can interact, even if he or she is currently not looking at the instruction panel.

2. Textual descriptions of transfer steps are necessary
   In some steps, the transfer movements that have to be conducted were not apparent for the user. Therefore, it might be helpful to have an additional description of each step.

3. Timeline is unnecessary
   The timeline, which should indicate the current step and the progress of the video, was found to be unnecessary. Since the videos are short, there is no need to indicate the progress. Furthermore, it is sufficient to indicate the current step in textual form.

4. Add borders around the buttons
   Borders should be added around the buttons to separate them visually from the rest of the panel. Without the buttons, it is not clear which area belongs to the buttons. This could lead to errors if.

Design Improvements

The design was improved according to the findings from the cognitive walkthrough (see Fig. 4.9). The controls were removed from the instruction panel and added to a separate panel. The mute button remains on the instruction panel as it will presumably not be used often. Selecting the button once should mute the audio for all steps of the current transfer. Therefore, it only has to be selected once at most for each transfer conduct. The instruction panel should still be in a fixed position in relation to the bed, but the control panel should move with the head movement and always be in the user's field of view to allow an independent interaction. The textual descriptions for the transfer steps were added below the name of the transfer. Furthermore, the timeline was removed, which made the design look less cluttered, and grey borders were added around all buttons to separate them visually from the rest of the panel.
Some other changes beyond the findings from the walkthrough were made. A darker blue tone was chosen for the panels as the original color looked washed out on the HoloLens. The head gesture icons were also modified to make them better recognizable.
A clean, minimalist design, which contains only the necessary elements, was achieved. By removing all unnecessary elements, more room for video was made, as this should be especially well visible.

Figure 4.9: Improved design of the user interfaces for eye gaze and voice on the left and head gestures on the right.

4.2 Implementation

In this section, the implementation process is described, starting with the selection of hardware and the development environment. After that, the components of the user interface and their implementation are described. Lastly, the implementation of the two hands-free interaction techniques is explained. The methodical approach for the implementation was iterative. The prototype was regularly improved.

4.2.1 Hardware and Software Setup

Hardware

Before the development of the application could begin, suitable head-worn AR glasses had to be selected from the current range of AR glasses. The AR glasses were selected against different criteria. First of all, the AR glasses obviously had to support voice input and eye tracking as this is needed for the interaction technique eye gaze and voice. Furthermore, it was important that no device-related limitations exist. In the related work by Kopetz et al. [14], it was stated that the authors encountered device-related problems with the Google glasses. Due to these problems, they could not even implement voice control. Therefore, similar problems should be avoided and the AR glasses should be more advanced regarding voice input. The last criteria was that the AR glasses should have a relatively large display so that the instructions are well visible. On a small display, it might be difficult to see the video, especially smaller details or movements. For contexts with real patient, the related work by Prilla et al. [16] avoided large AR glasses as they looked like helmets and might disturb the patients. Due to the patient transfer training context, it was possible to choose larger, more prominent AR glasses.
The most suitable choice seemed to be the Microsoft HoloLens 2. It supports eye tracking and allows to combine eye gaze with other input modalities like voice [13]. Moreover, the HoloLens is technically advanced and no device-related limitations or problems were known. Through testing of the hardware, it was found that the HoloLens has a large display compared to other AR glasses and virtual objects are well visible with them.

Development Environment

The application was developed with Unity 3D, version 2020.3.11f1 with Universal Windows Platform Build Support. Since the application is intended to run on the HoloLens, the computing platform was the Universal Windows Platform. For the development, the Mixed Reality Toolkit (MRTK) and the Windows XR plugin were used. The MRTK is for the development of application for the Microsoft HoloLens. It provides components and functions for the development for the HoloLens [30]. The MRTK was used for the implementation of the user interfaces and the hands-free interaction technique eye gaze and voice. Furthermore, the Room Marker package was used [31]. It works with the Vuforia Engine to scan image targets and place virtual objects in relation to them [32]. This was used for the placement of the instruction panel in the 3D context. Furthermore, the Head Gesture Detector from the Unity Asset Store was used for the implementation of the hands-free interaction technique [33]. The usage of these components is further described later on.

4.2.2 User Interface Components

For each hands-free interaction technique, a slightly different user interface was implemented. Both user interfaces consist of two independent components: the instruction panel and the control panel. For the implementation, mostly prefabricated UI elements from the Mixed Reality Toolkit (MRTK) were used, as they comply with Microsoft design recommendations for the development for the HoloLens 2. The two components and their behavior in the 3D context are discussed separately in the following.

Instruction panel

The instruction panel is a larger panel, which displays the instructions for each step of the patient transfer (i.e. textual description and video) (see Fig. 4.10). The panel was purposely made large so that the video is well recognizable. On a smaller panel, details in the video might be hard to recognize. In addition to that, the instruction panel contains the button to mute and unmute the audio instructions. Upon starting the application, the instruction panel first displays a button to start the training (see Fig. 4.11) and after the last step, it displays a button to start anew.

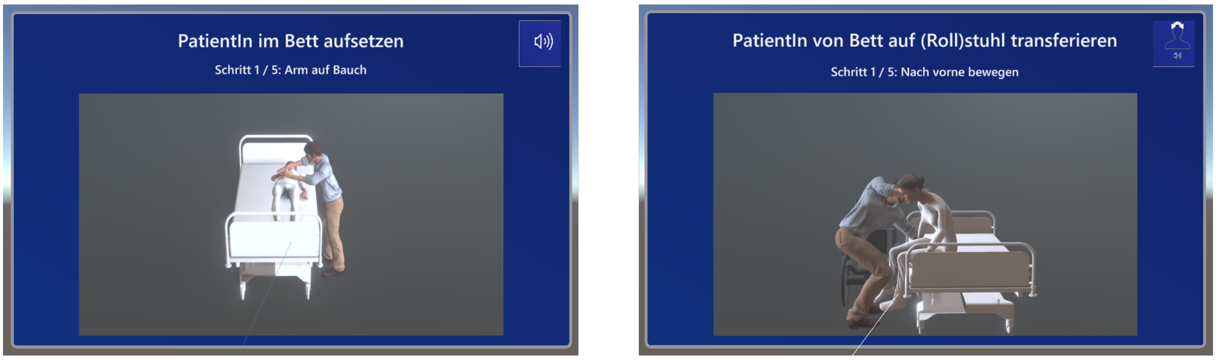

Figure 4.10: Instruction panel of eye gaze and voice on the left and head gestures on the right.

As decided during the design phase, the instruction panel should be in a fixed position in relation to the bed. For that, a marker was used to place the instruction panel in the room, aligned with the marker. The marker is an image target that can be scanned by the HoloLens. It can be hung on the wall in the room in the desired position. Upon starting the application, the marker is scanned and the panel is placed in a centered position to the marker (see Fig. 4.11). As mentioned before, the Room Marker Package was used for that [31]. The marker should be placed at a distance of 1.6 meters from the edge of the bed where the nurse is standing. According to Microsoft recommendations, flat interactions like watching a video should should be set to a distance of approximately 2.0 meters to maximize the comfort [34]. Therefore, 1.6 meters was found to be a good distance, where the instruction panel is not too far away and watching the video is still comfortable.

Figure 4.11: Placement of the instructions panel aligned with the marker.

Control panel

The control panel is a smaller panel, which contains the buttons to interact with the instructions (see Fig. 4.12). These are the back and next button and, depending on the state of the video, the pause, play or replay button. The buttons of the eye gaze and voice interface have a 'See it, say it' label, which means that a label with the voice command is displayed when the eye gaze is pointing at the button. The buttons of the head gestures interface have icons that illustrate the head gestures.This is also the case for the button to mute or unmute the audio, which is located on the instructions panel. As described before, the visible interaction commands should make the interaction easier.

Figure 4.12: Control panel of eye gaze and voice on the left and head gestures on the right.

For the position of the control panel in the 3D context, a Solver was used. Solvers are components that control the position of an object [35]. The MRTK offers different solvers. From the MRTK, the Orbital Solver, which locks the object to a defined position, was used. The control panel moves with the user's head movement, but it is locked to a fixed position in the lower part of the field of view. That way, it is always in the user's sight without obscuring the view on the training partner.

4.2.3 Hands-free Interaction Techniques

In the following, the implementation of the two hands-free interaction techniques (i) eye gaze and voice and (ii) head gestures is described.

Eye Gaze and Voice

For the implementation of eye gaze and voice, components from the MRTK were used. The eye tracking functionality was added to the buttons by adding the 'EyeTrackingTarget' component from the MRTK. The 'EyeTrackingTarget' is a method to use the eye gaze as a focus pointer and it allows to combine eye gaze with other inputs [36]. As decided before, only one voice command is used. Therefore, the same voice command was assigned to each button. The voice command requires focus, this means, that the target must be focused on via eye gaze to respond to the voice command. Without gazing at the target, the voice command alone has no effect. Each button can only be activated when the eye gaze is currently pointing at it and the correct voice command is said. A small cursor indicates the user's eye gaze. When the eye gaze meets a button, it is highlighted and the voice command is displayed on a label below the button. This so-called 'See it, say it' label disappears again when the eye gaze leaves the target. The visual feedback indicates that the button is currently selected and can now be activated by saying the voice command. This can be seen in Figure 4.13, where the eye gaze is pointing at the pause button. The button is highlighted and the voice command is displayed. The selection of the pause button can now be confirmed by saying the voice command, which would lead to pausing of the video.

Originally, the voice command 'Select', which is the standard voice command of the HoloLens, was used. Due to an unknown reason, perhaps a software update, the 'Select' voice command could no longer be used as it did no longer lead to a target activation in the application. Therefore, it was replaced with the voice command 'Confirm'. In pre-tests, it was found that users pronounced the voice command differently. Some pronounced the 'o' in 'Confirm' like an 'o', others pronounced it more like an 'e'. If it was pronounced like an 'e', the voice command was often not recognized. To avoid differences in the pronunciation and recognition of the voice command between users, another voice command, which can not be pronounced in different ways, had to be chosen. The choice fell on 'Click', which was also used in the related work by Klinker et al. [18]. 'Click' is even shorter than 'Confirm' and was believed to be easier to pronounce. Furthermore, the pronunciation of 'Click' is the same as the German word 'Klick', therefore, non-English speakers can also pronounce it without problems. Furthermore, 'Click' might be intuitive for the users as it might be associated with a mouse click. Most people know that a target on a computer is selected by moving the cursor with the mouse to the target and then performing a mouse click. Here, a cursor is moved with the eyes to a target, and instead of performing a physical click, it has to be said out loud. Furthermore, it was important that the voice command is not a word that is frequently used in conversations, like 'Yes' or 'Ok'. This might have led to unintentional activations when saying the voice command during verbal communication with the training partner. With click, that was unlikely.

Figure 4.13: User interface of the interaction technique eye gaze and voice. The gaze is currently pointing at the pause button and the user receives visual feedback. The selection can be confirmed by saying the voice command.

Head Gestures

A threshold approach was applied for the implementation of the head gestures, based on the 'Head Gestures Detector' Asset from the Unity asset store [33]. With this approach, thresholds for head rotations around the x-, y-, and z-axis were set. The head rotation is calculated as the angle between the neutral head position and the current head position. If it exceeds a threshold, the rotation is interpreted as the corresponding head gesture. Additionally, a time-out was set. A head gesture has to be completed within a specified time frame, otherwise, it is rejected and has to be performed anew. The head gesture has to be performed in one continuous, swift motion. This reduces the chance that normal head movements are interpreted as head gestures.

However, the head gestures were still not stable enough with only the pre-set thresholds and the timeout. The Midas Touch effect occurred frequently while conducting the transfer movements in pre-tests. To make them more stable, the threshold approach was expanded by another condition. It should only be possible to execute a head gesture if the user is looking at the instruction panel. For that, the head gaze was used. The head gaze is a raycast, which is projected from the user's head [37]. For each head gesture, it is checked whether the head gaze

meets the panel at some point during the head rotation. If not, the head gesture is rejected. Thereby, it is avoided that head gestures are triggered unintentionally while not looking at the panel, e.g. while performing a transfer movement.
To sum up, a head rotation is interpreted as a head gesture if it exceeds the pre-set threshold within a given time frame and if the head gaze meets the instruction panel. It was tried to find a good balance between not restricting the user too much and making the interaction via head gestures easy on the one hand, and making the head gestures more stable on the other hand.

As previously described, the head gestures nodding, shaking the head, turning the head to the left, and turning the head to the right were planned to be used as head gestures. However, it was found that the head gestures 'turning to the left' and 'turning to the right' are not compatible with 'shaking the head' as shaking the head contains a turning to the side motion. When shaking the head, the turning to the right or left gestures were triggered as their thresholds were exceeded during the shaking movement. Therefore, shaking the head was replaced with nodding sideways, which is a movement where the head is tilted to the left and the right side. The new assignment of the head gestures to the interaction tasks is visualized in Figure 4.14. The use of these head gestures was found to be the most stable solution as all gestures are a rotation around different axes. Nodding up and down is a rotation around the x-axis, turning to the side around the y-axis, and nodding sideways around the z-axis. Therefore, the head gestures are distinguishable from each other by the system.
Furthermore, the turning to the left or right gestures were also slightly more restricted to make their unintentional activation less likely. It is not only required with these gestures to turn the head to the side, but it also has to be moved back to the neutral position. A turning to the side movement is only interpreted as a gesture if the head is back in the neutral position after turning it to the side. Only turning the head to the side was found to be too prone to the Midas Touch effect as the patient transfers involve a lot of turning.

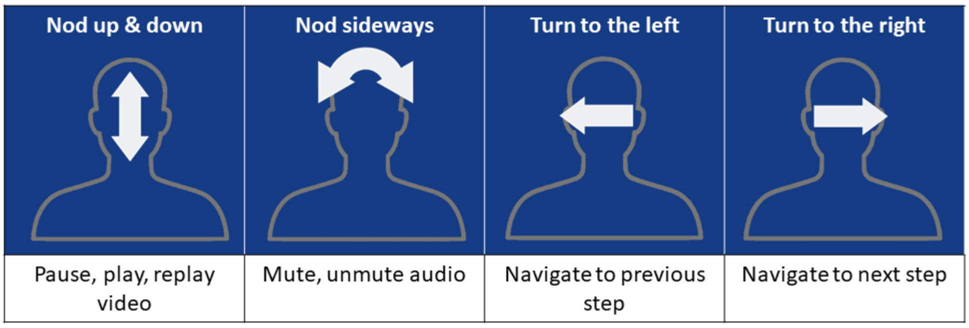

Figure 4.14: Assignment of the head gestures to the different interaction tasks.

Through testing, it was found that 40° is a good threshold for turning to the side, 20° for nodding sideways, and 10° for nodding up and down. All thresholds were set to rather high values to reduce the occurrence of the Midas Touch effect as bigger gestures are harder to trigger unintentionally. The transfer of patients involves a lot of movement and smaller gestures would have been triggered during the movement flow too easily. Furthermore, the timeout was set to 2 seconds to keep the time frame in which head gestures have to be performed as small as possible. Again, to reduce false positives. Figure 4.15 shows the user interface of head gestures.

Figure 4.15: User interface of the interaction technique head gestures.

4.3 Limitations

The head gestures with the threshold approach have limitations in terms of the Midas Touch effect. Despite efforts to make head gestures as stable as possible, the Midas Touch effect could not be completely avoided. Its occurrence could only be reduced by the countermeasures that were taken. The patient transfer training context involves a lot of movement. Therefore, head gestures are often triggered in the course of conducting a transfer movement. Here, it is not possible to distinguish intentional from unintentional movements with the threshold approach. When a head rotation exceeds the pre-set threshold within a given time frame and if the head gaze meets the instruction panel, it is interpreted as a head gesture, no matter if it was intentional or not.
The only option with the threshold approach to make it more stable would have been to restrict the interaction even more. The large head gestures, the short time frame in which they have to be executed, and the condition to look at the panel were already enough restrictions. Adding more restrictions might have affected the usability of the head gestures. It would have been harder to trigger commands by accident, but it would also have been harder to perform an intended interaction. Therefore, the current state of the head gestures was found to be the best balance. Interaction commands can be activated unintentionally, but at the same time the overall interaction is still easy and unintended actions are easily reversible and have no bigger impact.

The prototypes that were developed and evaluated in the study only support the two patient transfers that were used as a task in the study. This should purposely restrict participants, as they were not free to choose a transfer but had to conduct a certain transfer that was chosen as a task. For a real training situation, nursing students should of course be able to choose from a greater variety of transfers. Therefore, the prototypes could be expanded for real patient transfer training by offering more transfers that can be practiced.

5 Comparative Study

A study was conducted to compare the two hands-free interaction techniques (i) eye gaze and voice and (ii) head gestures in a patient transfer training context. The comparative study is described in this Chapter. In Section 5.1, the design of the study is explained. In Section 5.2, the study results are presented along the research questions. In Section 5.3, the results from Section 5.2 are then discussed. Lastly, limitations of the study are briefly outlined in Section 5.4.

5.1 Study Design

For the comparative study, a within-subjects design with two independent variables was applied. The independent variables are the two hands-free interaction techniques (i) eye gaze and voice and (ii) head gestures. Within-subjects design means that "each subject experiences all levels of the variable" [38]. In other words, each participant tested both interaction techniques in the study. The disadvantage of a within-subjects design is that participants can practice the task [38], which was in that case not desired. To avoid this so-called carry-over effect, two different tasks were used. One task was to transfer a mobile patient from bed to wheelchair, the other task was to sit up an immobile patient to the bedside. Both transfer tasks consist of five steps. Mobile in this context means that the patient has a high degree of mobility and can actively participate in the transfer. Immobile means that the patient has a low degree of mobility and can not participate much in the transfer, the caregiver has to provide more support. In the patient transfer training context, the training partner has to simulate the patient according to the degree of mobility to allow a realistic practice of transfers for different types of patients. Both transfer tasks are different but still comparable regarding the number of transfer steps and the level of difficulty. To ensure internal validity, the conditions and tasks were counterbalanced with a Greco-Latin Square. For that, the conditions and tasks were crossed and tested in a balanced order.
In the following, the study design is described more detailed. In Section 5.1.1, the planning of the study is described along the DECIDE framework. Section 5.1.2 gives an overview of the participants, including the demographic data of the participants. In Section 5.1.3, the setting of the study is described before moving on to the procedure of the study in Section 5.1.4.

5.1.1 DECIDE Framework

The planning of the evaluation was based on the DECIDE Framework from the book "INTERACTION DESIGN: beyond human-computer interaction" by Rogers, Sharp and Preece [39]. It defines the following six steps, which were followed iteratively.

Determine the Goals

The goal of the evaluation was to determine benefits and downsides of the two hands-free interaction techniques (i) eye gaze and voice and (ii) head gestures to support the training of ergonomic patient transfers. As explained before, both interaction techniques seemed in theory suitable to support the training. However, they have never been evaluated in such a context. Therefore, it should be found out what benefits and downsides they have when used in practice.

Explore the Questions

The research questions (RQ), which should be answered by the study, are described in the following. Here, RQ1-RQ4 are based on the requirements that were discussed in Section 2.3.

RQ1: *To what extent do the two conditions (i) eye gaze and voice and (ii) head gestures affect the verbal communication during the training of ergonomic patient transfers?*
Since verbal communication is an essential aspect of the patient transfer training, this question should help determine how well the user can communicate verbally with the training partner despite the interaction with the system or how much the verbal communication is affected by each interaction technique. Which technique affects verbal communication more?

RQ2: *To what extent do the two conditions (i) eye gaze and voice and (ii) head gestures affect the non-verbal communication during the training of ergonomic patient transfers?*
Similar to the first question, this question aims to find out how well the user can communicate non-verbally with the training partner despite the interaction with the system or how much non-verbal communication is affected by each interaction technique. Which technique affects non-verbal communication more?

RQ3: *To what extent does the Midas Touch effect affect the training of ergonomic patient transfers with the two conditions (i) eye gaze and voice and (ii) head gestures?*
During the implementation, measures were taken to make the interaction techniques as stable as possible to avoid the occurrence of the Midas Touch effect. Yet, interaction commands might still be triggered unintentionally during the transfer conduct. Therefore, the question is how much the Midas Touch effect disturbs or complicates the conduct of patient transfers in case it occurs. With witch techniques does it occur more frequently?

RQ4: *To what extent are the two conditions (i) eye gaze and voice and (ii) head gestures socially acceptable for the training of ergonomic patient transfers?*
The training of patient transfers is a social situation, which involves two people. The question now is if the interaction with the system is deemed to be acceptable for this social context. Does the user feel comfortable with the interaction with the system and think it is appropriate for the patient transfer training context? Which interaction technique is more socially acceptable?

RQ5: *How good is the User Experience with the two conditions (i) eye gaze and voice and (ii) head gestures during the training of ergonomic patient transfers?*
This question is not based on the requirements but is still highly relevant as systems should in general provide a good user experience. User Experience describes the experience of a user during the interaction with a system and is often defined as an extension of Usability [22]. It should be determined with this question how good the user experience with both interaction techniques is and if the goal to provide a good user experience was fulfilled. With which interaction technique is the user experience better?

RQ6: *To what extent do the two conditions (i) eye gaze and voice and (ii) head gestures affect the applicability of the instructions?*
Since the system should support the training of patient transfers, it should be examined how well the user can apply the given instructions and if the interaction with the system impacts the applicability negatively. There might be a connection between this question and RQ3: the occurrence of the Midas Touch effect could affect the applicability of the instructions. Is there really a connection between RQ3 and RQ6? Which interaction technique affects the applicability of the instructions more?

Choose the Evaluation Methods

The relevant data has to be collected to answer the research questions. Data was collected through questionnaires, a semi-structured interview and participant observation. Both quantitative and qualitative data was collected. While questionnaires are a measure instrument to collect quantitative data, qualitative data is collected through interviews and observation of the participants. For both interaction techniques, the same questionnaire were used, they were only adjusted to each technique. All questionnaires and the semi-structured interview can be found in the Appendix. In the following, the used measure instruments are further described.

Questionnaires:

- Demographic questionnaire
  A demographic questionnaire was used to collect general data about the participants, such as age or gender. Furthermore, the questionnaire asked for physical impairments, like visual impairment or injuries, since that might have an impact on the ability to perform the task and the interaction. Lastly, the questionnaire should help determine the participants' level of experience with Augmented Reality apps, Augmented Reality glasses, and patient transfers using 5-point Likert scales.

- Verbal communication
  A customized questionnaire was created to assess verbal communication using 5-point Likert scales. It asks the participants how well they could communicate verbally with the respective interaction technique, how much the interaction with the system disturbed, interrupted, and prevented the verbal communication, and how much the interaction with the system affected how much they communicated verbally. In the last question, it additionally asks to specify whether the verbal communication was reduced or increased.

- Non-verbal communication
  The same questionnaire from verbal communication was used to assess non-verbal communication. Instead of verbal communication, it asks for non-verbal communication.

- Midas Touch effect
  A customized questionnaire for the Midas Touch effect was created. In the first question, a 5-point Likert scale is used to measure how frequently the Midas Touch effect occurs with the respective interaction technique. In case it occurred, the next two questions ask how much it disturbed and complicated the conduct of the patient transfer, again, using 5-point Likert scales.

- Social acceptability
  To measure social acceptability, a questionnaire was adapted from Ahlström et al. [40]. The first two questions measure how comfortable the user felt during the interaction with the system and how acceptable the respective interaction technique is for the patient transfer training context using 5-point Likert scales. In the third and the fourth question, the participants have to choose from a selection of audiences and locations they would deem acceptable for the interaction with the system. This should help find how

acceptable the training partner and the training room are compared to other audiences and locations. In the last question, it is measured how acceptable the sub-components of the interaction techniques are. For eye gaze and voice, the two subtasks to select a target via eye gaze and to confirm it via voice command have to be rated on 5-point Likert scales. For head gestures, the four different head gestures have to be rated on 5-point Likert scales as well.

- UEQ
  The UEQ is a standardized questionnaire to measure user experience. It defines a 7-point scale with 26 opposite items on both sides, e.g., fast - slow. It assesses user experience in the five dimensions attractiveness, perspicuity, efficiency, dependability, stimulation, and novelty. Thereby, multiple opposite items form one dimension.

Semi-structured interview:
The semi-structured interview was used as an additional instrument to the questionnaire that allowed to go more into detail about RQ1-RQ5 and gain a better understanding. Furthermore, RQ6 should be answered through the interview. The interview focuses more on the comparison between both interaction techniques for each research question as to what was different and why it was different. At the point where the semi-structured interview took place in the study, the participants had tested both interaction techniques. Therefore, they had a direct comparison and could draw comparisons between them.

Identify the Practical Issues

One issue concerned the selection of appropriate participants. The target group for the application to be tested are nursing students, which already have experience with patient transfers and prior knowledge of kinaesthetics. However, due to Covid measures, which were still in force at the time of the study planning, it was not possible to conduct the study with real nursing students. Instead, students from the University of Konstanz were admitted as participants. Most of the students did not have prior experience with patient transfers or kinaesthetics. This restricted the evaluation in some aspects. Aspects like the correct execution of the transfer movements or the system's helpfulness to promote the learning of ergonomic patient transfers could not be evaluated as the participants lacked professional skills and knowledge and could not draw on previous experiences. Therefore, the research questions had to be adapted to this circumstance.
Another issue was the selection of measuring instruments. Most of the research questions have not yet been examined in a patient transfer training context by previous work. Therefore, no standardized questionnaires for these research questions exist. Customized questionnaires had to be created to answer these specific research questions.

Decide How to Deal with the Ethical Issues

The primary ethical issue concerned the privacy of the participants. To ensure their privacy, all collected data was kept confidential and pseudonymized. Participants were only identifiable through an assigned code during the analysis and documentation of the data. None of the data contained the participants' real names. Video and audio recordings were stored safely, only accessible to the evaluator. The recordings might be shown to third parties for research purposes and used for the presentation of the study results, but only with the permission of the participants. They were informed about all points mentioned above in an informed consent they had to sign to give their consent before the study began. Furthermore, the participants were sufficiently enlightened about the purpose and procedure of the study and were free to leave at any time.

Evaluate, Analyze, Interpret, and Present the Data

The evaluation, analysis, interpretation, and presentation of the data is described in Section 5.2.

5.1.2 Participants

The study was conducted with 12 participants. Seven participants were female and five were male. Moreover, their ages ranged from 18 to 26 years ($M = 21.9$, $SD = 2.4$). The participants were all students from the University of Konstanz, who studied computer science (3), life science (2), teaching (2), psychology (1), philosophy (1), physics (1), political science and law (1), and history (1). Seven participants reported a visual impairment, one a hearing impairment and two had a difficulty telling left from right. Using 5-point Likert scales, the participants' levels of experience with Augmented Reality applications, Augmented Reality glasses and patient transfers were measured ($1 =$ no experience, $5 =$ a lot of experience). The participants had an overall low level of experience with AR apps ($M = 1.8$, $SD = 1.3$) and AR glasses ($M = 1.4$, $SD = 0.8$). The majority of these participants who had prior experience knew AR from tablet or smartphone apps. Only two had used the Microsoft HoloLens previously. Regarding the experience with patient transfers, some participants stated previous experience ($M = 1.5$, $SD = 1.2$) from internships at hospitals, watching the transfer of a relative, and from being a paramedic. None of the participants was familiar with the kinaesthetics care concept and consequently, none had visited a kinaesthetics course before.

5.1.3 Apparatus

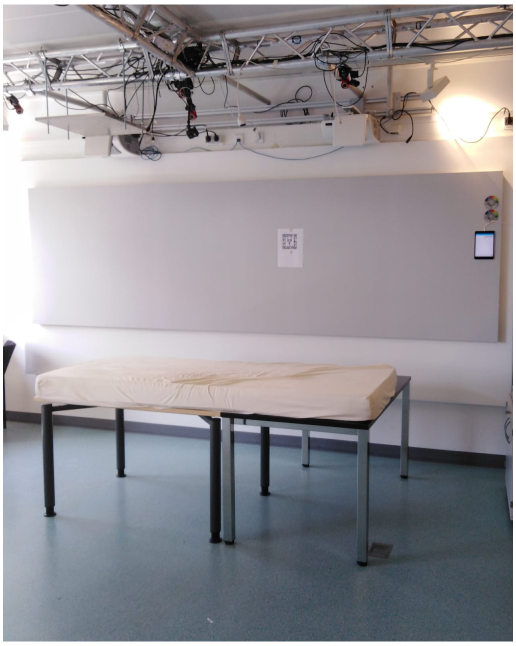

Figure 5.1: Setup of the room where the study was conducted.

The study took place in a room at the University. For the patient transfers, a bed and a wheelchair were needed. Since the University did not provide hospital beds or wheelchairs, the equipment had to be improvised. Two tables were put together with a mattress on top as a bed. Instead of a wheelchair, a normal chair was used. The distance between the wall and the outer edge of the bed where the participants were standing amounted to 1.6 meters. In a central position behind the bed, the marker was hung on the wall. With the marker, the instruction panel was aligned parallel to the bed. While the distance between the marker and the bed was always 1.6 meters for each participant, the height of the marker was variably adjusted to each participant's eye level. Over the bed, a GoPro camera was installed to record the study sessions. The camera was operated via the Quick app, which was installed on an iPad. The setup of the study room can be seen in Figure 5.1.

5.1.4 Procedure

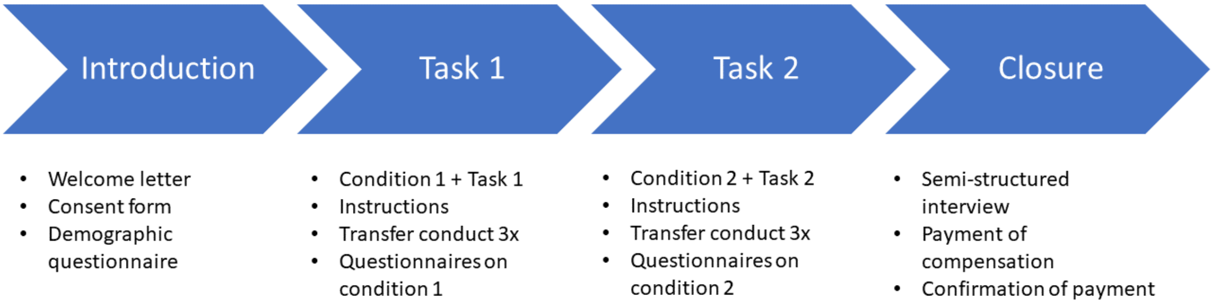

Figure 5.2: Procedure of the study, consisting of an introduction, task 1, task 2 and closure.

The study was divided into four components, consisting of a short introduction period, the first task, the second task, and a closure period. The introduction took approximately 10 minutes, the tasks 15 minutes each, and the closure another 15 minutes, leading to a duration of under 60 minutes for the whole study. The training partner was played by a fellow student, who acted according to the patient's mobility degree for each transfer scenario to make the simulation as real as possible.

Introduction
The participants were first welcomed and were given a welcome letter to read, which briefly explained the purpose and procedure of the study. After that, they had to sign an informed consent form in order to participate in the study. The consent form disclosed details regarding the collection and use of data. By signing it, the participants agreed to the stated terms. Furthermore, the participants filled out the demographic questionnaire.

Task 1
As explained before, the conditions and the tasks were counterbalanced to avoid that the participants can practice the task with the first condition. Depending on the counterbalancing, the first condition to be tested was either eye gaze and voice or head gestures with the task to sit up a patient to the bedside or to transfer a patient from bed to wheelchair. The respective task and interaction technique were explained to the participants. Before the task started, the participants' eye height was measured and the marker was placed accordingly. When the condition to be tested was eye gaze and voice, the eyes were calibrated before starting with the task. Then, the participants started with the first conduct of the patient transfer, which was meant to be a training round to become familiar with the interaction technique. The transfer was conducted two more times. After the third transfer round was completed, the participants were asked to fill out the questionnaires on the first interaction technique they tested.

Task 2
Then, the other condition was tested with the other transfer task. The participants were instructed on the task and the interaction technique before they started with the first transfer conduct. Again, the patient transfer was repeated two more times after the first conduct. Afterwards, the questionnaires on the second interaction tech-

nique that was tested were filled out.

Closure
Lastly, a semi-structured interview was conducted with the participants. After that, the participants received 10€ as compensation for their participation and were asked to sign a confirmation of payment. The participants were thanked for their participation and seen off.

5.2 Study Results

In this section, the study results are presented. First, it is briefly explained how the gathered data was analyzed. After that, the results are reported along the research questions RQ1-RQ6. All questions, results and quotes were translated from German to English. Identifiers in the form of T[1-12] were used for the different study participants to mark statements and quotes. Each participant has a unique identifier.

5.2.1 Data Analysis

In the study, quantitative data was collected from the questionnaires and qualitative data from the semi-structured interview. Their analysis is discussed separately in the following.

Quantitative Data
The UEQ was analyzed with the provided Data Analysis Tool for Excel [41]. The tool computed the mean scores of the different dimensions and compared the scale means of both interaction techniques through a t-test to find possible differences.
The data from the other questionnaires were analyzed with Excel and SPSS. For all questionnaires, the mean scores and standard deviations were determined. With a Kolmogorov-Smirnov Test, it was first checked if the data had a normal distribution. The data of verbal-communication and social acceptability had a normal distribution. Therefore, paired t-tests were used to find possible statistical differences between *eye gaze and voice* and *head gestures*. The data of non-verbal communication and the Midas Touch effect had no normal distribution. Thus, they did not comply with the conditions for t-tests and instead Wilcoxon signed-rank tests were used to find statistical differences between *eye gaze and voice* and *head gestures*.

Qualitative Data
The qualitative data from the semi-structured interview was analyzed following the procedure for a thematic analysis, which was proposed by Virginia Braun and Victoria Clarke, and consists of the following six steps [42]:

1. Familiarize yourself with your data
2. Assign preliminary codes to your data in order to describe the content
3. Search for patterns or themes in your codes across the different interviews
4. Review themes
5. Define and name themes
6. Produce your report

5.2.2 Verbal Communication

The results from the verbal communication questionnaire indicate that participants had a slightly better verbal communication with *head gestures*. Yet, the results of a t-test showed no significant differences between *eye gaze and voice* and *head gestures* in terms of how well the participants could communicate verbally ($t(11) = -1.59$, $p = .14$), how much the interaction with the system disturbed ($t(11) = 0.17$, $p = .87$), interrupted ($t(11) = 1.00$, $p = .34$) or prevented the verbal communication ($t(11) = 1.83$, $p = .10$), as well as how much it affected how much was communicated verbally ($t(11) = 0.62$, $p = .55$). The mean scores of the questionnaire 'Verbal communication' are visualized in Figure 5.3.
All participants specified in the verbal communication questionnaire that the interaction via *eye gaze and voice* had an impact on how much they communicated verbally with the training partner. For 10 participants, it led to a reduced verbal communication. With *head gestures*, 10 participants indicated that the interaction with the system had an impact on how much they talked to the training partner. All of them reported a reduced verbal communication.

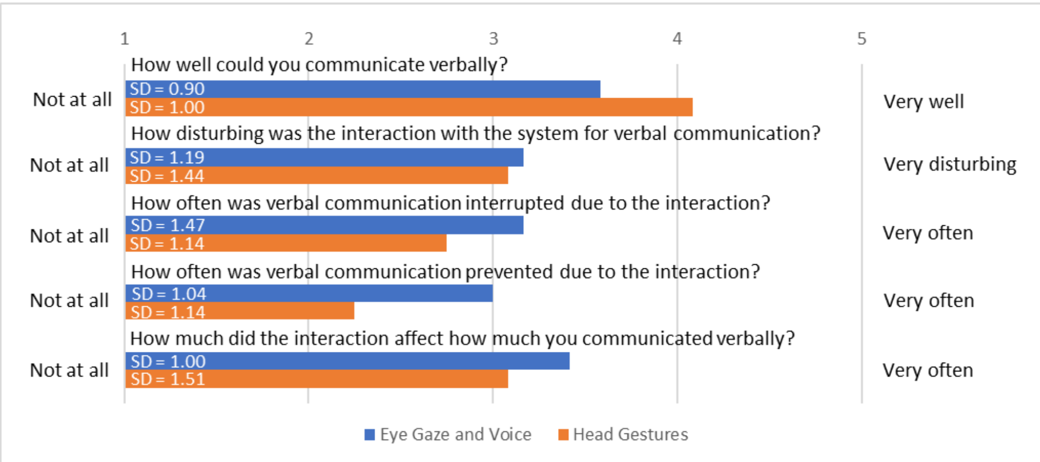

Figure 5.3: Mean scores of the two hands-free interaction techniques *eye gaze and voice* and *head gestures* regarding verbal communication. The results were taken from the questionnaire 'Verbal communication'.

In the semi-structured interview, the participants were asked with which interaction technique they could communicate better verbally and which technique affected the verbal communication with the training partner more. Eight participants stated they could communicate better verbally when using *head gestures* and that *eye gaze and voice* affected the verbal communication with the training partner more (T1, T3, T4, T6-T10). The most named reasons were that, unlike with *eye gaze and voice*, the verbal communication with *head gestures* was not interrupted (T1, T3, T8), disturbed (T3, T8), or prevented (T10) by the speech command.

"[Eye gaze and voice] prevented me from starting a communication when I knew that I had to say 'click' right away and I wouldn't have finished my sentence by then anyway." (T10)

Four participants further explained that they could talk while executing a head gesture, but with *eye gaze and voice*, it was difficult to interact with the system and talk to the training partner simultaneously (T4, T6, T7, T10). Participant 4 further explained that he always had to wait until he finished speaking before the voice command could be said.

Only four participants could communicate better verbally with *eye gaze and voice* and found that *head gestures* affected the verbal interaction more (T2, T5, T11, T12). Three participants stated that they found it more difficult to talk to the training partner when moving the head away (T5, T11, T12). Two participants further described that they could integrate the interaction via *eye gaze and voice* into the verbal communication and were, therefore, not restricted (T5, T12).

"Because I mean when I'm talking to someone and suddenly I'm doing this [head gesture], it's difficult to keep talking. But with [eye gaze and voice], I can say 'click' and continue talking and listening [to the training partner] at the same time." (T5)

Another participant stated that the verbal communication was affected by the Midas Touch effect that occurred with *head gestures* when instructions were played unintentionally (T2).

5.2.3 Non-verbal Communication

A Wilcoxon signed-rank test showed that there are no significant differences between *eye gaze and voice* and *head gestures* in terms of how well the participants could communicate non-verbally ($Z = 0.00$, $p = 1.00$), how much the interaction with the system disturbed ($Z = -0.92$, $p = .36$), interrupted ($Z = -0.55$, $p = .58$) or prevented non-verbal communication ($Z = -0.43$, $p = .67$). Neither was a significant difference found between both techniques in terms of how much the interaction with the system affected how much was communicated non-verbally with the training partner, $Z = -0.59$, $p = .56$. Figure 5.4 shows the mean scores of the questionnaire 'Non-verbal communication'.
From the 11 participants that specified in the non-verbal communication questionnaire that the interaction via *eye gaze and voice* had an impact on how much they communicated non-verbally, 9 participants reported a reduced non-verbal communication. With *head gestures*, also 11 participants specified the interaction had an impact on how much they communicated non-verbally. 9 participants, too, found that the non-verbal communication was reduced.

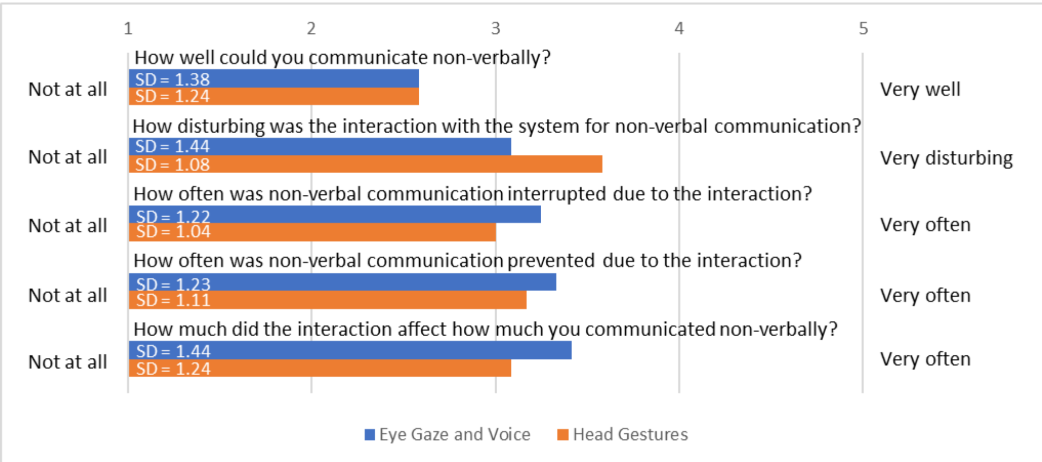

Figure 5.4: Mean scores of the two hands-free interaction techniques *eye gaze and voice* and *head gestures* regarding non-verbal communication. The results were taken from the questionnaire 'Non-verbal communication'.

In the semi-structured interview, the participants were asked with which interaction technique they could communicate better non-verbally and which technique affected the non-verbal communication with the training partner more. Eight participants saw the interaction techniques as equal in terms of non-verbal communication and were torn between both (T1-T5, T7, T9, T10). They argued that non-verbal communication was difficult with both techniques due to multiple factors. Mentioned factors, which were independent of the interaction techniques, were the HoloLens (T4, T9), the videos (T1, T10), and the position of the training partner (T5). The HoloLens itself, which was like a barrier, and the need to watch the video restricted the non-verbal communication. Furthermore, the training partner was better visible when she was in a lying position than in a sitting position, where she was covered by the instruction panel, according to participant 5.

"I found that [non-verbal communication] was difficult with both of them because you usually look more into the eyes. I was so inside my glasses [the HoloLens] that I didn't really keep eye contact." (T9)

Another participant mentioned that with *head gestures*, the gestures that were used as interaction commands could not be used in the non-verbal communication with the training partner, and with *eye gaze and voice*, less eye contact was made (T3).
However, four of these torn participants had a stronger tendency towards *eye gaze and voice* (T1, T2, T4, T5) as some of them found the head movements with *head gestures* restricted the non-verbal communication comparatively more (T1, T4-T5). One torn participant expressed a tendency towards *head gestures* because the non-verbal communication was less restricted as there was no need to fixate on a target with the eyes (T9).

Three other participants had a clearly better non-verbal communication with *eye gaze and voice* and described that *head gestures* affected the non-verbal communication more because the head had to be moved away (T6, T11-T12).

"Because even if I sometimes have to concentrate to direct my gaze to the button, it's less of a loss of eye contact than if I always move my head completely away." (T6)

Only one participant had a clearly better non-verbal communication with *head gestures* as he could make more eye contact compared to *eye gaze and voice* (T8).

"With eye gaze and voice, I had to focus a lot more on the interaction and less on the patient. With head gestures, I watched the video, then performed the action, and then did the head gesture. It's also a bit disturbing, but it's not that bad. You can still interact with the person." (T8)

5.2.4 Midas Touch Effect

The results of the Midas Touch effect questionnaire indicate that the Midas Touch effect occurred more frequently with *head gestures* ($M = 3.17, SD = 1.40$) than with *eye gaze and voice* ($M = 1.08, SD = 0.29$). While only one participant experienced the Midas Touch effect with *eye gaze and voice*, it occurred for eleven participants with *head gestures*. A Wilcoxon Signed-Rank Test showed a significant difference between both interaction techniques regarding the frequency of occurrence of the Midas Touch effect, $Z = -2.96$, $p < .01$. *Head gestures* had statistically more occurrences compared to *eye gaze and voice*.
On a 5-point Likert scale (1 = not at all, 5 = very strongly), the one participant that experienced the Midas Touch effect with *eye gaze and voice* rated it a 3 in terms of how much it disturbed and a 2 in terms of how much it complicated the conduct of the transfer. For *head gestures*, the mean score of how much the Midas Touch effect disturbed is 3.27 ($SD = 1.35$) and the mean score of how much it complicated the conduct of the transfer is 2.27 ($SD = 1.01$). Since the Midas Touch effect occurred for only one participant with *eye gaze and voice*, the sample size was too small to compare both techniques in terms of how much the Midas Touch effect disturbed and complicated the transfer conduct to find possible differences. The mean scores of the questionnaire 'Midas Touch effect' can be seen in Figure 5.5.

These results correspond with the findings from the semi-structured interview. All participants who experienced the Midas Touch effect stated that it occurred more frequently with *head gestures* than with *eye gaze and voice*

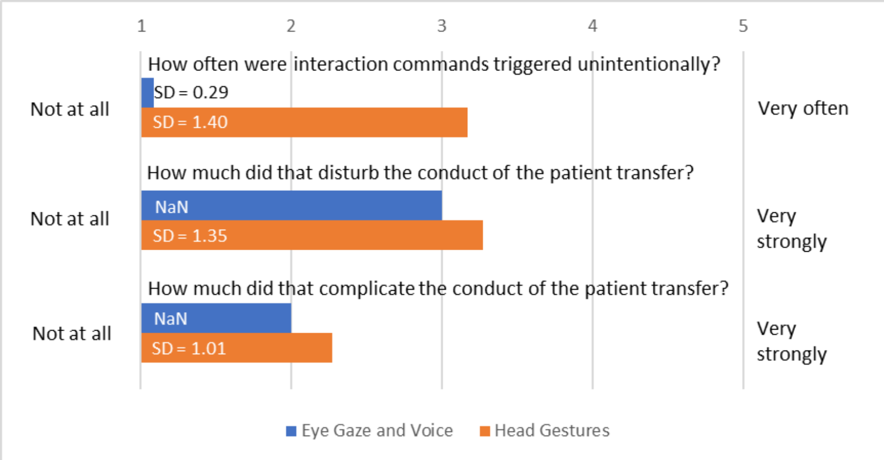

Figure 5.5: Mean scores of the two hands-free interaction techniques *eye gaze and voice* and *head gestures* regarding the Midas Touch effect. The results were taken from the questionnaire 'Midas Touch effect'.

(T1-T2, T4-T12).

"[With head gestures], it happened to me more often that I navigated to the next step compared to [eye gaze and voice]. There, nothing was accidentally triggered because you actually had to target and then activate." (T11)

One participant explained that even when targeting with the eye gaze at the wrong button, the voice command prevented the unintentional activation (T9).

"With [eye gaze and voice], you might have targeted wrong [with the eyes] sometimes, but because you had to say 'click' you were secured." (T9)

Other participants stated that they did not even know if they would have been able to activate an interaction command by accident with *eye gaze and voice* (T6) and that saying a voice command does not happen by accident (T4).

Furthermore, the participants were asked which commands were triggered with *head gestures*. For ten participants, the turning to the side gesture was triggered unintentionally (T1, T2, T4-T8, T10-T12). For four participants, the nodding gesture was activated by accident (T6-T9). In contrast to that, the nodding sideways head gesture was never triggered accidentally.
Gestures were often triggered unintentionally during a transfer movement, as participant 5 explained.

"Because I wanted to look at the patient and we wanted to turn us. And then it went [a step] back." (T5)

Participant 6 stated that she triggered a command unintentionally when nodding her head to communicate non-verbally with the training partner.

"[...] because sometimes I just nod my head and then the video was paused." (T6)

To the question of how the occurrence of the Midas Touch effect affected the patient transfer conduct, nine participants answered that the transfer took longer than it normally would as the unintentional activation of gestures interrupted the transfer and created longer pauses in between (T1-T2, T6-T12).

"It slowed [the transfer procedure] down but didn't bother me extremely. It was so 'oh no, now I have to do it again' [...]"

One participant was confused when it occurred (T4). Another participant described that, as a countermeasure, she executed the transfer movements in such a way that the head gestures were not executed by accident (T5).

"I had to be careful to turn and not look into [the training partner's] face and eyes because that was also a command." (T5).

5.2.5 Social Acceptability

The results of the social acceptability questionnaire indicate that the users felt slightly more comfortable with *eye gaze and voice* ($M = 3.42$, $SD = 1.00$) compared to *head gestures* ($M = 3.33$, $SD = 1.37$). However, a t-test showed no significant difference between both interaction techniques $t(11) = 0.15$, $p = .88$. *Eye gaze and voice* ($M = 3.83$, $SD = 0.94$) and *head gestures* ($M = 3.83$, $SD = 1,27$) were rated equally in terms of acceptability for the patient transfer training context. Consequently, no significant difference was found, $t(11) = 0.00$, $p = 1.00$. The mean score of the questionnaire 'Social acceptability' are visualized in Figure 5.6.

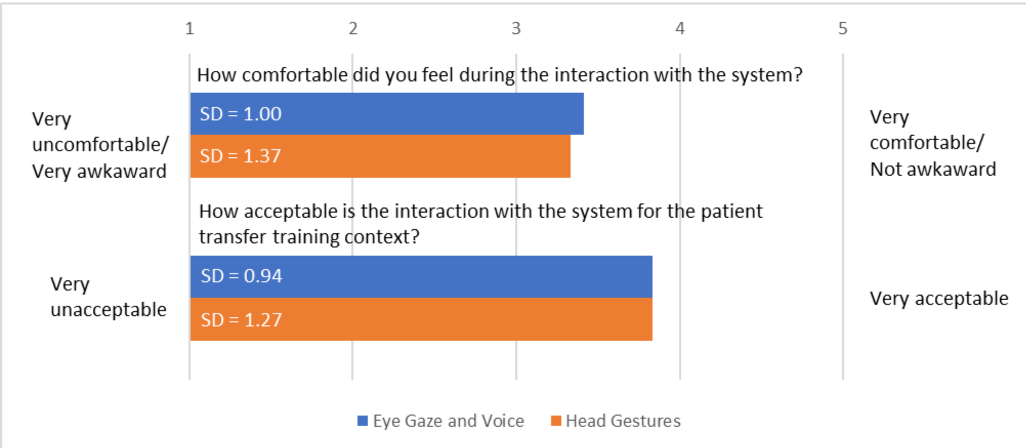

Figure 5.6: Mean scores of *eye gaze and voice* and *head gestures* regarding social acceptability. The results were taken from the questionnaire 'Social acceptability'.

To evaluate how acceptable the interaction via *eye gaze and voice* or *head gestures* is for certain audiences and locations, the acceptances rates for these audiences (see Fig. 5.7) and locations (see Fig. 5.8) were determined based on the results of the social acceptability questionnaire. The results reveal that participants would feel the most comfortable to interact via either *eye gaze and voice* or *head gestures* when being alone, in front of their partner, family, or a training partner. Approximately 83% would feel comfortable to interact via *eye gaze and voice* in front of this audience. With *head gestures*, even approximately 92% would accept the same audience.
For the locations, 100% of the participants found their home the most acceptable for both interaction techniques, followed by a training room with an acceptance rate of approximately 92%.

The first subtask of *eye gaze and voice*, which is to select the target via eye gaze, was rated higher ($M = 4.17$, $SD = 0.94$) in the social acceptability questionnaire in terms of how comfortable participants felt compared to the second subtask, which is to confirm via voice command ($M = 2.70$, $SD = 1.15$). A significant difference was found between both subtasks through a t-test, $t(11) = 3.76$, $p < 0.01$. The participants felt statistically more comfortable with the eye gaze than with the voice command.
The ranking of the *head gestures* revealed that participants felt the most comfortable with turning to the left ($M = 3.70$, $SD = 1.00$), followed by nodding up and down ($M = 3.58$, $SD = 1.31$), turning to the right

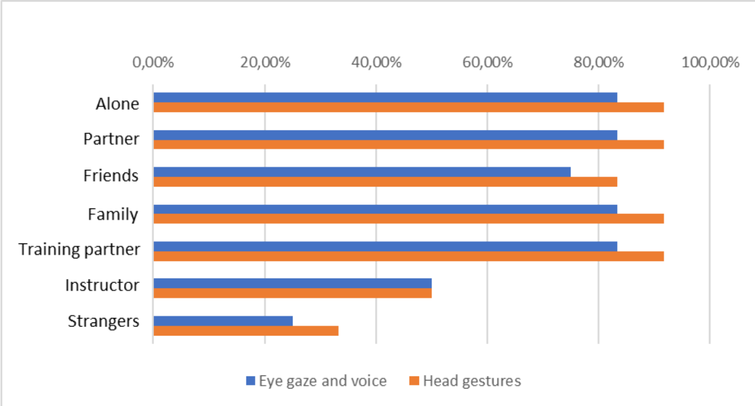

Figure 5.7: Acceptance rates for audiences of the two hands-free interaction techniques *eye gaze and voice* and *head gestures*. The results were taken from the questionnaire 'Social acceptability'.

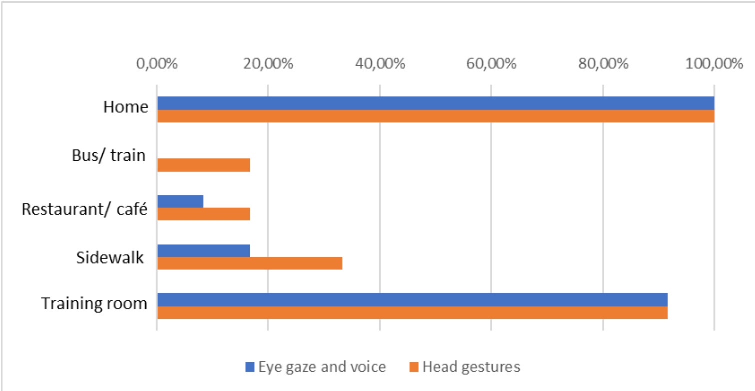

Figure 5.8: Acceptance rates for locations of the two hands-free interaction techniques *eye gaze and voice* and *head gestures*. The results were taken from the questionnaire 'Social acceptability'.

($M = 3.42$, $SD = 1.24$) and nodding sideways ($M = 3.42$, $SD = 1.16$). A Friedman-Test, however, showed no significant differences between the different gestures, Chi-Quadrat $(3) = .71$, $p = .87$, $N = 12$.

In the semi-structured interview, the participants were asked which interaction technique they felt more comfortable or less awkward with. Seven participants felt more comfortable and less awkward with *head gestures* (T1, T2, T7-T11). All of them stated that with *eye gaze and voice* the voice command was awkward, especially when it had to be repeated multiple times before the system accepted it.
Three participants felt more comfortable with *eye gaze and voice* (T4, T5, T12). One participant explained that she found it awkward to perform the *head gestures*, especially when they had to be repeated due to the Midas Touch effect (T5). Two participants found *eye gaze and voice* less awkward because it was faster (T4, T12), whereas the *head gestures* were an intervention in the behavior (T12).
Two other participants felt uncomfortable with both techniques and could not decide between them (T2, T6). In principle, they felt more comfortable with *head gestures*, but the Midas Touch effect (T2) and the extreme head movements (T6) made them uncomfortable.

Furthermore, the participants were asked which interaction technique they found more acceptable for the patient transfer training. Five participants found *eye gaze and voice* more acceptable for the patient transfer training context compared to *head gestures* (T5, T6, T8, T11, T12). The mentioned reasons were that the social interaction with the training partner was better when interacting via *eye gaze and voice* (T11, T12), fewer errors were produced (T5, T6), and that the *head gestures* were unnatural (T8).

"If you move your head back and forth all the time, people will also wonder what you are doing. It looks more unnatural [...]" (T8)

Four participants believed that *head gestures* are more acceptable (T1, T3, T9, T10). They mostly stated that the verbal communication was better compared to *eye gaze and voice*, where it was affected by the voice command (T1, T3, T9).
Three other participants (T2, T4, T7) were not sure which techniques is more acceptable. Two of them would have found *head gestures* more acceptable if it was not for the Midas Touch effect (T2, T7). Participant 7 further described that *head gestures* is more acceptable in front of other people, but due to the Midas Touch effect, *eye gaze and voice* is better suited for the patient transfer training context. Participant 4 had a tendency towards *eye gaze and voice*, but saw the voice command critical:

"In a normal conversation with a patient, it would be weird to say 'click'. But if you overlook that, I would find [eye gaze and voice] nicer [...]." (T4)

5.2.6 User Experience

The UEQ assesses the user experience in terms of attractiveness, perspicuity, efficiency, dependability, stimulation and novelty. The mean scores of these dimensions of *eye gaze and voice* and *head gestures* can be seen in Figure 5.9. A t-test showed no significant differences between both techniques in these dimensions. The t-test was conducted with an alpha-level of 0.05 and it delivered the following results: attractiveness ($p = 0.84$), perspicuity ($p = 0.10$), efficiency ($p = 0.94$), dependability ($p = 0.39$), stimulation ($p = 0.84$), novelty ($p = 0.70$).

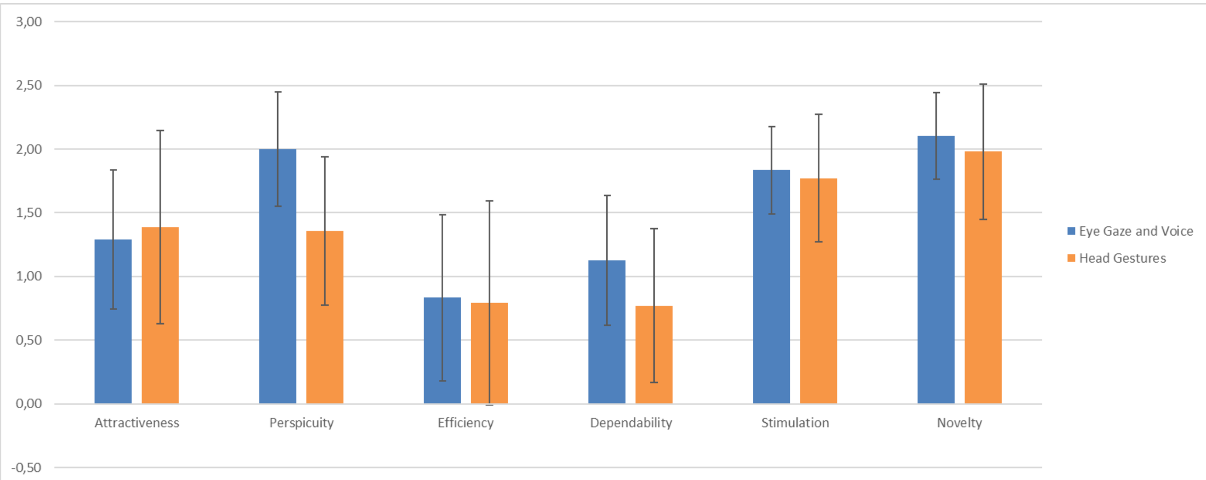

Figure 5.9: Scale means of the two hands-free interaction techniques *eye gaze and voice* and *head gestures*, which were assessed through the UEQ. The results were taken from the questionnaire 'User experience' (UEQ).

When asked about their experience in the semi-structured interview, six participants stated that they had a better experience with *head gestures* (T1, T2, T6, T8-10), while five had a better experience with *eye gaze and voice* (T2, T4, T5, T7, T11). Those who had the better experience with *head gestures* mostly found that they worked better than *eye gaze and voice* (T1, T2, T8-10). One participant stated that it was less complex to perform the head

	Eye Gaze and Voice	Head Gestures
Positive	+ no unintentional activation of commands (5) + fast (4) + no need to move the head (3) + precise (3) + only one command (1) + visual feedback (1) + intuitive (1)	+ head gestures work well (better than eye gaze and voice) (8) + fast (3) + no need to speak (2) + affects verbal communication less (2) + easy (1)
Negative	- voice command is not always recognized (7) - difficult to fixate on target with eye gaze (6) - affects verbal communication (4) - strenuous for eyes (1)	- unintentional activation of commands (7) - different interaction commands (5) - large movements (4) - affects social interaction (3) - not intuitive (2) - looks weird (1)

Table 5.1: Positive and negative aspects of *eye gaze and voice* and *head gestures* that were found in the semi-structured interview.

gesture than to gaze at the target and say the voice command (T6).
Of the participants who had a better experience with *eye gaze and voice*, three stated that it was due to the unintentional activation of interaction commands with head gestures, which disturbed them (T2, T4, T5). Other arguments were that it was faster (T5) and more intuitive than head gestures (T11).
One participant could not decide between *head gestures* and *eye gaze and voice* (T12). He liked *eye gaze and voice* from the concept more but found that it was more difficult to use. From the implementation, he preferred *head gestures*, even though he perceived it as less innovative and more disturbing.

Furthermore, the participants were asked about difficulties to learn and execute *eye gaze and voice* and *head gestures*. Although the gestures were constantly visible as icons on the buttons, the participants found it mainly difficult with *head gestures* that there were different interaction commands (T2, T3, T7, T10, T12), Furthermore, they found it difficult that interaction commands were triggered too easily by accident (T2, T7). Two participants added that the gestures were confusing (T12) and not intuitive (T10).

"It was also difficult to remember the commands. I don't usually pause a video with a nod." (T12)

One of the main difficulties with *eye gaze and voice* was that the voice command was not accepted immediately and had to be repeated multiple times at once (T2, T10, T11). The other frequently mentioned difficulty was to fixate on the target with the eyes as the participants had never used eye tracking before (T4, T6, T8, T9, T11).

"To learn, [eye gaze and voice was more difficult] because you really have to stay on the button. But once you get the hang of it, it works well." (T4)

Moreover, the participants were asked what they found positive and negative about each interaction technique. Table 5.1 presents the positive and negative aspects that were found from this question and from the previous questions regarding user experience.

Lastly, the participants were asked about their preferences. The majority stated that they would prefer *eye gaze and voice* (T2, T4, T5, T6, T8, T11, T12). Participant 6 explained her choice:

"Because I think if you train that little bit more to hold your gaze and can do it better, it's less disturbing than head gestures."

Only four participants would prefer *head gestures* (T1, T3, T9, T10). Participant 7 had no clear preference and believed that *eye gaze and voice* is more disturbing for the communication but more precise for the learning compared to *head gestures*.

5.2.7 Applicability of instructions

When the participants were asked which technique affected the application of the instructions more, five participants named *head gestures* (T2, T4, T5, T11, T12). Four of them stated that the transfer conduct was affected by the Midas Touch effect (T2, T4, T5, T11). Participant 5 explained how the Midas Touch effect restricted the conduct of the patient transfer:

"I had to be careful not to look at the patient properly because that was also a command with the head gestures. That prevented me from looking at how good I am with the patient or if I was doing something wrong. Because I can't look properly." (T5)

Participant 12 was affected by the extreme head movements with *head gestures* that forced him to look away from the training partner, where he was currently executing the transfer movement. He could not keep a proper eye on the training partner. Furthermore, he saw *head gestures* as a risk factor for the patient transfer conduct due to the physical aspects of this context.

"I could imagine that [with] physical strain, it would be more important to keep your head and back straight and you can do that [with eye gaze and voice], but if I make head gestures, there is a risk." (T12)

Three participants found that *eye gaze and voice* affected the transfer conduct more (T1, T3, T10). The interaction with the system took longer because the voice command was not always immediately accepted, which led to an interruption in the transfer conduct (T1, T3). Participant 10 was less distracted from the transfer with *head gestures* and stated:

"[With head gestures], I had to focus less on [the interaction] and could concentrate more on the execution because it was easier to go to the next step." (T10)

Four participants stated that there was no difference between the interaction techniques (T6-T9). Participants 6 and 8 saw both interaction techniques as a small impairment. With *eye gaze and voice*, the movement flow is interrupted and less smooth, while it is restricted with *head gestures* due to the Midas Touch effect (T6, T8).

Overall, the participants had no problems applying the instructions and conducting the patient transfers. They mostly found that the given instructions provided good or sufficient support, especially through the combination of video and audio instructions. Some mentioned deficiencies were that the videos were not precise enough, unrealistic, and complicated. Proposed improvements were to indicate the movements in the videos with an arrow or show static pictures to avoid re-watching the videos frequently. Other improvements were to note details or highlight them in the video.

5.3 Discussion

In this section, the study results that were presented in Section 5.2 are discussed. Again, the discussion is along the research questions.

5.3.1 Verbal Communication

The research question that was investigated regarding verbal communication is RQ1:

To what extent do the two conditions (i) eye gaze and voice and (ii) head gestures affect the verbal communication during the training of ergonomic patient transfers?

From the quantitative data, no significant differences were found between *eye gaze and voice* and *head gestures* in terms of verbal communication. The results indicate that both techniques affected the verbal communication to a similar extent and led to a reduced verbal communication.

The qualitative data from the semi-structured interview was more informative. The results indicate that *eye gaze and voice* affected verbal communication with the training partner more compared to *head gestures.* Two thirds of the participants, which is the clear majority, could communicate better verbally with *head gestures* and only one third could communicate better verbally with *eye gaze and voice.* The voice command of *eye gaze and voice* had a negative impact on the verbal communication by disturbing, interrupting, or even preventing verbal communication with the training partner. The participants found it difficult to talk to the training partner and interact with the system simultaneously, only a few could integrate the interaction via *eye gaze and voice* into the verbal communication. The impact *head gestures* had on verbal communication seems far less. While most participants found it possible to talk with the training partner while executing head gestures, only a few participants had difficulties doing both simultaneously. These results come to no surprise considering that *eye gaze and voice* is a verbal interaction techniques that involves speech, while *head gestures* is not verbal and involves no speech. It is not possible to say two things at the same time, but it is in principle possible to perform a gesture with the head and talk simultaneously. Therefore, *head gestures* seems to be more compatible with verbal communication compared to *eye gaze and voice.*

Main Findings related to RQ1

Although there were no statistically significant differences between *eye gaze and voice* and *head gestures* regarding verbal communication with the training partner, the results from the interview indicate that *eye gaze and voice* affects the verbal communication to a greater extent than *head gestures.* The voice command disturbs, interrupts and often prevents verbal communication with the training partner. With *head gestures*, it is mostly possible to combine the execution of the gestures with verbal communication.

5.3.2 Non-verbal Communication

The research question that was investigated regarding non-verbal communication is RQ2:

To what extent do the two conditions (i) eye gaze and voice and (ii) head gestures affect the non-verbal communication during the training of ergonomic patient transfers?

From the quantitative data, no significant differences were found between *eye gaze and voice* and *head gestures* in terms of non-verbal communication. The results indicate that non-verbal communication was equally affected and reduced by both techniques.

The results from the semi-structured interview indicate that non-verbal communication was to a large extent affected by factors independent of the interaction techniques, namely wearing the HoloLens, watching the videos, or the position of the training partner. Wearing the HoloLens seemed to create a barrier between the participants and the training partner, and watching the video prevented them from making eye contact. The participants seemed to pay less attention to non-verbal communication as they were more focused on watching and applying the instructions. Furthermore, the training partner was covered by the instruction panel in certain positions, especially in a sitting position. These three factors restricted non-verbal communication in general, independent of the techniques.

Besides the mentioned independent factors, the non-verbal communication was affected by factors dependent on the interaction techniques, namely the fixation on the target with the eyes and the head movements. The participants found that the non-verbal communication, especially the eye contact, was mostly restricted due to the need to focus on a target with the eyes for *eye gaze and voice* and the need to move the head away for *head gestures*, which interrupted the eye contact. Even though many participants saw both techniques as similar regarding non-verbal communication at first, they expressed a tendency towards *eye gaze and voice* over the course of the interview. They found that *head gestures* affected the non-verbal communication comparatively more and that they could better communicate non-verbally with *eye gaze and voice*. With *eye gaze and voice*, the head could at least be kept in the same position and did not have to be moved away completely. Only the eyes had to be moved away, which interrupted the non-verbal communication less. Moving the eyes away might be a faster and smaller movement than moving the whole head away. In addition to that, it was not possible with *head gestures* to use the head gestures for non-verbal communication with the training partner because they were used as interaction commands, and using them would have triggered the corresponding command. For example, it was not possible to nod to the training partner during non-verbal communication to express approval as one might do in a normal conversation because the nodding gesture was used as interaction command to pause or play the video. Nodding the head would have either paused or played the video. As this action was not intended, this form of non-verbal communication was avoided. While *eye gaze and voice* restricted only eye contact, *head gestures* restricted eye contact and additionally the use of non-verbal head gestures. One could argue that more forms of non-verbal communication were affected by *head gestures*.

Main Findings related to RQ2

No statistically significant differences were found between *eye gaze and voice* and *head gestures* regarding non-verbal communication with the training partner. The results from the semi-structured interview indicate that non-verbal communication is overall affected by factors independent and dependent on the interaction techniques. Independent factors are wearing the HoloLens, watching the videos, and the position of the training partner. Dependent factors are the fixation with the eye gaze for *eye gaze and voice* and the head movements for *head gestures*, which both lead to a restricted non-verbal communication. In comparison, moving the whole head away makes non-verbal communication, especially eye contact, more difficult than only moving the eyes away. In addition to that, *head gestures* prevents the use of non-verbal head gestures in the interaction with the training partner. Thus, *head gestures* seems to affect the non-verbal communication more compared to *eye gaze and voice*, based on the qualitative data.

5.3.3 Midas Touch Effect

The research question that was investigated regarding the Midas Touch effect is RQ3:

To what extent does the Midas Touch effect affect the training of ergonomic patient transfers with the two conditions (i) eye gaze and voice and (ii) head gestures?

The quantitative data showed a significant difference between *eye gaze and voice* and *head gestures* in terms of how often the Midas Touch effect occurred. With *head gestures*, the Midas Touch effect occurred statistically more often. All participants, except for one, experienced the Midas Touch effect with *head gestures*, while solely one participant reported an unintentional activation with *eye gaze and voice*.

The qualitative data from the interview also indicate that *eye gaze and voice* is very safe and prevents the Midas Touch effect. The Midas Touch effect seemed to be prevented due to the combination of eye gaze with voice, where two subtasks have to be performed. As the participants described, selecting the wrong target via eye gaze had no effect without the confirmation via voice command. The visual feedback indicates the target selection. Therefore, participants are able to notice if the selection was wrong and have the chance to correct their selection without activating a target unintentionally. There was a strong opinion among the participants that commands with *eye gaze and voice* can not be triggered by accident. It indeed seems highly unlikely that two subtasks are performed by accident, especially since the interaction via *eye gaze and voice* required concentration and was perceived as rather complex. The selection of the voice command might have also played a role in the avoidance of the Midas Touch effect. 'Click' is not a word that is frequently used in conversations. Therefore, it was never said in the verbal communication unintentionally. This might have been different with a voice command that is frequently used in conversations.
In contrast to that, the results indicate that *head gestures* were easily triggered by an unintentional movement during the transfer flow or when using a head gesture for non-verbal communication with the training partner. Especially the turning to the side and the nodding gestures were triggered frequently. From observations, it was found that the turning to the left gesture was activated frequently during a movement in the bed-wheelchair transfer, where the participants had to turn the training partner in a leftward motion from the bed to the chair. Many participants performed the turning movement and looked quickly back to the video. This turning to the left and turning quickly back to the right was interpreted as a turning to the left head gesture. Consequently, the system jumped to the previous step. Furthermore, the nodding gesture was often triggered when the participants looked from the video down at the training partner and quickly back up at the video. The looking down and back up was interpreted as nodding and the video was consequently either paused or played.
This shows that turning the head to the side and looking up and down (i.e. nodding) are movements that are often executed in the course of the transfer conduct. In contrast to that, nodding sideways (i.e. tilting the head to the left and right) was never triggered unintentionally. Possible reasons might be that turning the head around the z-axis is a rather rare movement that does not occur in a transfer movement or that is more difficult to execute and therefore not easily performed by accident. This assumption coincides with the findings from Prilla et al. [16], who found that tilting the head is complex and difficult to perform. It might also have cultural reasons as nodding the head sideways has no specific meaning in this cultural area and therefore it is not accidentally used as a non-verbal gesture in non-verbal communication, unlike nodding up and down, which is used by habit to indicate 'Yes'.
The results from the semi-structured interview with the participants indicate that the Midas Touch effect with *head gestures* affected the transfer conduct. It primarily slowed down the procedure and interrupted it. It was observable that the Midas Touch effect created pauses in between the transfer steps when the participants were busy reversing the unintended action. As mentioned above, the Midas Touch effect frequently occurred while turning the patient. There, the training partner had to wait in a standing position until the participants found the correct instruction again and could proceed with the transfer.

"She [the training partner] stood for a longer time because I had to search for the video." (T1)

This might be critical in a clinical context with a normal patient who has difficulties standing. This is not the case in the patient transfer training context, but it still seems to be an unattractive side effect of *head gestures* and should be avoided in the future.

Main Findings related to RQ3

A statistically significant difference was found between *eye gaze and voice* and *head gestures* regarding the Midas Touch effect. The quantitative data indicates that *head gestures* has statistically more occurrences of the Midas Touch effect than *eye gaze and voice*. The data from the semi-structured interview also supports this finding and indicates that *eye gaze and voice* prevents the Midas Touch effect. With *head gestures*, the Midas Touch effect occurs frequently, especially with the turning to the left or right gestures and nodding up and down, while nodding sideways seems stable. The gestures are often triggered unintentionally during transfer movements or when using a head gesture for non-verbal communication with the training partner. The Midas Touch effect affects the transfer conduct mainly by interrupting the procedure and creating longer pauses in between, which slows the transfer procedure down. The Midas Touch effect with *head gestures* seems to affect the patient training to a far greater extent than *eye gaze and voice*, where it hardly ever occurs.

5.3.4 Social Acceptability

The research question that was investigated regarding social acceptability is RQ4:

To what extent are the two conditions (i) eye gaze and voice and (ii) head gestures socially acceptable for the training of ergonomic patient transfers?

From the quantitative data, no significant differences were found in terms of how comfortable the participants felt with *eye gaze and voice* and *head gestures* and how acceptable the interaction techniques are for the patient transfer training context. The acceptance rates for audiences and locations indicate that a training partner and a training room are both highly acceptable for the interaction via *eye gaze and voice* or *head gestures*. The majority of the participants would feel just as comfortable interacting via *eye gaze and voice* or *head gestures* in front of a training partner as when they were alone, with their family or partner. The training room was considered almost as acceptable as the home for both interaction techniques. The results further indicate that the feeling of discomfort with *eye gaze and voice* was primarily caused by the voice command. The participants felt statistically less comfortable with the voice command than with the eye gaze. The different *head gestures* were rated similarly in terms of how comfortable the participants felt and did not differ significantly from each other.

The qualitative data from the interview also indicates only small differences between *eye gaze and voice* and *head gestures*. While the majority felt less comfortable with *eye gaze and voice* due to the voice command which sometimes had to be repeated multiple times before it was recognized by the system, both techniques were perceived similar in terms of acceptability for the patient transfer training context.
Both interaction techniques seem to have some factors that affect social acceptability. With eye gaze, it was the voice command and especially the frequent repetition that made the participants uncomfortable and affected the verbal communication in the training context. With *head gestures*, it was the extreme movement of the head that was perceived as unnatural and affected the social interaction. Furthermore, the Midas Touch effect also led to a repetition of the gestures. They both seem to make the user feel uncomfortable and affect the overall social situations by affecting the social interaction or communication, which is an important aspect of this social context. Both techniques are rather noticeable, obtrusive, and not subtle. In Section 2.3, it was described that the interaction should be subtle or unobtrusive [24]. Therefore, they do not meet the definition of social acceptability. However, given the context of patient transfer training, both techniques might be more acceptable for this context than for a clinical context. In the patient transfer training context, the training partner is well aware of the interaction with the system, while patients in a hospital might be highly confused. As some participants described, saying 'Click' in a conversation with a patient or moving the head all the time in front of a patient

might be weird. In the context of patient transfer training, the situation is different. One participant described this:

"Because that is a context where the other person knows what you see in front of you or that you see something in front of you. Then [...] that's a less big deal." (T11)

The previously discussed acceptance rates of auditions and locations also reflect that the interaction in front of a training partner in a training room would be more acceptable than in front of less known people in a less private space.

Main Findings related to RQ4

The qualitative data indicates that there are no significant differences between *eye gaze and voice* and *head gestures* in terms of social acceptability. The acceptance rates for audiences and locations indicate that a training partner and a training room are both highly acceptable for *eye gaze and voice* and *head gestures*. Furthermore, participants feel statistically more comfortable with the eye gaze than with the voice command for *eye gaze and voice*, while there was no significant difference between the different *head gestures*. The findings from the semi-structured interview also show that both techniques are similar regarding social acceptability. *Eye gaze and voice* and *head gestures* do both not meet the classical definition of social acceptability as they are obtrusive and highly noticeable due to the voice command and the large head movements. Yet, they might be acceptable for the patient transfer training context, where the only spectator is aware of the interaction with the system and the interaction takes place in a non-public environment.

5.3.5 User Experience

The research question that was investigated regarding user experience is RQ5:

How good is the User Experience with the two conditions (i) eye gaze and voice and (ii) head gestures during the training of ergonomic patient transfers?

Regarding the user experience, no significant differences were found between *eye gaze and voice* and *head gestures* from quantitative data. The results from the UEQ show that both interaction techniques provided an equally good user experience in terms of attractiveness, perspicuity, stimulation, and novelty. They only fell behind regarding efficiency and dependability.

The qualitative data from the interview also indicates that *eye gaze and voice* and *head gestures* are close together in terms of user experience. While six participants had a better experience with head gestures, five had a better experience with eye gaze and voice. The overall user experience was good and many positive aspects of *eye gaze and voice* and *head gestures* were found, but the participants also mentioned some factors that affected the user experience. With *head gestures*, the user experience was mainly affected by the Midas Touch effect. With *eye gaze and voice*, the user experience was primarily affected by the need to repeat the speech command multiple times before it was recognized by the system or led to a target activation. One could say that while it was too easy to execute interaction commands with *head gestures*, it was too difficult with *eye gaze and voice*. This might have also been the reason why both techniques scored comparably badly in the UEQ in terms of efficiency and dependability. They were probably perceived as less efficient as the interaction took more effort and time when the voice command had to be repeated or unintended actions caused by the Midas Touch effect had to be reversed. They were probably also perceived as less dependable when they did not always work as expected, i.e.,

when commands were either not executed or executed without intention.
The difficulties with *eye gaze and voice* were surprising, especially since there was an observable big difference between the participants' performances. While some had no difficulties at all, did not have to repeat the speech command multiple times, and accomplished the interaction very quickly, others had bigger difficulties, had to repeat the voice command multiple times and it took them remarkably longer to accomplish the interaction. No obvious explanation from the demographics was found for that, neither was it explainable with previous experience with eye tracking as no participant had experience. The difficulties were closer investigated. It was not believed that the voice command was the main cause of these difficulties because the speech recognition of the HoloLens is very sensitive and no prior issues with the speech recognition were known. Some statements from the participants confirmed the assumption that the problem might have been caused by the eye gaze component. Several factors that might have caused the difficulties were found.

Several participants stated during the interview that they found it difficult to focus on the target with the eye gaze. Some participants explained that they did not concentrate enough and lost focus on the button. Participant 6 stated:

"I tried to concentrate on it [the button], noticed something out of the corner of my eye and my eye went straight there and the eye contact broke off. When I looked at it [the button], the voice command worked fine."

Another participant reported that her eye gaze always drifted downwards just before she wanted to say the voice command (T10). It was observed that she blinked with her eyes before or while saying the voice command. A possible explanation could be that the eye gaze drifted downwards due to the blinking, where the eye tracking might have been lost during the brief moment of closing the eyes. Another explanation could be the 'See it, say it label', which appears under the button when the eyes are gazing at it. The participant might have looked down at it unconsciously and lost focus.
One participant noticed that he had to open his eyes wide so that they were tracked (T12). Otherwise, his eyes were probably covered partially by the eyelid or too small to be detected by the eye trackers. This coincides with findings from Pai et al. [15], who found that the eye trackers had difficulties with certain eye shapes or sizes. Note that they did not use HoloLens eye trackers, but this might be a general shortcoming of eye tracking.
It was also mentioned by another participant that it was hard to focus on the buttons because the control panel was moving with the head movements (T11). She lost focus on the buttons because her head was moving.
Above all, there seemed to be a strong training effect. One participant, for example, improved observably the longer he used *eye gaze and voice* and after realizing what he did wrong before and why it did not work well. He stated:

I think I made the mistake of looking away. [...] When I concentrate and really look at it [the button] all the time, then it works better. (T4)

Other participants also believed that they would improve with more practice and that eye tracking was just extremely new for them. With enough practice, the mentioned factors might be overcome. The difficulties were perceived as resolvable, while *head gestures* had, besides the Midas Touch effect, the additional difficulty that different interaction commands were used. Therefore, *eye gaze and voice* might be in the long term easier to use than *head gestures*.

This was also reflected in the participants' preference as the majority preferred *eye gaze and voice*. Interestingly, even participants who had a better experience with *head gestures* saw more potential in *eye gaze and voice* in the long term.

Main Findings related to RQ5

The results from the qualitative data indicate that the overall user experience with *eye gaze and voice* and *head gestures* is similarly good, but both techniques have some shortcomings in terms of efficiency and dependability. The quantitative data shows that some participants encountered difficulties with *eye gaze and voice*, where they had to repeat the voice command multiple times, and experienced the Midas Touch effect with *head gestures*, both of which reduced the user experience. The difficulties with *eye gaze and voice* seem to be mainly personal due to a lack of concentration and practice to fixate on a target with the eye gaze. Additional external disruptive factors might be the moving control panel and the 'See it, say it' label. Despite the difficulties, the majority preferred *eye gaze and voice*.

5.3.6 Applicability of Instructions

The research question that was investigated regarding the applicability of instructions is RQ6:

To what extent do the two conditions (i) eye gaze and voice and (ii) head gestures affect the applicability of the instructions?

The results indicate that both interaction techniques affect the applicability of the instructions, but *head gestures* affects the transfer conduct more than *eye gaze and voice*, predominantly due to the Midas Touch effect. This shows that there is a connection between RQ3 and RQ6. RQ3 already found that the Midas Touch effect slows the transfer procedure down and creates longer pauses in the transfer. Now, it was additionally found that the Midas Touch effect restricts the applicability of the instructions or the execution of the transfer movements. In the interview, it was mentioned by participants that they adjusted their movements in a way that the Midas Touch effect does not occur. This behavior was also noticed during observations. The Midas Touch effect often occurred during a certain movement in the bed-wheelchair transfer, where the participants had to turn the training partner from the bed to the chair, as explained before. They were supposed to turn together with the training partner to support her during this movement. Some participants, however, avoided this critical turning movement in the second and third transfer conduct after having encountered the Midas Touch effect in the first round. They only turned the training partner without turning their own body to support her. Instead, they stayed in the position facing the bed and the instruction panel to avoid the turning to the left gesture being triggered. This leads to the assumption that the Midas Touch effect with *head gestures* promotes the incorrect execution of transfer movements. In the attempt to avoid the unintentional execution of interaction commands, participants seem to apply the instructions in an incorrect way.
Independent of the Midas Touch effect, *head gestures* could also lead to an incorrect body posture during the patient transfer due to the head movements, which might be a risk factor in general. This contradicts the ergonomic approach, where correct postures are important to avoid injuries and straining of the back.
In contrast to that, the impact *eye gaze and voice* has on the application of the instructions seems less serious because all instructions can be applied correctly. It just slows the procedure down because the interaction takes longer due to the repetition of the voice command. This is not ideal, but considering that there is no time pressure in the patient transfer training context, it might be tolerable.

Main Findings related to RQ6

The results indicate that *head gestures* affects the application of the instructions to a greater extent than *eye gaze and voice*, mostly due to the Midas Touch effect. The Midas Touch effect that occurs with *head gestures* not only makes it difficult to apply the instructions, but it also restricts the correct applicability and seems to promote the incorrect execution of transfer movements. With *eye gaze and voice*, all instructions can be applied correctly, the transfer procedure is just slowed down due to the repetition of the voice command. Given the patient transfer training context, applying the movements incorrectly might be more problematic than a slowed-down transfer procedure.

5.4 Limitations

The study was not conducted with real nursing students as participants and one intern person as the training partner. The choice of using normal students from the University as participants was due to the Covid restrictions, which were still in force at the time of the study planning. It was decided to use only one training partner because it was important for the training partner to act according to the patient's mobility level (i.e. immobile or mobile). Using a different training partner for each participant might have changed the conditions for the different participants.
Having normal students as participants limited the evaluation in some aspects. For example, it could not be assessed if the system promotes the correct application of instructions or the training of kinaesthetics due to the participants' lack of experience with patient transfers. Furthermore, the students could not draw upon previous experience with patient transfer training or bring in prior knowledge. Since only one training partner was used, the training partner's perspective on the interaction was not evaluated. This would have been especially relevant for the evaluation of social acceptability to find out how the training partner perceives the interaction with the system. Therefore, social acceptability could only be assessed from the user's perspective. This restricts the general validity of the results in terms of social acceptability.

The participants had no physical impairments, except for visual and hearing impairments. Therefore, it is not known how the interaction techniques would behave with other physical impairments and whether there are limitations in their usability for certain users. It would be thinkable that especially for head gestures certain physical abilities are required due to the large head movements. For users with back or neck injuries or movement restrictions in these areas, it might be difficult to execute the head gestures.

As explained in Section 4.3, the head gestures mechanism with the threshold approach had some limitations in terms of stability as commands could be triggered unintentionally. The study results only represent this threshold approach with the Midas Touch effect. Other approaches like a machine learning approach might lead to different results as the head gestures might behave more stable.

6 Conclusion and Future Work

6.1 Conclusion

In this bachelor thesis, a design concept, the implementation and evaluation of the two hands-free interaction techniques (i) eye gaze and voice and (ii) head gestures to support the training of ergonomic patient transfers were presented. The study examined both interaction techniques along six research questions to find benefits and downsides. In the following, the main findings are briefly summarized.

It seems that eye gaze and voice affects verbal communication more due to the voice command, which interrupts, disturbs or prevents verbal communication with the training partner. Head gestures on the other hand seems to have less of an impact on verbal communication as it does not involve speech and it is mostly possible to combine the execution of the head gestures with verbal communication. However, it needs further investigation to determine the full impact of both techniques on verbal communication as no statistically significant differences were found.
Non-verbal communication seems to be more affected by head gestures due to the head movements, which interrupt the eye contact, and the restriction that head gestures can not be used for non-verbal communication with the training partner. Eye gaze and voice, on the other hand, seems to affect non-verbal communication less because the head does not have to be moved away and head gestures can be used as a form of non-verbal communication. However, this needs further investigation as no statistically significant differences were found.
In terms of the Midas Touch effect, a significant difference was found between both techniques. Eye gaze and voice is overall safe against the Midas Touch effect. In contrast to that, head gestures is prone to the Midas Touch effect. It occurs frequently during transfer movements and when head gestures are used as a form of non-verbal communication. For future work this means that eye gaze and voice is an effective technique to avoid the Midas Touch effect. For head gestures, a better implementation approach to avoid the Midas Touch effect has to be found by future work.
Both techniques seem to be equal regarding social acceptability. They are both highly noticeable and affect the social context due to the voice command, especially its frequent repetition, and the large head movements. Yet, they might be socially acceptable specifically for the patient transfer training context, where the spectator is aware of the interaction. However, it has to be further investigated if they are really socially acceptable for the training context as only the users perspective was evaluated. It is not known how the spectator would perceive the interaction. Future work should try to make both techniques more subtle. Eye gaze and voice might be less obtrusive if the problem that the voice command has to be repeated multiple times is avoided. For head gestures, smaller head gestures that are less noticeable should be used to make them appear less weird.
Furthermore, it was examined how good the user experience is with both techniques. The results indicate that they provide a similar good user experience, but have shortcomings in terms of efficiency and dependability. With eye gaze and voice, some participants encountered difficulties that the voice command had to be repeated multiple times before it led to a target activation. This presumably resulted from a lack of concentration and practice with eye tracking, and was not caused by the speech recognition. With head gestures, the Midas Touch effect reduced the user experience. It needs further investigation to confirm that the difficulties with eye gaze and voice were really due to personal abilities with the eye gaze or if there are limitations in the speech recognition or eye tracking. Furthermore, it has to be further investigated if the user experience can be maximized by resolving the difficulties of both techniques.

Lastly, it was found that the given instructions are overall applicable with eye gaze and voice, but the Midas Touch effect with head gestures seems to restrict the applicability. Furthermore, it seems that the incorrect execution of transfer movements with head gestures is promoted due to attempts to avoid the Midas Touch effect. It needs further investigation to find if the applicability of the instructions can be improved by resolving the Midas Touch effect for head gestures or if they are in general disadvantageous for the application of transfer movements.

Overall, the results indicate that both interaction techniques are promising solutions with many benefits. Yet, they need further investigation and improvement. For both interaction techniques, two major downsides were found. With eye gaze and voice, it is the repetition of the voice command. With head gestures it is the Midas Touch effect. Both downsides seemed to have a big impact on many of the aspects that were evaluated. Without these difficulties, (i) eye gaze and voice and (ii) head gestures might perform better in many of the examined aspects. Future work should investigate these downsides further and try to resolve them to improve both techniques. Proposals to solve them are presented in Section 6.2. Note that the difficulties with eye gaze and voice were believed to be due to personal abilities, yet some external factors were found that might have complicated the interaction. Avoiding them might facilitate the interaction in general.

The results of this evaluation give more insight about the two hands-free interaction techniques (i) eye gaze and voice and (ii) head gestures to support the patient transfer training. This thesis showed where the benefits, but also the downsides and limitations of both techniques are. Future work might benefit from theses results in the further investigation of hands-free interactions for the training of patient transfers. So far, little was known about their benefits and downsides in this context. In the beginning of this thesis, it was described that, to my knowledge, no empirical data about hands-free interactions with AR glasses in the patient transfer training context exist. This is unfortunate because the topic is highly relevant and AR glasses that enable hands-free interaction seem to be a promising solution for a modern approach to support nursing students during the self-training of patient transfers. Therefore, this bachelor thesis took a first step in this direction and could contribute to the investigation of hands-free interaction techniques for the patient transfer training.

6.2 Future Work

In the evaluation, some downsides were found for both interaction techniques. In the following, implications are proposed for future work, which could resolve the main difficulties. The proposed ideas target the design and implementation of user interface and interaction techniques to achieve a general improvement.

Different placement of the instruction panel
The fixed panel position is disadvantageous for some patient transfer movements. When a patient is, for example, transferred from bed to (wheel-)chair, the user has to perform a 90 degree rotation away from the bed and the instruction panel. To watch the video of the next step, the user has to turn his or her head back to the bed, where the instruction panel is placed. This might be uncomfortable and straining for the neck in the long term. A solution could be an instruction panel that is fixed along the y-axis, but moves along the x-axis. That way, the panel would still be at the user's eye level and not cover the training partner too much, but it would move when the user turns away from the bed and be always visible in all positions.
Furthermore, it could be considered to place the instruction panel in a different position and not parallel to the bed, directly in front of the user. It was found that the panel covered the training partner in certain positions, especially a sitting position. It could be moved more to the side of the bed instead of being parallel to the bed. This, of course, would have the disadvantage that the head has to be turned to see the instructions.

Improvement of the instructions
The given instructions, especially the combination of video and audio, were overall perceived as useful by partic-

ipants and should be maintained. However, some participants wished for more precise instructions. Mentioned proposals for an improvement of the instructions were to indicate movements with arrows and highlight details in the video. Future work could consider this. Other options could be to provide additional textual descriptions of transfer movements for each step when they are not apparent from the video, or to provide more detailed audio instructions.

Fixed control panel & avoidance of 'See it, say it' label
Some participants found the interaction via eye gaze and voice difficult. Despite difficulties that can be traced back to a lack of concentration and practice, some factors were found that seemed to complicate the interaction. One mentioned factor was the moving control panel. It seemed that it was more difficult to focus on a moving target. Therefore, the control buttons should either be in a fixed position, which might however restrict the interaction, or at least be restricted in movement. The proposal for the instruction panel that was mentioned above could also be applied to the control panel. The control panel could also be in a fixed position on the y-axis and only move along the x-axis. With a movable instruction panel, it could also be considered to combine instruction and control panel. The other factor that seemed to be distractive was the 'See it, say it' label, which appears under a button when it is met by the eye gaze. The statement from one participant led to the assumption that users might unconsciously look down at the label when it appears and lose focus on the target. An alternative to the label could be to integrate the voice command into the button. That way, there would be no need to look down. Additionally, the size of the buttons could be increased as it might be easier to focus on a larger target with the eye gaze.

Machine learning approach for head gestures
Future work should consider using a different approach for the implementation of head gestures. The threshold approach showed to be a decent solution that works overall well for the detection of head gestures, but it has weaknesses in terms of the Midas Touch effect. Even though countermeasure can be taken to minimize the chance that commands are triggered unintentionally, it seems that it can not be completely avoided with this approach without restricting the user too much. Especially in a patient transfer training context that involves a lot of movement, this approach seems to reach its limits. Approaches like machine learning might be work better for this specific context to discern intended from unintended head movements.

Smaller head gestures
The large head movements affected many aspects, like social acceptability, and was overall perceived as negative. Future work should consider using smaller, less noticeable head gestures that appear more natural. As explained before, using smaller head gestures was not possible due to the Midas Touch effect. But with other approaches for the implementation of head gestures where the Midas Touch effect might be avoided, like the machine learning approach described above, it might be possible to user smaller head gestures. Smaller head gestures might be less disturbing and more natural.

Head gestures in combination with another input modality
An alternative to the machine learning approach for head gestures to avoid the Midas Touch effect could be to use head gestures in combination with another input modality for selection. The combination of eye gaze with voice showed to be effective in the avoidance of the Midas Touch effect. Therefore, an idea could be to combine eye gaze with head gestures. A target could be selected via eye gaze and confirmed via a head gesture. With eye gaze and voice, the eye gaze had to stay on the selected target when saying a voice command to lead to a target activation. For head gestures, it has to be considered that the eye gaze will most likely move away from the target when performing a head gesture. Therefore, an idea could be to set a timer. When a target is selected via eye gaze, it has to be confirmed via head gesture within a specified time frame after moving the eye gaze away. Otherwise, it has no effect.
The combination of head gestures with another input modality would have the additional advantage that only one head gesture has to be used. In the study it was found that participants found the different head gestures difficult. Therefore, using only one head gesture might reduce the difficulty.

References

[1] William Nehra. *Germany's shortage of nursing staff continues to worsen.* IamExpat. Jan. 14, 2022. URL: https://www.iamexpat.de/career/employment-news/germanys-shortage-nursing-staff-continues-worsen (visited on 03/06/2022).

[2] Inga-Lill Engkvist, Ewa Hjelm, Mats Hagberg, Ewa Menckel, and Lena Ekenvall. "Risk Indicators for Reported Over-Exertion Back Injuries among Female Nursing Personnel". In: *Epidemiology (Cambridge, Mass.)* 11 (Sept. 2000), pp. 519–22. DOI: 10.1097/00001648-200009000-00006.

[3] Jiska Cohen-Mansfield, William J. Culpepper, II, and Patricia Carter. "Nursing Staff Back Injuries: Prevalence and Costs in Long Term Care Facilities". In: *AAOHN Journal* 44.1 (1996). PMID: 8694975, pp. 9–17. URL: https://doi.org/10.1177/216507999604400106.

[4] Lars L Andersen, Alex Burdorf, Nils Fallentin, Roger Persson, Markus D Jakobsen, Ole Steen Mortensen, Thomas Clausen, and Andreas Holtermann. "Patient transfers and assistive devices: prospective cohort study on the risk for occupational back injury among healthcare workers". In: *Scandinavian Journal of Work, Environment & Health* 1 (2014), pp. 74–81. DOI: 10.5271/sjweh.3382. URL: https://www.sjweh.fi/show_abstract.php?abstract_id=3382.

[5] European Kinaesthetics Association (EKA). *Was ist Kinaesthetics?* URL: https://www.kinaesthetics.de/download/eka/infoblaetter/deutsch/Infoblatt_1_Was_ist_Kinaesthetics.pdf (visited on 05/23/2022).

[6] Manuel Roier. "Kinästhetik - Konzept und Einsatzmöglichkeiten in Gesundheitsberufen". In: *Handbuch für Gesundheitsberufe III. Ergonomie.* Nov. 2013, pp. 147 –158. ISBN: 978-3-9501360-3-6. URL: https://www.researchgate.net/publication/258554505_Kinasthetik_-_Konzept_und_Einsatzmoglichkeiten_in_Gesundheitsberufen (visited on 05/23/2022).

[7] Maximilian Dürr, Ulrike Pfeil, Jens Müller, Marcel Borowski, Carla Gröschel, and Harald Reiterer. "Learning Patient Transfers with Technology: A Qualitative Investigation of the Design Space". In: *Proceedings of Mensch Und Computer 2019.* MuC'19. New York, NY, USA: Association for Computing Machinery, 2019, 79–90. URL: https://doi.org/10.1145/3340764.3340784.

[8] Mitsuhiro Nakamura, Yasuko Kitajima, Jun Ota, Taiki Ogata, Zhifeng Huang, Chingszu Lin, Noriaki Kuwahara, Jukai Maeda, and Masako Kanai-Pak. "The Effects of the Robot Patient's Patient-Likeness on Nursing Students". In: *Digital Human Modeling. Applications in Health, Safety, Ergonomics, and Risk Management: Ergonomics and Design.* Ed. by Vincent G. Duffy. Cham: Springer International Publishing, 2017, pp. 457–465. URL: https://doi.org/10.1007/978-3-319-58463-8_38.

[9] Zhifeng Huang, Ayanori Nagata, Masako Kanai-Pak, Jukai Maeda, Yasuko Kitajima, Mitsuhiro Nakamura, Kyoko Aida, Noriaki Kuwahara, Taiki Ogata, and Jun Ota. "Self-Help Training System for Nursing Students to Learn Patient Transfer Skills". In: *IEEE Transactions on Learning Technologies* 7.4 (2014), pp. 319–332. DOI: 10.1109/TLT.2014.2331252.

[10] Maximilian Dürr, Marcel Borowski, Carla Gröschel, Ulrike Pfeil, Jens Müller, and Harald Reiterer. "KiTT - The Kinaesthetics Transfer Teacher: Design and Evaluation of a Tablet-Based System to Promote the Learning of Ergonomic Patient Transfers". In: *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems.* CHI '21. New York, NY, USA: Association for Computing Machinery, 2021. URL: https://doi.org/10.1145/3411764.3445496.

[11] Ronald T. Azuma. "A Survey of Augmented Reality". In: *Presence: Teleoperators and Virtual Environments* 6.4 (Aug. 1997), pp. 355–385. URL: https://doi.org/10.1162/pres.1997.6.4.355.

[12] Jan Patrick Kopetz, Daniel Wessel, Katrin Balzer, and Nicole Jochems. "Smart glasses as supportive tool in nursing skills training". In: *Zukunft der Pflege: Tagungsband der 1. Clusterkonferenz 2018 - Innovative Technologien für die Pflege*. Vol. 1. Oldenburg, Germany: BIS-Verlag der Carl von Ossietzky Universität Oldenburg, June 2018, pp. 137–141. ISBN: 978-3-8142-2367-4. URL: https://www.pflegeinnovationszentrum.de/wp-content/uploads/2018/12/26.-Smart-Glasses-as-Supportive-Tool-in-Nursing-Skills-Training.pdf (visited on 05/23/2022).

[13] Microsoft. *Hands-free - Mixed Reality*. Oct. 3, 2022. URL: https://docs.microsoft.com/en-us/windows/mixed-reality/design/hands-free (visited on 05/23/2022).

[14] Jan Patrick Kopetz, Daniel Wessel, and Nicole Jochems. "User-Centered Development of Smart Glasses Support for Skills Training in Nursing Education". In: *i-com* 18.3 (2019), pp. 287–299. DOI: doi:10.1515/icom-2018-0043. URL: https://doi.org/10.1515/icom-2018-0043.

[15] Yun Suen Pai, Tilman Dingler, and Kai Kunze. "Assessing hands-free interactions for VR using eye gaze and electromyography". In: *Virtual Reality* 23.2 (June 2019), pp. 119–131. DOI: 10.1007/s10055-018-0371-2.

[16] Michael Prilla, Marc Janßen, and Timo Kunzendorff. "How to Interact with Augmented Reality Head Mounted Devices in Care Work? A Study Comparing Handheld Touch (Hands-on) and Gesture (Hands-free) Interaction". In: *AIS Transactions on Human-Computer Interaction* 11.3 (Sept. 30, 2019), pp. 157–178. DOI: 10.17705/1thci.00118.

[17] Benjamin Hatscher, Maria Luz, Lennart E. Nacke, Norbert Elkmann, Veit Müller, and Christian Hansen. "GazeTap: Towards Hands-Free Interaction in the Operating Room". In: *Proceedings of the 19th ACM International Conference on Multimodal Interaction*. ICMI '17. New York, NY, USA: Association for Computing Machinery, 2017, 243–251. URL: https://doi.org/10.1145/3136755.3136759.

[18] Kai Klinker, Manuel Wiesche, and Helmut Krcmar. "Digital Transformation in Health Care: Augmented Reality for Hands-Free Service Innovation". In: *Information Systems Frontiers* 22.6 (Dec. 1, 2020), pp. 1419–1431. URL: https://doi.org/10.1007/s10796-019-09937-7.

[19] Alexandra Daldrup, and Dagmar Keggenhof. *„Gewusst wie – und der Rücken bleibt gesund!" Bewegen von Pflegebedürftigen in der häuslichen Pflege*. Unfallkasse NRW. 2018. URL: https://nfp.rms2cdn.de/nfp/artikel-dokumente/praevention_nrw_52.pdf (visited on 05/16/2022).

[20] Enid Montague, Ping-yu Chen, Jie Xu, Betty Chewning, and Bruce Barrett. "Nonverbal Interpersonal Interactions in Clinical Encounters and Patient Perceptions of Empathy". In: *Journal of Participatory Medicine*. Aug. 14, 2013; 5:e33. URL: https://participatorymedicine.org/journal/evidence/research/2013/08/14/nonverbal-interpersonal-interactions-in-clinical-encounters-and-patient-perceptions-of-empathy/ (visited on 04/09/2022).

[21] Enginess. *The 6 Principles Of Design, a la Donald Norman*. Nov. 3, 2014. URL: http://www.enginess.io/insights/6-principles-design-la-donald-norman (visited on 04/11/2022).

[22] Andreas Butz and Antonio Krüger. *Mensch-Maschine-Interaktion:* De Gruyter Oldenbourg, 2017. ISBN: 9783110476378. URL: https://doi.org/10.1515/9783110476378.

[23] Calkin S. Montero, Jason Alexander, Mark T. Marshall, and Sriram Subramanian. "Would You Do That? Understanding Social Acceptance of Gestural Interfaces". In: *Proceedings of the 12th International Conference on Human Computer Interaction with Mobile Devices and Services*. MobileHCI '10. New York, NY, USA: Association for Computing Machinery, 2010, 275–278. URL: https://doi.org/10.1145/1851600.1851647.

[24] Marion Koelle, Swamy Ananthanarayan, and Susanne Boll. "Social Acceptability in HCI: A Survey of Methods, Measures, and Design Strategies". In: *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*. New York, NY, USA: Association for Computing Machinery, 2020, 1–19. URL: https://doi.org/10.1145/3313831.3376162.

[25] Joseph J. LaViola Jr., Ernst Kruijff, Doug A. Bowman, Ivan Poupyrev, and Ryan P. McMahan. *3D User Interfaces: Theory and Practice.* Second Edition. Addison-Wesley Professional, 2017. ISBN: 978-0-13-403447-8. URL: https://learning.oreilly.com/library/view/3d-user-interfaces/9780134034478/ (visited on 05/17/2022).

[26] Pin-Sung Ku, Te-Yen Wu, and Mike Y. Chen. "EyeExpress: Expanding Hands-Free Input Vocabulary Using Eye Expressions". In: *The 31st Annual ACM Symposium on User Interface Software and Technology Adjunct Proceedings.* UIST '18 Adjunct. New York, NY, USA: Association for Computing Machinery, 2018, 126–127. URL: https://doi.org/10.1145/3266037.3266123.

[27] Monika Elepfandt and Martin Grund. "Move It There, or Not? The Design of Voice Commands for Gaze with Speech". In: *Proceedings of the 4th Workshop on Eye Gaze in Intelligent Human Machine Interaction.* Gaze-In '12. New York, NY, USA: Association for Computing Machinery, 2012, pp. 1–3. URL: https://doi.org/10.1145/2401836.2401848.

[28] Alina Solovjova, Benjamin Hatscher, and Christian Hansen. "Influence of augmented reality interaction on a primary task for the medical domain". In: *Mensch und Computer 2019 - Workshopband.* Bonn: Gesellschaft für Informatik e.V., 2019. DOI: 10.18420/muc2019-ws-133-07.

[29] Rex Hartson and Pardha Pyla. *The UX book: Agile UX design for a quality user experience.* Second Edition. Boston: Morgan Kaufmann, 2018. ISBN: 978-0-12-805342-3. DOI: https://doi.org/10.1016/C2013-0-19285-9.

[30] Microsoft. *MRTK-Unity Entwicklerdokumentation - Mixed Reality Toolkit.* May 14, 2022. URL: https://docs.microsoft.com/de-de/windows/mixed-reality/mrtk-unity/ (visited on 05/25/2022).

[31] GitLab. *Room Marker Package.* URL: https://gitlab.inf.uni-konstanz.de/ag-hci/research/room-marker (visited on 05/18/2022).

[32] Vuforia. *Image Targets | VuforiaLibrary.* URL: https://library.vuforia.com/objects/image-targets (visited on 05/25/2022).

[33] Unity Asset Store. *Head Gesture Detector.* URL: https://assetstore.unity.com/packages/tools/input-management/head-gesture-detector-23585 (visited on 05/05/2022).

[34] Microsoft. *Komfort - Mixed Reality.* Apr. 18, 2022. URL: https://docs.microsoft.com/de-de/windows/mixed-reality/design/comfort (visited on 05/26/2022).

[35] Microsoft. *Solver overview - Mixed Reality Toolkit.* Jan. 7, 2021. URL: https://docs.microsoft.com/en-us/windows/mixed-reality/mrtk-unity/features/ux-building-blocks/solvers/solver (visited on 05/25/2022).

[36] Microsoft. *Eye Tracking Target Selection - Mixed Reality Toolkit | Microsoft Docs.* May 17, 2021. URL: https://docs.microsoft.com/en-us/windows/mixed-reality/mrtk-unity/features/input/eye-tracking/eye-tracking-target-selection?view=mrtkunity-2021-05#2-independent-eye-gaze-specific-eyetrackingtarget (visited on 05/13/2022).

[37] Microsoft. *Gaze - Mixed Reality Toolkit.* Jan. 7, 2021. URL: https://docs.microsoft.com/en-us/windows/mixed-reality/mrtk-unity/features/input/gaze (visited on 05/30/2022).

[38] Kasper Hornbæk. "Some Whys and Hows of Experiments in Human–Computer Interaction". In: *Foundations and Trends® in Human–Computer Interaction* 5.4 (2013), pp. 299–373. URL: http://dx.doi.org/10.1561/1100000043.

[39] Yvonne Rogers, Helen Sharp, and Jenny Preece. *INTERACTION DESIGN: beyond human-computer interaction, 3rd Edition.* Wiley, 2011. ISBN: 978-0-470-66576-3. URL: https://learning.oreilly.com/library/view/interaction-design-beyond/9780470665763/ (visited on 03/08/2022).

[40] David Ahlström, Khalad Hasan, and Pourang Irani. "Are You Comfortable Doing That? Acceptance Studies of around-Device Gestures in and for Public Settings". In: *Proceedings of the 16th international conference on Human-computer interaction with mobile devices & services.* MobileHCI '14. New York, NY, USA: Association for Computing Machinery, 2014, 193–202. URL: https://doi.org/10.1145/2628363.2628381.

[41] *User Experience Questionnaire (UEQ)*. URL: https://www.ueq-online.org/ (visited on 05/18/2022).

[42] Ditte Hvas Mortensen. *How to Do a Thematic Analysis of User Interviews*. The Interaction Design Foundation. URL: https://www.interaction-design.org/literature/article/how-to-do-a-thematic-analysis-of-user-interviews (visited on 05/14/2022).

7 Appendix

In the following, the welcome letter, the demographic questionnaire and the questionnaires for both interaction techniques are provided.

Welcome Letter

Willkommen

Liebe/r Teilnehmer/in,

vielen Dank für deine Teilnahme an dieser Studie, welche im Rahmen meiner Bachelor-Arbeit stattfindet. Im Folgenden werden kurz die wichtigsten Informationen und der Ablauf der Studie erläutert.

Diese Studie dient dazu, zwei verschiedene Varianten einer Anwendung, welche Krankenschwestern- und Krankenpflegeschüler beim selbstständigen Training von ergonomischen Patiententransfers anleiten soll, zu testen. Patiententransfers, z.B. vom Bett auf einen Rollstuhl, sind eine essentielle Aufgabe von Krankenschwestern und Krankenpflegern. Jedoch ziehen sich viele Krankenschwestern und Krankenpfleger dabei Rückenverletzungen zu. Ergonomische Patiententransfers sollen es ermöglichen, einen Patienten auf schonende Art und Weise zu transferieren und dabei Rückenverletzungen vermeiden. Daher ist das Üben dieser ergonomischen Patiententransfers sehr wichtig. Die Anwendung soll nun das selbstständige Üben der Transfers außerhalb von Trainingskursen und ohne die Hilfe von einem Lehrer ermöglichen. Dafür werden visuelle Instruktionen für die unterschiedlichen Transfer Schritte, welche durchgeführt werden müssen, auf einer Brille angezeigt.

Um die Anwendung zu testen, wirst du eine Augmented Reality Brille tragen und anhand der angezeigten Instruktionen zwei verschiedene Patiententransfers Schritt für Schritt durchführen.

Zunächst solltest du bitte eine Einverständniserklärung unterschreiben und einen demografischen Fragebogen ausfüllen. Dann folgt das Durchführen der Patiententransfers. Mit jeder Variante der Anwendung wird nacheinander ein Patiententransfer je drei Mal durchgeführt. Die erste Durchführung dient dabei als Training zum Üben der Interaktion. Nach der dritten Durchführung mit der jeweiligen Variante folgt das Ausfüllen von Fragebögen. Zum Schluss werden dir in einem Interview noch einige Fragen gestellt.

Falls du Fragen hast, kannst du diese gerne jetzt oder auch zu jedem späteren Zeitpunkt während der Studie stellen.

Demographic Questionnaire

Teilnehmer ID: ______

Demografischer Fragebogen

Alter ____________

Geschlecht ☐ Weiblich ☐ Männlich ☐ Divers

Studiengang ________________________ **Semester** ____________

ODER

Beruf ________________________

Hast du eine Sehschwäche oder -störung (z.B. Kurz- oder Weitsichtigkeit)?

☐ Ja ☐ Nein

Wenn ja, welche ____________________________________

Hast du eine Hörbeeinträchtigung (z.B. Schwerhörigkeit)?

☐ Ja ☐ Nein

Wenn ja, welche ____________________________________

Hast du eine sprachliche Beeinträchtigung (z.B. Stottern)?

☐ Ja ☐ Nein

Wenn ja, welche ____________________________________

Hast du eine körperliche Beeinträchtigung (z.B. Verletzung)?

☐ Ja ☐ Nein

Wenn ja, welche ____________________________________

Hast du eine eingeschränkte Beweglichkeit des Kopfs?

☐ Ja ☐ Nein

Wenn ja, welche ____________________________________

⇨ **Bitte wenden**

Hast du eine Rechts-Links-Schwäche?

☐ Ja ☐ Nein

Wie viel Erfahrung hast du mit Augmented Reality Anwendungen?

☐ ☐ ☐ ☐ ☐
keine Erfahrung viel Erfahrung

Wenn du Erfahrung damit hast, beschreibe kurz in welchem Zusammenhang du Augmented Reality genutzt hast

____

____

Wie viel Erfahrung hast du mit Augmented Reality Brillen?

☐ ☐ ☐ ☐ ☐
keine Erfahrung viel Erfahrung

Wenn du Erfahrung damit hast, beschreibe kurz mit welchen Augmented Reality Brillen du Erfahrung hast

____

____

Wie viel Erfahrung hast du mit Patiententransfers?

☐ ☐ ☐ ☐ ☐
keine Erfahrung viel Erfahrung

Wenn du Erfahrung damit hast, beschreibe kurz in welchem Zusammenhang du diese gesammelt hast

____

____

Kennst du das Kinästhetik Konzept aus der Pflege?

☐ Ja ☐ Nein

Falls ja, wie viel Erfahrung hast du mit Kinästhetik?

☐ ☐ ☐ ☐ ☐
keine Erfahrung viel Erfahrung

Hast du schon einmal einen Kinästhetik Kurs besucht?

☐ Ja ☐ Nein

Verbal Communication Questionnaire (Eye Gaze and Voice)

Teilnehmer ID: ______

Verbale Kommunikation

Wie **gut** konntest du mit dem Trainingspartner **verbal kommunizieren** (mithilfe der Sprache)?

☐ ☐ ☐ ☐ ☐

gar nicht — sehr gut

Als wie **störend** hast du die Interaktion via Anvisieren und Sprachbefehl für die verbale Kommunikation mit dem Trainingspartner **empfunden**?

☐ ☐ ☐ ☐ ☐

gar nicht — sehr störend

Wie **häufig** wurde die verbale Kommunikation mit dem Trainingspartner aufgrund der Interaktion via Anvisieren und Sprachbefehl **unterbrochen**?

☐ ☐ ☐ ☐ ☐

gar nicht — sehr häufig

Wie **häufig** wurde die verbale Kommunikation mit dem Trainingspartner aufgrund der Interaktion via Anvisieren und Sprachbefehl **verhindert**?

☐ ☐ ☐ ☐ ☐

gar nicht — sehr häufig

Wie **stark** hat sich die Interaktion via Anvisieren und Sprachbefehl darauf ausgewirkt, **wie viel** du mit dem Trainingspartner verbal kommuniziert hast?

☐ ☐ ☐ ☐ ☐

gar nicht — sehr stark

Falls es sich ausgewirkt hat, hat es zu einer verminderten oder vermehrten verbalen Kommunikation geführt?

☐ Vermindert ☐ Vermehrt ☐ Kein Effekt

Verbal Communication Questionnaire (Head Gestures)

Teilnehmer ID: ______

Verbale Kommunikation

Wie **gut** konntest du mit dem Trainingspartner **verbal kommunizieren** (mithilfe der Sprache)?

☐ ☐ ☐ ☐ ☐

gar nicht — sehr gut

Als wie **störend** hast du die Interaktion via Kopfgesten für die verbale Kommunikation mit dem Trainingspartner **empfunden**?

☐ ☐ ☐ ☐ ☐

gar nicht — sehr störend

Wie **häufig** wurde die verbale Kommunikation mit dem Trainingspartner aufgrund der Interaktion via Kopfgesten **unterbrochen**?

☐ ☐ ☐ ☐ ☐

gar nicht — sehr häufig

Wie **häufig** wurde die verbale Kommunikation mit dem Trainingspartner aufgrund der Interaktion via Kopfgesten **verhindert**?

☐ ☐ ☐ ☐ ☐

gar nicht — sehr häufig

Wie **stark** hat sich die Interaktion via Kopfgesten darauf ausgewirkt, **wie viel** du mit dem Trainingspartner verbal kommuniziert hast?

☐ ☐ ☐ ☐ ☐

gar nicht — sehr stark

Falls es sich ausgewirkt hat, hat es zu einer verminderten oder vermehrten verbalen Kommunikation geführt?

☐ Vermindert ☐ Vermehrt ☐ Kein Effekt

Non-verbal Communication Questionnaire (Eye Gaze and Voice)

Teilnehmer ID: ______

Nonverbale Kommunikation

Wie **gut** konntest du mit dem Trainingspartner **nonverbal kommunizieren** (ohne Verwendung von Sprache, sondern durch z.B. Gesten oder Blickkontakt)?

☐ ☐ ☐ ☐ ☐
gar nicht … sehr gut

Als wie **störend** hast du die Interaktion via Anvisieren und Sprachbefehl für die nonverbale Kommunikation mit dem Trainingspartner **empfunden**?

☐ ☐ ☐ ☐ ☐
gar nicht … sehr störend

Wie **häufig** wurde die nonverbale Kommunikation mit dem Trainingspartner aufgrund der Interaktion via Anvisieren und Sprachbefehl **unterbrochen**?

☐ ☐ ☐ ☐ ☐
gar nicht … sehr häufig

Wie **häufig** wurde die nonverbale Kommunikation mit dem Trainingspartner aufgrund der Interaktion via Anvisieren und Sprachbefehl **verhindert**?

☐ ☐ ☐ ☐ ☐
gar nicht … sehr häufig

Wie **stark** hat sich die Interaktion via Anvisieren und Sprachbefehl darauf ausgewirkt, **wie viel** du mit dem Trainingspartner nonverbal kommuniziert hast?

☐ ☐ ☐ ☐ ☐
gar nicht … sehr stark

Falls es sich ausgewirkt hat, hat es zu einer verminderten oder vermehrten verbalen Kommunikation geführt?

☐ Vermindert ☐ Vermehrt ☐ Kein Effekt

Non-verbal Communication Questionnaire (Head Gestures)

Teilnehmer ID: ______

Nonverbale Kommunikation

Wie **gut** konntest du mit dem Trainingspartner **nonverbal kommunizieren** (ohne Verwendung von Sprache, sondern durch z.B. Gesten oder Blickkontakt)?

☐ ☐ ☐ ☐ ☐
gar nicht — sehr gut

Als wie **störend** hast du die Interaktion via Kopfgesten für die nonverbale Kommunikation mit dem Trainingspartner **empfunden**?

☐ ☐ ☐ ☐ ☐
gar nicht — sehr störend

Wie **häufig** wurde die nonverbale Kommunikation mit dem Trainingspartner aufgrund der Interaktion via Kopfgesten **unterbrochen**?

☐ ☐ ☐ ☐ ☐
gar nicht — sehr häufig

Wie **häufig** wurde die nonverbale Kommunikation mit dem Trainingspartner aufgrund der Interaktion via Kopfgesten **verhindert**?

☐ ☐ ☐ ☐ ☐
gar nicht — sehr häufig

Wie **stark** hat sich die Interaktion via Kopfgesten darauf ausgewirkt, **wie viel** du mit dem Trainingspartner nonverbal kommuniziert hast?

☐ ☐ ☐ ☐ ☐
gar nicht — sehr stark

Falls es sich ausgewirkt hat, hat es zu einer verminderten oder vermehrten verbalen Kommunikation geführt?

☐ Vermindert ☐ Vermehrt ☐ Kein Effekt

Midas Touch Effect Questionnaire (Eye Gaze and Voice)

Teilnehmer ID: ______

Unbeabsichtigtes Auslösen von Interaktionskommandos

Wie **häufig** wurden bei der Interaktion via Anvisieren und Sprachbefehl Interaktionskommandos **unbeabsichtigt ausgelöst**?

☐ ☐ ☐ ☐ ☐
gar nicht — sehr häufig

Wenn du ‚gar nicht' angekreuzt hast, kannst du an dieser Stell den Fragebogen beenden. Andernfalls, beantworte bitte die untenstehenden Fragen.

Wie **stark** hat das die Durchführung des Patiententransfers **gestört**?

☐ ☐ ☐ ☐ ☐
gar nicht — sehr stark

Wie **stark** hat das die Durchführung des Patiententransfers **erschwert**?

☐ ☐ ☐ ☐ ☐
gar nicht — sehr stark

Midas Touch Effect Questionnaire (Head Gestures)

Teilnehmer ID: ______

Unbeabsichtigtes Auslösen von Interaktionskommandos

Wie **häufig** wurden bei der Interaktion via Kopfgesten Interaktionskommandos **unbeabsichtigt ausgelöst**?

☐ ☐ ☐ ☐ ☐
gar nicht ... sehr häufig

Wenn du ‚gar nicht' angekreuzt hast, kannst du an dieser Stell den Fragebogen beenden. Andernfalls, beantworte bitte die untenstehenden Fragen.

Wie **stark** hat das die Durchführung des Patiententransfers **gestört**?

☐ ☐ ☐ ☐ ☐
gar nicht ... sehr stark

Wie **stark** hat das die Durchführung des Patiententransfers **erschwert**?

☐ ☐ ☐ ☐ ☐
gar nicht ... sehr stark

Social Acceptability Questionnaire (Eye Gaze and Voice)

Teilnehmer ID: ______

Soziale Akzeptanz

Wie hast du dich bei der Interaktion via Anvisieren und Sprachbefehl gefühlt?

☐ ☐ ☐ ☐ ☐

sehr unwohl/ es war mir peinlich — sehr wohl/ es war mir nicht peinlich

Wie **akzeptable** findest du die Interaktion via Anvisieren und Sprachbefehl in dem Patiententransfer Training Kontext (Training mit einem Trainingspartner in einem Trainingsraum)?

☐ ☐ ☐ ☐ ☐

sehr inakzeptabel — sehr akzeptabel

Vor wem würdest du dich **wohl fühlen,** die Interaktion via Anvisieren und Sprachbefehl auszuführen? Kreuze **eine oder mehrere** Optionen an.

☐ ich würde mich **nicht** wohl fühlen sie auszuführen, selbst wenn ich alleine bin

Oder

☐ wenn ich alleine bin ☐ vor PartnerIn ☐ vor Freunden ☐ vor Familie

☐ vor TrainingspartnerIn ☐ vor DozentIn ☐ vor Fremden

Wo würdest du dich **wohl fühlen,** die Interaktion via Anvisieren und Sprachbefehl auszuführen? Kreuze **eine oder mehrere** Optionen an.

☐ ich würde mich **nicht** wohl fühlen sie auszuführen, egal wo ich bin

Oder

☐ Zuhause ☐ in Bus oder Zug ☐ in Restaurant oder Café

☐ auf Gehweg ☐ in Trainingsraum

⇨ **Bitte wenden**

Wie **wohl** hast du dich beim Ausführen der jeweiligen Unteraufgabe gefühlt?

	sehr unwohl				sehr wohl
Ziel mit den Augen anvisieren:	☐	☐	☐	☐	☐
Mit Sprachbefehl bestätigen:	☐	☐	☐	☐	☐

Social Acceptability Questionnaire (Head Gestures)

Teilnehmer ID: ______

Soziale Akzeptanz

Wie hast du dich bei der Interaktion via Kopfgesten gefühlt?

☐ ☐ ☐ ☐ ☐

sehr unwohl/ es war mir peinlich — sehr wohl/ es war mir nicht peinlich

Wie **akzeptable** findest du die Interaktion via Kopfgesten in dem Patiententransfer Training Kontext (Training mit einem Trainingspartner in einem Trainingsraum)?

☐ ☐ ☐ ☐ ☐

sehr inakzeptabel — sehr akzeptabel

Vor wem würdest du dich **wohl fühlen** die Kopfgesten auszuführen? Kreuze **eine oder mehrere** Optionen an.

☐ ich würde mich **nicht** wohl fühlen sie auszuführen, selbst wenn ich alleine bin

Oder

☐ wenn ich alleine bin ☐ vor PartnerIn ☐ vor Freunden ☐ vor Familie

☐ vor TrainingspartnerIn ☐ vor DozentIn ☐ vor Fremden

Wo würdest du dich **wohl fühlen** die Kopfgesten auszuführen? Kreuze **eine oder mehrere** Optionen an.

☐ ich würde mich **nicht** wohl fühlen sie auszuführen, egal wo ich bin

Oder

☐ Zuhause ☐ in Bus oder Zug ☐ in Restaurant oder Café

☐ auf Gehweg ☐ in Trainingsraum

⇨ **Bitte wenden**

Wie **wohl** hast du dich beim Ausführen der jeweiligen Kopfgeste gefühlt?

	sehr unwohl				sehr wohl
Kopf nach links drehen:	☐	☐	☐	☐	☐
Kopf nach rechts drehen:	☐	☐	☐	☐	☐
Nicken (auf und ab):	☐	☐	☐	☐	☐
Nicken (links und rechts):	☐	☐	☐	☐	☐

User Experience Questionnaire (Both Techniques)

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