Hands-free Interactions with Augmented Reality Smartglasses during Patient Transfers in a Clinical Setting

Bachelor Thesis

submitted by

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Abstract

When a caregiver in a clinic makes a small mistake while conducting a patient transfer, it is likely that on a long-term time span, they will encounter negative health consequences, such as back or neck injuries. A technical assisting system that follows ergonomic safe patient handling guidelines could be very beneficial in protecting caregivers and patients.

This thesis presents an application for head-mounted Augmented Reality smartglasses that shows ergonomically approved step-by-step video instructions for caregivers to follow during practice.

However, in order to navigate through the app and especially jump in-between the instructions, some kind of hands-free interaction is required. Two interaction methods were tested with smartglasses: Voice Commands and Head Gestures. Both versions were used during a comparative study with 12 participants in a simulated clinical setting. Each participant had to do multiple rounds of a human patient transfer (e.g. from a bed to a wheelchair) while wearing the smartglasses and interacting by both mentioned methods. Subsequently collected data through questionnaires, surveys and log files helped to identify advantages and disadvantages of voice and head interaction in a patient transfer setting.

The findings show how even though both ways of interactions have their advantages and disadvantages, one interaction technique outperforms in almost every context-relevant category.

Vorwort

Die gegebene Arbeit basiert zum Teil auf den beiden Dokumentationen:

1. E. Ipekli. Bachelor Seminar Report: Hands-free Interactions with AR Glasses during Patient Transfers in a clinical Setting (2021)

2. E. Ipekli. Bachelor Project Report: Hands-free Interactions with AR Glasses during Patient Transfers in a clinical Setting (2022)

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1. Introduction

Shortage of nursing care personnel is worldwide problem that is reaching a peak especially due to the current COVID-19 pandemic. Some caregivers quit their jobs because of the psychological stress that comes with it [1]. However, a considerable amount of nursing personnel have to leave their professions because of physical work-related musculoskeletal disorders (WMSDs), like for example lower back pain (LBP), that often occur during the transfer of a patient [2]. This has significant consequences for the health care sector. Although european care conceptions teach nursing-care students the principles of safe patient handling, in Germany there is little to no support during daily clinical practice [3]. In order to support the learning of ergonomically correct transfers also in a clinical work setting, risk-reducing strategies, like the integration of assistive help-tools in form of technological devices might help.

1.1. Motivation

Figure 1.1.: a basic patient transfer from bed to wheelchair

One of the most frequent tasks of caregivers is to transfer their patients. This involves many kinds of transfers, like for example, transfers from bed to wheelchair like shown in Figure 1.1, but also transfers from a lying position into a sitting position or transferring the patient upwards. If not done carefully, wrongly handled transfers can have an impact on the nurse's well-being. Many studies have shown a link between the frequent transfer of patients by caregivers and the increased risk of getting work-related musculoskeletal disorders [2, 4, 5]. Most

of these studies focus specifically on back pain and lower back injuries with back impairments being the most prevalent musculoskeletal issue among nursing staff [6]. However, fewer studies also show that neck, shoulders, upper and lower extremities can be affected, too [7].
There are more incidences of WMSD recorded among caregivers than any other profession [8]. As a consequence, physically affected caregivers can no longer pursue their work in the hospital. The high injury rates also have a negative impact on the job satisfaction which makes even more staff wanting to quit the nursing profession. According to Aiken et al. [9], 54% of the healthcare workers under the age of 30 plan to quit their work within 1 year because of physical and psychological problems. Furthermore, WMDs also have an economic impact on healthcare organizations, with surgery being the most expensive medical service for people with back and neck problems [10].
Nurses build an essential part of the healthcare system. Especially due to COVID-19 but also before, the shortage of nursing personnel is becoming a worldwide problem. For example in Germany, a shortage of around 500,000 caregivers is expected in 2030 [11].
On the other hand, more and more people are becoming care-dependent: In December 1999, there were 2.02 million people in need of care in Germany, and in December 2019, the number increased to 4.13 million people [12]. With the number of nursing staff decreasing and the number of care-dependent patients increasing at the same time, something must be done to minimize the attrition from the nursing profession.
Especially care-dependent patients need safe assistance in the completion of daily tasks - in order to provide them the same amount of life quality that healthy people get to have, it is important to make sure their mobility is provided. There are plenty reported cases where patients were accidentally dropped during a transfer and suffered physical impairments. There is even a known case where a patient died after falling during a transfer [13].
To protect patients from injury and caregivers from work-related musculoskeletal disorders, certain care concepts have been developed.

Kinaesthetics Care Conception, Courses and the Problem they come with

A very famous care concept is kinaesthetics. This care conception is offered by the European Kinaesthetics Association (EKA) [14]. The historical and theoretical background will be talked about in more detail in Chapter 2. Generally speaking, kinaesthetics is the study of body motion awareness. It teaches the ability to intentionally use the understanding of one's own body- and movement awareness as a competence to work with people [15]. The goal is that care-giving personnel learn to promote the patient's own movement abilities instead of performing tasks for him, like for example, carrying the patient.
In Germany, nursing-care schools offer courses on correct movements during patient transfers based on the concepts of kinaesthetics. In these courses, nursing students are educated on how to execute ergonomic patient transfers correctly to preserve both the nurse's and the patient's well-being and prevent any kind of injuries. The teaching involves both theoretical and practical knowledge. For the practical part, nursing-care schools offer special training rooms that simulate the look of a clinical room and provide equipment, like for example wheelchairs or adjustable beds [16]. However, the course is typically only a basic course limited to three nonconsecutive days of lectures and its learning concept is highly dependent on self-active learning [16, 14]. In a study conducted by

Dürr, Pfeil, and Reiterer [17], some of the nursing students noted in an interview that they quickly forgot the movements they had learned in their kinaesthetics course and had problems with the practical application. The courses usually consist of a teacher that demonstrates correct conducts and the students have to subsequently practice the transfers in a group of three where each student plays the role of (1) the nurse, (2) the patient and (3) the observer. Nevertheless, one teacher is mostly responsible for multiple groups in parallel and therefore, individual monitoring is severe [17]. Some students criticized the fact that they had no opportunity to refresh the knowledge about the movements they had learned. In addition, there were wishes for instructions *during* the patient transfer. Many more previous works have revealed that the present support for learning patient transfers still has significant limitations, for example Dürr et al. (2019) [16] noted during the observation of such a kinaesthetics transfer course that the limited realism during the courses could impede the application of learned movements in the practical work. Fringer, Huth, and Hantikainen [18] annotate that it is crucial to obtain more frequent professional follow-up assistance and education beyond the kinaesthetics training sessions you receive during your education in order to consistently apply the learned concepts into daily nursing practice.

1.2. Approach: Hands-free Interactions with Smartglasses that show Instructions during Patient Transfers

Commonly-used assistive devices are, among others, ceiling-lifts and intelligent beds [8]. Vinstrup et al. investigate the relationship between the accumulation of physical exposure and the risk of suffering from WMSDs. They found out that the consistent use of the above mentioned patient-handling equipment tend to reduce the physical workload during patient transfers and therefore, may reduce the prevalence of WMSDs among nursing personnel. However, they also have their downsides. First of all, nursing personnel have to be taught how to use the equipment correctly. Besides, insufficient maintenance endangers the safe and optimal use of the equipment [20]. According to Wardell [21], many hospitals also lack room to store the equipment in the individual hospital units and therefore handling equipment is often not available to use. As a consequence, it is important that nurses can transfer their patients manually for when there is no equipment available.

This work focuses on correct movements and the appliance of ergonomically approved patient transfers that follow the kinaesthetic concepts without relying on special handling equipment. The aim is to find a technical assistive tool that functions solely as a thought support for the skills and knowledge and that the caregivers have already acquired during their participation in the kinaesthetic basic courses. The goal is for them to remember the correct steps needed for a successful patient transfer the way they already learned it and have a tool that shows these while they can continue to pursue their normal work routine. This work proposes an application that shows video instructions that exemplify the ergonomical conduct of different transfer scenarios which caregivers can follow step-by-step during practice in clinics. A very modern approach is to use Head Mounted Displays, in our case Augmented Reality (AR) smartglasses, like Prilla, Janßen, and Kunzendorff [22] already introduced in the concept of their so called *Care Lenses*. Nevertheless, they focus on using them in general care which also involves home care. Our proposed system concentrates specifically on patient transfers in clinics.

One benefit of using Augmented Reality Glasses within the scope of this application is that AR Glasses do not require the caregiver to look at a monitor to see the instructions [23], instead, it is directly in their field of view. Now the following question arises: When the caregiver is watching a video instruction, how can he, for example, jump to the next video instruction or replay the previous one if he is currently supposed to be having her hands on the patient? Considering this, some kind of hands-free interaction is needed here. There are various hands-free interaction techniques, and this work will aim to choose the most suitable ones for the use in daily clinical practice in chapter 4.

Figure 1.2.: Planned concept: unobtrusive smartglasses during a patient transfer, HMD display showing video instructions.

There already exists a tablet-based learning system called KiTT [24] where the nurse can select a mobility degree that suits the patient and the correct transfer scenario and gets displayed a video sequence, however this application runs on a tablet, so it requires the hands to navigate. Another system called NurseCare was introduced by Dürr et al. [3]. It includes a smartphone app that works with a wearable in form of a chest belt that has a small sensor to track the user's posture. The above mentioned *Care Lenses* [22] support hands-free interaction through head gestures. However, to my knowledge, there has not been any system that specifically concentrates on patient transfers in clinics by interacting hands-free.

Goal of this Thesis

This thesis intends to address the lack of kinaesthetical support during the daily practice in clinics and aims to find a technical solution that does not require the use of hands so that the caregiver can execute his regular workflow and the system plays only the role of an unobtrusive aid.

1.3. Outline

This thesis is divided into eight chapters. In the current chapter the topic was introduced and the problem space discussed as to why there is a need for assisting technology in clinical care practice.
In Chapter 2, some theoretical foundations of Kinaesthetics will be explained.
Chapter 3 describes the methodology of this thesis that relies on the UX Design Lifecycle described by Hartson and Pyla in *The UX Book: Agile UX Design for a Quality User Experience*.
In chapter 4, first, a context analysis will show the current situation in clinics and explain how patient transfers are presently done with and without the use of assistive tools. Then, a literature analysis will follow and related work that already addresses our problem will be addressed. There are already some existing applications that will be looked at. Based on these results and findings, requirements will be defined that the system should fulfill. Next, the most cited hands-free interaction techniques will be presented and compared with the previously defined requirements. For the comparative study that follows later, the ones that fulfill the requirements the best were chosen.
Chapter 5 details the proposed system that is used in this thesis: the underlying idea will be explained and the process that involves design thinking and implementation described.
Later, in chapter 6 the Research Questions (RQs) of this paper will be introduced. Some prior planned RQs are also described. The rest of this chapter deals with the study that was conducted within the scope of this work. The focus first lies on the Study Design that follows the DECIDE framework described by Rogers, Sharp, and Preece in Chapter 13 of *Interaction Design: Beyond Human - Computer Interaction* [26]. Then, the study's data will be evaluated and the results will be delineated and discussed. There will also be shown some limitations.
Finally, chapter 7 provides a conclusion and an outlook.

2. Theoretical Foundations

In this chapter, some theoretical foundations will be covered to get a deeper understanding of the topic and its context. Section 2.1 starts with in-depth information about the underlying principles of kinaesthetics and the historical background. Later, in Section 2.2, some information on Augmented Reality and Head Mounted Displays (HMDs) will be given. Finally, Section 2.3 introduces a well-known but at the same time undesired problem called Midas Touch.

2.1. Kinaesthetics: Concepts and History

The core idea of kinaesthetics was already introduced in chapter 1. This section will provide a deeper understanding of the theoretical aspect. Kinaesthetics is a nursing care approach for safe patient handling [27]. It mainly deals with the conscious perception of one's own body movement. The word *kinaesthetics* has its origin in the two ancient greek terms *kinesis* = movement and *aisthesis* = sensation. Nurses are supposed to become a deeper understanding of their own movement. Hatch, Maietta, and Schmidt describe this process in their book *Kinästhetik* [15] as an integration of knowledge into one's own movement. From time to time, nurses develop a feeling for human movement capabilities and learn how to *only assist* patients in moving and balancing their own weight. Instead of carrying the patients body weight, they encourage patients to participate more. They help them, for example, to shift positions or to stand up. This way, patient's development processes are promoted. Hatch, Maietta, and Schmidt call this approach a "systematic help for self-help" for patients. On the other hand, the risk of suffering from work-related musculoskeletal disorders, such as LBP, are greatly reduced among healthcare workers. [14]. Caregivers and patients both benefit from this approach.
Kinaesthetics is divided into six main concepts: the concept of interaction, concept of functional anatomy, concept of human movements, concept of effort and the concept of human functionalities [28]. Any movement can be analyzed and experienced using these six concepts. Figure 2.1 shows the an example of a kinaesthetics transfer from a sitting position into a lying position.
Kinaesthetics is being professionally teached since the 1980s in various healthcare and social institutions all over Europe. The concept was first developed and introduced by F. Hatch and L. Maietta and their approach turned out to be very successful. The European Kinaesthetics Association [29] is now the union of all Kinaesthetic country organizations.

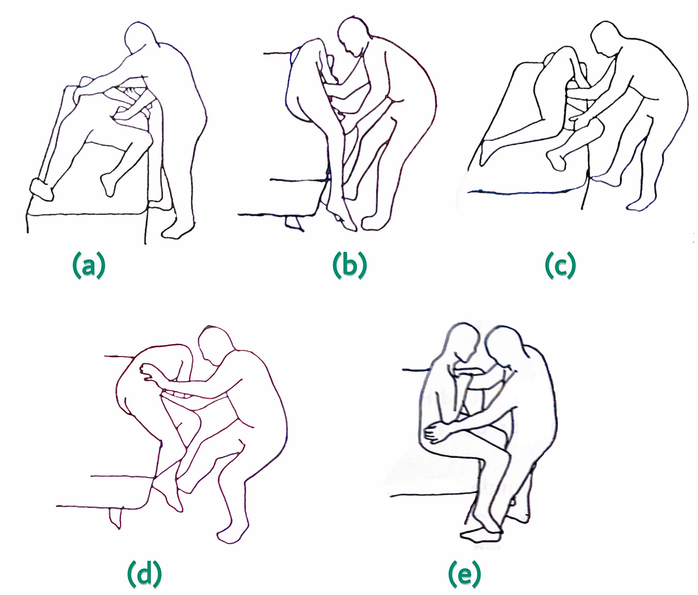

Figure 2.1.: Transfer steps to sit up a patient based on kinaesthetic conception. In (a), the patient's arm is bented to a position next to his head that prevents him from rolling out of bed. For step (b), the other arm is moved into a crossing position. The patient's hand is placed the edge of the bed so that the patient can use it later to press against the bed. In (c), the chest is rolled diagonally forward onto the nurses' hand that is closer to the head of the bed. (d) shows how the patient's legs are moved out of the bed. The leg at the edge of the bed comes first. For the final movement (e), the head and the pelvis are rolled forward. This causes the chest to automatically roll forward. The weight of the patient's upper body runs to the legs. The pelvis is tilted toward the surface of the bed while continuing to roll the rib cage forward with the other hand. The counter-rotating motion of pulling and pushing moves the patient spiralis to sit on the edge of the bed. (source: Hatch, Maietta, and Schmidt, *Kinästhetik* [15], p.168)

2.2. Augmented Reality Smartglasses

> Combining the real and the virtual in order to assist the user in performing a task in a physical setting is called Augmented Reality [30].
>
> *Dubois and Nigay*

The above citation is one out of many definitions for Augmented Reality but it underlines the importance of Augmented Reality in the context of this work. The nurse plays the role of the user and gets technological assistance while performing the task of transferring a patient in a physical clinic setting. The given context completely fulfills this definition. However, the following subsections will introduce the concept and properties of Head Mounted Displays, specifically Augmented Reality smartglasses, and finally, explain why a much more popular definition of Augmented Reality does not apply to the concept of "smartglasses" like it is used in the scope of this work.

2.2.1. Head-Mounted Displays

Head-mounted displays (HMDs) are devices worn over the user's head. The user gets to see a display in front of him. There are three optical configurations for HMDs: monocular, biocular and binocular [31]. Monocular HMDs show the image source only in one eye. They are the lightest and cheapest of all three versions. However, they have the smallest field of view (FOV). In contrary, binocular HMDs show the same imagery in both eyes and therefore have a larger FOV. Finally, biocular HMDs form a combination of both - the image is shared by both eyes. They are the heaviest, most obtrusive and most expensive version of HMDs. Melzer [31] compared the characteristics of these three kinds of HMDs in his work.

2.2.2. Smartglasses

Augmented Reality Smartglasses (ARSGs) are "smart" devices worn over the head that display 2D information in front of (mostly) one eye. There are also a few models with binocular sight, but most of them are monocular. The difference to regular Augmented Reality glasses is that they can only display 2D images. However, they are much lighter and have a simple and inconspicuous design. Figure 2.2 shows 4 different models of smartglasses.

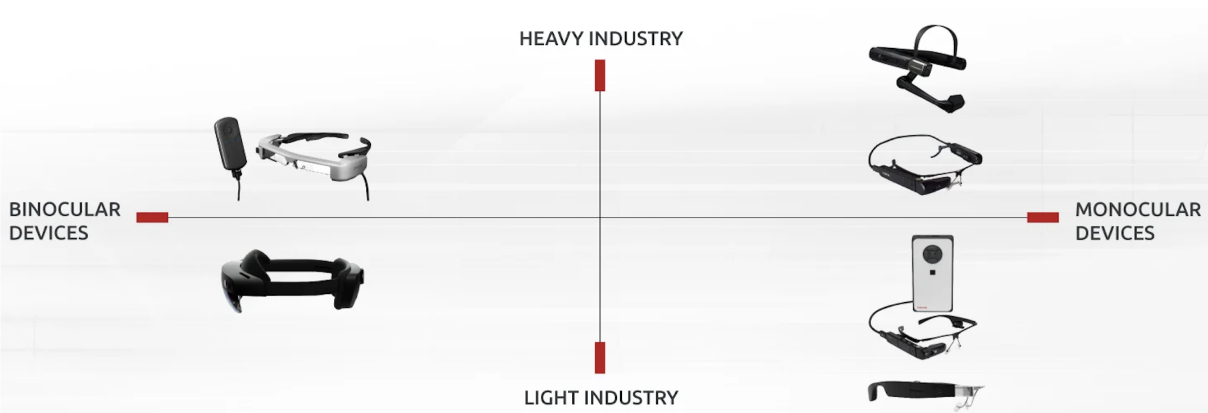

Figure 2.2.: Different models of smartglasses. Left side shows binocular smartglasses, right side monocular ones. (source: https://www.teamviewer.com/en/supported-hardware/smart-glasses-guide/)

2.2.3. Augmented Reality after Azuma

> AR systems have the following three characteristics:
> 1) Combines real and virtual.
> 2) Interactive in real time.
> 3) Registered in 3-D. [23]
>
> *Azuma*

This definition for Augmented Reality by Azuma is by far the most popular one. It should be clear by now that characteristic (3) does not apply to the concept of smartglasses because they only display 2D information. Azuma's definition of Augmented Reality therefore does not apply here. Nevertheless, as already formulated in chapter 1, the goal is to integrate an unobtrusive technical tool into practice that assists the caregiver in executing his task, namely in transferring his patient safely. The choice of hardware will be further discussed in chapter 5 but it is already clear that smartglasses are advantageous due to their unobtrusive and light design.

Several researchers, like for example Kopetz et al. already investigated the use of Augmented Reality smartglasses during nursing skills training. They also implemented an application that supports nursing students during the training of patient transfers. However, the system did not support hands-free interaction with the device.

2.3. Midas Touch Effect

This subsection deals with the history and problem of a known phenomena that has to be considered when designing any type of user interface. The so-called Midas Touch Problem has its origin in Greek mythology [33]. The famous King Midas had one wish free due to his nice hospitality for Dionysus old acquaintance. Therefore, Dionysus wanted to reward him and told Midas that he could ask for whatever he wants. Midas instant wish was that everything he touched would turn into gold. Dionysus granted him his wish. At first he was very content with the choice he made, however, soon he realized that he could not touch anything without it turning into gold. This involved, for example, food but also physical touch: he was not able to touch his daughter anymore. This was referred to as the golden touch, or the Midas touch.
The so-called Midas Touch Problem was derived from this story. It occurs when certain commands get activated unintentionally [33]. We perform many kinds of gestures in our everyday life without exactly noticing them. If they are used as input modality in a system, it can happen very fast that we accidentally play with the controls of a system. The Midas Touch Effect can occur with every input interface but should specifically be avoided when designing an interface.

3. Methodology

In this chapter, the methodology during the planning process of this thesis is described. The two big approaches that were followed during the entire phase are firstly, the UX Design Lifecycle as described by Hartson and Pyla for the interface design, implementation and entire concipation the system. Secondly, for the study design the DECIDE framework [26] was utilized and followed in order to plan the entire study setting. This current chapter mainly focuses on the methodology of the introductory part. The methodology for the evaluation of the study is just briefly explained and will be discussed in-depth in chapter 7 alongside with the study evaluation and interpretation.

3.1. UX Design Lifecycle

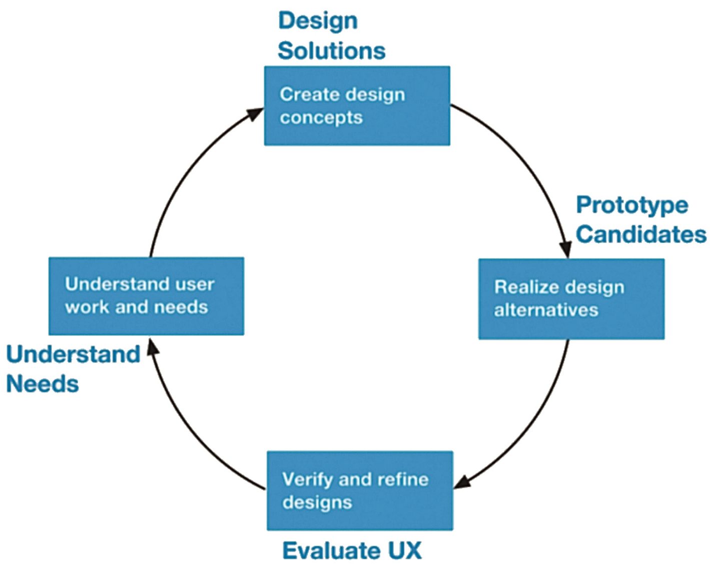

Figure 3.1.: The basic UX Design Lifecycle. (source: *The UX Book: Agile UX Design for a Quality User Experience*, p.30)

The UX Design Lifecycle [25] describes an iterative design process that is shown in Figure 3.1 in form of a flowing chart diagram. It was used as framework for the design thinking process of the patient transfer application. The circle “starts” at the point where the designer has to analyze and understand the needs of the user. This will be covered in the next chapter when we look at the related work review the current context. It will also be looked at existing applications. Based on these findings, user needs are listed. This will include, for example, social aspects that are unavoidable in regards to nurse-patient relationships in clinics. Chapter 5 will cover the creation of design concepts, as well as the realization of other design alternatives. The last step in the Lifecycle is the evaluation where design prototypes may be refined further. Figure 3.1 shows the UX Design Lifecycle.

3.2. DECIDE Framework

The DECIDE Framework is a framework to guide the evaluation process. It was introduced by Rogers, Sharp, and Preece [26]. It provides a checklist with six points to integrate into the evaluation planning:

However, the DECIDE Framework is still an iterative process model, so the order of the checkpoints does not matter. It is even desired to jump back and forth the steps and iterate over the same step because some decisions will impact other process steps [26]. The appliance of this framework is described in section Section 7.1.

4. Context Analysis

The following chapter analyzes the context of my research. Various researchers have already addressed similar problems and provided possible solutions in the field of patient transfers and hands-free interaction techniques. In the following Section 4.1., the focus lies on related work and already existing applications that address the described problem space. Section 4.2. provides requirements that arise through the inspected existing work and that have to be considered when the interaction techniques are chosen afterwards. Then, in Section 4.3. several hands-free interaction techniques will be compared and depicted against the defined requirements from 4.2.. The aim is to choose the most suitable way of interaction for the clinical setting.

4.1. Related Work and existing Applications

In this section, some existing work that deals with the topic of patient transfers, as well as hands-free interaction techniques, is examined. Dürr et al. (2021) investigated the described lack of kinaesthetic-based training by introducing *KiTT - The Kinaesthetics Transfer Teacher* [24]. KiTT is a tabled-based learning system that helps nursing students learn ergonomic patient transfers based on the Kinaesthetics care conception. However, it is built for training sessions that take place in nursing schools. As part of their research, a user study was conducted. One very interesting finding was that nine participants wished that the KiTT application would support them directly during their daily work, so that they can "have a quick look at how it is done" [24] during a transfer. Lastly, Dürr et al. (2021) also indicate that a head-mounted device could be useful to visualize instructions in the learner's field-of-view, without him having to look back and forth between display and patient.
A similar approach was followed with *NurseCare* [3] which was designed to conduct ergonomic and kinaesthetics-based patient transfers during work. NurseCare is a smartphone-based system that uses a wearable to evaluate the movements. Dürr et al. (2020) did an 'in-the-wild' evaluation of their system. During their evaluation, participants of their study stated that they liked that the mobile instructions were always available [3]. Overall, the final results of the evaluation show that mobile instructions helped to conduct more ergonomic patient transfers. In another work, Dürr et al. (2019) also analyze how interactive technology can extend current practices in kinaesthetics education [16] . They focused on rather complex patient-transfer scenarios that also include bodily and social interactions between caregivers and their patients. The importance of these criteria will be explained and underlined in Section 4.2.. Based on the findings of their qualitative research, they created a concept for a tablet-based learning system. This concept was the inspiration for the design process of the above mentioned KiTT [24] app.

Apart from the mentioned application approaches, there are also two commercial apps published by the *MH Kinaesthetics - The Original* [34]. "MH Kinaesthetics" is a smartphone app that visualizes general information about the principles of Kinaesthetics. Furthermore, the tablet app "Kinaesthetics Care" is a training app to learn safe patient transfers for caring relatives. The app combines theoretical teaching content and integrated training videos. Most systems in this research field use handheld approaches, like for example, tablet-based or smartphone-based solutions. There is only little research on Augmented Reality or smartglasses as assisting technology during patient transfers. Kopetz et al. [32] investigated the use of augmented reality smartglasses in nursing skills training, even specifically during the training of patient transfers. They also saw the lack of education in this area and developed an application that instructed the students. However, the authors state that in order to jump in between the video instructions, the students had to tap on the frame of the glasses and that this form of interaction was sufficient for training purposes *only*. Another form of interaction was required, free of any kind of touch-gestures [32].

Overall, there exists quite a lot research on movement learning and patient transfer learning. Some of them, like for example, the KiTT [24] application are assisting nursing students during the transfer process through video sequences, however, most of them focus on the use of these assistive technologies during patient transfer training. In contrast to existing work, this thesis investigates the use of these technologies during clinical work amongst professional caregivers. This leads to different needs and requirements on which will be looked at in Section 4.2.. Another key aspect is the need for hands-free interaction techniques. Different ways of hands-free interaction will be compared in Section 4.3. based on other previous related work.

4.2. Requirement Elicitation

The idea of the upcoming system is to show step-by-step instructions for a professional caregiver directly during a patient transfer through smartglasses. The aim of this section is now to elicit requirements that have to be considered before choosing a way of interaction in order to jump inbetween the instructions that are shown on the caregiver's glasses. As mentioned before, it is not sufficient to focus only on correct movements when it comes to patient transfers with real human patients during practice in clinics. Many external factors have an influence on the situation. This includes for example nurse-patient experiences. Based on our context analysis, five requirements (R) derived that have to be considered when choosing the most suitable interaction techniques for the upcoming system that will support caregivers during patient transfers. The following requirements are mainly based on the research of Dürr et al. [16], Caris-Verhallen, Kerkstra, and Bensing [35] and Koelle, Ananthanarayan, and Boll [36] and will be explained in detail in this section:

R1: Verbal Communication between nurse and patient should not be disturbed by the interaction with the system. simultaneously.

R2: Non-verbal Communication between nurse and patient should not be disturbed by the interaction with the system.

R3: The way of interaction should be socially accepted by the patient and feel socially accepted from the caregiver's point of view.

R4: The interaction should occur fast and not take an unnecessary amount of time.

R5: The Midas Touch Problem should be avoided during the interaction.

In the following, the above defined requirements will be explained in detail.

R1: Verbal Communication between nurse and patient should not be disturbed by the interaction with the system.

It is common knowledge that nurses communicate verbally with their patients. This involves, of course, normal conversations, like for example asking the patient how he feels or if he liked his dinner. However, when it comes to kinaesthetics patient transfers, the aspect of instructing the patient is mandatory. As already described in Chapter 2 where the fundamental theory behind the concepts of kinasthetics were covered, kinaesthetics relies on the patient's participation during the transfer. Therefore, nurses have to give instructions. This involves sentences like for example, "*Bend your leg here.*"". Dürr et al. call this process an "activation of the patient". Even if both sides decided to forego normal conversations, it is impossible to conduct a kinaesthetics transfer without verbal communication in the means of instructing the patient through the transfer. The way of interaction should therefore not be a barrier for verbal communication between nurse and patient.

R2: Non-verbal Communication between nurse and patient should not be disturbed by the interaction with the system.

Previous research has shown that non-verbal behaviours are important in establishing a good relationship with the patient [35]. This includes communication without spoken word, for example, patient-directed eyegaze, affirmative head nodding, smiling, forward leaning and affective touch. Caris-Verhallen, Kerkstra, and Bensing state that especially elderly patients are dependent on communicating with nursing personnel in order to create good interpersonal relationships in which there is room for socializing, affection and empathy since they may have little social contact. If the interaction with the system prevents non-verbal communication, it might have a huge impact on the patient's social life and self-esteem. Furthermore, as already explained above, nurses tend to instruct their patients through a transfer. This also affects non-verbal gestures. It should, for example, be possible to reach for a patient's hands to indicate that they should stand up together.

R3: The way of interaction should be socially accepted by the patient and feel socially accepted from the caregiver's point of view.

Patient transfers during practice, i.e. in clinics, happen in a social context. Not only the nurse and the patient are present, mostly also other patients that share a room together or other caregivers are in immediate proximity to the happening. Social acceptability forms a core quality of human-machine interactions [37]. Koelle, Ananthanarayan, and Boll explain how this goes into two directions: On the one hand, (a) the *spectator* (in our case the patient) is the person that observes and (b) the *performer* is the person that interacts with the system (i.e. the nurse). The duality of these two roles can influence if, how and where human-machine interfaces will be used [36]. According to Montero et al. [38], there are two dimensions of social acceptability: The first one is the subjective impression on how he (the performer) is perceived. A lack of social acceptability can negatively affect the overall user experience [39] and the user's self perception [37]. This is very important in the given context because it is desired that nurses continue to use the technology. If they gain bad social experiences, they might not want to use it again. On the other hand, the social acceptance from the spectator's point of view means that he gains an impression of the user [36]. Especially elderly patients with dementia may be triggered the most by obtrusive interaction methods that they are not familiar with. Therefore, the interaction with the system should be as discreet as possible and feel comfortable performing in front of a public audience.

R4: The interaction should occur fast and not take an unnecessary amount of time.

The interview results of Dürr et al. [16] show that the aspect of time management is not covered in the kinaesthetics transfer courses. The interviewed nursing students explained that during practical work in real life, they suffer from stress and have a constant time pressure. This characteristic also matters for the choice of an interaction technique. It implicates that the interaction should not take long because of the time pressure nurses have to face.

R5: The Midas Touch Problem should be avoided during the interaction.

The Midas Touch Problem was introduced in Chapter 2. It is undesired and should be avoided that commands get activated unintentionally when interacting with the patient or performing gestures that are necessary for the transfer.

4.3. Hands-free Interaction Techniques

There are several hands-free interaction techniques for AR head-mounted devices supporting the medical field that have been evaluated in previous scientific work. However, it is clear that not every hands-free interaction technique is suitable for the given context. This section provides a literature analysis of work that has already investigated the use of various hands-free interaction techniques. Their findings will specifically be analyzed in regard to the identified requirements from the previous section.

Head Movements

Prilla, Janßen, and Kunzendorff compared head movements with a handheld touch-based approach for the control of their *Care Lenses* system [22] that supports caregivers during various patient-care tasks. Their hands-free interaction concept includes nodding for selectional tasks, head shaking for reverting, tilting the head to the side for switching buttons and turning the head to the side for jumping back and forward. Figure 4.1 shows the set of head movements ("head gestures"). For the comparative study, they made caregiving participants (both clinic and elderly care professionals as well as homecare providers) perform different tasks. The authors state that even though the participants sometimes forgot the correct gesture to process, once the nurse was familiar with the workflow, he paid more attention to the patient and thus, **verbal** and **non-verbal communication** were unhinderedly possible after getting used to the system. As for the **social acceptability**, some participants explained that older patients, especially those with dementia, were sometimes triggered but also speculated that "in later generations, patients will possibly not have this problem" and that patients would "accept the Care Lenses if they get a proper explanation" (see [22], [40]). However, this is related to the entire idea of wearing a HMD and not specifically the way of interaction with the device. Since the gestures are very natural and most people are used to them, they were reported to be **fast to perform** while executing the workflow. However, the prototype they used was error-prone and therefore, the system often did not recognize gestures correctly. This lead to uncertainty among the participants and more time was needed when asking for help or receiving support. Nevertheless, during the interview they noted that performing head gestures always "triggered a certain function directly" and that this was a speed advantage over pointing and clicking. The **Midas Touch Problem** was only mentioned in terms of a statement where the authors explain that one of the reasons why they chose the head gestures was that they wanted to prevent the participants from accidentally activating commands when communicating with patients.

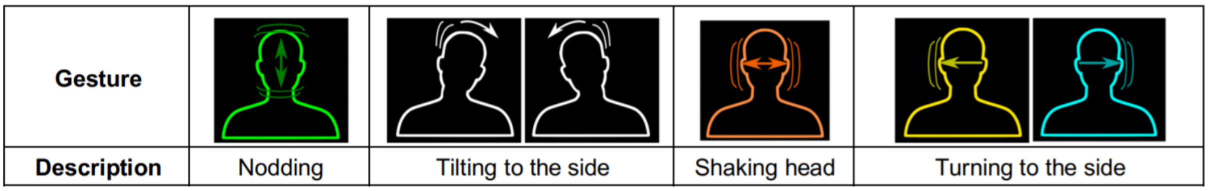

Figure 4.1.: The gesture set for the head gestures used in the work of Prilla, Janßen, and Kunzendorff. (source: "How to Interact with Augmented Reality Head Mounted Devices in Care Work?" [22], p.165)

Gaze Interaction

Gaze interaction means using your eye gaze to initiate a command. Interacting by gaze is in principle **fast** [41]. However, as one can already imagine, it is very prone to activating commands unintentionally, i.e. having the **Midas Touch Problem** occur [42]. One solution for this is using a *dwell time* [43] - the user concentrates on a target until the selection response is perceptible. However, a dwell time that is too long can be uncomfortable because looking at the same spot for a longer period of time **is unnatural** in daily life [42]. Considering the context, it is imaginable that some patients may feel awkward and misinterpret the eye gaze interaction that is initiated by the nurse. Hatscher et al. [44] state that they have discarded eye-gaze-only interaction because prior informal studies have shown that the Midas Touch Problem occured too often.
So far, mainly a rather smaller part of the medical sector was discussed. Another important case in medical settings where the hands are occupied and hands-free interaction techniques are needed are surgeries. They suggested to use a multimodal approach where eye gaze is used for pointing at a target but another interaction modality to confirm a choice. In their work, they introduced *eye gaze and foot* which is a combination of eye gaze and foot movements. Here, the user has to gaze at a target and confirm his choice by performing a triple-tap with the foot. However, the foot has to stay in a steady position in one fix, marked spot on a tactile floor (see Figure 4.2). This kind of foot interaction is not applicable to the patient transfer context since nurses need to move and twist during a conduction of a transfer. Besides, for example, if the transfer scenario involves the patient standing up, the system may confuse the feet of the nurse and the patient.

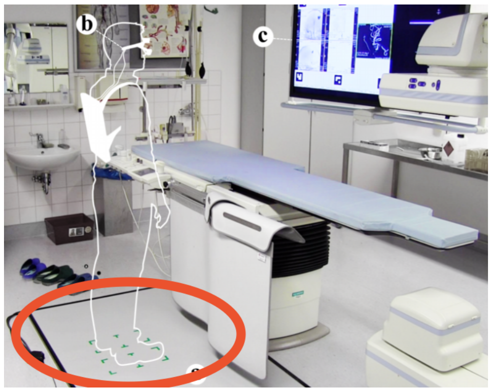

Figure 4.2.: Foot interactions during surgeries in the operating room. A red ellipse highlights the floor that recognizes foot taps. (source: "GazeTap" [44])

Another combination of interaction techniques is *eye gaze and voice*: here, eye gaze is again used for pointing at a target and voice commands are spoken to confirm. Klinker, Wiesche, and Krcmar [45] investigated the use of hands-free interactions with AR smartglasses among health care professionals during wound treatments. They conducted a study with the aim to compare (1) *eye gaze and voice* and a second approach (2) *eye gaze and blink*: the user has to hold the gaze and then blink to activate the command. The results showed that most health care professionals preferred eye gaze with blinking over eye gaze with voice commands. However, participants with contact lenses did not like eye blinking approach because repeated blinking felt uncomfortable. Eye blinking has shown to be faster. The authors guess that having to look up individual voice commands on the interface might have slowed down the process. Furthermore, the blinking was only simulated with a Wizard of Oz approach. This may lead to faster completion times. As for the **social acceptance**, there were no real patients in the experiment involved and the participants could not estimate if patients would react strange to them wearing smartglasses during a wound treatment.

Voice Control

Voice recognition is the most known hands-free interaction technique nowadays. It is used by popular systems, like for example, *Siri* or *Alexa*. Kopetz et al. [32] analyzed the integration of smartglasses into nursing training for patient transfers. The authors state that voice commands could be a good hands-free interaction technique to work further with. Marukami et al. [46] investigated the application of voice control input to an electronic nursing record system. The study results revealed that voice input is very fast. Jian et al. [47] found out that voice recognition has a high acceptance rate among healthcare workers. Overall, there has been little research on voice control in the medical sector. Assuming that it can affect verbal communication between nurse and patient, it should not disturb the non-verbal communication.

Table 4.1 shows the analyzed interaction techniques in comparison to the previously defined requirements from 4.2.. This sums up the main results from the conducted literature analysis and will help to make a decision.

Interaction Technique	Reference	R1	R2	R3	R4	R5
Head Gestures	[22]	verbal communication possible and improving after getting used to the workflow	non-verbal communication possible and improving after getting used to the workflow	"patients will accept the Care Lenses if they get a proper explanation" [22]	fast interaction	no information
Eye Gaze and Dwell	[44, 41, 43, 42]	verbal communication possible	non-verbal communication disturbed by double-role of the eye	long dwell-times are unnatural and can make people uncomfortable	fast interaction	Midas Touch Problem occurs when dwell time > 1.5 s
Eye Gaze and Foot (*eliminated in advance*)	-	-	-	-	-	-
Eye Gaze and Blinking	[45]	no information	no information	participants can not assess patient's reactions	fast interaction	not explicitly mentioned but Midas Touch Problem can occur because blinking is a natural gesture
Eye Gaze and Voice	[45]	no information, but assumingly affected	no information, but voice commands should not disturb non-verbal communication	participants can not assess patient's reactions	fast interaction, but slower than eye gaze and blinking	no information
Voice Control	[45, 46, 32, 47]	no information, but assumingly affected	no information, but voice commands should not disturb non-verbal communication	accepted by the user himself, no information on social acceptability from patient's side	fast interaction	no information

Table 4.1.: Comparison of hands-free interaction techniques that have been covered in related literature and requirements from 4.2.. Fulfilled requirements are highlighted in red, unfulfilled requirements are highlighted green.

4.4. Conclusion: Which sort of hands-free interaction is suitable?

Based on the results in the previous sections, the most suitable techniques for the given context will be chosen. It is safe to say that head gestures seem very promising and fulfill almost every requirement. It is fast and seems not to be a disturbing factor for the verbal or non-verbal communication among caregiver and patient. It is not clear yet if patients will socially accept this kind of interaction or if nurses may feel uncomfortable performing the gestures but the concept is worth a deeper investigation.

As Hatscher et al. [44] already stated, eye gaze and dwell is too likely to unintentionally activate commands everywhere you look and is therefore not very suitable. If for example, a nurse would hold eye contact with a patient for a longer period of time and the dwell time is exceeded, the Midas Touch Problem would occur. This is just one scenario out of millions where this could happen during a patient transfer. For the other multimodal combinations of eye gaze with different interaction techniques can be summarized as follows: Eye gaze and foot was eliminated in advance because of the given bodily restrictions (nurses have to move during the transfer and do not count the steps they make). If for example, the nurse takes two fast little steps back and the patient steps on his feet in that exact moment, the system might recognize a triple-tap and activate a command. Eye Gaze and Blinking is probably the fastest under all presented interaction techniques, however, it is uncomfortable for people that wear contact lenses and it is more likely for people to wear lenses instead of normal glasses to their workplace if they know in advance that they are going to wear smartglasses during work. Eye gaze and voice seems like a good candidate. Nevertheless, why not use pure voice commands without the gaze? It is important to consider that eye gaze is only available on larger HMD devices, like for example the Microsoft Hololens, that are very prominent and look much more like helmets. This again, might interfere with the personal relation between nurse and patient [22]. Another characteristic that makes eye gaze unattractive in this setting is the fact that the eye-tracking precision has to be maintained and therefore, abrupt and extreme movements should be avoided [44].

In summary, head gestures and voice commands seem to be very promising and will be used for the upcoming system.

5. Proposed System

With an insight into the context and the different hands-free interaction techniques that were described in the previous chapter, now the proposed system and the underlying process that involves design thinking and implementation will be presented.

5.1. Concept Idea

The patient transfer application is supposed to support nurses with patient transfers during practice to compensate the existing limitations of the basic courses during their nursing education and the lack of follow-up support by professional kinaesthetics trainers in practice. The use of AR HMD technology was chosen because the nurses on one hand, cannot use their hands for other (e.g. touch-based) devices while providing care and on the other hand, should not have to look up at a monitor-based device to maintain the social aspects that play a big role in patient care. The conceptual idea behind the application that will be presented in this section is inspired by the results from Dürr et al. [16] where they conducted a qualitative analysis and based on the results, stated design implications future systems that support caregivers. The insights of this work revealed that future technology should help to make transfer instructions better accessible. This is the underlying vision for this application: to demonstrate instructions make every instruction step easily accessible.

5.1.1. Workflow

In order to explicitly define which kind of head movements/ voice commands should solve which tasks, one has to think about which functionalities the system will provide in the first place.
If one logically imagines the routine that the nurse is going to have with the application flow, the following steps come into mind: First, the nurse has to somehow let the system know *from which place to which place* the patient should be transferred. For example, if the patient is currently lying in his bed and wants to go to the bathroom, he has to stand up or has to be seated into his wheelchair. In total, there are three main transfer scenarios that nurses often need to carry out: (i) transferring a patient upward in his bed, (ii) transferring the patient from a lying position into a sitting position ("sitting up the patient"), and (iii) transferring a patient from the bed into a wheelchair [24]. This is the first step that will be used for the composition of this patient transfer application and will be summarized in the following Design Goal (DG):

DG1: The first step in the workflow should allow the user to choose and select the correct transfer scenario.

Continuing the logical flow: after choosing the correct transfer scenario, the nurse would want to start with the movements. However, lets say one patient is fully movable and needs only little help during the transfer and the other one has been paraplegic for a long time - are the instructions that are displayed in front of the nurse going to be the same for these two types of patients? While visiting kinaesthetics transfer courses, Dürr et al. observed that the course teachers showed different movements for different patients with higher or lower movement capabilities [16]. Their findings suggest that, since there are different sequences depending on a patient's movement capabilities, future technology should aim to provide support for different categories of patients. This is the second hint that will be used for the composition of this application:

DG2: The second step in the workflow should allow the user to choose and select a suitable mobility degree for the patient that will be transferred.

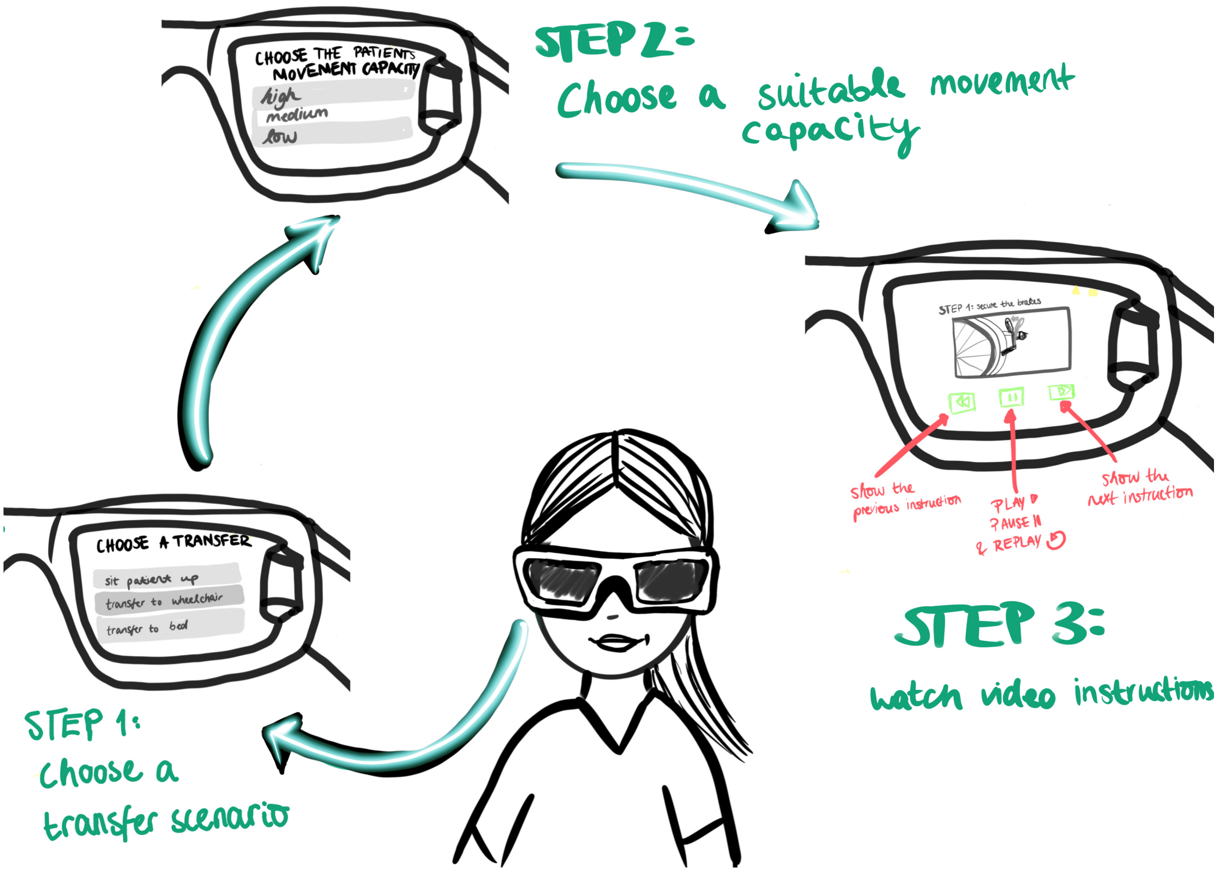

Figure 5.1.: Very early conceptual sketches that demonstrate the design goals and steps of the workflow.

After choosing the transfer scenario and movement capability of the patient, the main functionality of the program starts. The user will be shown short video-instructions with each a corresponding textual description of the transfer step. Prilla, Janßen, and Kunzendorff state that a caregiver cannot provide support for care tasks in a strict continuous way and that the system needs to give them the opportunity to navigate flexibly through the single steps of their tasks [22]. Therefore, the nurse should be able to play, pause and replay the videos and jump in between the instructions.

DG3: In the set of video instructions, the user should be able to:
1. Select play to start the tutorial.
2. Select pause to pause the tutorial.
3. Select replay to show a tutorial that is already finished again.
4. Jump to the ”next instruction” by direct selecting.
5. Jump to the ”previous instruction” by direct selecting.

The interaction design concept will follow in the next section. However, the nurse should always be able to reminded how to interact act what specific commands have to be activated. The corresponding interaction commands should be visible in the user interface. This follows the approach by Klinker, Wiesche, and Krcmar [45].

DG4: The interaction commands should be visible for the user at all times.

5.2. Design

In order to design patient transfer application that supports nurses during practice, the iterative UX design lifecycle [25] was followed step-by step. This process model was already described in Chapter 3. In this section, design concepts will be created and realized. At the same time, the iterative creative process is described.

5.2.1. Interaction Design: Tasks and Gestures

This subsection will explain how the user will interact with the system. For the first two steps, the user has to choose something out of a list: this involves choosing a transfer scenario out of multiple transfer scenarios and choosing a movement capability out of a list of multiple movement capabilities. These type of tasks are selectional tasks and will require three types gesture interactions and three voice commands. Two of the gestures/voice commands are needed to jump to the next and previous button in the menu, the third is required to confirm the choice. The duality of this flow and the next one where the instructions are shown is the following: one head movement/ voice command will be used for jumping from one menu item to the next. The same interaction can then be used to jump to the next video instruction. The is could be applied in order to “go backwards”, i.e., jumping to the previous menu item or dually, the previous video instruction. Then, the third head gesture could be used to confirm a selection in the menu as well as playing/ pausing/ replaying a video. This concept is inspired by many video platforms, like for example YouTube [48].

Head Gesture Set

As explained above, three different head gestures were needed for the interaction with the application. The choice of which head movement should solve which task will now be explained. Yi et al. [49] state that people intuitively associate *nodding* with approval. Therefore, the nodding gesture is a perfect fit for the confirmation of a button. For example, when a button that says “low movement capability” is highlighted and the nurse nods, it will be selected. In the work by Prilla, Janßen, and Kunzendorff [22] that was discussed in chapter Section 4.2., they chose turning to the head to the side for going forward and backward between the steps. This same concept will be used here too because they are very natural and may not even be noticed by the patient. In contrary, other head gestures, like for example, tilting the head, are very unnatural and not common in interpersonal interaction. The chosen head gestures are shown in Figure 5.2.

Voice Command Set

The idea behind the voice commands is nearly the same. One voice command was chosen for jumping to the previous step, one for jumping to the next step and one for confirming the selection. It was tried to use unobtrusive voice commands that are comfortable to speak out loud in front of another person. This is why mostly natural words were chosen. The chosen voice commands are: *previous step, okay, play, pause, replay, next step* and are shown in Figure 5.2. Initially, the commands *go left* instead of *previous step* and *go right* instead of *next step* were considered, however, after reviewing this concept with my advisor, we came to the conclusion that these commands might confuse the patient during a conversation.

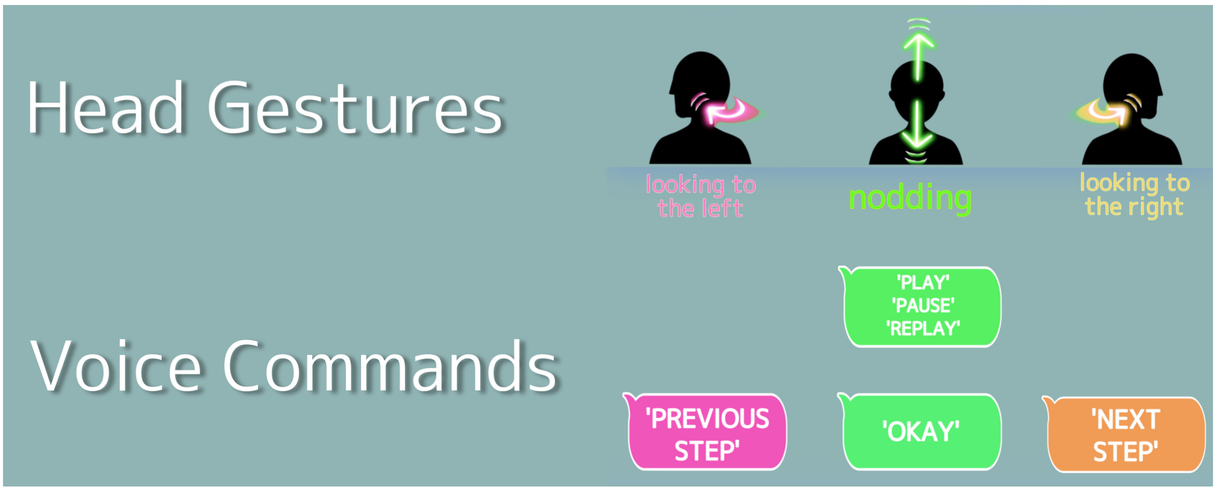

Figure 5.2.: The duality between the final head gesture set and voice command set that are used for interacting with the application.

5.2.2. Generative Design Process

The aim was to follow the Generative Design Process that is described in Chapter 14.1.4 of the UX Book [25]. These generative design activities include ideation, sketching, critiquing and refining. Ideation means spawning as many ideas as possible. The ideation phase went hand-in-hand with the sketching phase where sketches were made with varying levels of fidelity. Figure 5.3 shows some of the early prototype designs and example screenshots from the final design. One part of this process was a *Cognitive Walkthrough* with a participant from the Human-Computer Interaction department. In order to get feedback for the design, every frame of the application was printed. The participant was instructed to "navigate through the app" and conduct a patient transfer by following the video instructions. For this, we used a mannequin as patient and an iPad that showed the video because the system was not implemented yet. This way, it was visible if the logic of the workflow was intuitive for someone that had never seen or used it before. Figure **??** shows some insight from this day. An idea that came up during the Cognitive Walkthrough was to show the head for the head movement icons from the back because the participant could not identify the correct movement he had to perform with the early icon sketches. The icons were corrected and were added more precision. Figure 5.4 gives an insight on what the Cognitive Walkthrough looked like.

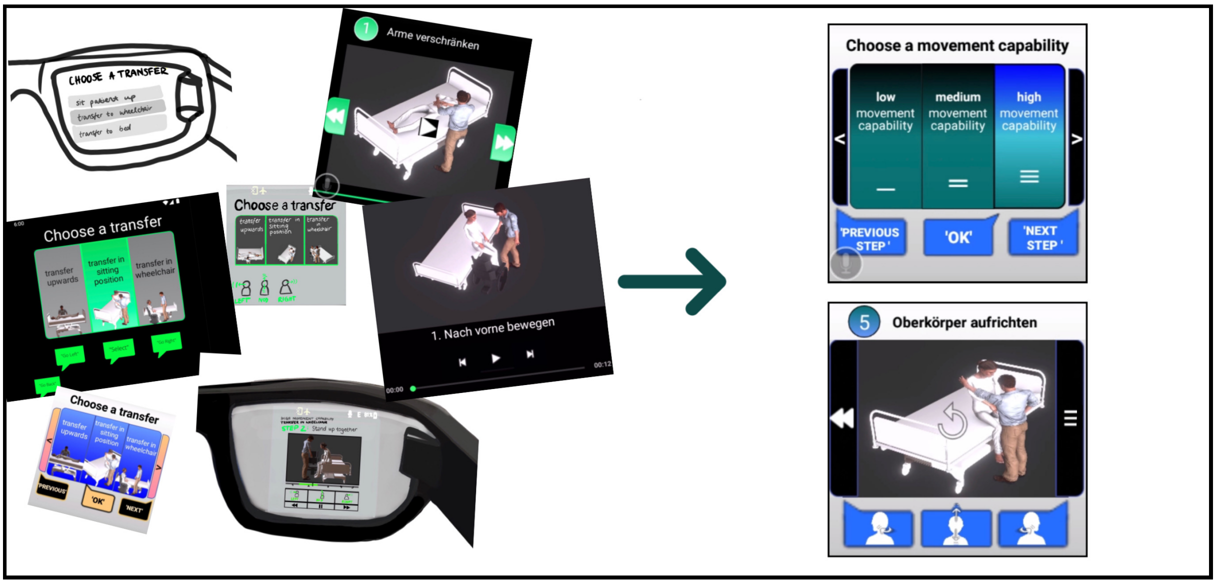

Figure 5.3.: Generative Design Process: Left side shows the ideation, sketching and refining of many early design possibilities. The screenshots on the right show the final design: the upper one shows a menu where a movement capability can be selected by interacting via voice commands and the bottom one shows an example of a video instruction that can be replayed or changed by interacting via head gestures.

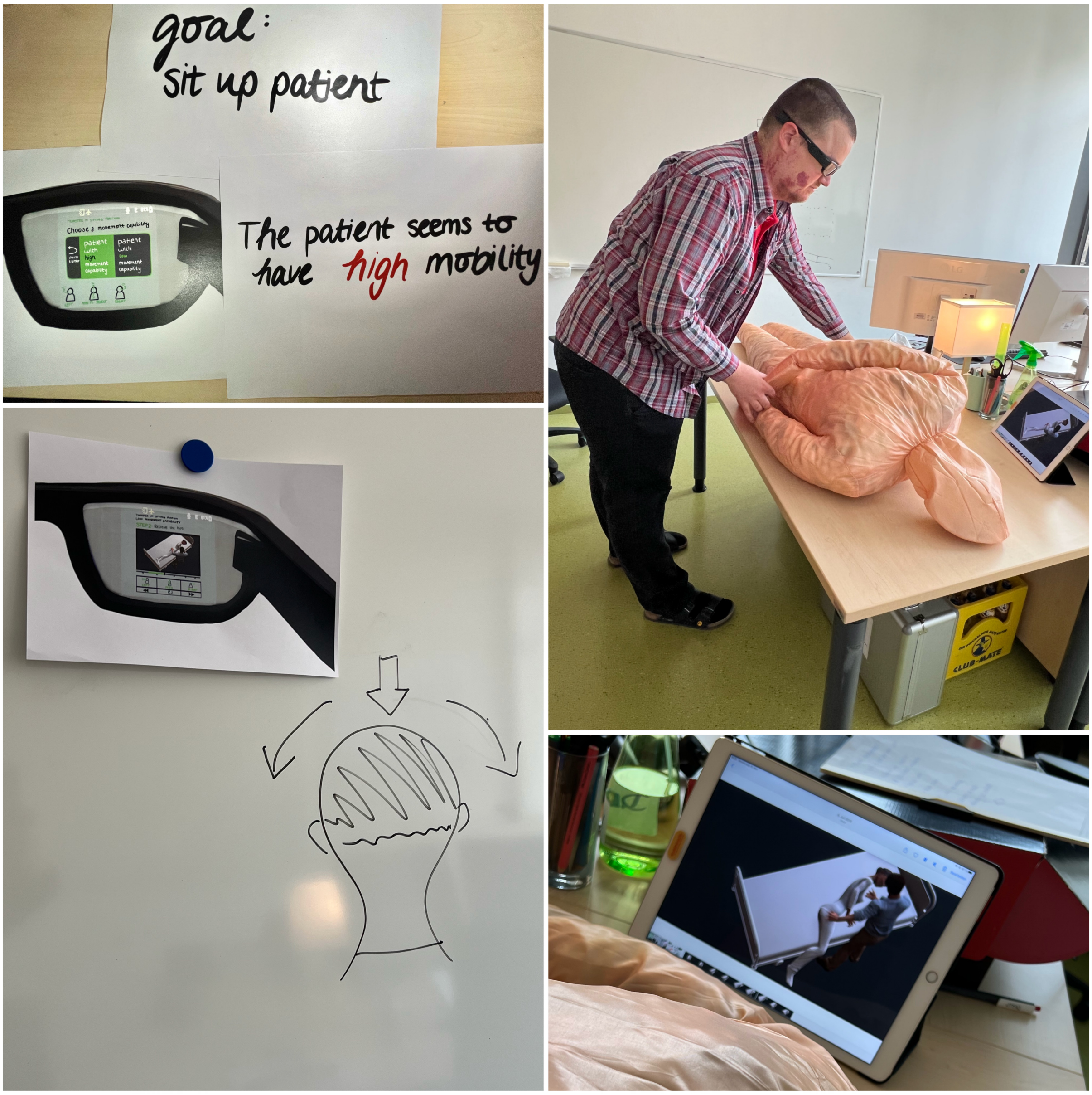

Figure 5.4.: Cognitive Walkthrough setup and patient transfer simulation with mannequin.

5.3. Implementation

Now that the design has been planned out, this section will discuss the technical implementation of the prototype. Section 5.3.1. will explain the choice in hardware. Then, in Section 5.3.2., the final application alongside with the implementational approach will be described and some technical limitations that arose during the implementation will be explained.

5.3.1. Hardware Selection

There are various Augmented Reality Head-Mounted Displays on the market and the theoretical knowledge in Chapter 2 has already shown the benefits of using Augmented Reality smartglasses because they are much lighter and have a rather inconspicuous design. Of course, it is important to also consider that larger HMDs are more advanced in terms of technology. However, Prilla, Janßen, and Kunzendorff state that "such devices might interfere with their personal relations with their often vulnerable patient." [22]. For the choice of a device, the focus in this section will lie on the elicitation of technical requirements. As already mentioned, it is important that the used device should be perceived "as natural" as possible in order to maintain the social acceptability. Another important aspect is that the system is made for the integration into the daily clinical work life, and therefore it is essential that the device has a solid battery life. It would be extremely inefficient if the battery could not even last for the conduction of one single patient transfer. The estimated time for one patient transfer is 15 minutes. Of course, nurses will not be wearing them full-time. The idea is that they can take them on before transferring a patient and take them off afterwards. Consequently, it should be easy and fast to take the glasses on and off. Some devices, like for example, the Microsoft Hololens need to be adjusted which would take too much time since there already exists time pressure among nursing personnel in clinics. For the interaction, *Head Gestures* and *Voice Control* were chosen in Section 4.4. The device should therefore support voice tracking integration. One important aspect for the integration of the usage of voice control into a clinical setting is that most patients are not alone in their room, they have visitors or share the room with other patients, who, again, have their own visitors, therefore, background noises are inevitable. The device should provide noise-canceling microphones in order to dim these background noises and prevent the commands from getting activated unintentionally.
The approach for the implementation of the Head Gesture recognition will be discussed in the next section, however, after the procedure that was described by Prilla, Janßen, and Kunzendorff [22] and Yi et al. [49], the chosen HMD has to have built-in motion sensors such as accelerometers and gyroscopes. In the following, the *Device Requirements* (DR) will be summed up:

DR1: The HMD should have an unobtrusive design.

DR2: The battery life of the device should last for at least two patient transfers with an estimated time of approx. 15 minutes for each.

DR3: The device should allow the user to take it on and off very fast, without having to adjust.

DR4: The device should support voice tracking integration

DR5: The device should have a noise-cancelling microphone.

DR6: The device should have built-in motion sensors (namely: accelerometer, gyroscope).

Potential hardware choices were the Vuzix Blade [50], Nreal Light [51], Microsoft Hololens 2 [52], and Google Glass Enterprise Edition 2 [53]. Their technical specifications will be compared to the defined requirements in Table 5.1.

	Battery Life	Design	Easy to take on and off	Voice Control Integration	Noise-cancelling Microphone	Sensors for Head Tracking
Vuzix Blade	3-4 hours	lightweight (90g) unobtrusive design	✓	✓	✓	✓
Nreal Light	3 hours	lightweight (106g) unobtrusive design	✓	✓	x	✓
Microsoft Hololens 2	2-3 hours	heavy (566g) very eye-catchy design	needs to be adjusted for every user	✓	✓	✓
Google Glass Enterprise Edition 2	8 hours	lightweight (46g without additional frame) unobtrusive design	✓	✓	✓	✓

Table 5.1.: Specifications of the Vuzix Blade, Nreal Light, Microsoft Hololens 2 and Google Glass Enterprise Edition based on the technical requirements.

Hardware Conclusion

As it is visible in the table above, nearly all of the glasses fulfill the properties that are needed. The Microsoft Hololens 2 is a great device, however, not suitable for the specific context we are dealing with because of its appearance and weight. The focus of this work lies especially on the integration of an assistive technology that *supports* professional caregivers during practice, and does not immerse them into another "dimension" since this can have an impact on the social acceptability (see Section 4.2). The Nreal Light does not provide noise-cancelling-microphone and this makes the device more likely to cause the Midas Touch Problem. The Vuzix Blade and the Google Glass Enterprise Edition 2are very similar in their properties and would both qualify for this project, nevertheless, the Vuzix Blade was already available at the University of Konstanz so it qualified as the best choice. Furthermore it is widely used in the medical field [54]. Figure 5.5 shows the Vuzix Blade smartglasses.

Figure 5.5.: Vuzix Blade Smartglasses with a thin and lightweight design. (source: [55])

5.3.2. The final Application

The implementational process and the final results will now be discussed step by step. The chosen Vuzix Blade smartglasses are Android-based and have a monocular display in form of a square with the measurements 4000x4000px [50]. For the development of the software, Android Studio [56] was utilized. The coding languages were Java in combination with XML. The Android OS that is running on the Vuzix Blade is a modified version of Android 5.1.1 (Lollipop), which was adapted to the components and capabilities of the device [57].

The following section addresses the realization of the Design Goals that were defined in Section 5.1.1. Figure 5.6 provides an overview of all levels of the application.

DG1. The application provides a menu where the nurse can choose a transfer scenario (e.g. “transfer in wheelchair”). The menu is laid out horizontally. Initially, the middle item is highlighted blue and can be selected via the suitable gesture (left side) or voice command (right side) that are shown at the bottom bar. The bubble in the middle that demonstrates how to select a button moves along with the highlighted menu item (see middle left image in Figure 5.6 where the middle bubble’s neck points the highlighted right menu item).

DG2. The application provides a second level menu where the nurse can choose the suitable movement capability for the patient (e.g. “high movement capability”).

DG3. After choosing the correct movement capability, the first video instruction is automatically played. If the system is used with via voice commands, the bubble that demonstrates the interaction at the bottom shows *’PAUSE’*. Once the video is finished, the text switches to *’REPLAY’* and a corresponding replay button appears in the middle of the video. On the left and right side of the video are buttons that allow the nurse to jump back to the menu or continue with the second video instruction. Once the second video instruction starts playing, the left button changes its functionality and the menu icon disappears. The nurse can now only go back to the previous video instruction or move forward to the next. If the last video instruction is reached, the menu icon appears again, this time on the right side.

DG4. The interaction commands are visible for the nurse at all times (see description of **DG1** and **DG3**).

Figure 5.6.: The three levels of the final implementation of the application. Images on the left side and right side are identical, except for the interaction icons in the bubbles. Left shows the interface for the interaction via head gestures and the right side shows the interaction via voice commands. In the Menu 1, nurses select the transfer scenario. Then, Menu 2 follows where the movement capability of the patient is chosen. Nurses are provided with step-by-step video instructions. The bottom level of the figure shows an example of a video instruction. After completing a transfer, nurses are redirected to the main menu where they can select a different transfer. (Images include © Google Material Design Icons; video content was provided by the Human-Computer Interaction Department)

Two identical software versions of the patient transfer application were implemented. The only difference was the interaction method: one version was made for the interaction via voice commands and the second one for interaction via head gestures. It will now be dived into these approaches individually:

Integration of Voice Commands

The Vuzix Blade smartglasses support Voice Control and have an integrated platform base vocabulary. Existing phrases can be deleted by using *speechclient.deletePhrase("*")*.

As a first step while working with the Vuzix Speech SDK [57], a VuzixSpeechClient was created. This class contains the methods needed for adding and deleting voice commands. Events can be triggered from here.

```
// Create a VuzixSpeechClient
        VuzixSpeechClient speechClient = new VuzixSpeechClient(iActivity);
```

In order to trigger custom actions, BroadcastReceiver class was etxended. The following code snippet shows how a speech intent gets registered:

```
public class VoiceCmdReceiver  extends BroadcastReceiver {

    public VoiceCmdReceiver(MainActivity iActivity) {

        mMainActivity = iActivity;
        mMainActivity.registerReceiver(this,
        new IntentFilter(VuzixSpeechClient.ACTION_VOICE_COMMAND));

    }
}
```

By doing this, you can override the **onReceive()** function. The speech intent *VuzixSpeechClient.ACTION_VOICE_COMMAND* is handled here. The inserted phrases from before are provided in the received intent.

Integration Approach for Head Gestures

The most common approach to implement Head Gestures on smartglasses is to use built-in motion sensors, i.e. accelerometers and gyroscopes. Yi et al. [49] and Prilla, Janßen, and Kunzendorff [22] both followed this approach. Accelerometers measure the acceleration of objects and can detect their position in space. In contrast, gyroscopes measure the movement direction of objects that are in motion. Accelerometers and gyroscopes have a high electromechanical sensitivity [49]. The approach that was tried in [49] and [22] was the following: First, they made a pre-test with users in different activities (e.g. running, walking and standing) with and without the use of head gestures to find the most appealing configuration. Simultaneously, the sensor data from the accelerometers and gyroscopes was collected. This data included movement direction and speed along the coordinate axes. Yi et al. implicate that they notices how head gestures mainly consist of rotations rather than accelerations. After collecting enough data, they set gyroscope thresholds for each gesture and calculated the rolling standard deviation during the motion. If the rolling standard deviation was below the threshold value, they automatically discarded the samples because they concluded that it was a normal movement, and not a gesture. However, if it was above the value of the rolling standard deviation, the data from the accelerometer also started buffering. Whenever the rolling standard deviation starts dropping again, it was indicated that the user is no longer in motion and the head gesture has been completed. This was the process for the detection of gestures. For the recognizing of gestures, templates from the collected gestures using a clustering algorithm called affinity propagation were created and a dynamic time warping algorithm was used to measure how well two gestures match. To avoid the system from falsely detecting gestures when users simply moved their head, we used pre-set thresholds for head rotation and directions changes to detect gestures [49].

Unfortunately, the software component for the detection of head movements was not implemented in time. For the study, a Wizard of Oz method was used to simulate the head gesture recognition. This method lets participants interact with an interface without knowing that in reality, the responses are being generated by an unseen person (i.e., “ the wizard”) [58]. Figure 5.7 shows an image from 1984 that was published by IBM. The participant (on the left) speaks into a “Listening Typewriter”. Another person plays the wizard and types in the participant’s words that will be shown on the computer of the participant. This makes it look like the computer processes his speaking.
The Wizard of Oz set-up for our system will be described in detail in chapter 6 where the study design is planned. The final implementation of the system therefore involves not only the application on the smartglasses, but also a computer with implemented key events and a stable internet connection to send data between the smartglasses and the computer.

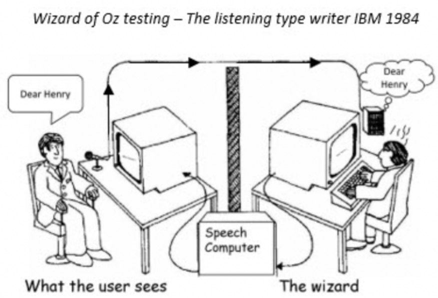

Figure 5.7.: Wizard of Oz testing – The listening typewriter IBM 1984 (source: [58])

6. Study

The general aim of this thesis is to compare different ways of hands-free interaction with Augmented Reality smartglasses during patient transfers in clinics. In Chapter 2, various hands-free interaction techniques were compared and two were chosen for further investigation. These two were used in a comparative study with twelve participants in a simulated clinical setting in order to see how they differ in their application, what benefits and disadvantages they bring, and which would perhaps be a better approach for the integration into practice. This chapter will talk about the study in detail. The upcoming section Section 6.1 outlines the study design that follows the process model of the DECIDE Framework that was already introduced in Chapter 3. Then, Section 6.2 the research questions will be presented and explained. The results of the study will be discussed in Section 6.4 and then discussed in the succeeding Section 6.5. Finally, Section 6.6 and Section 6.7 will show limitations and implications that arose during this process.

6.1. Study Design after the DECIDE Framework

The methodological approach was described in Chapter 3. The six steps of the DECIDE Framework that were presented there will now be applied. Since it is an iterative process model, not all steps will be in the given order.

DECIDE 1: Determine the goals

The goal of this Thesis was formulated in Chapter 1:
"*This thesis intends to address the lack of kinaesthetical support during the daily practice in clinics and aims to find a technical solution that does not require the use of hands so that the caregiver can execute his regular workflow and the system plays only the role of an unobtrusive aid.*"

Consequently, the goal of conducting a comparative study can be formulated as follows:
The study intends to compare two hands-free interaction techniques (namely: head gestures and voice control) that are used to interact within an application for Augmented Reality smartglasses that assists nurses in clinics during practice.

By now it is clear that Augmented Reality HMDs seem very promising in for a use in the medical field. However, for the integration into practice in real life, some external aspects have to be inspected and remaining questions have to be answered. The next section sums up the research questions of this study.

6.1.1. Research Questions

DECIDE 2: Explore the questions

The research in this thesis addresses the following research questions (RQs) that were partially influenced by the contextual analysis and the concluded interaction requirements from Section 4.2:

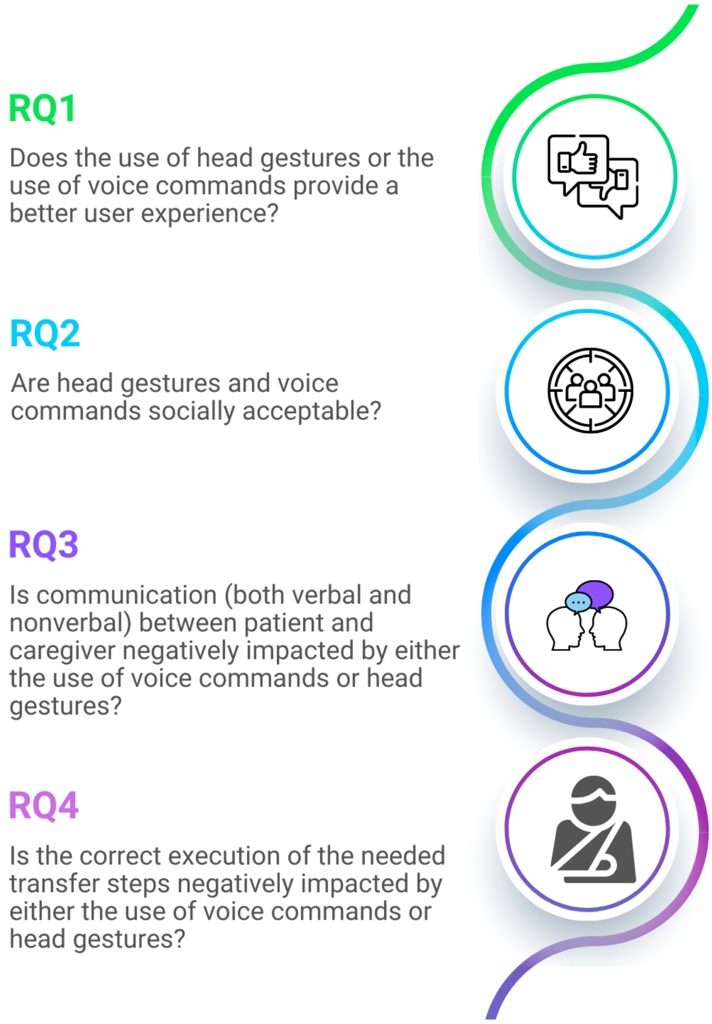

Figure 6.1.: template source [59]

Initially, two more research questions were planned. The reason for their elimination will be described shortly.

(RQ5: Do head gestures or voice commands provide better usability for the patient transfer application?)
This Research Question turned out to be unnecessary in combination with RQ1. User experience is measured quantitatively with the standardized User Experience Questionnaire (UEQ) [60]. Classical usability aspects (like, e.g. efficiency, perspicuity, dependability) are already covered in this questionnaire.

(RQ6: Does any of the interaction techniques suffer from the Midas Touch Problem?)
After deciding to use a Wizard-of-Oz approach in the study, this research question could not have been fully investigated. However, for the version of the application that uses voice control, a logging method was used because the functionality of the voice commands was implemented anyway. Whenever the system recognized a voice command, it was written in a log file, and whenever the wizard pressed a key, it was also logged. These log files were later evaluated to see how often the Midas Touch Problem would have occurred if the system had been used normally.

6.1.2. Variables and Experimental Design

DECIDE 3: Choose the evaluation methods

Before choosing the concrete evaluation methods, the independent variables had to be determined and an experimental design had to be chosen. The independent variables are the following: **(1) interaction via head gestures** and **(2) interaction via voice commands**. The aim of a study is to explore the effects that *independent variables* have on dependent variables. Independent variables are variables that the experimenter manipulates. In contrary, dependent variables are the direct effects of the independent variables. They are the ones that are tested and measured [61]. The dependent variables that will be measured in this study will be explained alongside with the methods for the data collection in Section 6.1.3. First, it should be discussed how the participants were assigned to the independent variables. HCI experiments most frequently use a within-subject design in studies [62], meaning that each participant tests all conditions, i.e. all independent variables. The within-subject design was used for this study. If the contrary experimental design, the *between-subjects design* was chosen, each participant would have only tested one condition. Nevertheless, the decision was made in regard to the statistical advantages that within-subject design offers: If the number of participants is already rather small, it makes more sense to assign every participant to every condition because otherwise, the use of between-subject-design would shrink the collected data by the number of conditions (e.g., here: two conditions).

6.1.3. Methods for Data Collection

The process of data collection involved three different methods: **Questionnaires**, **Logging** and a **semi-structured Interview**. This section will give an insight into how these methods were applied and which dependent variables were selected.

Quantitative Data

Questionnaires. All questionnaires are attached in the appendix (in German language) and will be described shortly.
At the beginning of every study run, the participant had to fill out a **demographics questionnaire**. These type of questionnaires provide general data about the participant, such as age, profession, or subject-specific prior knowledge. It was specifically asked if they had helped to transfer a care-dependent person before and if they had experience in the clinical field. Further, participants were asked if they had experience with AR smartglasses. Because of the fact that the tasks required bodily interaction, they were also asked if they had any sort of physical impairments. Another important aspect was if the participant had any problems with their eyesight. This was asked because it was necessary to see good enough to see all the details that were displayed in the videos considering that the display of the Vuzix Blade smartglasses is rather small.
After testing each condition, the participant had to fill out four more questionnaires. Two of these were standardized and the other two were custom questionnaires based on questionnaires that were already used in related work. One of the standardized questionnaires was the **User Experience Questionnaire (UEQ)** [60]. This questionnaire has a seven-stage scale and consists of 26 rows filled with attributes. The right ending of the scale shows the most positive answers, the left ending the most negatives. The UEQ measure both classical usability aspects (dependent variables like efficiency, perspicuity, dependability) and user experience aspects (originality, stimulation). It was later evaluated with the official UEQ Excel Tool. This helped to answer RQ1.
The second standardized questionnaire that participants had to fill out was the Task Load Index (NASA TLX) [63]. The NASA TLX questionnaire captures workload at multiple levels: this involves mental demands, physical demands, time demands, performance, effort, and frustration. All of these are dependent variables. It was aimed to find an answer for RQ4 with the help of this questionnaire (among others).
A custom questionnaire regarding the social acceptability of the two interaction methods was created based on previous work of Rico and Brewster [64] who came up with the *audience-location-axis*. This axis originally involved the following two questions: *In which locations would you use this gesture?*, and *Who would you perform this gesture in front of?*. Multiple-Choice possibilities, like for example, “family”, “friends” for the audience and “at home”, “while driving” for the location were given. Later, many researchers modified this scale [36]. For example, Pearson, Robinson, and Jones [65] used a 5Pt Likert Scale instead of a Multiple-Choice possibility. This approach was used for this study too. The questions were formulated as follows: (1) *How comfortable would you feel using this form of interaction in the presence of the following people?* with the possible answers *in the presence of my friends, family, colleagues, my partner, strangers, only when alone* and (2) *How comfortable would you feel using this form of interaction in the following places?* with the possible answers *at home, in public transport, on*

the sidewalk, in a pub or a restaurant, at work, at work with patients in clinics. Participants had to mark the Likert Scale from 1: very uncomfortable to 5: very comfortable. These questions helped to answer RQ2.
The last questionnaire was adapted from Daly-Jones, Monk, and Watts [66] in a way that addresses verbal and non-verbal communication between the nurse and the patient during patient transfer. Again, a 5Pt Likert Scale was used where the participant had to choose between 1: I do not agree at all and 5: I agree fully. The questions involved, for example, *I was very aware of the presence of my conversation partner, i.e. the patient.* and *I could easily tell when the patient was focusing on what I was saying.* (for more, see Appendix). In the last question, the participant was asked to rate the conversation from 1 to 5 based on how much effort he felt it took to have an effective conversation. The scale went from 1: very much effort to 5: very little effort. These questions regarding the verbal and nonverbal communication aimed to answer RQ3.

Data Logging. The decision to implement a logging system was made because of the Wizard of Oz approach that was used during the study. The system was able to recognize the voice commands but not the head gestures, therefore both were simulated during the experiment. However, in order to see if the voice commands would have been triggered unintentionally, whenever the system recognized a voice command, it was written in a log file, and whenever the wizard pressed a key, it was also logged. This partially played a role for (RQ6) which was later discarded from the list of research questions.

Qualitative Data

Semi-structured Interview. The data collection of qualitative data involved a semi-structured interview that was conducted at the end of the study, after the participant had tried all the conditions and filled every questionnaire. These interview questions in a semi-structured interview are planned out in advance in the interview guide; however, the order of the questions is flexible and ad-hoc-questions are also allowed. Semi-structured interviews employ a blend of closed- and open-ended questions that are often followed by follow-up why or how questions [67]. Participants were asked about their preference, subjective advantages and disadvantages, subjective opinions on how they perceived the communication with the patient, if they would feel ashamed to use the interaction techniques during practice, if the interaction was disturbing the correct execution of the transfer movements and which commands they would have preferred over the given ones. An example of a question from the interview is *Which of the two variants (head gestures and voice commands) did you find better? Why?* (for more questions, see Appendix). The interview questions that were asked affected all research questions. During the data evaluation process, the interviews were transcribed and a qualitative content analysis after the approach of Mayring [68] was carried out. After transcribing the interviews, the important statements were grouped into a system of categories. There are two types of categories: main categories and subcategories. The main categories concentrate on the main aspects that will help to evaluate the results and mostly consist of further subcategories, however, not every main category has subcategories [69]. According to Mayring [68], categories can be formed inductively as well as deductively. Inductive means that the categories are developed from the interview content, whereas with the deductive approach, the categories are built in the beginning and statements are added into these categories later on. Both methods of category development can also be combined. The approach that was used here is also a mixed approach: the main categories were already built deductively based on the interview questions. However, the subcategories were formed later on based on the interview material. The categories were identified with the help of the MAXQDA software [70].

DECIDE 4: Identify the practical issues

DECIDE 5: Decide how to deal with the ethical issues

Study Procedure

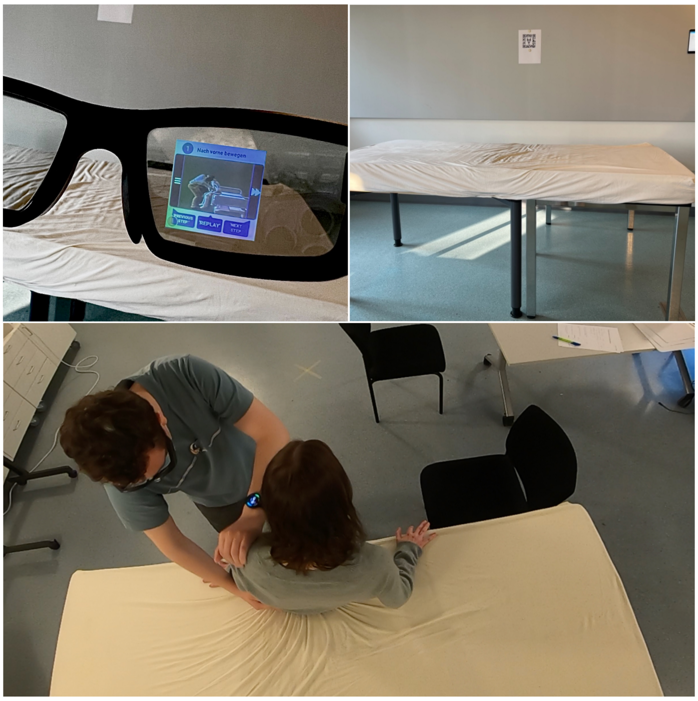

Figure 6.2.: Study setup and execution

The study was carried out in a laboratory room at the University of Konstanz. Due to Covid-19 restrictions, it was not possible to do it in a real clinic; however, the clinical setting was simulated by a bed and a chair that acted as a wheelchair. Twelve participants took part in the study. Whenever a participant came in, first he was seated and had to read a welcome letter where the procedure and all formalities were explained. He also had to sign the informed consent (which was created based on [26]) and complete the demographic questionnaire. All study documents can be found in the Appendix. The study was pseudonymous, which means that every participant was assigned to an unique ID. This ID assigned list was kept separate from the other documents at all times to protect the privacy of the participants. After filling out the demographics questionnaire, the participant received the smart glasses and had to complete a training task. This training task involved trying out the voice commands. The participant had to say each once. For the head movements, he was shown an animation of a person performing the head movements. These also had to be performed once by the participant. Then, he was given the first task. The wizard was seated laterally in the corner. The participant was able to see him, however, was not aware of the "manipulation". Because of the previously described Within-Subject-Design, every participant was meant to use both conditions, i.e. he interacted one via head gestures and once via voice commands. All tasks involved transferring either a patient with medium movement capability from bed to wheelchair or a patient with low movement capability from a lying position into a sitting position. Every transfer procedure had to be performed three times in a row. Research shows that during studies that use Within-Subject-Design, it is common that participants mature by gaining experience in the previous rounds [62]. Therefore, the conditions had to be counterbalanced, i.e. evened out to improve the internal validity of the study. The participants were introduced to the patient before the first transfer and were instructed to converse with them like in a real clinical setting with a real patient. This included natural conversations, as well as instructions that the "nurse" gave. After completing the first task, the questionnaires had to be filled. Every condition had the same four questionnaires. Then, the same procedure took place with the second condition. There, again, after three rounds of the same transfer, the questionnaires had to be filled. Lastly, a semi-structured interview took place. The interview was taped via microphone and the cameras were recording full-time. This was mentioned in the written consent form, nevertheless the participants had the right to choose if they allowed to use their pictures and recordings during the final presentation and in this thesis. At the very end, the participants were compensated with 10. The entire described procedure took one hour each.

6.2. Results

DECIDE 6: Evaluate, analyze, interpret, and present the data

This section explores the results of the study. After presenting participant related information that was gathered from the demographics questionnaire, the findings from the quantitative and qualitative analysis will be shown, with the goal to answer the Research Questions that were formulated in Section 6.1.1 later on.

6.2.1. Participants

Twelve students from the University of Konstanz participated in the study. They were students from various different departments, including Life Science, Law, Teaching, Economy, Biology, Physics and Psychology. Two of the participants were male, ten female. The participants were between 19 and 26 years old (M = 21.8, SD = 2.03). Three participants had prior experience in the medical field: two of these had worked in a nursing home and the other one had an internship in a psychiatric facility. Only one person stated that they had helped transferring a care-dependent person in the past. Four of the people had a bad eyesight but were wearing contact lenses. None of the participants complained about physical impairments, namely, pain in the shoulder, hips or back. None of them had prior experiences with Augmented Reality smartglasses, however, one participant had worn a Virtual Reality HMD before.

6.2.2. Findings

In the following, the findings will be evaluated for each topic. Since the interviews were held in German language, all quotes were translated from German to English. Participants get pseudonyms from P1-P12.

User Experience and Midas Touch

"*I just thought the head gestures were much cooler. It was much more pleasant to just turn my head for a moment than to talk to myself all the time.*"

"*The head movements were kind of exhausting. I have the feeling that when I move my head, I don't have the patient in view and I am mentally away for a short time. The voice commands were just better.*"

These two example interview quotes implicate that participants perceived the attractiveness of the two interaction techniques very different. Figure 6.3 shows scale means that are compared to data from a benchmark data set of 21175 persons from 468 studies [60]. The shown measurement attributes are explained in Figure 6.4, however, they were in this case used for the evaluation of the interaction method rather than the "product".

Participants were asked about their preference. Seven participants preferred using the head gestures, fout voted for interacting via voice commands and one participant was torn. Figure 6.4 shows advantages and disadvantages that the participants stated to explain their choice.

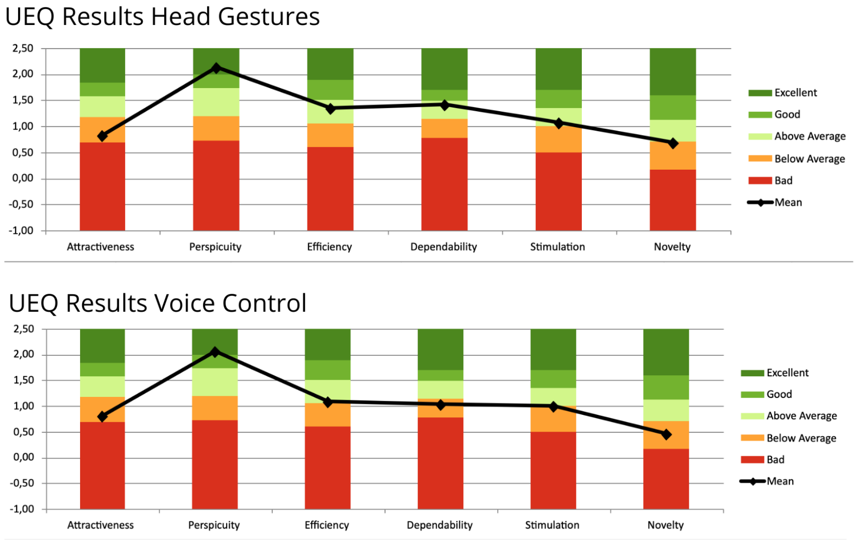

Figure 6.3.: UEQ benchmark comparison for head gestures (top) and voice control (bottom) (generated by [60])

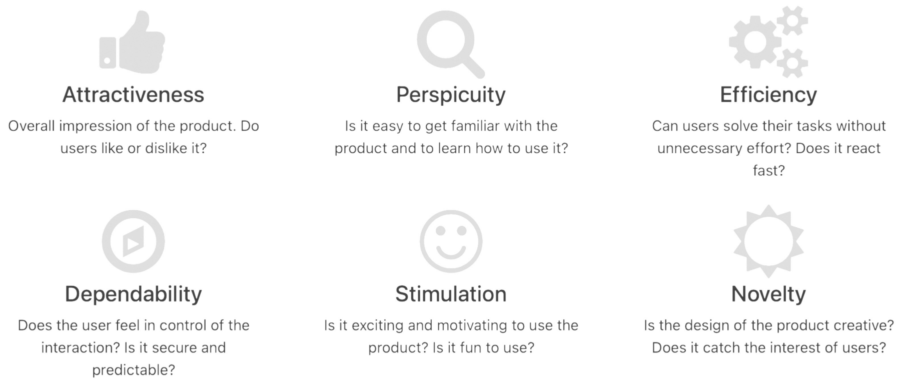

Figure 6.4.: User Experience Measurement Attributes: *attractiveness, perspicuity, efficiency, dependability, stimulation, novelty*

The evaluation of the User Experience Questionnaire shows that the mean value of the attractiveness of the use via head gestures (M = 0.82, SD = 1.07) was very similar to the values of the use via voice control which were M = 0.81 and SD = 1.09 for attractiveness. Even though the numbers are rather low, during the interview, for example, participant P12 said that he loved the interaction via head gestures and that he would "buy this" if he was in the medical field. An interesting difference is seen in the dependability: the dependability value (M = 1.42, SD = 0.92) of the use via head gestures was rated above average, in contrary, the dependability of voice control (M = 1.04, SD = 1.02) was rated below average. In relation to this, participant P3 stated the fear of activating a voice command accidentally while talking to a patient and guiding him through the transfer steps:

> "*I think that if you really want to communicate with a patient and talk about what you are going to do next and so on, I think it could happen that the glasses misunderstand my words.*"

It is important to note that the study was conducted as a Wizard of Oz Experiment (see Chapter 5). The Midas Touch Problem was therefore completely eliminated for both interaction techniques. Nevertheless, the fear of accidentally activating the commands was still present. The log files confirm this assumption. One participant (P2) for example, used the word "*okay*" almost after every sentence. The word was perceived from the system exactly 23 times during all three transfer rounds and the captured keystrokes of the wizard, in comparison, showed only 6 keystrokes for okay. During the interview, the participants were asked if they would preferred other voice commands over the existing ones ("previous step", "okay","next step", "play", "pause", "replay") for the interaction with the glasses. Nine participants wished for shorter commands, like "Weiter" which means "Next" in English. P9 added that "Okay" should be replaced by "Yes", however, he then added that this again could confuse the patient in a conversation where a yes-no-question comes up.

	advantages	disadvantages
Head Gestures	• more comfortable to use during a conversation (n=7) • interaction via head gestures is easier • faster and not obtrusive • more attention on the patient • more intuitive	• patient not always in focus, focus on the interaction (n=5) • you have to get used to it • eyes not on the transfer during the interaction with the system (n=2) • negative impact on correct movement execution • feels unnatural (n=2)
Voice Commands	• holding eye contact with the patient is easier (n=3) • faster • efficient	• communication with the patient is harder • conversation has to be stopped (unnatural) (n=5) • inattention towards patients • requires multitasking (n=3) • patients might be confused

Figure 6.5.: Interview Results: advantages and disadvantanges that were stated during the interviews. N indicates the number of participants that made the same statement.

Another conspicuousness among the values was the perspicuity which was rated excellent for both interaction techniques (head gestures: M = 2.14, SD = 0.73, voice control: M = 2.06, SD = 1.0). Even though none of the participants had experience with Augmented Reality smartglasses before, they all learned how to get along with the interaction very quickly.

Finding 1

The user experience of the usage of the app via the two interaction techniques is according to the UEQ in most categories average and very similar. The only considerable difference in these results is the dependability. Participants wish for shorter voice commands and are, at the same time, scared of activating commands unintentionally. When asked about their favorite technique, the majority preferred using the head gestures for the interaction with the system.

Social Acceptability

"*Speaking voice commands is way less embarrassing than doing weird head twitches.*"

"*I feel like some patients wouldn't even realize I was doing head movements because they were so fast but voice commands are just so noticeable.*"

Asking the participants about which kind of interaction they would prefer using in the hospital in front of other people, including patients, visitors or colleagues, there were two divergent views: some preferred the voice commands because they found it embarrassing to perform the head gestures in front of others. The other participants perceived it vice versa. During the interview, five participants stated that the head movements were so unobtrusive and that patients would not even notice they were watching videos. This made the head gestures more comfortable and less embarrassing for them in regard to the social acceptability. This is also visible in the results of the **'Social Acceptability Audience Questionnaire'** (see Figure 6.6).

The mean scores of the question about in front which audience they would feel comfortable performing each of the interaction techniques show that head gestures are on average preferred to use in front of their friends (Mean Score Head Gestures M_{HG} = 3.42, Mean Score Voice Control M_{VC} = 3.17), colleagues (M_{HG} = 3.67, M_{VC} = 3.33), partner (M_{HG} = 3.75, M_{VC} = 3.58) and even strangers (M_{HG} = 2.83, M_{VC} = 2.92). Only in the categories family and alone, voice commands show a higher mean score (family: HG = 3.17, M_{VC} = 3.75). The lower diagram reveals that one person chose *'very uncomfortable'* in every category except alone regarding the voice commands. However, in the diagram above that shows the results for the use of head gestures, in five out of six categories, no participant chose *'very uncomfortable'*. The second question *How comfortable would you feel performing this interaction at these locations?* indicates similar results as with the audience. Again, the mean score is in most categories higher for the use of head gestures, these involve at home (M_{HG} = 4.08, M_{VC} = 4.33), in public transport (M_{HG} = 2.17, M_{VC} = 1.92), on a sidewalk (M_{HG} = 2.17, M_{VC} = 2), in a pub or restaurant (M_{HG} = 2, M_{VC} = 1.58) and in a clinic. The only category that shows a higher mean score for Voice Control is 'at work' (M_{HG} = 2.67, M_{VC} = 3.17).

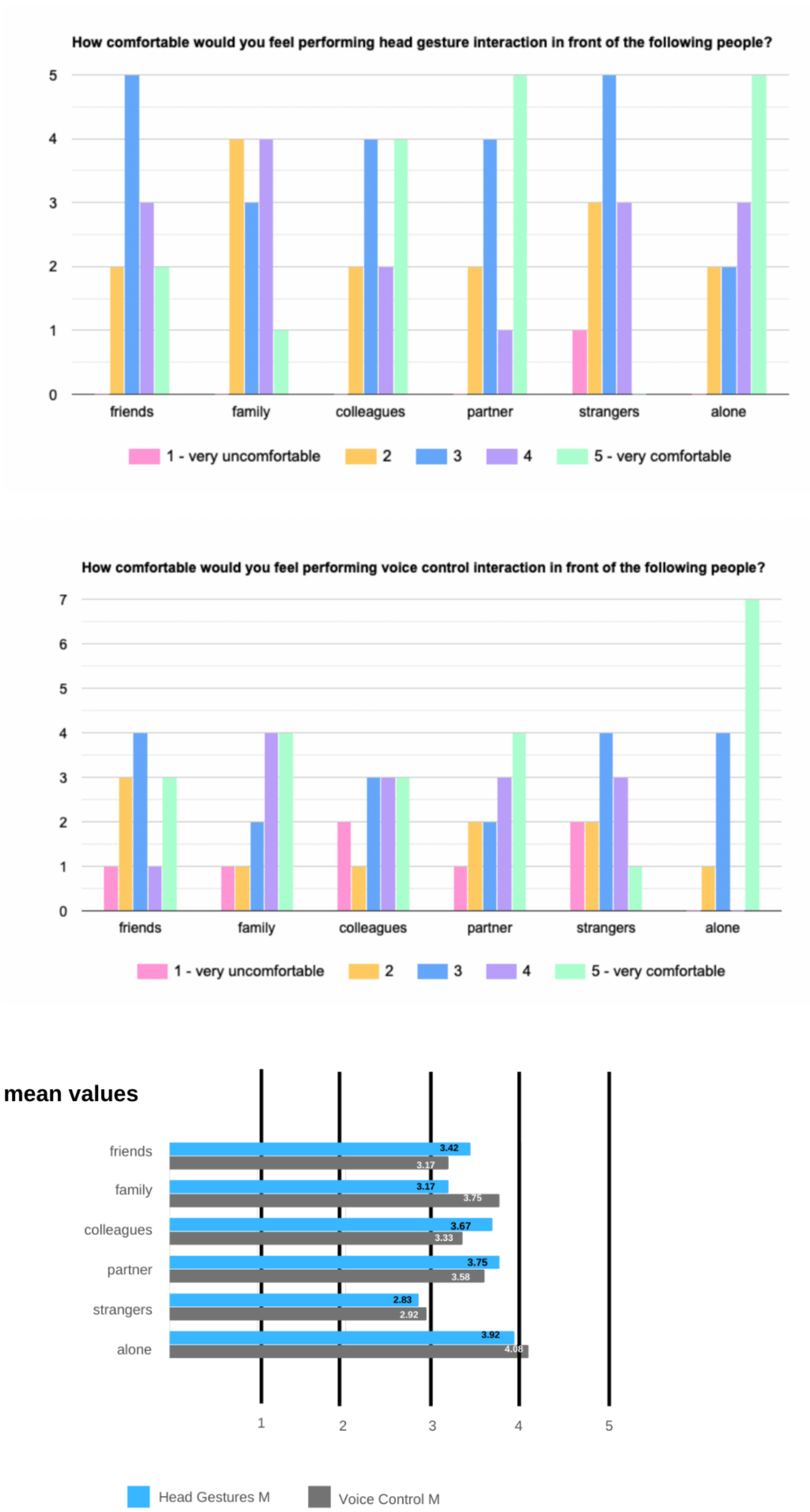

Figure 6.6.: *How comfortable would you feel performing this interaction in front of the following people?* - Results of the 5Pt. Likert Scale for custom 'Social Acceptability Audience Questionnaire' (top: Head Gestures, middle: Voice Control). Diagram at the bottom shows the mean scores of the above diagrams (1 = *very uncomfortable*, 5 = *very comfortable*). [71]

Figure 6.7.: *How comfortable would you feel performing this interaction at these locations?* - Results of the 5Pt. Likert Scale for custom 'Social Acceptability Location Questionnaire' (top: Head Gestures, middle: Voice Control). Diagram at the bottom shows the mean scores of the above diagrams (1 = *very uncomfortable*, 5 = *very comfortable*). [71]

Finding 2

Participants state two different point of view during the interview: (1) the use of head gestures is not noticeable and therefore less embarrassing but (2) if they are noticed by the audience, voice commands are better socially accepted. The questionnaires, however, show a clear preference for the use of head gestures in terms of social acceptability.

Verbal and Non-Verbal Communication

"When you spoke with the glasses, the conversation with the patient was interrupted."

Five participants had this same view on the fact that the communication with the patient during the transfer had to be stopped every time a voice command was spoken. Three participants also noticed that it required multitasking to manage both the transfer and the conversation at the same time. When asked if the non-verbal communication with the patient was possible, three participants answered that holding eye contact while speaking voice commands was easier than with head gestures. One participant expressed:

"When I was concentrated and wanted to switch to the next video and moved my head for this, I only focused on the glasses and forgot about the patient."

This applies to both verbal and non-verbal conversations. Nevertheless, the custom 'Conversation Questionnaire' in Figure 6.8) divulges that the mean score of the statement *"I was very aware of the patient's presence"* was higher with the use of head movements than voice control (M_{HG} = 3.75, M_{VC} = 3.42).
In the interview, when specifically asked about the non-verbal communication while using the head gestures, five participants revealed that they had not even paid attention to try to converse non-verbally. P1 stated:

"I think gestures and facial expressions are a bit difficult, especially facial expressions, I think, now and then a smile, yes, but I couldn't see much more."

The mean score of "I could easily tell when the patient was focusing on what I was saying." was the same for both interaction techniques (M_{HG} = M_{VC} = 3.50). Figure 6.9 displays that on average, the subjective effort that it took to have an effective conversation was perceived lower with the use of voice control (M_{HG} = 2.67, M_{VC} = 2.92), however, also lower for the statement *I was able to focus on the task* (M_{HG} = 3.50, M_{VC} = 3.33).

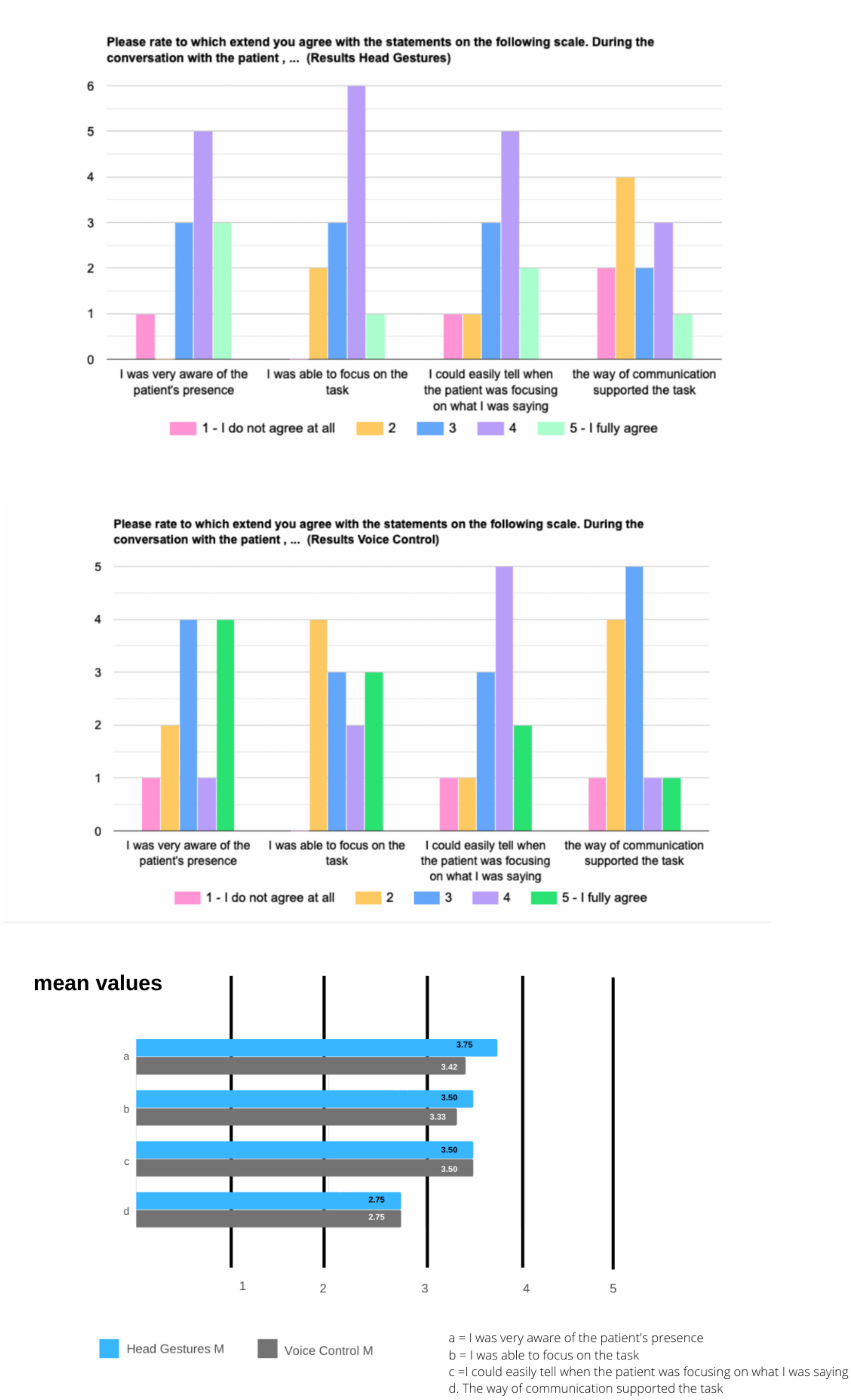

Figure 6.8.: Results of the 5Pt. Likert Scale for custom 'Conversation Questionnaire' (top: Head Gestures, middle: Voice Control). Diagram at the bottom shows the mean scores of the above diagrams (1 = *I do not agree at all*, 5 = *I fully agree*).[71]

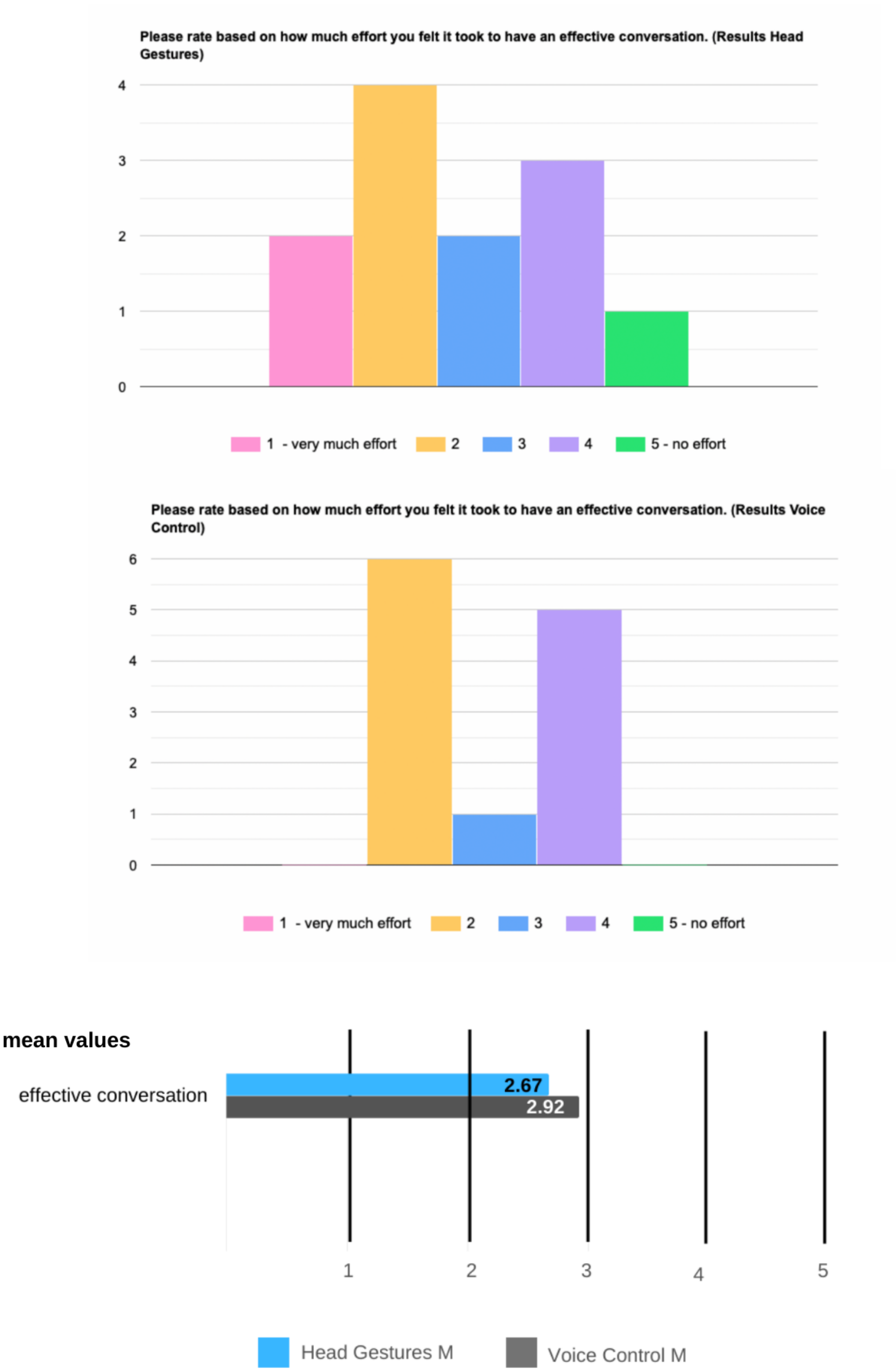

Figure 6.9.: Results on how much effort the participants perceived to have an effective conversation (top: Head Gestures, middle: Voice Control). Diagram at the bottom shows the mean scores of the above diagrams (1 = *very much effort*, 5 = *no effort*). [71]

Finding 3

Speaking voice commands interrupted the conversation with the patients, yet, the eye contact was steady. When they moved their heads for interaction, they could not hold the non-verbal communication upright but could still talk potentially in parallel. Nonetheless, many participants seem to have focused excessively on the interaction with the system rather than the conversation. It took on average less effort to have an effective conversation while interacting via voice control but this also resulted in less focus on the actual task.

Correct Execution of Transfer Steps

During the interview, five out of all twelve participants explained that they first watched the video sequence and then, after watching it till the end, started with the execution of the movements. Participant P2 elucidated it like this:

> "*I thought to myself, okay, I'll focus on learning how to move the patient correctly first, and then I'll take care of the rest.*"

During the second and third rounds of transfers, it was observed that some participants did not watch the videos anymore. They transferred the patient directly and skipped through the videos at the end. They were informed that they had to continue to interact with the system in order to get reliable results. This topic was addressed in the interviews. After asking why they stopped watching the videos, their response was the same. They explained that they already memorized the movements and would not have needed the videos any further.
For the question if the voice commands has had a negative impact on the correct execution on the steps, all twelve participants responded with no. In contrary, four participants said that the head gestures disturbed the movements sometimes. Participant P9 stated during the interview:

> "*Especially when we turned to the left to put the patient in the wheelchair on the left side and I had to turn my head to the right for the next video, the patient kind of arched with me to the right.*"

The mean scores of the NASA-TLX show that the mean physical demand, the mean subjective performance, the mean effort and the mean frustration of the head gesture usage are higher than for voice control. This indicates that the use of head gestures had a negative impact on the task.

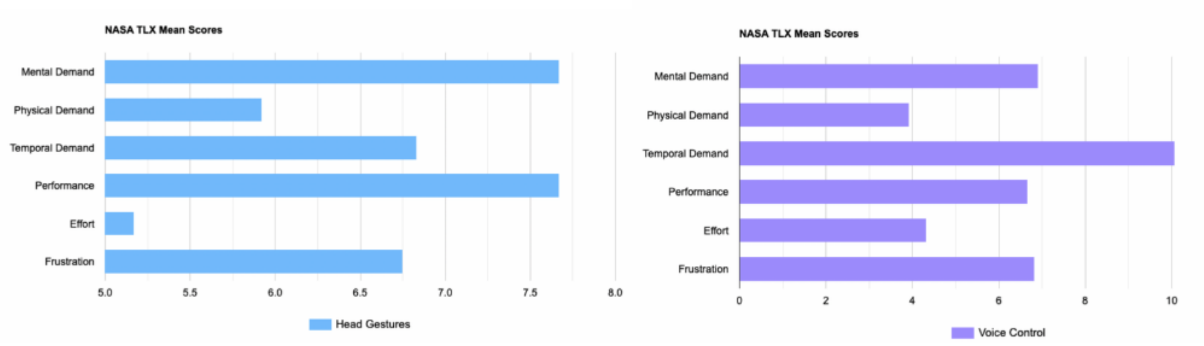

Figure 6.10.: Mean Scores NASA TLX Questionnaire [71]

Finding 3

Some participants watch the instructions before executing the steps, therefore, the interaction method does not disturb the correct execution. All agreed that speaking voice commands has no effect on the correct execution of transfer movements, however, making head movements did in fact negatively influence some of the participants. Furthermore, it seems like the participants understood the technique of the transfer very fast and felt like they did not need the technological assistance anymore.

6.3. Discussion

The findings from the previous section will now be discussed with the aim to answer the Research Questions and formulate implications that could be investigated in future systems that aim to support nurses during patient transfers.

6.3.1. RQ1: Does the use of head gestures or the use of voice commands provide a better user experience?

The first research question was asked to find out if assistive hands-free technology in form of AR smartglasses could make nurses in clinics use a system that not only brings them joy, but also makes them benefit in their jobs and prevent them from getting injured. The overall user experience with the system was, at least according to the qualitative interviews, good. Future research in this domain is suggested. The overall tendency between the two interaction techniques for a better user experience goes towards the direction of head gestures. The UEQ results have shown very similar numbers for both interaction techniques. Especially with regard to *attractiveness* where both values are almost equal. One could speculate that this arises from the use of the Wizard of Oz approach. Both interaction techniques were fast and did not trigger any undesired outcomes. It is obvious that if the Wizard of Oz approach would have not been used during the experiment, the voice command "*okay*" would have caused the Midas Touch Problem many times. In future work, this command should definitely be exchanged for a possible use in a real setting. Many participants also wished for shorter commands instead of "*previous step*" and "*next step*", therefore it should be considered to exchange all three voice commands. During the design phase, it had already been considered to use shorter voice commands, i.e. "previous" and "next" instead of "previous step" or "next step", however, this idea was discarded due to the fear that the patients could mistake these for an instruction towards him, for example, like "Next, please turn around and take my hand". Furthermore, both interaction techniques stand out by very good perspicuity. This implies that the integrated training tasks were a good addition for first-time use. This could also be helpful for the integration into practice and should definitely be considered if such a system will be integrated into clinics.

The majority of participants preferred the head gestures over the voice control interaction. This bias could arise from the fact that this concept of head gestures was completely new to them. In the demographic questionnaire, all participants stated that they had no kind of prior experience with AR glasses, therefore it is safe to say that they had never used head movement detection before. Voice commands are everywhere, on the contrary. Siri, Alexa and many other applications on the market make use of voice commands. Voice Control is nowadays found everywhere, there even exist smart lamps that can be controlled via voice (see e.g. Philips Hue [72]). In the interview, it was stated that *you have to get used to the head movements first.* Future work should focus on a long-term study on the user experience of head gestures.

Another major aspect is the social acceptability that could have an influence on the overall user experience of both techniques, however, this will be discussed in the next section.

Implication 1

Future systems should consider not using ""Okay"" as voice command. Furthermore, for an integration into clinical work, personnel should have the opportunity to train the interaction in their first use.

6.3.2. RQ2: Are head gestures and voice commands socially acceptable?

The Audience and Location Questionnaires have helped to identify that head gestures are on average the more favorable interaction technique in terms of social acceptability. However, this does not mean that the voice control is not socially accepted. This topic is very subjective and the interview results show different ways of thinking: Some think head gestures are inconspicuous and therefore less embarrassing, others see it vice versa. It could be conjectured that this depends on the self-confidence level of the participants. While some might think that they would be judged less because voice commands are *known* among the population, others do not care about what the audience could think about the way they are interacting with the system. It is very important to note that the participants were not even exposed to real patients or visitors that could potentially judge them. In the future, this application should be tested in a more realistic setting.

The results also show that in clinics, the use of head gestures would on average feel more comfortable for the participants than anywhere else (see results from Custom Social Acceptability Location Questionnaire).

Implication 2

People are less ashamed when using head gestures compared to using voice commands. Nevertheless, future work should do a deeper and more realistic research in a real clinical setting.

6.3.3. RQ3: Is communication (both verbal and nonverbal) between patient and caregiver negatively impacted by either the use of voice commands or head gestures?

The results have shown that the communication is definitely affected by the use of an assistive technology. Instead of just focusing on the patient, the caregiver has to execute a second task simultaneously. This was especially mentioned with regard to the interaction via voice commands. On the one hand, the communication had to be stopped every time a voice command was spoken, on the other hand the nonverbal communication was not affected that much because the eye contact was not interrupted. In order to execute a head movement, one has to look away for a moment which takes the focus from the patient.

Implication 3

Voice commands work better with nonverbal communication. In contrary, head gestures do not interrupt the verbal communication.

6.3.4. RQ4: Is the correct execution of the needed transfer steps negatively impacted by either the use of voice commands or head gestures?

The concept behind kinaesthetics transfers are very complex and should be learned or at least heard of once. Only following strict videos will not guarantee a safe transfer. It is a very good approach to watch and study the videos before the actual transfer, like some participants did; however, it is very unrealistic for a real integration into practice because the time is somewhat limited. Future work could simulate the stress factor that exists in real clinics see how the correct execution is influenced. Another really important part that came up during the interviews was the question of *how long* nurses would need to use this system. The approach in this project was to balance out the limitations that some students had to face during the kinaesthetics courses and the lack of follow-up support after the courses. Therefore, the idea was that nurses wear the smartglasses as long as they want to wear them and as long as they need them to get really familiar with the idea behind kinaesthetics. It is not only about just a strict sequence of movements in a video. For future studies, if the participants are not used with the concept, they would definitely benefit from a short introduction into the principles of kinaesthetics.

Implication 4

Future work should respect the time pressure that exists in real clinics. Furthermore, participants should at least know about the basic principles of kinaesthetics.

6.4. Limitations

The results have been evaluated but there are some limitations that need to be stated. It has to be taken into consideration that due to the restrictions of Covid-19 at the time of the study, it was not possible to conduct the study with real nursing personnel. All participants were students with little or no knowledge about patient transfers. It is assumed that nurses attended at least the basic kinaesthetic courses during their education. In addition, professional nurses have much more experience with patient transfers, as it is a task they have to perform multiple times a day. The video instructions are supposed to let nurses experience an *aha-moment* when they realize that they have transferred patients way too complicated and inefficient before. Also, they have no inhibitions when it comes to physical touch. Some participants blushed when they had to touch the patient, for example, on the hips, which is unlikely to happen in real life with real nurses and patients. Another aspect is the fragility of real patients. The person who played the role of the patient during the study was a young 22-year-old girl with no physical impairments. Especially patients who are care-dependent and need help with transferring in the first place are mostly heavily injured. Last but not least, during the study, the participants did not have a time limit, which means that the stress that nurses have in clinics was not simulated. Another important aspect is, that the application only had a small and fixed set of transfer videos. For the future, these could definitely be extended by adding more transfer scenarios.

7. Conclusion and Future Work

This chapter is concerned with how this topic could be addressed and combined in future work. In the end, a conclusion will summarize the key aspects of this work.

7.1. Future Work

One major component that was not addressed in the concept of the application is the lack of feedback. Existing patient transfer applications, such as, for example, the NurseCare application [3]. NurseCare provides in-situ feedback as well as long-term feedback to the nurse through a smartphone and a Bluetooth wearable, which would be a very beneficial addition to the smartglass application.
The system that is described here would in theory also be suitable for other application contexts, like for example, in the automotive industry. Further work could also investigate the use of head gestures in this field.

7.2. Conclusion

This thesis addressed the problem space of the lack of expertise on right movements during patient transfers among nursing personnel. As described in the introduction, nursing-students usually visit kinaesthetic courses during their education, however, previous work has shown that there exist various limitations during these courses and also a lack of follow-up support in clinics. In order to help prevent injuries caused by wrong movements and overexertion during patient transfers, this work presented an application that shows video instructions on AR smartglasses that guide nurses step-by-step during a transfer in a clinical setting. Since they need their hands on the patient, a hands-free interaction concept was needed. The procedure of finding the "perfect match" started off by an in-depth analysis of existing work and applications, followed by defining the requirements that the interaction concept must fulfill. The aim was to find suitable hands-free interaction techniques that seemed promising in relation to the requirements and that were worth further investigation to see if they would be a good choice for integration into the daily routine of healthcare workers. As a second step, the design concept and implementation were described from the very first idea to the final application. The generative design process was based on the iterative UX Lifecycle described by Hartson and Pyla [25]. This involved, among other things, a Cognitive Walkthrough to evolve and grow the ideas. Subsequent to the implementation, a comparative study

setting was planned that aimed to set the two chosen interaction techniques side by side. Study participants tested both the interaction via head gestures and the interaction via voice commands. The study design followed another iterative process model, the DECIDE Framework [26]. The main goals of this study were to find out how these two interaction techniques performed in terms of user experience, social acceptability, verbal and non-verbal communication, and how far they might disturb the correct movements during a patient transfer.
The data collection involved qualitative and quantitative methods, namely, interviews, questionnaires, and log files. A Wizard of Oz approach, combined with implemented logging was used for the execution. The study results show excellent ratings in perspicuity for both interaction techniques but generally a very similar user experience. However, head gestures seem to outperform voice commands in almost every category: In addition to being the favorite choice of most of the interviewed participants, they also deliver better results with regard to social acceptability and better communication flow with patients during the transfer. Concluding, even though there is much room for improvement, an advanced version of the AR application proposed here that shows ergonomic video instructions during patient transfers could be - in combination with head gestures - a very beneficial addition to the medical sector in the future.

A. Appendix

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A.1. Study Documents

Willkommen

Ela Ipekli
Universität Konstanz

Sehr geehrter Teilnehmer,

Ich freue mich, dich bei meiner Studie für meine BA-Arbeit begrüßen zu dürfen. In diesem Schreiben möchte ich dir allgemeine Informationen zur Studie geben und dich aufklären. Das Thema der Studie ist die handfreie Interaktion mit einer Augmented Reality Brille während dem Transfer von Patienten bei der Arbeit im Klinikum. Wir probieren heute auf zwei verschiedene Arten der Interaktion aus. Der geplante Durchlauf sieht wie folgt aus: du wirst beim Aufsetzen der Brille zunächst einmal in einem Menü landen, in dem du das Transferszenario und den Mobilitätsgrad des Patienten auswählen sollst. Danach werden dir Schritt-für-Schritt Videoinstruktionen angezeigt. Die Idee ist, dass du zwischen diesen Videosequenzen hin und her springst indem du die gewünschte Interaktion ausführst. Ich werde dir alle Befehle zu Beginn der Studie demonstrieren.

Beigefügt zu diesem Dokument sind noch eine Einwilligungserklärung und ein demografischer Fragebogen. Ich bitte dich, dir beides durchzulesen und die Erklärung zu unterschreiben.

Nach jeder Durchführung des Experiments wird es noch jeweils einen Feedback Fragebogen geben. Außerdem möchte ich am Ende ein kurzes Interview machen, in dem ich dir ein paar Fragen stelle. Abschließend erhältst du dann deine Auszahlung und die Auszahlungsbestätigung.

Falls du noch unbeantwortete Fragen haben solltest, kannst du mich jederzeit ansprechen.
Vielen Dank, dass du dir die Zeit genommen hast, hier herzukommen.

Mit freundlichen Grüßen

Ela Ipekli
Studiendurchführerin

04. APRIL 2022 Teilnehmer-ID: ___________

Einwilligungserklärung

1. **Was ist das Ziel dieser Studie?**
   Ziel dieses Forschungsprojekts ist es zu verstehen, wie sich zwei ausgewählte Arten der Interaktion während dem Transfer eines Patienten unterscheiden. Nicht du als Teilnehmer wirst getestet! Die grundsätzliche Intention ist, lediglich neue wissenschaftliche Erkenntnisse aus den unterschiedlichen Systemvarianten zu gewinnen.

2. **Aufzeichnung:** Audio und/oder Videosequenzen können bei der Durchführung aufgenommen werden um spätere Auswertungsschritte zu vereinfachen.

3. **Risiken:** Mit dieser Studie sind im Normalfall keinerlei erwarteten Risiken verbunden. Da deine Teilnahme allerdings physische Interaktion erfordert, besteht natürlich ein Verletzungsrisiko. In diesem Fall haften wir nicht.

4. **Zeitaufwand:** Wir schätzen, dass das Experiment nicht länger als 60 Minuten dauern wird.

5. **Auszahlung:** Deine Teilnahme wird mit 10€ vergütet.

6. **Teilnehmerrechte:** Wenn du dieses Formular gelesen und dich entschieden hast, an diesem Projekt teilzunehmen, verstehe bitte, dass deine Teilnahme freiwillig ist und du das Recht hast, deine Einwilligung jederzeit zu widerrufen oder die Teilnahme abzubrechen. Deine Identität wird in keinem veröffentlichten und schriftlichen Material, das sich aus der Studie ergibt, offengelegt. Deine Informationen werden nur **pseudonymisiert** in Übereinstimmung mit dem Einwilligungsformular und den gesetzlich vorgeschrieben Regeln verwendet. Du hast das Recht, eine Löschung deiner erhobenen Daten zu beantragen. Nach Auswertung oder Veröffentlichung der Daten ist dies jedoch nicht mehr möglich.

Teilnehmer-ID: ___________

Autorisierung zur Verwendung Ihrer Ergebnisse für Forschungszwecke

Da die Informationen persönlich und privat sind, dürfen sie im Allgemeinen nicht ohne deine schriftliche Genehmigung in einer Forschungsstudie verwendet werden. Wenn du dieses Formular unterschreibst, gibst du diese Genehmigung.

Ich bestätige hiermit, die Daten wie angegeben zu verwenden.

____

Ela Ipekli, *Human Computer Interaction student at University of Constance*

Ich bestätige hiermit, alles durchgelesen zu haben und mit den vereinbarten Konditionen einverstanden zu sein.

____

Unterschrift des Teilnehmers / Datum

Demographischer Fragebogen

Alter: ________________

Geschlecht: ☐ männlich ☐ weiblich ☐ divers: _________

Bist du aktuell beruflich tätig? ☐ ja, ich arbeite als ______________________ ☐ nein

Bist du aktuell in Ausbildung oder studierst du? ☐ StudentIn ☐ Auszubildende(r) ☐ keines der beiden

(ggf.) Studiengang: _______________________

(ggf.) Fachsemester: _______

Hast du schon einmal einen pflegebedürftigen Menschen transferiert bzw. mobilisiert? ☐ ja ☐ nein

Hast du berufliche Erfahrungen im klinischen Bereich? ☐ ja, ______________________ ☐ nein

	sehr Technik-affin	1	2	3	4	5	**gar nicht Technik-affin**
Wie Technik-affin würdest du dich einstufen?		☐	☐	☐	☐	☐	

	sehr häufig	1	2	3	4	5	**sehr selten**
Wie häufig benutzt du Sprachkommandos (z.B. für Siri oder Alexa) im Alltag?		☐	☐	☐	☐	☐	

Teilnehmer-ID: ______

Hast du Erfahrung mit Augmented Reality Smartglasses?

- ☐ ja, mit ______________________
- ☐ nein

Kennst du eine (oder mehrere) handfreie Interaktionstechniken? Wenn ja, welche?

- ☐ ja, ______________________
- ☐ nein

Leidest du an einer Sehschwäche?

ja, ich bin ☐ kurzsichtig ☐ weitsichtig

☐ nein

Falls ja, korrigierst du deine Sehschwäche? (z.B. durch eine Brille oder Kontaktlinsen)

- ☐ ja, mit ______________________
- ☐ nein

Leidest du an Schulter-, Becken- oder Rückenbeschwerden?

- ☐ ja, ______________________
- ☐ nein

Teilnehmer-ID: _____

Interaktionstechnik: ______________________________

Der nachfolgende Fragebogen besteht aus Gegensatzpaaren von Eigenschaften, die Systemvariante haben kann. Abstufungen zwischen den Gegensätzen sind durch Kreise dargestellt. Durch Ankreuzen eines dieser Kreise kannst du deine Zustimmung zu einem Begriff äußern.

	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

Quelle: https://www.ueq-online.org

Teilnehmer-ID: _____

Interaktionstechnik: ________________________________

Bitte beurteile auf der folgenden Skala, inwieweit du den Aussagen zustimmst.

Wie angenehm wäre es dir diese Form der Interaktion in der Anwesenheit folgender Personen zu nutzen?

	sehr unangenehm	***1***	***2***	***3***	***4***	***5***	***sehr angenehm***
in Anwesenheit meiner Freunde		☐	☐	☐	☐	☐	
in Anwesenheit meiner Familie		☐	☐	☐	☐	☐	
in Anwesenheit meiner Kollegen		☐	☐	☐	☐	☐	
in Anwesenheit meines Partners		☐	☐	☐	☐	☐	
in Anwesenheit von Fremden		☐	☐	☐	☐	☐	
wenn ich alleine bin		☐	☐	☐	☐	☐	

Wie angenehm wäre es dir diese Form der Interaktion an den folgenden Orten zu nutzen?

	sehr unangenehm	***1***	***2***	***3***	***4***	***5***	***sehr angenehm***
Zuhause		☐	☐	☐	☐	☐	
in öffentlichen Verkehrsmitteln		☐	☐	☐	☐	☐	
auf dem Gehweg oder Bürgersteig		☐	☐	☐	☐	☐	
in einem Pub oder Restaurant		☐	☐	☐	☐	☐	
bei meiner Arbeit		☐	☐	☐	☐	☐	
bei der Arbeit mit Patienten im Krankenhaus		☐	☐	☐	☐	☐	

Interaktionstechnik: ________________________________

Bitte beurteile auf der folgenden Skala, inwieweit du den Aussagen zustimmst.

	ich stimme überhaupt nicht zu 1	2	3	4	5 ***ich stimme vollkommen zu***
Ich war mir der Anwesenheit meines Gesprächspartners, d.h. des Patienten, sehr bewusst.	☐	☐	☐	☐	☐
Während der Kommunikation mit dem Patienten konnte ich mich auf die anstehende Aufgabe konzentrieren.	☐	☐	☐	☐	☐
Während der Kommunikation mit dem Patienten konnte ich leicht erkennen, wenn mein Partner beschäftigt war und mir nicht zuhörte.	☐	☐	☐	☐	☐
Ich konnte leicht erkennen, wann der Patient sich auf das konzentrierte, was ich sagte.	☐	☐	☐	☐	☐
Die Art der Kommunikation unterstützte die Zusammenarbeit.	☐	☐	☐	☐	☐

	sehr positiv 1	2	3	4	5 ***sehr negativ***
Deine Eindrücke von Ihrem Gesprächspartner:	☐	☐	☐	☐	☐
Gib bitte eine Gesamtbewertung der Kommunikationsmöglichkeiten.	☐	☐	☐	☐	☐

	sehr viel Aufwand 1	2	3	4	5 ***sehr wenig Aufwand***
Bitte bewerte nun danach, wie viel Aufwand du für eine effektive Konversation empfandest.	☐	☐	☐	☐	☐

Teilnehmer-ID: _____

Interaktionstechnik: ________________________________

Bitte gib jetzt für jede der unten stehenden Dimensionen an, wie hoch die Beanspruchung war. Markiere dazu auf den folgenden Skalen, in welchem Maße du dich in den sechs genannten Dimensionen von der Aufgabe beansprucht oder gefordert gesehen hast.

Beispiel:

X

gering hoch

Geistige Anforderungen
Wie viel geistige Anstrengung war bei der Informationsaufnahme und -verarbeitung erforderlich (z.B. Denken, Entscheiden, Rechnen, Erinnern, Hinsehen, Suchen...)? War die Aufgabe leicht oder anspruchsvoll, einfach oder komplex, erforderte sie hohe Genauigkeit oder war sie fehlertolerant?

gering hoch

Körperliche Anforderungen
Wie viel körperliche Aktivität war erforderlich (z.B. Ziehen, Drücken, Drehen, Steuern, Aktivieren,…)? War die Aufgabe leicht oder schwer, einfach oder anstrengend, erholsam oder mühselig?

gering hoch

Zeitliche Anforderungen
Wie viel Zeitdruck empfanden Sie hinsichtlich der Häufigkeit oder dem Takt, mit dem Aufgaben oder Aufgabenelemente auftraten? War die Abfolge langsam und geruhsam oder schnell und hektisch?

gering hoch

Quelle:NASA Task Load Index (TLX)
Kurzfassung Deutsch

Interaktionstechnik: ________________________________

Leistung
Wie erfolgreich haben Sie Ihrer Meinung nach die vom Versuchsleiter (oder Ihnen selbst) gesetzten Ziele erreicht? Wie zufrieden waren Sie mit Ihrer Leistung bei der Verfolgung dieser Ziele?

gut — schlecht

Anstrengung
Wie hart mussten sie arbeiten, um Ihren Grad an Aufgabenerfüllung zu erreichen?

gering — hoch

Frustration
Wie unsicher, entmutigt, irritiert, gestresst und verärgert (versus sicher, bestätigt, zufrieden, entspannt und zufrieden mit sich selbst) fühlten Sie sich während der Aufgabe?

gering — hoch

Quelle:NASA Task Load Index (TLX)
Kurzfassung Deutsch

Fragebogen für semi-strukturiertes Interview

1 Welche der beiden Varianten (Kopfgesten und Sprachkommandos) fandest du besser? Wieso?

	Vorteile	**Nachteile**
Was war bei den Kopfgesten besser/schlechter?		
Sprachkommandos		

Teilnehmer-ID: _____

Fragen Sprachkommandos

2 Konntest du nebenbei ungehindert **verbal** (d.h. mit Worten) mit dem Patienten kommunizieren? Inwiefern unterschied es sich von normaler verbaler Kommunikation?

Konntest du nebenbei ungehindert **nicht-verbal** (d.h. ohne Worte) mit dem Patienten kommunizieren? Inwiefern unterschied es sich von normaler nicht-verbaler Kommunikation?

3 Haben die Sprachkommandos bei der korrekten Ausführung der Bewegungen bei dem Transfer gestört? Inwiefern?

4 Würdest du andere Sprachbefehle bevorzugen? Wenn ja, welche und warum?

Fragen Kopfgesten

5 Konntest du nebenbei ungehindert **verbal** (d.h. mit Worten) mit dem Patienten kommunizieren?

Konntest du nebenbei ungehindert **nicht-verbal** (d.h. ohne Worte) mit dem Patienten kommunizieren?

6 Haben die Kopfbewegungen bei der korrekten Ausführung der Bewegungen bei dem Transfer gestört? Inwiefern?

7 Würdest du andere Kopfbewegungen bevorzugen? Wenn ja, welche und warum?

8 Welche der beiden Varianten würdest du eher (in der Öffentlichkeit) im Krankenhaus bevorzugen? Wieso?

9 Welche Variante hat dich deiner Meinung nach beim Transfer des Patienten besser unterstützt? Wieso?

4. APRIL 2022

Auszahlungsbestätigung

Ich bestätige hiermit, die Auszahlung (10€) für die Teilnahme an der Studie erhalten zu haben.

____

Name des Teilnehmers

____

Unterschrift des Teilnehmers / Datum

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