

Concept Development of Suitable User Interfaces for a Non-Intrusive Assistance System in Prehospital Emergency Medicine

Bachelor's Thesis at the
Media Computing Group
Prof. Dr. Jan Borchers
Computer Science Department
RWTH Aachen University

*by
Jonas Bernd Boxler*

Thesis advisor:
Prof. Dr. Jan Borchers

Second examiner:
Prof. Dr. Klaus Radermacher

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Boxler, Jonas
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Abstract

Treating prehospital emergency patients requires rapid decision-making and frequent manual interaction with systems and patients. At the same time, prehospital care faces limited resources in highly variable environments. Consequently, Emergency Medical Services (EMS) personnel face a high cognitive load, which increases the risk of human errors, such as medication dosage miscalculations. While cognitive aids exist, they often lack context awareness. To address this gap, this thesis explores the concept development of a non-intrusive, Assisted Reality (AsR) assistant system designed to present relevant medical information directly in the user's field of view.

Following a requirement analysis, a visual user interface prototype was developed using color waveguide AsR glasses. The concept was evaluated through an explorative user study involving eight EMS professionals who tested the system across three simulated emergency scenarios. The findings indicate that medics value pharmacological assistance, access to critical patient data, and operational support. However, they prefer a user-initiated reference tool over automated clinical decision-making in order to preserve their professional autonomy. Ultimately, this research provides ten core design guidelines for prehospital AsR systems. For instance, it emphasizes the necessity for minimal and peripheral visual interfaces, transparently verifiable data, and hygienic interaction methods.

Überblick

Die Behandlung prähospitaler Notfallpatienten erfordert eine schnelle Entscheidungsfindung sowie häufige manuelle Interaktionen mit Systemen und Patienten. Gleichzeitig ist die präklinische Versorgung mit begrenzten Ressourcen in stark variierenden Umgebungen konfrontiert. Folglich ist das Rettungsfachpersonal einer hohen kognitiven Belastung ausgesetzt, was das Risiko menschlicher Fehler, wie beispielsweise Fehldosierungen von Medikamenten, erhöht. Obwohl kognitive Hilfsmittel existieren, mangelt es diesen oft an Kontextbewusstsein. Um diese Lücke zu schließen, untersucht diese Arbeit die Konzeptentwicklung eines nicht-intrusiven Assisted-Reality (AsR) Assistenzsystems, das darauf ausgelegt ist, relevante medizinische Informationen direkt im Sichtfeld der Anwendenden darzustellen.

Basierend auf einer Anforderungsanalyse wurde ein Prototyp für eine visuelle Benutzeroberfläche unter Verwendung einer farbigen Waveguide-AsR-Brille entwickelt. Das Konzept wurde durch eine explorative Nutzerstudie mit acht Rettungsdienstmitarbeitenden evaluiert, die das System in drei simulierten Notfallszenarien testeten. Die Ergebnisse zeigen, dass die Einsatzkräfte pharmakologische Unterstützung, den Zugriff auf kritische Patientendaten sowie einsatzbezogene Unterstützung schätzen. Sie bevorzugen jedoch ein nutzerinitiiertes Referenzwerkzeug gegenüber einer automatisierten klinischen Entscheidungsfindung, um ihre berufliche Autonomie zu wahren. Letztendlich liefert diese Forschung zehn zentrale Designrichtlinien für prähospitaler AsR-Systeme. Beispielsweise wird die Notwendigkeit von minimalen und peripheren visuellen Benutzeroberflächen, transparent überprüfbar Daten und hygienischen Interaktionsmethoden hervorgehoben.

Bachelor Thesis

for

Mr. Jonas Boxler, Matr.-Nr. 445358

**Topic: Konzeptentwicklung geeigneter Mensch-Maschine-Schnittstellen für ein
nicht-intrusives Assistenzsystem in der prähospitalen Notfallmedizin
 Concept development of a suitable human-machine interface for a non-
intrusive assistance system in prehospital emergency medicine**

Task description:

Treating emergency patients demands rapid decision-making despite initially limited information and constrained resources. Environmental variability, frequent manual interaction with heterogeneous technical systems, and collaboration within non-fixed, ad hoc teams further complicate the task of maintaining consistent treatment quality. To date, emergency care still heavily depends on the cognitive capacities of paramedics and Emergency Medical Technicians (EMTs) to integrate multimodal information and recall Standard Operating Procedures (SOPs) from memory.

To address these challenges, a manufacturer-independent platform is currently under development, aiming to connect diverse systems and services using standardized communication protocols, unified nomenclatures, and established health data standards. By consolidating multiple data streams—from medical devices and services to highly structured team communication (e.g., influenced by Crew Resource Management, CRM)—this platform is expected to enhance systemic situational awareness significantly. To effectively leverage both raw and processed information, appropriate Human-Machine Interfaces (HMIs) must be designed. These interfaces should integrate suitable hardware with user-centered content presentation, delivering relevant information at the right time while minimizing workflow disruptions. A well-designed Emergency Medical Service (EMS) assistant should provide critical, aggregated, and prioritized information—or even actionable instructions—while ensuring usability, efficiency, learnability, and effectiveness. Besides robustness, a key requirement is non-intrusiveness, enabling seamless integration into existing workflows and ensuring robustness under varying operational conditions. This work focuses on designing concepts for human-machine interfaces that fulfill the requirements of a non-intrusive EMS assistance system. The following components are essential:

1. Literature Review – Conduct a structured analysis of existing research and developments in both general HMI technologies and (prehospital) emergency medicine. This includes reviewing state-of-the-art interface concepts and hardware solutions.
2. User and Requirements Analysis – Engage emergency medical personnel to identify representative use cases and derive User Requirement Specifications (URS). Define appropriate evaluation criteria based on these insights.
3. Concept Development – Develop a prototype concept that includes hardware components and potential UI/UX elements, considering relevant standards such as IEC 60601 and IEC 62366.
4. Evaluation and Validation – Perform formative evaluations to assess the concept's usability and user acceptance under realistic conditions.
5. Documentation and Discussion – Provide a clear, structured, and comprehensive analysis of the selected approach and results. Include a critical discussion of their implications and outline potential directions for future improvement.

Supervising Professor

.....
Prof. Dr. Jan Borchers

Assisting Supervisor

.....
Philipp Schollmaier, M.Sc.

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Conventions

Throughout this thesis we use the following conventions:

- The thesis is written in American English.
- The first person is written in plural form.
- Unidentified third persons are described in female form.

Short excursuses are set off in colored boxes.

EXCURSUS:

Excursuses are set off in orange boxes.

Where appropriate, paragraphs are summarized by one or two sentences that are positioned at the margin of the page.

This is a summary of a paragraph.

Chapter 1

Introduction

“Paradox: perform optimally and rapidly”

—Keebler et al. [2017]

Fitts’s law, as put into words by Keebler et al. [2017], describes a speed-accuracy tradeoff. In Emergency Medical Services both are required, making optimal and rapid performance necessary. Patients need to be diagnosed accurately, stabilized, and transported to a hospital. Additionally, EMS personnel work in a challenging environment. They face challenges such as environmental variability, frequent manual interaction with systems and patients, collaboration within non-fixed, ad hoc teams, rapid decision making, limited information, and constrained resources. This opens up potential for errors or time delays. Each challenge contributes to the cognitive load of EMS personnel. For instance, frequent manual interaction with systems and patients makes it difficult to keep track of critical patient data. At the same time, environmental variability adds to their cognitive load since they, for example, need to keep evaluating the scene, safety, and situation.

EMS requires both speed and accuracy, but demanding environments and high cognitive load increase the risk of errors and delays.

The goal of this thesis is to reduce cognitive load through an AsR glass assistant system.

As Keebler et al. [2017] describes,

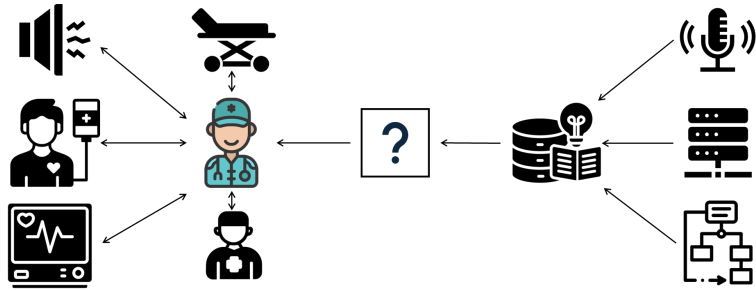


Figure 1.1: Scope of this Thesis. Connecting the inputs (voice, vitals, SOPs) of the assistant system with the user.

"One way to improve memory and cognition is to off-load those processes onto physical artifacts that support decision-making. Specifically, procedures and cognitive aids (e.g., checklists) can help ensure that processes are being done correctly and relevant information is being considered" (Gawande, 2010, as cited in Keebler et al. [2017])

A prehospital assistance system should combine context-aware data integration—from voice, devices, and SOPs—with a minimally distracting Assisted Reality display.

However, current aids are often paper-based, fragmented, or lack context awareness. This indicates a need for minimally distracting, context-aware assistance systems for pre-hospital use. Such a system should combine two key aspects. First, it should be context-aware by gathering and interpreting information from voice data, medical devices, standard operating procedures, and medical algorithms. Second, it should use assisted reality, a subcategory of augmented reality, to present 2D information in the user's field of view. This interface offers a high information capacity, can convey information in noisy environments, and allows users to keep their surroundings visible.

The main research question follows naturally from this gap.

How can an assistant system be designed to support paramedics during EMS scenarios by presenting relevant information in a useful, timely, and minimally distracting way?

The focus of this thesis is, as shown in Figure 1.1, to develop a user interface concept for an assistant system for prehospital medical emergency services. Here, the assumption will be that we are able to gather live voice data from each medic, data from medical devices such as the ECG, and the locally relevant standard operating procedures. Then this information will be used to determine the current emergency context. This includes information about the patient as well as the procedures performed by the EMS personnel. The technical background of gathering and processing this data will not be part of this thesis. Instead, the question mark in figure 1.1 symbolizes the user interface, the focus of this thesis. The thesis will include concept development, requirements, prototype, user study, and evaluation.

The thesis focuses entirely on the UI concept and evaluation, explicitly excluding backend data processing.

1.1 Outline

The remainder of this thesis is structured as follows. Chapter 2 provides the technical and medical background needed to understand EMS work and the challenges addressed by the system. Chapter 3 discusses related work on existing assistance systems for EMS. Chapter 4 derives use cases, feature candidates, and non-functional requirements for an assistant system. Chapter 5 describes the concept development and prototype, including the selection of output modalities, hardware, and user interface design. Chapter 6 presents the user study used to evaluate the concept and prototype. Chapter 7 discusses the evaluation results and presents ten main design guidelines for AsR assistant systems for EMS. Finally, Chapter 8 summarizes the contributions of this thesis and outlines directions for future work.

Chapter 2

Technical and Medical Background

This chapter will first present the tasks of EMS and the challenges they face. Next, the causes of errors and how to mitigate them will be presented.

2.1 Emergency Medical Services

Oster [2024] describe how volunteer medics should treat patients, while Flake [2026] focuses on professional emergency medical technicians (EMTs). Flake et al. [2022] provides a quick reference book for medics, and Jahn et al. [2025], Koppenberg et al. [2024], and Fleischmann et al. [2023] list several emergency scenarios as examples. These sources serve as a detailed reference on the tasks of EMS personnel. Additionally, many of the challenges EMS personnel face become clear when analyzing the mentioned emergency scenarios.

2.1.1 Tasks of EMS Personnel

Firstly, it is important to understand the tasks of EMS

Paramedics and EMTs are the ambulance's staff. They transport patients and perform rescue operations.

(emergency medical services) personnel. Afterwards, supporting their workflow with an assistance system will become more intuitive. In general, paramedics and Emergency Medical Technicians (EMTs) are the staff of an ambulance. They facilitate the transport and care of patients in emergency situations. While this could mean that they transport a patient from hospital A to hospital B, in the following, we will mainly focus on rescue operations. They consist of providing life support and stabilizing a critical patient for transport. Next, we will walk through the steps paramedics take to care for a critically ill patient.

The Scene, Safety, and
Situation comes first.

The first main task of EMS personnel is to ensure the safety of the scene. If the rescue personnel enter an unsafe scene, they might risk their own well-being, thereby also reducing their ability to help others. Therefore, they need to look out for dangerous chemicals, electricity, weapons, power tools, cars, and people. Only after ensuring a safe enough scene can they start diagnosing their patient.

EMS personnel
diagnose the patient.
Some conditions can be
guessed at first sight.

The second primary task of EMS personnel is to assess the patient. This consists first and foremost of visually inspecting the patient. Oftentimes, paramedics might already see the main cause of concern at first glance at a patient. For example, cyanosis, which is when the lips turn blue due to low oxygen saturation, is a clear indicator. Similarly, a stroke can be very obvious. A face with a clear drop of the mouth corner is going to ring the alarm bells of any paramedic. However, even if a medical status might be obvious at first sight, it is still necessary to continue examining the patient.

Communication is key
for EMS staff. They
need to communicate
with the team and
patients.

Communicating with patients is an integral part of EMS personnel's responsibilities. They should explain each procedure and the steps that need to be taken. At the same time, they should calm patients and relatives down or ask bystanders to leave the scene. Likewise, communication within the team is essential. This includes communicating the patient's state and what the next steps are. It also includes communicating clearly during a handover between paramedics and emergency physicians. Communication is even highlighted in the crew resource management (CRM) guidelines for rescue personnel (Rall and Dieckmann). For

instance, Rall et al. [2022] suggest taking about 10 seconds to get every team member on the same page regarding the patient's state and what measures need to be taken in the next 10 minutes. This is called the 10-for-10 rule.

Another primary task of paramedics is to treat patients. Paramedics treat patients based on the xABCDE schema (Thim et al. [2012]). The focus here is on measures to stabilize the patient. Therefore, paramedics ensure that vital parameters are stable. This includes stopping extreme bleeding (X), a clear airway (A), sufficient breathing (B), and stable circulation (C). For instance, in trauma patients, immobilization of the cervical spine is essential to prevent life-long damage.

Treatment follows clear schemas, e.g. xABCDE.

As shown, paramedics perform a great variety of tasks simultaneously. They therefore have a high cognitive load during missions. An excessive workload, limited personnel, rising utilization, increasing demands, new medical knowledge, and changing operating procedures put pressure on paramedics. At the same time, they work in variable environments, with frequent manual interaction with systems and patients, collaborate within non-fixed, ad hoc teams, perform rapid decision-making, use limited information, and work with constrained resources.

EMS work is challenging and EMS staff face high cognitive load.

2.1.2 The Players

EMS is one part of the broader healthcare system and interacts with several other actors along the patient pathway. It includes EMTs, paramedics, and emergency physicians, and it is closely connected to emergency departments, hospitals, general practitioners, dispatch centers, and other involved agencies such as the police and fire department. In Germany, organizations such as the DRK (Deutsches Rotes Kreuz - German Red Cross), ASB (Arbeiter-Samariter-Bund), and Malteser also play an important role in EMS provision.

2.1.3 Medical Devices Found in a Typical Ambulance

Typical ambulances are equipped with a range of medical devices needed for prehospital care, including monitoring systems for vital signs and ECG (electrocardiogram), defibrillators, ventilators, and infusion pumps.

2.1.4 Challenges for EMS Personnel

Environmental
variability

EMS personnel work under highly variable environmental conditions. Depending on the situation, they may have to operate in extreme temperatures, rain, or snow. In addition, the location of an emergency can create further difficulties, for example in narrow hallways, private homes, a moving ambulance, or outdoor environments. Their work is also frequently affected by surrounding distractions such as bystanders, moving vehicles, or animals.

Frequent manual
interaction with systems
and patients

Another major challenge is the frequent manual interaction with both medical systems and patients. EMS personnel must handle medical devices, perform medical procedures such as administering medication or intubation, move patients physically, communicate with patients in order to calm them down or explain procedures, stay in contact with the dispatcher, and document the mission.

Collaboration with
non-fixed, ad hoc teams

Furthermore, EMS personnel often collaborate in non-fixed and ad hoc teams. Depending on the incident, these teams may include people performing first aid at the scene, EMTs and paramedics, emergency physicians and assistants, firefighters, police officers, or tele-EMS physicians. Since these teams are assembled dynamically, effective cooperation and communication are essential.

Rapid decision-making
required

The work of EMS personnel also requires rapid decision-making. They need to determine which medication to administer, which hospital is the most appropriate destination, whether quick transport or preclinical treatment is preferable, and how to ensure the paramedic's own safety.

In addition, EMS personnel often have only limited information available. Unlike general practitioners, they usually have no access to a patient’s medical history and often receive only a few keywords before arriving at the scene.

Limited information

Finally, EMS work is constrained by limited resources. Personnel, time, tools, and medications are often restricted, which further increases the complexity of the mission and places additional pressure on the team.

Constrained resources

2.1.5 Issues EMS is Facing

Due to the challenges mentioned above, the following issues arise for EMS personnel or the patients they care for.

Some issues are due to the organization and how most emergency medical services are operated. For instance, due to the lack of time available to paramedics, documentation is often incomplete or poor Bai et al. [2025]. This also means that sometimes documentation is completed only after the end of the mission Odberg et al. [2025]. Difficult-to-operate documentation systems with text and buttons that are too small on tablets contribute to this issue Odberg et al. [2025].

EMS documentation is often incomplete or delayed because paramedics lack time and the tablet-based systems are difficult to use.

2.1.6 Heuristics in EMS

Other issues that can be found in prehospital medical emergency care are rather due to the nature of human thinking. Specifically, Keebler et al. [2017] explains that humans use heuristics to simplify their thought processes and decision-making. Gigerenzer and Gaissmaier [2011] defines a heuristic as "a strategy that ignores part of the information, with the goal of making decisions more quickly, frugally, and/or accurately than more complex methods." Because of the limited time and resources that EMS personnel have, they have to rely on heuristics. As Gigerenzer and Gaissmaier [2011] explains, heuristics can be beneficial; however, they can also be misleading. Keebler et al. [2017] describe examples of misleading heuristics that can be com-

EMS personnel rely on heuristics under time pressure, but these shortcuts can also lead to misleading judgments and bias.

monly found in EMS. The categories that they define are anchoring and adjustment, availability, and confirmation bias. Each of those heuristics can additionally be found in EMS literature and case studies (see section 2.1.8).

Anchoring and adjustment occurs when first impressions become an anchor that people insufficiently revise after receiving new information, even when the information is unrelated.

The first heuristic, **anchoring and adjustment**, refers to the phenomenon that the information one receives first is taken as an anchor. After receiving new information, people tend to under-adjust from the initially received information, the anchor. Tversky and Kahneman (1974), as cited by Keebler et al. [2017], also claim that the two pieces of information do not have to be contextually linked. They can be completely independent. The authors further explain that this heuristic applies to EMS personnel as well as patients.

Availability causes people to judge something as more likely when similar cases are easy to recall, which can lead to mistaken assumptions in EMS.

The second heuristic, **availability**, makes people overestimate the probability of something occurring, since it is more available to them. For instance, it explains why a medic who has several patients with the same rare disease one after another assumes that this condition is not rare. Keebler et al. [2017] gives a heatwave as an example. Here, EMS personnel will assume that a patient presenting with nausea and circulation problems has a heat-related condition. Availability can also be applied to event medics. For instance, medics working at a theme park might be confronted with several patients experiencing nausea. On a cloudy and cold day, medics will probably assume that the nausea of someone who went on a rollercoaster is caused by the rollercoaster itself. However, that must not be true and further diagnosis is necessary. A detailed anamnesis might reveal alternative causes. Sometimes it could be something like the flu or consuming oral tobacco for the first time.

Confirmation bias is when people favor evidence that supports their hypothesis.

The third heuristic, **confirmation bias**, is similar to the others but focuses on a misleading hypothesis. People tend to only look for information to support their hypothesis and thereby possibly miss information pointing against it.

Some heuristics can improve decisions, as shown by the fast-and-frugal tree, which outperformed a 50-factor logistic regression in detecting acute ischemic heart disease.

Heuristics can be misleading, as shown in the examples above; however, this is not true for every heuristic. As Gigerenzer and Gaissmaier [2011] explains, only considering a specific subset of information to make a decision can lead to better decisions. For instance, Figure 2.1 shows a

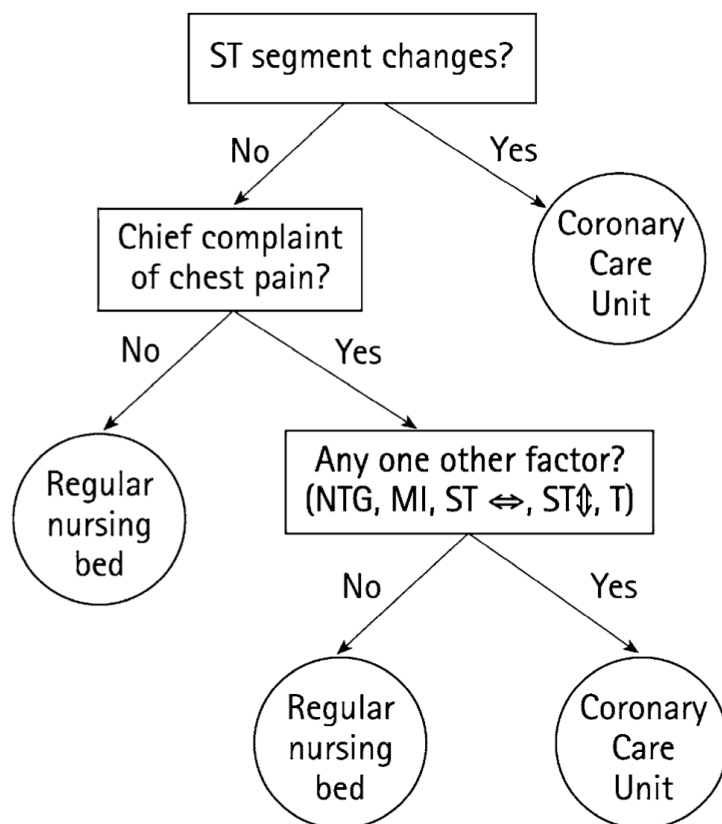


Figure 2.1: Fast-and-frugal tree for the detection of acute ischemic heart disease. This tree outperformed a 50-factor logistic regression in detecting acute ischemic heart disease. Image taken from Gigerenzer and Gaissmaier [2011].

fast-and-frugal tree that was used to detect acute ischemic heart disease in arriving patients at a hospital. The tree only considers a specific element of the patient's ECG (ST segment changes), whether chest pain is the chief complaint of the patient, and, lastly, a few further ECG factors. Green and Mehr (1997), as cited by Gigerenzer and Gaissmaier [2011], found that this tree was more accurate than a logistic regression model that considered 50 factors. Gigerenzer and Gaissmaier [2011] lists several other examples of heuristics that can lead to similarly accurate decisions as more complex methods.

Overall, heuristics are a necessary part of the work of EMS

Heuristics can help or mislead EMS personnel, and later sections discuss them in more detail.

personnel. They can be both beneficial and misleading. Misleading heuristics such as anchoring and adjustment, availability, and confirmation bias are mostly formed unconsciously and without scientific reasoning. They can lead to wrong assumptions and diagnoses. However, heuristics based on scientific reasoning and evidence, like the fast-and-frugal tree shown in Figure 2.1, can improve decision making in fast-paced environments like EMS. In the following sections, heuristics will be further discussed and how they are applied in EMS.

2.1.7 Human Errors

Assistant systems for EMS should account for human error and be designed to prevent or mitigate it without creating new ones.

Norman classifies human errors as slips and mistakes, each with subcategories.

Slips are execution errors, such as failing to place an IV or forgetting a procedure step.

To develop an assistant system concept for EMS, it is important to understand the different categories of human errors. This is because an assistant system should be designed to prevent or mitigate these errors. Additionally, the user interface and the way the assistant system is designed should avoid introducing new sources of errors. Since introducing new potential for errors is unavoidable, the assistant system should plan to mitigate any potential human errors.

Norman [2013] classifies human errors by differentiating between slips and mistakes. He further breaks those categories down into subcategories. Figure 2.2 gives an overview of these categories.

Norman [2013] defines slips as errors that happen when the performed action and the intention of a person do not match. For instance, missing an IV (intravenous catheter) placement would be considered an action-based slip. The paramedic has the correct goal, identifies the right vein, and follows the correct procedure, but the placement of the needle simply fails. This is an example of an action-based slip, since only the execution failed. This could be due to slight misalignment, patient movement, or poor tactile feedback. Another subtype of slips are memory-lapse slips. Continuing with the previous example, a memory-lapse slip would have occurred if the paramedic forgot to perform a step in the procedure of setting up an IV line. For example, omitting the step of disinfecting the skin before inserting the

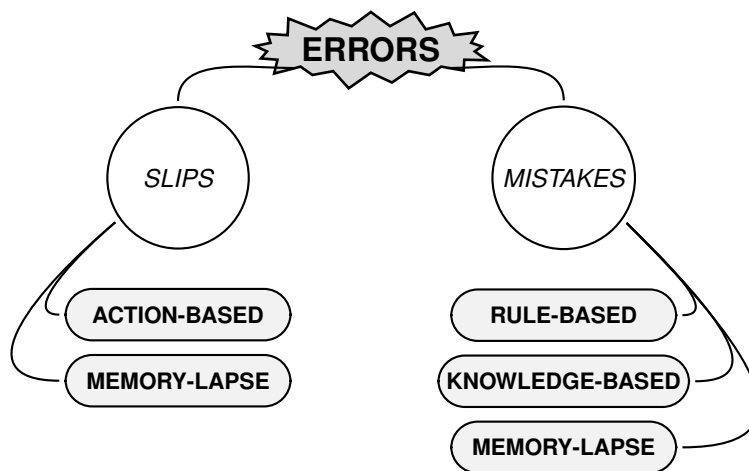


Figure 2.2: Classification of Errors into Slips and Mistakes. Image redrawn based on Norman [2013].

needle would be a memory-lapse slip. This could cause an infection. Both action-based slips and memory-lapse slips are, according to Norman [2013], typical for skilled workers. He explains that slips can happen even if personnel is well trained and are often caused by factors such as long working hours, distracting environments, or multitasking.

Mistakes are another form of errors. In contrast to slips, they occur when the strategy to reach a goal is wrong. Either the person applies the wrong strategy or they apply a known strategy in the wrong context. Additionally, Norman [2013] defines three subcategories. Mistakes can be rule-based, knowledge-based, or memory-lapse mistakes. A mistake is rule-based whenever a faulty rule is applied, a correct rule is applied in the wrong scenario, or the effects of the applied rule are incorrectly evaluated. Additionally, a mistake is knowledge-based if, due to missing or incorrect knowledge, the situation is wrongly evaluated, a wrong goal is set, or a wrong plan is made. Lastly, a mistake is a memory-lapse mistake if, at those same stages of evaluation, goal setting, or planning, something is forgotten.

Mistakes are wrong strategies or judgments, including rule-based, knowledge-based, and memory-lapse mistakes.

The seven stages of action, as shown in Figure 2.3, visualize the process of performing an action. They can be used to further understand during which steps of an action a mis-

The seven stages of action are goal formation, planning, specifying, performing, perceiving, interpreting, and evaluating.

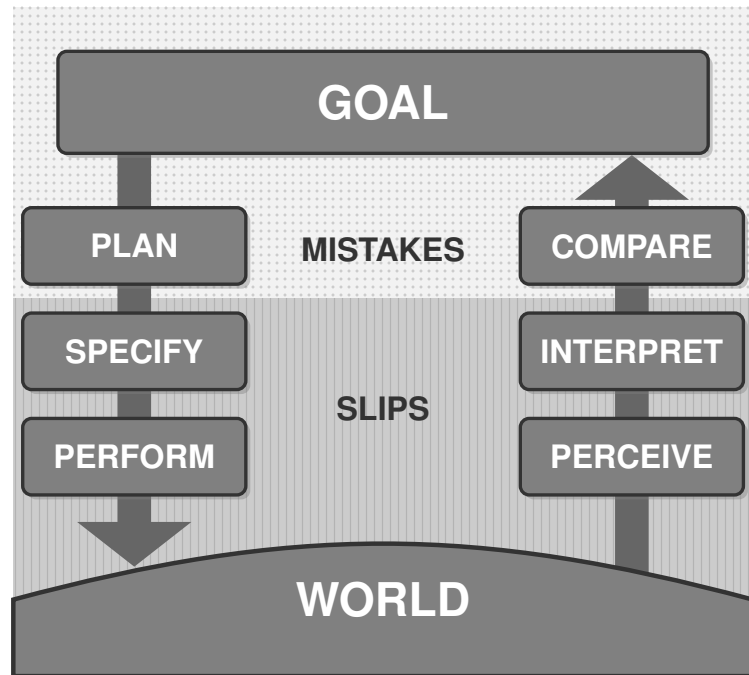


Figure 2.3: The Seven Stages of Action. Image redrawn based on Norman [2013].

take or slip can happen. The seven stages of action consist, according to Norman [2013], of the following steps: 1. forming the goal, 2. planning the action needed to reach the goal, 3. specifying an action sequence, 4. performing the action sequence, 5. perceiving the state of the world and possible changes due to the performed action (including feedback), 6. interpreting the perceived state of the world, and 7. evaluating the action and comparing it to the goal.

Zhang also classifies healthcare errors in earlier action stages, such as a pharmacist confusing Lamictal with Lamisil as a perception mistake.

Zhang et al. [2004] presents a modified version of the seven stages of action and the categorization of human errors specifically for healthcare. For instance, they define mistake categories for the perception, interpretation, specification, and performance stages as well. In contrast, as visible in Figure 2.3, Norman [2013]’s definition of mistakes focuses on the comparison, goal setting, and planning stages. Zhang et al. [2004] gives an example of a perception mistake. A pharmacist was looking for Lamictal (an anticonvulsant) but mistakenly selected Lamisil (an antifungal). Similarly to confirmation bias, the pharmacist only saw the

similarities between the drug names and thereby made a perception mistake.

While Zhang et al. [2004] and Norman [2013] use slightly different terms and definitions, they both aim to identify the underlying causes of human errors. This is done by identifying the exact action step where an error occurs. With this information, solutions can be developed to reduce errors and improve procedures.

Both frameworks locate the action step where an error occurs so it can be reduced or prevented.

2.1.8 Human Errors in EMS

Koppenberg et al. [2024] presents several case studies from German emergency medical services. It aims to list representative cases that are frequent and relevant in EMS. In some of those case studies human errors can be identified.

Koppenberg et al. [2024] presents EMS case studies that include identifiable human errors.

The patient in the first chapter is an unconscious 62-year-old male. His wife calls emergency services and, upon their arrival, they find the patient lying in a hallway. For an unconscious person, both an ambulance and an emergency physician are dispatched to the scene. In this case, the ambulance arrives within 6 minutes of the emergency call and the emergency physician within 14 minutes. Upon the arrival of the ambulance staff, they notice a dog’s loud barking. The wife assures them that the dog would not disrupt the EMS personnel; however, they are still concerned about the dog since its barking is very loud and aggressive. This situation makes communicating with the wife to find possible causes for her husband’s unconsciousness difficult. After the arrival of the emergency physician, the team decides to transport the patient into the ambulance to improve their working conditions. There they induce anesthesia. After doing a 10-for-10, which is a structured team discussion (see 2.2.2 for details), they find out that the blood sugar level has not yet been determined. After checking the blood sugar, they find out that the patient has severely low blood sugar. This makes the previously performed anesthesia unnecessary. The next steps consisted of giving the patient glucose and transporting him to a regional hospital. There the patient woke up after one hour.

An unconscious man was treated for low blood sugar only after a delayed check, making the anesthesia unnecessary.

The missed blood sugar check may have been either a knowledge-based mistake or a stress-induced memory lapse.

In the first chapter, the authors explain that in EMS it is usually standard practice to measure the blood sugar level of a patient whenever an IV line is set up. However, in the described case study the EMS personnel did not follow that standard practice and did not measure the blood sugar level of their patient. As a possible reason, the authors list that the personnel was new and therefore perhaps unfamiliar with the practice. In this case, not measuring the blood sugar level would be a knowledge-based mistake. Here the straightforward solution is further training. However, there is another possible reason for them to miss measuring the blood sugar. The authors explain that at the scene there was a dangerous dog present that stressed the medics out. This or other stress factors could have influenced the medics, thereby making them forget to measure the blood sugar. In that case, the error would be a memory-lapse slip. Here, the solution is not as straightforward as further training. Instead, it would be necessary to identify the stress factors and find ways to mitigate them. For instance, an assistant system could help mitigate this issue by reminding the personnel to measure the blood sugar level whenever they set up an IV line.

The emergency physician wrongly assumed that one step implied another had already been done.

Following the same case study, the authors describe another point for improvement. The emergency physician assumes after their arrival that the ambulance staff already measured the blood sugar level. He further assumes that if the blood sugar had been low, the medics would have notified him. Thereby, he makes a rule-based mistake. He assumes that since A requires B, if B is done A must also have been done.

2.2 Safety Design in Medicine

Safety design in EMS uses cognitive aids and CRM to support staff and improve patient safety.

In order to combat the previously mentioned challenges and issues, safety design can be applied to EMS. This includes, for instance, cognitive aids and crew resource management (CRM). These are existing approaches to support EMS personnel in their work and to improve patient safety. Assistant systems could play a similar role in EMS workflows; therefore, it is important to understand these tools.

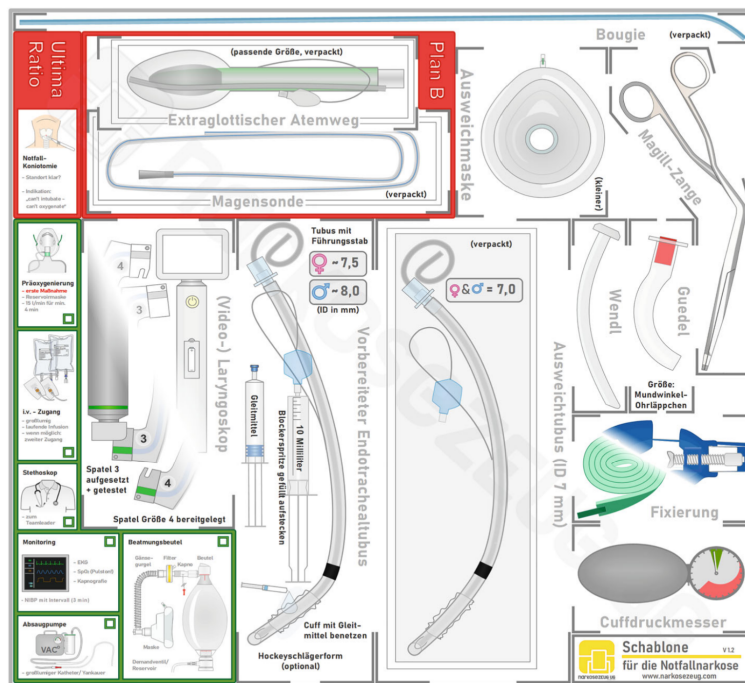


Figure 2.4: RSI Equipment Prep Mat. Image taken from Neumayr et al. [2025]. Image originally from Silja Wurm and Simon Schmidt-Torner [2026]

2.2.1 Cognitive Aids

In EMS, some of the cognitive aids that are in use are checklists, visual templates, memo cards, SOPs (standard operating procedures), and algorithms.

Checklists are often used before a "point of no return" is reached. That could, for example, be checking the ambulance before leaving the station. However, checklists are not ideal for every scenario. For instance, Neumayr et al. [2025] describes that going through a checklist might seem counterintuitive or wasteful of time, especially when done in time-critical situations. Chen et al. [2016] add to this thought by stating that checklists add extra time to the workflow. Especially too many checklists could result in a "checklist fatigue". Nevertheless, the authors also explain that checklists have proven to be effective in situa-

EMS cognitive aids include checklists, visual templates, memo cards, SOPs, and algorithms.

Checklists can prevent errors, but they also add time and can cause checklist fatigue.

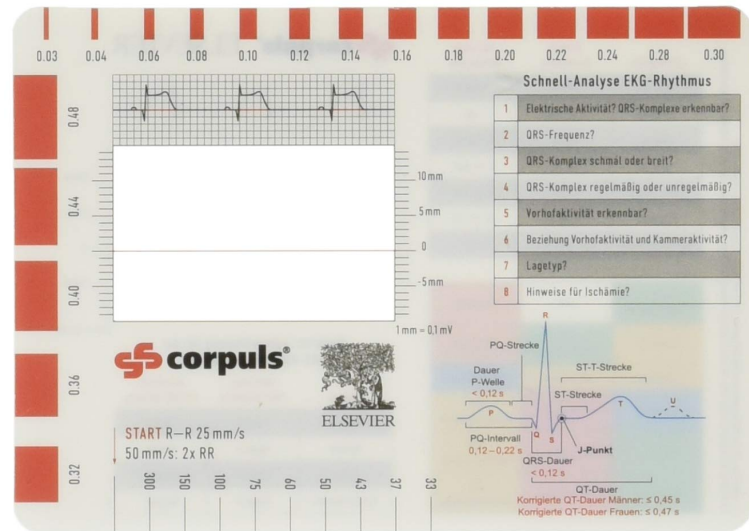


Figure 2.5: ECG-Card. Image originally from Jahn et al. [2024]. Image sourced from Amazon.de.



Figure 2.6: Memo Cards. Used as a quick reference tool by paramedics to look up data for pediatric patients. Image taken from Woods et al. [2019].



Figure 2.7: Dosage label on Epinephrine. Color coded for quick reference. Image taken from Woods et al. [2019].

tions such as prehospital airway management, and to improve the quality of patient care records (PCRs).

Visual templates, on the other hand, allow for a quick oversight if something is missing before starting a procedure. Neumayr et al. [2025] lists a rapid sequence induction (RSI) equipment prep mat as an example of a visual template that is used in EMS. See figure 2.4 for details. Another visual template is the ECG-Card, which can be used to interpret ECGs. For this purpose, the ECG-Card provides measurements and key ECG facts. It can be further placed above a printed-out ECG as mentioned by Jahn et al. [2024]. See figure 2.5 for details.

Visual templates help spot missing items or interpret ECGs quickly using tools like an RSI mat or ECG card.

Memo cards are another form of cognitive aid that is used by EMS personnel. These are small physical cards that EMS personnel can carry with them in their pockets. They contain important information that can be quickly accessed in emergency situations. For example, a memo card might contain the dosages of different medications or the steps for performing a specific procedure. Figure 2.6 shows memo cards which contain medication dosages. They were developed by Woods et al. [2019] and are used for specific pediatric emergency procedures such as rapid sequence intubation (RSI). They have color coded weight categories and corresponding lists of medication dosages. The specific system developed by the authors combines memo cards with color-coded labels on the medication itself. Figure 2.7

Memo cards give EMS personnel quick access to key dosages and procedure steps, especially in pediatric emergencies.

shows a commonly used medication, epinephrine, which is with children mostly used to treat anaphylaxis.

SOPs define step-by-step procedures, and algorithms are their more specific flowchart or decision-tree form.

Additional cognitive aids described by Neumayr et al. [2025] are standard operating procedures (SOPs) and algorithms. Rao et al. [2011] define SOPs as "a specific set of practices that are required to be initiated and followed when specific circumstances arise." They include detailed descriptions for each step of the patient journey. Starting with anamnesis and diagnostics, going to steps towards a preliminary diagnosis, including detailed treatment steps, and describing medication dosages. SOPs will often also include algorithms, which are clear step by step instructions. An algorithm is therefore a sub-category of a SOP. Algorithms are often conveyed through flow-charts or decision trees. An example for a decision tree which is used for the detection of acute ischemic heart disease can be seen in figure 2.1. A flow-chart algorithm can be seen in figure 2.8. Figure 2.8 shows a typical algorithm for EMS. The algorithm covers a specific working diagnosis and the necessary steps to treat it. As Zellerhoff [2026] shows, in EMS SOPs exist for specific medications (e.g. Paracetamol), treatments (e.g. inserting an intravenous line), general procedures (e.g. refusal of transport), main symptoms / clinical pictures (e.g. dyspnea / shortness of breath, shock, central nervous system (CNS) deficit, cardiogenic pulmonary edema), or non-medical rescue strategies.

2.2.2 Crew Resource Management (CRM)

CRM is an aviation-based teamwork and communication approach adapted for medicine, with 15 rules for EMS.

Crew Resource Management originally came from aviation and is a concept to reduce human errors, especially focused on communication and teamwork. CRM was adapted to also fit medicine and prehospital medical emergency services. EMS personnel learn and apply the 15. CRM rules as shown in table 2.9.

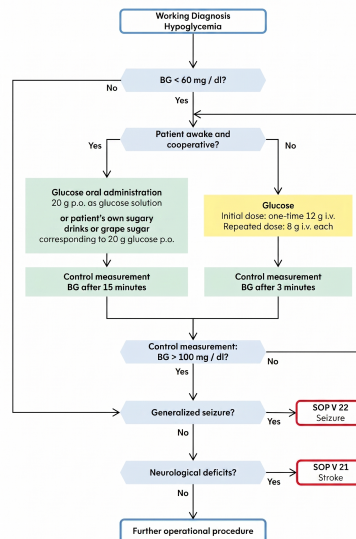


Figure 2.8: Hypoglycemia Algorithm. Image taken from Spielmann and Ziemer [2026] and translated with the help of Google's Gemini.

Table 2.9: CRM Guidelines.

1.	Know the environment
2.	Anticipate and plan
3.	Call for help early
4.	Exercise leadership and followership
5.	Distribute the workload
6.	Mobilize all available resources
7.	Communicate effectively
8.	Use all available information
9.	Prevent and manage fixation errors
10.	Cross (double) check
11.	Use cognitive aids
12.	Re-evaluate repeatedly
13.	Use good teamwork
14.	Allocate attention wisely
15.	Set priorities dynamically

Source: Rall et al. [2022] Originally from Rall M, Gaba DM: *Human Performance and Patient Safety*, in Miller 6th edition 2005

Chapter 3

Related Work

Möllenhoff et al. [2022] explain that there are many approaches to aid paramedics with digital tools. Some are already in use while others are still in research (Zhang et al. [2022]).

In practice, we can find tablets for documentation purposes, software for keeping track of maintenance, and navigation apps in ambulances. Möllenhoff et al. [2022] describe which of those tools are prevalent in German practice. They further mention software for automated communication between the ambulance and the hospital. This may be used to register patients before arriving at the hospital, providing the hospital staff with details about the patient's status. At the same time, according to Möllenhoff et al. [2022], about 6% of rescue stations have teleconsultation available in their ambulances (as of 2022). That means that those ambulances can consult an emergency physician remotely.

In research, we can find prototypes of assistance systems for EMS. Jin et al. [2023], for example, developed a voice interface that can suggest protocols for treating patients. Paramedics would describe their patient condition and receive the top five protocol suggestions on their phone. In contrast, Zhang et al. [2022] used smart glasses combined with voice commands for their system. They focused on a dictation feature that automatically fills in information

Some digital tools are already in use in EMS, others are still in development.

German ambulances use documentation, maintenance, navigation, and hospital communication tools, and some also support remote physician consultation.

EMS research prototypes include voice-based protocol suggestions, hands-free documentation, and smart-glasses support for physician communication.

about the patient in their electronic health record. Therefore, documentation is the key feature of this system. The same authors, Zhang et al. [2024], additionally developed another system using smart glasses. Here the focus is on communication, specifically video calls with physicians and multimedia patient information sharing (images and vitals).

Chapter 4

Requirements

This chapter outlines the requirements for an assistance system for emergency medical services. It first presents candidate use cases and features that define the functional scope of the system. Subsequently, the identified non-functional requirements are discussed.

This chapter presents the system's use cases, features, and non-functional requirements for EMS assistance.

4.1 Methods

The following requirements were identified through literature research, personal experience as a volunteer medic, ambulance work shadowing, observing remote emergency physicians, raw study data, and a user study. The user study will be presented in a subsequent section. Part of the user study was the evaluation of the requirements gathered in this chapter. Considering the use cases, they were categorized, and a few were specifically chosen as focus points. To choose these focus points, current issues in EMS were taken into account, as well as common hurdles found in case studies. For example, some case studies were taken from Koppenberg et al. [2024].

The requirements were derived from literature, field experience, study data, and a user study, and the focus points were chosen based on current EMS issues and case studies.

4.2 Use Case and Feature Candidates

4.2.1 Overview

There are various use cases.	There are several use cases for assistance systems in EMS. They could find a diagnosis, suggest treatments, document procedures, improve quality control, provide real-time translation, navigate, help with disaster triage, and monitor vital signs.
Diagnosis support can help paramedics interpret ECGs, identify hard-to-recognize conditions, and access patient records.	Assistance systems can help with diagnosis, for example, by interpreting an ECG. Specifically, Möllenhoff et al. [2022] describe that currently, some patients need to be sent to the hospital only because the paramedics were not sure about the ECG. EMS personnel also expressed, in a study done by Rinkinen et al. [2024], that "artificial intelligence perhaps gives support in identifying, for example, rare disease states and emergency situations that are otherwise difficult to recognize." Another aspect described by Rinkinen et al. [2024] that could help with diagnosis is access to electronic health records.
Treatment support can warn about dosage limits and suggest the right protocol.	Another use case is suggesting treatment. Wang et al. [2025] suggests using medication reminders for the patients themselves to improve adherence and individualized medicine. Similarly, medication alerts or reminders could be used in an EMS setting. Bai et al. [2025] interviewed 20 EMS staff and found that they would like assistant systems to warn them about maximum medication dosages. In addition, they would like the system to proactively suggest which protocol to follow.
Automated documentation could help hospital staff prepare earlier, support legal protection, and improve currently insufficient EMS records.	Assistant systems should also automatically perform documentation. Zhang et al. [2022] explain that automated documentation would especially be useful for the receiving hospital staff. They could receive documentation about the patient before their arrival, giving them time to get ready for the patient. Wang et al. [2025] more generally considers smart systems as a viable source for electronic health records. Documentation is also important for legal reasons, to protect paramedics and emergency physicians. For example, if something is missing from documentation, it will

legally be assumed that it did not take place. In Germany, according to law, Gesetzgeber [1896], documentation is required for all medical procedures, and it must be complete and accurate. However, an analysis of emergency protocols in the German city Aachen, Klein et al. [2022], revealed that about 68,4% included suspected diagnoses and 2,7% complete vital parameters. The authors conclude that documentation is not sufficient. Assistant systems that could automate the generation of documentation present a possible solution.

A further use case for assistant systems is quality control. Combined with automatic documentation, quality management systems could give EMT personnel individualized feedback. Möllenhoff et al. [2022] similarly expresses that digital documentation could be used for quality management and that QM is of great relevance for EMS.

Quality control can use documentation data to give EMTs individualized feedback and support quality management.

EMTs and paramedics often mention specific mini tools when questioned about digital support systems for EMS. For instance, Zhang et al. [2022] implemented functionality to gather medication information by scanning barcodes. They also implemented a camera to take pictures hands-free, something that was also mentioned by Möllenhoff et al. [2022]. Wang et al. [2025] discusses real-time translation as well as navigation and positioning.

EMS users often mention barcode scanning, hands-free photo capture, real-time translation, and navigation as useful mini tools.

4.3 In Depth Use Cases

4.3.1 Workflow Support

Many procedures in emergency medical care are covered by standard operating procedures (SOPs). Chen et al. [2016] describes the rise in SOP development in EMS, while Zellerhoff [2026] provides a collection of SOPs used in several German regions, including Aachen. An assistant system could help EMS personnel by quickly retrieving and displaying the relevant SOP for the current situation.

An assistant system could quickly retrieve and display the relevant SOP for the current situation.

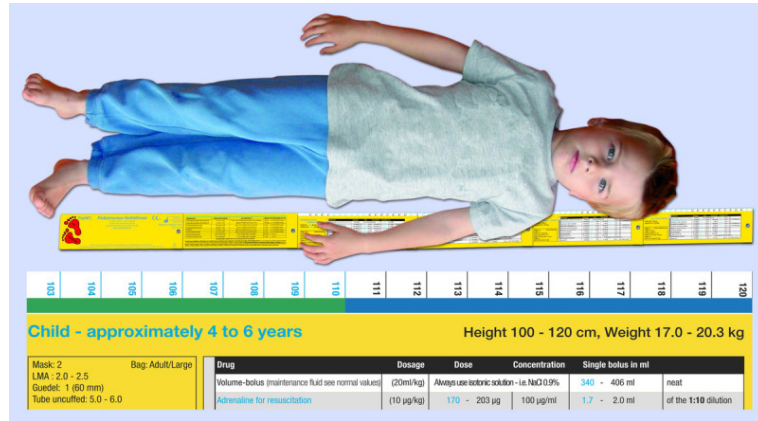


Figure 4.1: Pediatric Emergency Ruler. Image taken from Kaufmann et al. [2021].

4.3.2 Medication Decision Support

Medication decision support can provide dosage and contraindication guidance while factoring in allergies and current medications.

Assistant systems reduce prevalent medication errors by automating calculations and protocol checks.

Another specific use case is medication decision support. Here, the focus is on giving dosage information, contraindications, alternative medications, and further relevant information for the medication process. This will also include medical data gathered from the patient's electronic health record. That way, allergies and current medication can be taken into account.

Medication decision support is a relevant use case since it could reduce medication errors. In detail, a self-reported medication errors survey done in San Diego County, California, USA, with 352 participants Vilke et al. [2007] found that 9,1% reported having committed a medication error in the last 12 months. Of that 9,1%, 63% were dosage errors, 33% protocol errors, and 4% wrong medication errors. Additionally, 21,9% of the reported medication errors involved pediatric patients. Of those pediatric medication errors, 42% were dosage errors. Vilke et al. [2007] further describes the following reasons for medication errors: failing to triple-check, infrequent use of the medication, dosage calculation errors, and incorrect dosages given. These are also the exact errors an assistant system would address by calculating dosages and checking if the conditions are met for giving the medication.

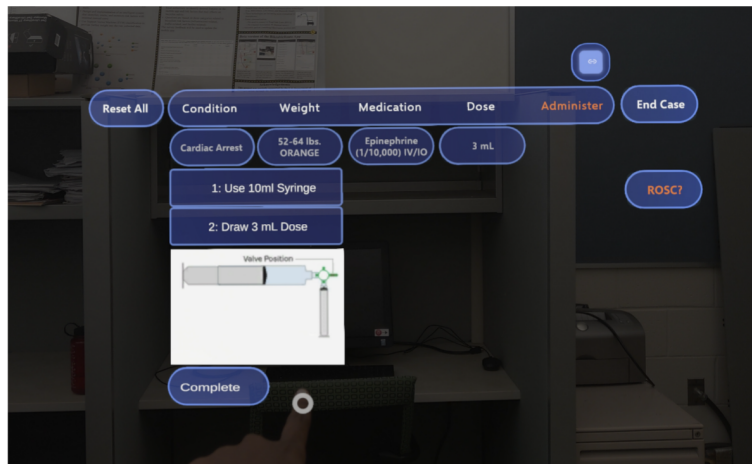


Figure 4.2: Mixed Reality Application for Pediatric Medication. Image taken from Ankam et al. [2024].

The previously mentioned percentages make it clear that pediatric cases are especially of concern. This is due to the fact that dosages need to be calculated for each individual patient based on weight. Kaufmann [2025] explains that it is therefore more difficult for paramedics to give pediatric patients the right dose, since they cannot memorize dosages. There are a few tools used to combat dosage errors with pediatric patients. One of them is the emergency ruler presented in a study done by Kaufmann et al. [2018]. It works by placing the ruler next to the patient and then reading off key information on the side of the ruler. This includes applicable sizes of medical devices such as masks and tubes, dosage information, and typical vital parameter ranges. See figure 4.1 for an example. The authors claim that the emergency ruler could reduce medication errors by 90%. Another one, which is still in its research phase, is a mixed reality application to reduce pediatric medication errors in prehospital emergency care. Ankam et al. [2024] presents a solution where medical staff are guided step by step through the medication process.

Concerning patients in general, measures such as the smart placement of medication in the ampule kit are used. Kaufmann [2025] describes, for instance, that similarly named medications are not placed next to each other.

Specialized physical and digital tools effectively mitigate the high risk of weight-based pediatric dosing errors.

Smart spatial organization of ampules mitigates the risk of medication mix-ups.

4.3.3 Handover (to Emergency Physician or Department)

Automated
documentation systems
prevent critical
information loss during
high-risk patient
handovers.

The fourth specific use case is the handover of patients to the emergency physician or to the hospital. Braverman et al. [2026] states that this is a critical moment where information can be lost. Braverman et al. [2026] found in their study done in Israel, for instance, in 36,1% of handovers, treatment details were missing, and in 55,4%, allergy details were missing. An assistant system could help with this by automatically documenting the patient's condition and the procedures performed, and giving a case report to hospital staff, in addition to an in-person handover Bloos et al. [2020]. This could improve patient safety by ensuring that all relevant information is communicated effectively during the handover process. Additionally, according to Bollie [2025], improving handovers is often overlooked, and EMS research is rather focused on improving medication dosages or other aspects that have less impact on patient outcomes. Therefore, this use case is worth investigating further.

4.4 Non-Functional Requirements

Operational and
environmental EMS
challenges directly
define the system's
non-functional
requirements.

As presented in section 2.1.4, EMS personnel face several challenges due to the nature of their work. Challenges such as environmental variability or frequent manual interaction with systems and patients shape non-functional requirements for an assistant system. Through those challenges and additional literature, non-functional requirements can be defined. They then consist of hardware and workflow requirements.

The system must
operate reliably
regardless of weather,
physical location, or
PPE requirements.

The assistant system needs to function in varying environments. This could refer to weather, and therefore it should work in any weather condition as described by Sumner et al. [2025]. Additionally, the work environment might be contaminated and therefore require the use of personal protective equipment (PPE). Multiple different types of PPE (e.g. gloves, goggles, masks, face shields, hazmat suits)

need to be supported by the assistant system as explained by Bai et al. [2025] and Sumner et al. [2025]. Moreover, the system should work independently of the medic's location. As medical staff works in tight hallways, in the moving ambulance, at a patient's home, in nature, or in large crowds, Odberg et al. [2025] presents, for instance, the issue of vibrations while driving.

In the field of EMS, frequent manual interaction with systems and patients presents a further challenge. Zhang et al. [2024] for example suggests using touchless interaction to interact with digital systems. Due to the frequent switching between systems and patients, hygienic requirements arise. Cobus et al. explains that the surface of a digital device needs to be disinfectable. As medics are performing various manual tasks, the device should also be made of breathable material. Cobus and Heuten [2019] describes that this is to prevent discomfort while sweating. They go further to explain that the hardware of the assistant system should be worn on the body to ensure that it does not get lost. Medics already have to ensure that they do not forget their equipment onsite. Having to carry and take care of another physical device could possibly add to the cognitive load of medics. Cobus and Heuten [2019] further require a device to be small and lightweight. Medics should likewise not have to worry about battery life or connection stability.

Manual EMS workflows demand non-intrusive, hygienic, and reliably wearable assistant systems.

Taking care of emergency patients requires teamwork and thereby interaction between everyone involved. An assistant system should not interfere with that interaction. It should further not negatively impact communication with patients as explained by Dosani et al. [2012]. That means that, for instance, some information needs to be hidden from the patient. Additionally, the UI should consider the patient's emotions. Bai et al. [2025] suggests that a loud alert can impact the patient's emotions negatively. Moreover, a paramedic asking the system about medication dosages openly might reduce the patient's trust in the paramedic's capabilities. Hidden input should therefore be possible.

Discreet system interactions are essential to maintain patient trust and preserve team communication.

Emergency patients further require time-critical treatment. Information should be shown without delays. Hardware

The system must guarantee zero-delay performance while utilizing cost-effective, adaptable hardware.

should be performant. Cobus and Heuten [2019] additionally describes that devices should be reusable, detachable, and fit multiple people in order to keep costs low.

Chapter 5

Prototype Concept Development

5.1 Methods

This work focuses on a visual user interface. An augmented reality glass, the Rayneo X3 Pro, is used to visually display information to medics. Users are able to interact with the system through swiping gestures on the frame of the glasses. The following chapter describes the decision-making process of selecting and building this user interface.

This chapter outlines the rationale behind selecting the gesture-controlled AR glass visual interface.

5.2 Perception Modalities

Human perception can be divided into vision, audition, somesthesia, olfaction, and gustation, as described by Proctor and Proctor [2021]. For the intended prehospital medical emergency assistant system, vision, audition, and somesthesia were considered as possible output modalities. Olfaction and gustation were excluded because, at the time of writing, they are difficult to control and impractical in EMS environments.

Practical constraints in EMS environments limit system output to visual, auditory, and somatosensory modalities.

5.2.1 Vision

Vision offers a highly dense, private method for information display.

Vision was selected as the primary modality because it can present large amounts of information. It is also private, as the display can, for instance, be hidden from the patient or bystanders.

Handheld devices are unsuitable because they occupy hands and cause retrieval delays during manual tasks.

Several visual implementations were considered. Handheld devices, such as smartphones or tablets, are already widely available and can display large amounts of information. Existing medical apps, for example dosage calculation apps, show that such devices are already used in practice. However, they occupy the user's hands, which is problematic since medics need to frequently interact manually with patients and systems. Additionally, they need to be retrieved from pockets and therefore may induce delays or be ignored if the hands are occupied.

Despite hands-free advantages, smartwatches are hindered by small displays and debated infection risks.

Wrist-mounted displays and smartwatches can provide critical information hands-free. Ma et al. [2025] investigated their use for alarm response in intensive care units, while Ali and Li [2019] applied them in nursing homes. Ali and Li [2019] was able to improve alarm response compared to traditional lights on each door and a central display in the nurses' station. However, the display size of smartwatches is limited. Hygiene is also a concern, as wristwatches have been described as a potential infection control hazard by Jeans et al. [2010]. Nevertheless, newer studies suggest that smartwatches may not significantly increase infection risk Ang et al. [2025].

Peripheral lights and static printed paper lack the detail or interactivity required for modern assistant systems.

Peripheral light displays can be useful for simple alerts or urgency indications, as explained by Cobus and Heuten [2019]. However, they cannot communicate detailed information. Printed paper is still widely used in Germany to analyze ECGs in EMS; however, it is static and does not support interaction.

AR glasses offer flexible, hands-free displays, but pose risks of visual obstruction and discomfort.

Augmented reality glasses provide information directly in the user's field of view. They convey information hands-free and without delay. They are flexible, since they may display small indicators as well as a large information

block. At the same time, they can disturb the field of view and be uncomfortable to wear.

5.2.2 Audition

Auditory output can provide information without requiring visual attention. This can be useful when the user's eyes are focused on the patient or environment. However, medical and emergency settings are often noisy, and auditory alarms can interfere with team communication or contribute to alarm fatigue.

Despite enabling eyes-free monitoring, auditory systems risk causing alarm fatigue and disrupting vital team communication.

Bone conduction was considered as one auditory implementation. It can provide relatively private audio output compared to external speakers Cobus and Heuten [2019]. Nevertheless, other previously mentioned drawbacks remain. It was therefore considered only as a possible supplementary modality.

Privacy benefits notwithstanding, inherent auditory drawbacks limit bone conduction to a supplementary modality.

5.2.3 Somesthesis

Somesthesis, especially vibrotactile feedback, was also considered. Vibrotactile displays are private and can be perceived independently of visual attention. Dosani et al. [2012] describe touch as an obligatory and unidirectional channel, allowing users to receive signals regardless of their current visual focus.

Vibrotactile feedback offers a private, non-visual method for guaranteed signal reception.

Vibrotactile displays have been studied for clinical alarms and physiological monitoring. Cobus et al. [2018], Dosani et al. [2012], and Barralon et al. [2009] describe that they are especially suitable for simple alerts, urgency levels, or changes in vital parameters, because such information can be mapped to vibration patterns or directions.

Vibrotactile patterns effectively convey simple clinical alerts and urgency levels.

However, tactile data displays can only convey a limited amount of information. Users may also require training to interpret vibration patterns accurately, as shown by Barralon et al. [2009]. For these reasons, vibrotactile displays

Information limits and training needs confine tactile displays to a supplementary modality.

were considered promising as a supplementary modality, but not as the primary interface for a multi-use-case assistant system.

5.2.4 Modality Selection

High information capacity makes vision the primary modality, supported by supplementary auditory and tactile alerts.

Based on this comparison, vision was selected as the primary output modality. It provides the highest information capacity and is well suited for structured medical information. Auditory and vibrotactile feedback may be useful as additional channels for alerts or confirmations, but they were not implemented as the main modality in this prototype.

5.3 AR Glass Selection Process

Technical and practical requirements for a visual display necessitated the exclusion of "camera-only" smart glasses.

The prototype requires AR or HUD glasses that can display custom visual content to the user. Therefore, "camera-only" smart glasses were excluded, since they do not provide a visual output channel. The selection process was based on both technical and practical criteria.

5.3.1 Selection Criteria

The following criteria were used to compare available AR glasses:

1. **Display capability:** The device must include an integrated display.
2. **Custom content support:** The device should allow custom content through an open API, Android app support, a web browser, screen mirroring, or use as an external display. Support as an external display is especially useful for rapid prototyping and testing.

3. **Low obstruction of view:** The glasses should obstruct the user's view as little as possible. This includes both the physical frame and the tint of the lenses.
4. **Availability:** The device should be purchasable in Germany, ideally by invoice.
5. **Technical specifications:** Relevant specifications include display resolution, color support, brightness, field of view, and battery life.
6. **Price:** The device should be affordable within the scope of the prototype development.

5.3.2 Considered Device Categories

The considered devices can be grouped into three main categories.

Color High-Resolution Birdbath Glasses

Birdbath glasses usually provide high-resolution color displays and often support connection as an external display. This makes them attractive for rapid development, since custom content can be tested through screen mirroring or standard display output. Examples include the Xreal One, Viture Luma, and Rokid Max.

Birdbath models are advantageous for rapid prototyping due to their high-resolution color displays and external connectivity.

However, birdbath glasses often have darker lenses and a larger optical structure. This can obstruct the user's view more than desired for EMS use, where continuous awareness of the patient and environment is important.

Bulky optical structures and dark lenses make birdbath glasses unsuitable for maintaining vital situational awareness.

Color High-Resolution Waveguide Glasses

Waveguide-based AR glasses can provide a more transparent display and may resemble regular glasses more closely. They are therefore promising for use cases where the user

Transparent waveguide displays enable essential visual contact with the real-world environment.

must maintain visual contact with the real environment. Examples include the RayNeo X3 Pro and Inmo Air 3.

Device-specific development demands greater effort but yields enhanced integration with native interaction features.

A disadvantage is that development is often more device-specific. Instead of simple external display support, these devices may require development through an API or Android application. This can increase implementation effort but allows better integration with the glasses' interaction features.

Monochrome Waveguide Glasses

Monochrome waveguide glasses are unobtrusive but limited due their single color display.

Some waveguide glasses use lower-resolution monochrome displays, often in green. Examples include the Even Realities G2 and other lightweight AR notification glasses. These devices can be less visually obstructive and may be suitable for simple notifications or status information.

Monochrome displays are unsuitable for use cases that rely on color-coded medication data.

However, the limited resolution and monochrome display restrict the amount and type of information that can be shown. This makes them less suitable for the medication use case, where the color code of the medication should be displayed clearly.

5.3.3 Selection Outcome

Color waveguide AR glasses provide the ideal compromise between visual capability and situational awareness.

For this prototype, color waveguide AR glasses were considered the most suitable category. They provide a compromise between information capacity and low obstruction of the user's view. Compared to birdbath glasses, they are better suited for maintaining situational awareness. Compared to monochrome waveguide glasses, they allow richer visual interface elements.

The RayNeo X3 Pro's color display and frame controls make it the best choice for testing the prototype.

The RayNeo X3 Pro was selected because it provides an integrated color AR display and supports custom interaction through the glasses frame. This makes it suitable for evaluating the proposed card-based visual interface in a wearable AR format.

5.4 Visual User Interface Elements

See B for screenshots of the prototype's user interface.

Chapter 6

User Study

6.1 Methods

6.1.1 Study Design and Objectives

The work environment of paramedics poses several challenges to them. As explained in section 2.1.4, environmental variability, frequent manual interaction, collaboration with non-fixed, ad hoc teams, rapid decision-making, limited information, and constrained resources contribute to a high cognitive load for paramedics.

The difficult working conditions in EMS lead to a high cognitive load.

The hypothesis of this thesis is that an assistant system which presents critical information visually to medics will reduce their cognitive load. The information is presented through assisted reality glasses. As a result, the lower cognitive load should lead to fewer errors and less mental load.

The thesis hypothesizes that visual AsR support reduces cognitive load and errors.

The user study addresses the following main research question:

How can an AsR assistant system be designed to support paramedics during EMS scenarios by presenting relevant information in a useful, timely, and minimally distracting way?

This research question contains a slight modification compared to the research question mentioned in the introduction. Here, the focus is explicitly on an AsR assistant system, not assistant systems in general. The focus was set on AsR as explained in Chapter 5.

This question is divided into the following subquestions:

- In which situations during EMS missions do paramedics perceive a need for support through an assisted reality system?
- Which types of information do paramedics consider useful or unnecessary when displayed during EMS scenarios?
- How do paramedics evaluate the visual presentation of information with regard to comprehensibility, timing, necessity, and distraction?
- Which interaction methods and manual control options are considered suitable under the physical, cognitive, and environmental constraints of EMS work?
- How do paramedics assess the form factor and practical acceptability of wearing assisted reality glasses during EMS missions?
- How does the prototype influence perceived behavior, usefulness, usability, and workload during the scenario?

6.1.2 Participants

The study recruited eight paramedics and EMTs from a mixed group of professional and volunteer medics.

Eight user study participants were recruited using a flyer. The flyer was distributed digitally to a group of German volunteer medics. The group contained both full-time staff as well as medics who only do volunteer work. As inclusion criteria, specific medical qualifications were required. Participants needed to be paramedics (Notfallsanitäterinnen und Notfallsanitäter), EMTs (Rettungssanitäterinnen und Rettungssanitäter), or currently in training.

6.1.3 Study Procedure Overview

The user study started with a consent form, a general questionnaire, and a quick introduction to the setup. In this phase, any questions that participants had were also answered. Next, three case studies were presented in which study participants treated a fictional patient. After each case study, they received a questionnaire consisting of standardized questions (NASA-TLX and UEQ-S) as well as room for general feedback. Finally, after completing all three case studies, participants received questions as part of a semi-structured interview.

The study consisted of an introduction, intro questionnaire, three simulated case studies with questionnaires, and a final interview.

6.1.4 Study Procedure

First, participants were asked to sign a data privacy and study participation consent form. They were then provided with detailed information about the study and given the opportunity to ask questions. Next, participants completed a questionnaire that included explanations of the differences between VR, AR, and assisted reality (AsR).

Participants started by signing consent forms, reviewing study details, and completing an introductory questionnaire.

Following this, participants were introduced to the assisted reality glasses. They were given a brief explanation of the hardware components and input options available. The first example scenario (febrile seizure) was then walked through together with the participant to ensure familiarity with the setup.

Participants were introduced to the hardware, controls, and a practice scenario.

Before proceeding to the scenario-based tasks, participants were informed about what to expect during the scenarios. They were instructed to treat simulated patients and explain any actions or examinations they could not perform due to missing materials or personnel. A disclaimer was provided to clarify that the study aimed to evaluate the general concept of displaying visual information via an assisted reality (AsR/AR) headset, not the specific glasses model. Participants were also informed that better models (e.g., lighter, higher resolution, longer battery life) are expected in the future.

Participants received scenario instructions and a hardware disclaimer before starting.

The scenario-based tasks consisted of three distinct cases:

- (A): Cardiopulmonary resuscitation (CPR)
- (B): Monotrauma with Suspected Dislocation Fracture of the Left Ankle
- (C): ST-elevation myocardial infarction (STEMI) with shock

Questionnaires after each scenario and a final interview evaluated the prototype.

After each scenario, participants completed a questionnaire to assess their experience. Finally, a semi-structured interview was conducted to gather qualitative feedback on the prototype and its impact on perceived behavior, usefulness, usability, and workload.

6.1.5 Apparatus and Environment

Real medical equipment and a functional training arm supported the study scenarios.

To aid in the realism of the simulated cases, medical devices were available to study participants. That means, for instance, that they were able to physically inject medications into a plastic arm. Likewise, they were wearing medical gloves to protect them from simulated bodily fluids. The simulation arm had functioning veins with running fake blood.

Participants were provided with specific medical equipment and medications to use during the simulated scenarios.

The red pouch, as seen in picture 6.1, contained syringes, needles, IV catheters, and plugs. The black pouch in the top center was filled with medications. Fentanyl, Midazolam, NaCl, Epinephrin, and Esketamin were included, each as 10 mL ampules. The light blue container on the right of the picture contained similar medical products. Included were an infusion set, a bandage packet, a splint kit, an oxygen nasal cannula, an oxygen mask, and a mask commonly used for bag-mask ventilation. User study participants were instructed to place those materials on top of the paper figure when they would normally give them a patient.

Participants wore the RayNeo X3 Pro AR glasses throughout the simulations.

In addition to the presented medical products, participants also wore the RayNeo X3 Pro AR glasses.



Figure 6.1: User study equipment structure in seating area. Medical equipment used during simulated emergency scenarios.

6.1.6 Data Collection and Metrics

Data was collected using a main questionnaire at the start, smaller questionnaires after each case study, and a semi-structured post-study interview.

Data was collected via questionnaires and a final interview.

The pre-study questionnaire consisted of questions about demographics, including the gender and age of participants. Further, the current highest medical qualification and additional rescue-related qualifications were asked. At the same time, they were questioned whether their qualification is practiced professionally or voluntarily by them, and for how long they have had it. Next, they were asked whether they wear glasses during missions. The next section covered prior experience with XR technologies. This included their experience with VR, AR, and AsR glasses as well as heads-up displays. Further questions went into the context of their XR use, asking where participants had used VR, AR, or assisted-reality applications, for instance gaming, museums, training, teaching, or other contexts. Finally, participants had to give an overall rating of their prior XR experiences from very bad to very good. The following section of the questionnaire queried participants' current EMS practices. Here they were asked about their use of memory aids or decision-support materials during missions. Options included checklists, SOPs, algorithms, pocket cards,

The pre-study questionnaire covered participant demographics, XR experience, current EMS practices, and desired digital support.

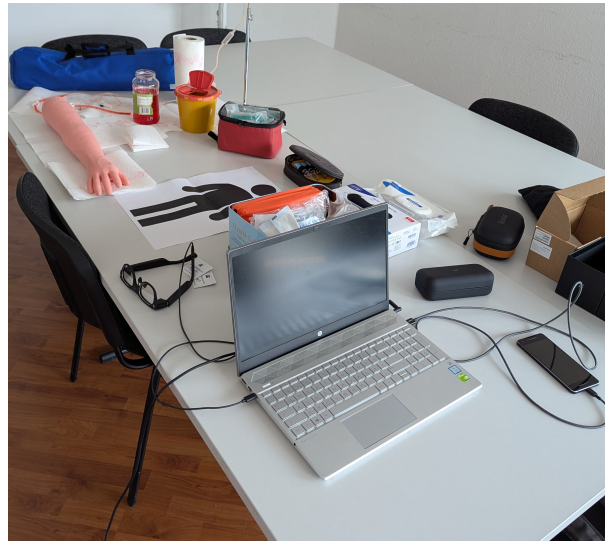


Figure 6.2: User study equipment structure in seating area from the point of view of the researcher. RayNeo X3 Pro glasses, laptop, and smartphone for the server application.

templates, or none. Lastly, the desired digital assistance in emergency medical services was questioned. Here, participants rated which areas they would like to have digital support from an assistant system. They rated each option on a 7-point Likert scale. Additionally, they had the option to give open feedback, considering additional areas or situations where support would be useful, as well as general final comments.

Workload and usability were assessed after each scenario via NASA-TLX and UEQ-S questionnaires.

After each of the three case studies, participants were presented with another questionnaire. This post-scenario evaluation asked participants to rate both their experienced workload (NASA-TLX) and their perception of the assistant system (UEQ-S). NASA-TLX asks participants about their perceived mental demand, physical demand, temporal demand, performance, effort, and frustration during each case study. The UEQ-S, on the other hand, evaluates the perceived pragmatic user experience of the assistance system, measured with the UEQ-S pragmatic quality scale. In addition, it measures the perceived hedonic user experience of the assistance system, measured with the UEQ-S hedonic quality scale.

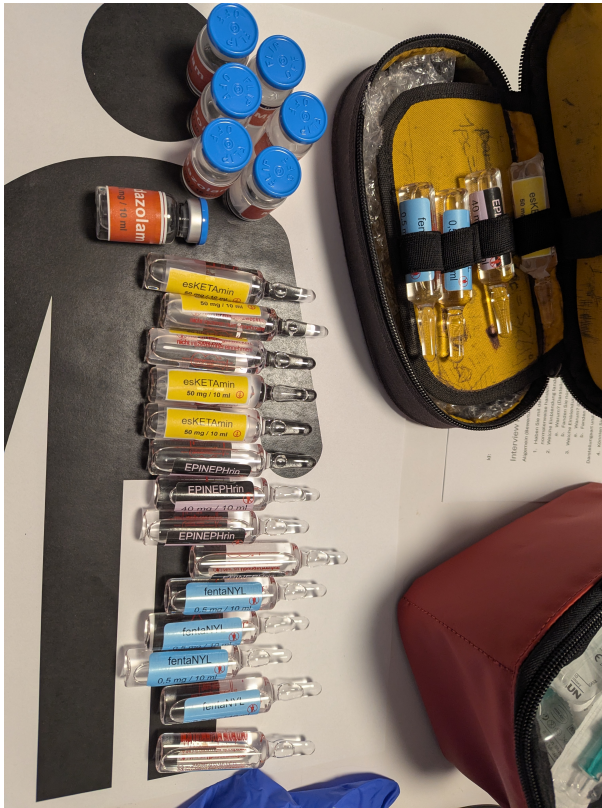


Figure 6.3: Available medications for the user study. Fentanyl, Midazolam, NaCl, Epinephrin, and Esketamin, each as 10ml ampoules.

Data was also collected through an interview. Here, participants were asked whether the assistance system changed their behavior compared to their usual actions. Next, they were questioned about which AsR overlays they considered helpful. They were further asked to consider factors such as the presentation format, timing, content, necessity, and distraction potential. Then they were asked to describe which AsR overlays they considered least helpful. Again, the same factors were considered. In addition, participants were asked whether they could imagine wearing AsR glasses during real EMS work. The next questions covered how participants imagined an ideal assistant system. First, the study asked during which situations EMS staff would like support, also referencing the pre-study main questionnaire and use cases that were suggested there. Secondly, the specific design requirements for an ideal assistance system

Concluding interviews gathered qualitative feedback on behavioral changes, helpful overlays, future adoption, and ideal system design.

were discussed. This includes the information that should be displayed, how it should be displayed, and what interaction methods should be available.

6.2 Results

6.2.1 Participant Demographics Summary

Participants comprised eight EMS personnel with varying levels of professional and volunteer experience.

All eight participants of the study were EMS personnel. Seven were EMTs and one was a paramedic. The mean age was 31.25 years, with a standard deviation of 11.57 and a range of 22-50 years. Regarding gender, seven participants were male and one was female. Figure 6.4 shows the experience of the participants. On average, participants had 12.88 years of voluntary EMS experience (SD = 11.15, range 2-30) and 3.69 years of professional EMS experience (SD = 5-13, range 0-15).

Half of the participants wore regular glasses, and most reported prior experience with VR and head-up displays despite limited AR familiarity.

Four participants were regular glasses wearers, while the other four did not regularly wear glasses during missions. Regarding their experience with XR, Figure 6.5 shows that most did not have any experience with AR or AsR. However, five out of eight participants had used VR at least a few times, and six out of eight had used head-up displays at least a few times. The most frequent settings were gaming at home (five participants) and training or education (three participants), while gaming outside the home was reported by two participants. Five out of eight participants rated their previous experience with VR (1 = very bad, 5 = very good). Three gave no response. The mean was 3.20, with values ranging from 2 to 4.

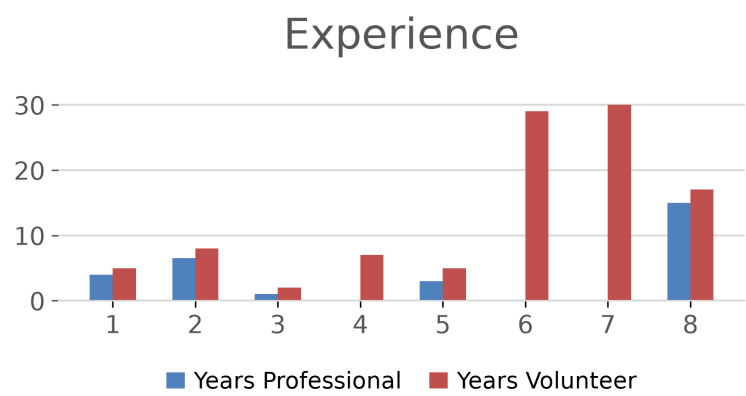


Figure 6.4: EMS experience of user study participants. In blue the individuals professional experience and in red the voluntary EMS experience.

6.2.2 User Evaluation of Use Cases

6.2.3 Workload and Usability Scores (Quantitative)

After each case study (3 in total) each participant filled out a questionnaire that included NASA-TLX and UEQ-S questions. See figure 6.7 for results.

6.2.4 User Feedback (Qualitative)

The following user feedback was gathered through the written responses on the questionnaires as well as a semi-structured interview at the end of each study. The quotes were translated from German into English, as the interviews were conducted in the native language of the participants, German.

Qualitative feedback was gathered from written questionnaire responses and post-study interviews, then translated from German to English.

Desired Capabilites of Prehospital AR Assistant Systems

Participants described several capabilities they would expect from a useful prehospital AR assistant system. These

Desired AR capabilities centered on medication support, patient data access, and logistical aid to improve workflow efficiency.

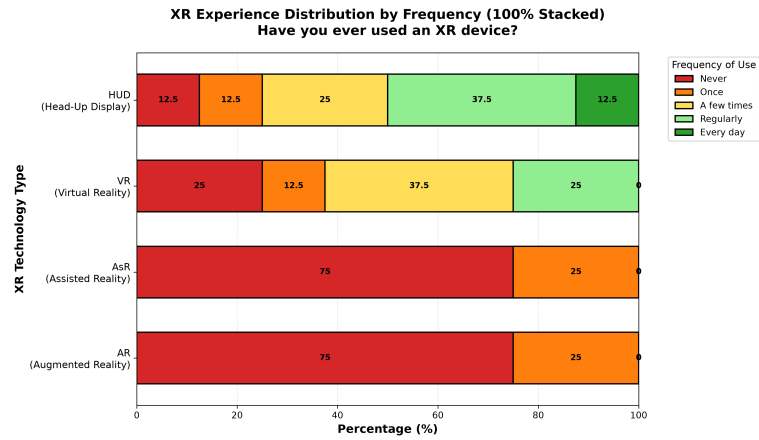


Figure 6.5: XR experience of user study participants. Most had experienced HUD and VR, few had experience with AsR and AR.

expectations focused on three areas: pharmacological assistance, access to critical patient data, and operational or logistical support. Rather than replacing clinical judgment, these capabilities were framed as supporting rapid information access, reducing the need to consult external materials, and improving situational awareness during EMS scenarios. This theme is further closely linked to the Assistant System Use Cases as presented in Figure 6.5.

Participants valued AR support for drug dosages, preparation details, and contraindications.

Firstly, pharmacological AR assistance is seen as useful. The strongest and most repeated need is dosage support. Participants repeatedly mentioned that medication dosages are helpful to have displayed, especially in pediatric cases. Several comments emphasize weight-based dosing. A second desired point is contextual medication information at the moment of application. This consists of dose, preparation, dilution/mixing ratios, contraindications, and warnings. At the same time, drug interactions and contraindications were mentioned as information that is rarely present. This data normally requires time-consuming lookup.

"The dosage of the selected medications, especially for children, would be very welcome. Support in that area is always very important. The same applies to things like interactions

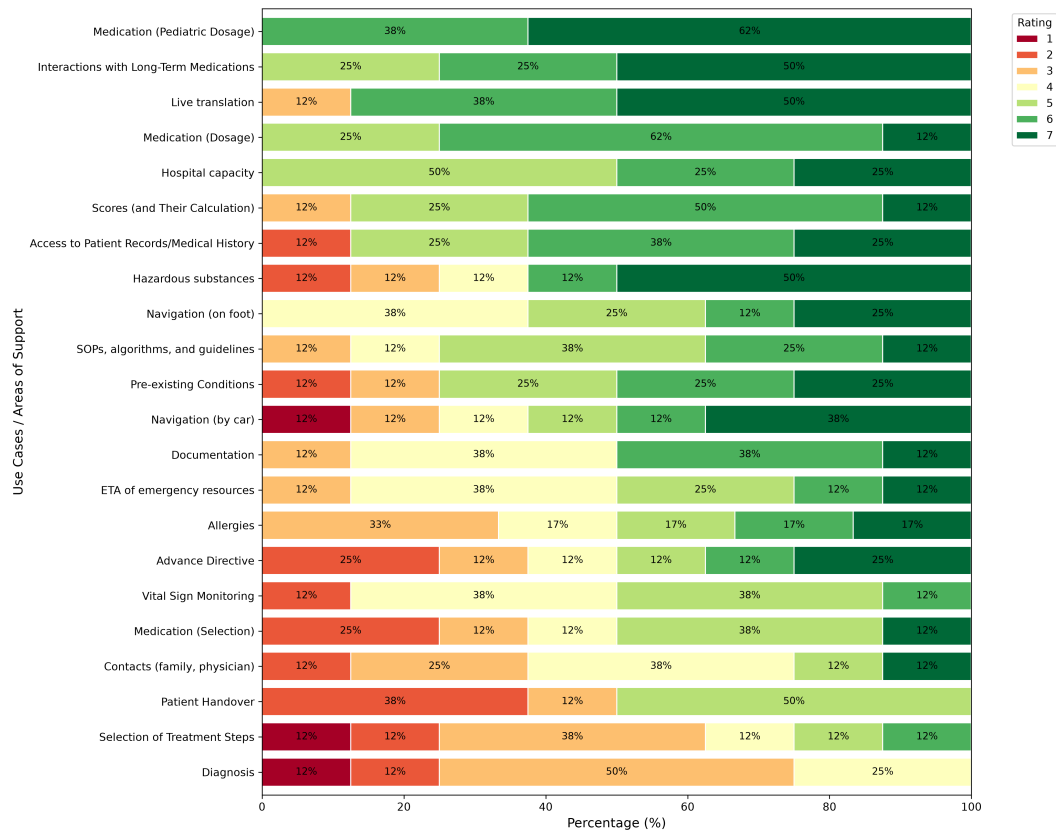


Figure 6.6: Assistance Use Cases - Areas of Support (Sorted by Mean Rating). As rated by study participants in pre-study questionnaire.

Table 6.7: Descriptive statistics for workload and usability scores by case scenario. NASA-TLX is reported as the raw total workload score; UEQ-S scores are reported on the transformed scale from -3 to +3.

Case scenario	NASA-TLX M (SD)	UEQ-S pragmatic M (SD)	UEQ-S hedonic M (SD)	UEQ-S overall M (SD)
Case A - CPR	8.13 (3.47)	1.53 (0.88)	0.97 (1.57)	1.25 (1.10)
Case B - Fracture	8.89 (3.01)	0.75 (0.57)	0.84 (1.43)	0.80 (0.90)
Case C - STEMI	8.08 (3.62)	1.31 (0.59)	0.62 (1.61)	0.97 (0.96)
Overall	8.36 (3.25)	1.20 (0.74)	0.81 (1.48)	1.01 (0.97)

with long-term medications. This is simply information that is rarely readily available and would otherwise have to be looked up in a time-consuming way." [P2]

Displaying vital parameters and score calculations directly in AR helps medics monitor patients without shifting their gaze.

Secondly, users desired the presentation of critical patient data such as vital signs, ECG interpretation, score calculation, and further patient information. This includes displaying vital parameters directly in the AR field of view, so that they do not need to look away at a monitor during patient care. The system should further calculate scores such as NEWS2 and notify medics if they are of concern.

"Scores, APGAR and things like that could be calculated in real time if the system has access to the data, and could then indicate if, for example, something is abnormal in NEWS2 or if the patient might be developing sepsis." [P5]

Participants also requested operational support, including handover assistance, resource ETAs, translation tools, procedural checklists, and step-by-step algorithms.

Thirdly, participants desired operational and logistical support. This included handover support, ETA of other rescue resources, translation support, checklists for complex procedures, and treatment algorithms. The handover function was especially appreciated when it reduced reliance on memory or scattered notes. A couple of interviewees initially thought it would not be necessary, but changed their view after seeing it in practice. AR glasses could support logistics by showing arrival times of other rescue resources, such as when an emergency physician or other units are expected to arrive. This was framed as important for planning and coordinating treatment on scene. Translation support was considered useful in operational communication with patients, relatives, or bystanders, especially when language barriers would otherwise require tools like Google Translate. Participants also imagined AR as a way to provide checklists for complex procedures, such as emergency anesthesia, major interventions or hospital handover. Participants further described selectable treatment pathways or algorithms, where the medic could work through decision points step by step instead of viewing a static full-page document.

"Overall, I found the overview for the handover very good — at least, especially in principle."
[P3]

Medics Demand Clear Separation of Responsibilities

Participants repeatedly emphasized that a clear separation of responsibilities is important. They mentioned that they felt pressured to follow the assistant system and performed measures that went against their personal judgment. This was criticized in the interviews. Here they voiced that they would prefer to make their own choices, such as selecting drugs. They further showed resistance toward automated clinical decisions. They voiced that their training made certain information provided by the system redundant. Additionally, they wanted to see their professional autonomy protected.

Participants resisted automated clinical decisions, stressing the importance of maintaining full control over medical choices like drug selection.

"Relying blindly on the glasses—well, in that case, I might as well put a curious monkey in an ambulance." [P8]

Participant P2 explained that they "do not consider diagnosis-finding to be useful. In [their] opinion, this should still be done by a human. The same applies to the selection of treatment steps." [P2]

Preference for User-Initiated Over Anticipatory Support

The same sentiment was also voiced in connection with the user experience. Here, participants voiced a preference for user-initiated over anticipatory support. They would like the system to act as a fast reference tool. Participant P6 explained that the system should present information that you would otherwise have to look up on pocket cards or Google, such as medication.

Participants preferred user-initiated reference tools over anticipatory automation, wanting quick access to lookup information like medications.

"I would [prefer to] say, 'Okay, I want to administer Fentanyl now, please help me carry out this intervention,' so that the action still originates in the human mind." [P2]

UI: Focus on Minimalism

Participants preferred a minimalist peripheral interface to maintain real-world visibility.

Concerning the user interface, one of the main themes is a focus on minimalism. In most contexts, a small UI was preferred. Users would like it to be in the periphery, as a full-screen view limits real-world visibility. However, for specific tasks some users were okay with a more obtrusive AsR display.

"Overall, rather more subtle hints around the edges, because a relatively large part of it still works via 'I'm looking at the patient'" [P3]

Regarding the current design of the AsR interface, P2 explained that they "still found it very present, very central on the screen, so that, if in doubt, [they] might not be able to look at [their] patient very well [...], so [they] would perhaps prefer it to be a bit more at the edge and in the periphery of the field of view." [P2]

Interaction Methods: Balancing Hygiene, Reliability, and Hands-Free Control

Users evaluated various control methods while raising concerns about voice interaction.

Users considered voice control, the currently implemented swiping gestures, gesture-based control, eye-tracking, and remote controls. Regarding voice controlled interfaces, users voiced concerns. They worried that speaking to the device could confuse or disturb patients, especially older patients, or interfere with the medic's actual communication with the patient.

"Older patients are already confused when we are on the phone. They then think that we are speaking to them." [P1]

The currently implemented swiping gestures were considered partly useful, especially because swiping feels simple, familiar, and relatively reliable. However, many also see touch interaction as problematic due to hygienic concerns. Participants would not want to touch glasses near their face with contaminated or bloody hands. This would additionally require regular disinfection of the glasses.

Swiping gestures were seen as intuitive but posed hygiene challenges.

"I would like a completely different operating concept, because when I'm working on a patient with gloves on, I don't want to have to touch my face with them. [...] If I had just had blood on my fingers and then wiped around on them, that's not exactly practical." [P6]

Finally, further alternatives were considered by users. They suggested using eye-tracking, gesture controls, or a physical remote control.

Alternative input methods suggested by users included eye-tracking, air gestures, and physical remote controls.

"I would have imagined it more as a remote control, because a smartwatch that I wear on my wrist all the time would also be inconvenient, especially if I'm bloody or something. Then I'd have some kind of small remote that I could simply throw into disinfectant if necessary and otherwise toss into the ambulance, rather than wearing it on my arm the whole time with bloody fingers." [P8]

System Should Present Understandable, Legally Usable and Reliable Data

According to study participants, incorrect information might be displayed. As a consequence, they would like to be able to detect incorrect information. Further, the legal

Participants stressed the need for error detection and addressed the legal risks of incorrect system data.

implications of using false information from an assistant system need to be addressed.

First, incorrect system suggestions.

Firstly, there were concerns about incorrect system suggestions. This could either be a system error or a cybersecurity and data integrity issue.

"I find it very problematic if, for example, someone receives the information that resuscitation should be withheld — that is, that an advance directive exists. Receiving that through glasses via an online system, where you don't know whether it has been hacked, and then, as a paramedic, trusting the glasses and not starting resuscitation — I find that very problematic."
[P6]

Secondly, being able to detect incorrect information.

Secondly, there was skepticism toward the inability to detect incorrect information. In general, this can be referred to as skepticism toward black-box diagnostics and the inability to verify system assertions. The system should therefore further explain dosage and treatment step suggestions. Additionally, users need to be able to verify system assertions.

"I found it difficult to rely solely on the information from the glasses without seeing, for example, the ECG myself." [P1]

"That you don't just say, for example, "Okay, you have Ketanest at 5 mg per milliliter and you should give 20," but also because the dose is 0.125 milligrams per kilogram of body weight. And then you have that written there again."
[P8]

Thirdly, legal consequences if incorrect information is used.

Lastly, users stated that since the system might present incorrect information, they might use that to make incorrect medical decisions. In that case, the legal implications need to be solved before using such an assistant system.

"I found it absolutely helpful that the first patient was marked as "no CPR." 106: The question, of course, is what the legal situation is — whether that information can be acted upon, or whether one would still say, well, there could be an error. That would definitely be interesting in the future." [P7]

System Should Take User and Context Into Account (Role, Qualification, Region)

The system should consider the medical qualification of its users. For instance, this could be the difference between an EMT and a paramedic or a volunteer and a professional. Consequently, the system could offer personalized support tailored to the qualification and knowledge level as well as the role of the user.

Participants recommended personalizing system features based on user qualifications and roles.

"I took measures that I would not normally take because they are not authorized for me where I come from." [P4]

"But if I think about this more broadly, for medical standby services or volunteers who don't do this regularly, it is, of course, even more helpful. Or even, thinking on a larger scale, in disaster response, where things can get complicated. In that context, it is definitely what people nowadays would call an absolute game changer." [P7]

Chapter 7

Discussion

7.1 Implications for Design

Based on the findings of the user study and the theoretical and empirical work discussed in the previous chapters, this section derives ten design guidelines for AsR-based assistance systems in EMS.

1. **Preserve professional autonomy through user-initiated support.** In general, the interface should be designed as a user-initiated reference tool rather than an automated clinical decision-maker. EMS personnel demand a clear separation of responsibilities and strongly resist systems that preemptively dictate treatment paths, select diagnoses, or mandate medication choices. However, contextual awareness remains important, for instance, to show critical warnings.
2. **Make all medical information transparent and verifiable.** The system should not present unsupported conclusions. For example, medication dosage support is an area where "black box" recommendations should be avoided. Instead, the system should display the underlying calculations, dilution ratios, and patient age and weight alongside the final dose. For

other support scenarios, referencing the corresponding SOP might be sufficient. This directly relates to CRM rule 10: "cross (double) check" as shown in Figure 2.9. Without this additional information, users would not be able to fulfill this rule.

3. **Use a minimal and peripheral visual interface.** EMS work relies heavily on maintaining direct visual contact with the patient and the surrounding scene. Therefore, the UI must avoid obstructing the central field of view. To do so, transparent color waveguide displays (e.g. RayNeo X3 Pro) may be used to place subtle visual hints in the periphery. Dense information blocks should only be displayed when required by a specific task and explicitly requested by the user.
4. **Match support to the EMS workflow and timing.** Assistance should appear at meaningful moments in the mission rather than as constant background information. The system should follow existing EMS workflows such as xABCDE, SOPs, algorithms, and CRM practices. Useful moments include preparing for a procedure, administering medication, detecting abnormal vital signs, requesting additional resources, preparing transport, and handing over the patient.
5. **Provide interaction methods that fulfill EMS requirements.** Interaction must remain reliable when users wear gloves, PPE, masks, or have contaminated hands. Touching the glasses near the face is problematic in hygienically critical situations, while voice input may disturb patients or interfere with team communication. Therefore, the system should support alternative input methods such as simple gestures, eye-tracking, or a small disinfectable remote control.
6. **Adapt information to role, qualification, and region.** The system should consider who is using it and under which regional SOPs they operate. EMTs, paramedics, emergency physicians, volunteers, and trainees may require different levels of detail and may be authorized to perform different interventions. Therefore, the assistant should only suggest or display actions that match the user's qualification, role, and local legal scope of practice.

7. **Support the prevention of cognitive biases, slips, and mistakes.** EMS personnel work under time pressure and often rely on heuristics. The system should help prevent fixation errors, confirmation bias, anchoring, and memory-lapse slips by reminding users of missing checks, showing alternative considerations, and supporting repeated re-evaluation. For example, it could remind users to check blood glucose in an unconscious patient or to reassess vital signs after an intervention.
8. **Transform static cognitive aids into dynamic pathways.** Existing aids such as memo cards, checklists, SOPs, dosage tables, and algorithms should not simply be copied into the AR display as static documents. Instead, they should be transformed into interactive, stepwise pathways that show only the currently relevant information.
9. **Enable discreet and patient-sensitive operation.** The system should avoid interactions that reduce patient trust or increase patient anxiety. For example, loudly asking the system for a medication dose or displaying sensitive information in a way that others can see may be inappropriate. The interface should support private, discreet information access and should avoid unnecessary alarms, confusing speech interaction, or visible uncertainty in front of patients and relatives.
10. **Prioritize the highest-value EMS areas of support: pharmacological assistance, access to critical patient data, and operational support.** Pharmacological assistance consists of supporting medication dosing, contraindications, allergies, interactions, and preparation steps. Giving access to critical patient data includes scores and their calculation, patients' records and medical history, pre-existing conditions, allergies, and vital sign monitoring. Operational support further refers to aiding with navigation, managing hazardous substances, live translation, hospital capacities, documentation, and the ETA of emergency resources. These are the highest-value EMS areas of support identified.

7.2 Limitations of the Study

The study has several limitations that affect the interpretation and transferability of the findings. First, the sample size was small, with only eight participants, and the participant group was unevenly composed, consisting mostly of EMTs and only one paramedic. Future studies should include a larger and more balanced sample to better capture differences in qualification and professional background.

Second, the scenarios were simulated and therefore could not fully reproduce the stress, noise, hazards, time pressure, and team dynamics of real EMS missions. In addition, the study was conducted with only one participant at a time, which means that the social and operational demands of team-based emergency care were not represented. The prototype also evaluated the interface concept rather than a fully functional context-aware system, so the results primarily reflect perceptions of the concept and not the performance of an end-to-end assistant.

Third, the study used a wizard-of-oz setup in which the timing of individual displays was controlled by the researcher. Although this allowed the concept to be tested in a realistic-looking way, the slight variations in timing may have influenced comfort and distraction ratings. The Ray-Neo X3 Pro hardware itself may also have affected the evaluation, as the display still offered a rather low resolution and a limited field of view. As a result, even information that was intended for the periphery could appear relatively central in the visual field.

Fourth, participants were aware that they were taking part in a study, which may have influenced their responses. No objective performance measures were collected, such as error rate, task completion time, gaze behavior, or a comparison of treatment quality. A control condition without glasses was also not included, which limits causal conclusions about the added value of the device.

Finally, not every use case and feature could be represented in the prototype due to time constraints. In particular,

quality-control and documentation scenarios were difficult to simulate in a way that would reliably lead participants to fail. The use cases were also not fully adjusted to the participants' qualification level, which means that some scenarios may not have matched the scope of practice of EMTs versus paramedics. Future work should include more advanced and qualification-specific use cases to avoid situations in which the assistant suggests treatment steps outside the user's authorization.

7.3 Broader Impacts and Ethical Considerations

A central ethical concern is the possible effect on paramedics' knowledge and independent decision-making. If users rely too heavily on an assistant system, they may gradually lose confidence in their own judgment or become less practiced in recalling procedures, dosages, and documentation steps without support. This creates a risk that work quality could deteriorate if the system fails, is unavailable, or provides incorrect information. In that sense, the assistant should support clinical reasoning rather than replace it.

This also raises the question of responsibility. In emergency care, false information from an assistant system could have direct consequences for patient safety. If paramedics actively disagree with a recommendation, the system should not force compliance; instead, users must remain free to follow their own professional judgment. At the same time, a system that is treated as if it cannot make mistakes may create a dangerous authority bias. Comparable patterns are known from aviation, where errors from superiors or automation were sometimes not challenged because they were assumed to be reliable by default. A similar risk exists here if users defer to the assistant even when something appears inconsistent.

For this reason, the interface should support critical questioning rather than passive acceptance. If the assistant out-

put conflicts with the user's assessment, the system should make it easy to inspect the underlying rationale, verify the relevant patient data, and fall back to independent judgment. The assistant should provide decision support, but the final responsibility must remain with the trained EMS professional.

Privacy is another important issue, particularly in relation to patient data and documentation. An assistant that displays records, contact details, diagnoses, or treatment notes must do so in a way that avoids unnecessary disclosure to bystanders, relatives, or other team members who do not need the information. This is especially relevant when documentation is generated automatically through accessing voice and medical device data. Such a system might mistakenly include irrelevant but sensitive information. Therefore, data protection should not be treated as a secondary implementation detail, but as a core requirement for any practical EMS deployment.

Chapter 8

Summary and Future Work

8.1 Summary and Contributions

This research aimed to find how an assisted system can be designed to support paramedics during EMS scenarios.

To determine a suitable interface, first, the main perception modality was selected. Here vision and concretely, AR glasses, were selected as they provide a highly dense, private, hands-free, and always available means of conveying information. Next, the specific glasses to be used for a prototype were selected. Here, color waveguide AR glasses provided the ideal compromise between visual capability and situational awareness. The RayNeo X3 Pro was specifically selected because it provides interaction through the glasses frame and provided an color AR display. Further, the concrete UI used a card based design as it provides improved readability over the real world, works with the limited display space of the RayNeo X3 Pro, and provides a clear grouping of information.

Based on literature and the results of an explorative user study, ten core design guidelines were deducted. In summary, an AsR assistant system for EMS should be designed

as a transparent, user controlled support tool, not as an autonomous decision-maker. Its primary opportunities lie in delivering high-value pharmacological assistance, providing rapid access to critical patient data, and offering operational support. Additionally, the system presents the opportunity to transform static cognitive aids into dynamic clinical pathways while actively helping EMS personnel prevent cognitive biases and medical errors. To ensure user acceptance, the interface should be minimal and peripheral, utilizing discreet, hygienic interaction methods. Finally, the provided assistance should seamlessly align with the timing of existing EMS workflows and strictly adapt to the user's specific role, qualifications, and regional protocols.

8.2 Future Work

Future work should use the 10 design guidelines to develop an improved prototype. This improved prototype should, for instance, be able to incorporate team dynamics. It should further be a fully functional, context-aware assistant system that can adapt to the user's qualification, role, and regional protocols. Additionally, this improved prototype should expand the use-case coverage. This means, adding support for documentation, translation, extended resource ETAs, and improved dynamic SOPs pathways. See Appendix A for a detailed list. Furthermore, a future prototype should evaluate additional interaction methods (e.g., eye tracking, a disinfectable remote, and gesture control) in an EMS setting. Lastly, different transparency features that help users verify system suggestions should be evaluated.

Secondly, future work should extend the user study concept. A larger evaluation under more realistic EMS conditions, e.g. a simulation lab, is needed to assess not only perceived usability, but also objective effects on task performance, error reduction, and workload.

Finally, in the extended future the goal should be to evaluate the assistant system in real word scenarios and run

clinical trials to test the effectiveness in improving patient care.

Appendix A

Overview of Collected Use Cases for Assistance Systems

#	Use Case	German	Notes
1	Medication (Selection)	Medikation (Auswahl)	Figure B.3
2	Medication (Dosage)	Medikation (Dosierung)	Figure B.4
3	Medication (Pediatric Dosage)	Medikation (Dosierung Kinder)	Figure B.5
4	Interactions with Long-Term Medications	Wechselwirkungen mit Dauermedikationen	
5	Vital Sign Monitoring	Vitalparameter-überwachung	Figure B.1
6	Patient Handover	Patientenübergabe	Figure B.6
7	Diagnosis	Diagnosefindung	
8	Selection of Treatment Steps	Auswahl von Behandlungsschritten	Figure B.2
9	Scores (and Their Calculation)	Scores (und deren Berechnung)	
10	Documentation	Dokumentation	
11	Access to Patient Records/Medical History	Einsicht in Patientenakte/Vorgeschichte	
12	Pre-existing Conditions	Vorerkrankungen	
13	Advance Directive	Patientenverfügung	
14	Navigation (by car)	Navigation (Auto)	
15	Navigation (on foot)	Navigation (Zu Fuß)	
16	Estimated arrival times of emergency resources (e.g., nearest available emergency physician, helicopter, turntable ladder)	Potenzielle Eintreffzeiten von Einsatzmitteln (z.B. nächster freier Notarzt, RTH, Drehleiter)	
17	Hospital capacity	Krankenhauskapazitäten	
18	Live translation	Live-Übersetzung	
19	Allergies	Allergien	
20	SOPs, algorithms, and guidelines	SOPs, Algorithmen und Leitlinien	
21	Hazardous substances	Gefahrenstoffe	
22	Contacts (family members, primary care physician)	Kontakte (Angehörige, Hausarzt)	

Table A.1: Overview of collected use cases for assistance systems.

Appendix B

Prototype

The following appendix chapter describes the developed prototype. This includes the UI as well as detailed descriptions of the presented scenarios (case studies). The aim is to present the workflow of the three scenarios as described in chapter 6 and the included visual assistance.

The UI text as presented in the user study was German only. Here, machine generated translations of the text are provided for your convenience.

Each of the case studies contains information about the patient, if vitals should be shown in AsR, and then a list of steps and comments. Considering the technical background, these details are stored in an XML file.

B.1 Case Study Configuration

The AR Glass application utilizes an XML-based configuration file to dynamically generate medical case studies. This approach separates the clinical scenario content from the application logic, allowing researchers to modify parameters, patient information, and interaction sequences without recompiling the software.



Figure B.1: Vital Data - Assisted Reality User Interface

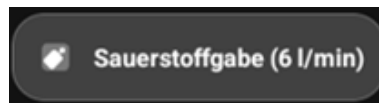


Figure B.2: Oxygen Prompt - Assisted Reality User Interface

A case study consists of overarching patient metadata (e.g., name, age, gender, baseline vitals) and a chronological sequence of *steps*. These steps define the specific user interfaces, alerts, and instructions displayed on the AR glasses.

Overview of Step Types

The system supports various step types to simulate different phases of a medical emergency. The following list provides an overview of the available configuration tags and their primary clinical or technical function:

`medication` Displays a medication administration interface. It specifies the drug name, required dosage, application form (e.g., IV, IM), and can optionally dis-

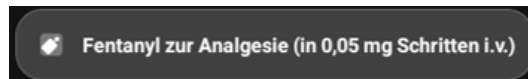


Figure B.3: Medication Prompt - Assisted Reality User Interface



Figure B.4: Medication Details - Assisted Reality User Interface

play safety warnings related to the administration. See figure B.4, and B.5.

`medication_detail` Provides in-depth pharmacological information, contraindications, or detailed preparation guidelines for a specific medication.

`alert` Triggers a critical clinical warning or reminder (e.g., "Check distal pulse!"). Alerts can be color-coded based on severity (green, yellow, red) to attract the user's immediate attention.

`prompt` Provides a standard text instruction or a call to action. It is typically used to guide the user through standard procedural steps. See figure B.2, and B.3.

`suggestion_prompt` Presents a text prompt alongside a list of multiple-choice suggestions. This is used when the user needs to make a clinical decision or select a specific diagnosis from predefined options.

`graphic_prompt` Displays an instruction that, upon interaction, opens a full-screen graphical layout (e.g., a triage algorithm or immobilization scheme).

`action_prompt` Displays a prominent instruction with a primary confirmation button. It is utilized for critical checkpoints where explicit user confirmation is required before proceeding.



Figure B.5: Medication Details Paracetamol - Assisted Reality User Interface

handover Initiates the patient handover documentation screen. It structures collected clinical data into standardized formats (e.g., xABCDE scheme, SAMPLER) and supports both minimal and detailed view modes. See figure B.6.

feedback Renders a temporary, non-blocking notification (similar to an Android Toast). It is used to confirm that an action was registered without interrupting the user's workflow.

vital_change A simulation control tag that modifies the patient's vital signs (e.g., Heart Rate, SpO2, Blood Pressure) on the paired glasses. It can be configured with a delay to simulate the gradual onset of a condition or medication effect. See figure B.1 to see how the vitals were displayed.

text_block Displays a static block of text on the server application. It is typically used for general information, extensive patient history, or context that does not require direct interaction. This information was then read aloud to the participants by the researcher.

comment Metadata used by the scenario authors for logical organization and researcher notes. These are ignored by the AR application but remain visible in the XML and the server application.

SINNHAFT

I: ♂, Herr Müller, 24J

ABCDE	BEFUND	MASSNAHME
A	frei	-
B	AF 16, SpO ₂ 96%	-
C	HF 86	18-G i.v.
D	-	Fentanyl, PSA (Midazolam, Esketamin)
E	Sturz beim MTB	Reposition, Samsplint

A - ANAMNESE
Keine Vorerkr., keine Meds, Allergie: Pollinosis, Letzte Mahlzeit: vor 2h

Figure B.6: Patient Handover Support Screen - Assisted Reality User Interface

Example Configuration

The following XML snippet illustrates how these steps are combined to form a coherent clinical scenario:

Listing B.1: Example XML configuration for a case study.

```
<case_study id="fracture_osg" title="Monotrauma_OSG"
  patient_name="Herr_Mueller" patient_age="24" patient_gender="m">

  <comment text="Researcher: Verify tracking before starting." />

  <step type="medication" drug="Fentanyl" dosage="0.15µg"
    application_form="iv" />

  <step type="alert" alert_type="yellow" title="Clinical_Alert"
    message="Check_distal_circulation!" action="next" />

  <vital_change hf="110" spo2="96" delay="1000" />

  <step type="handover" mode="minimal" />
</case_study>
```

B.2 Detailed Case Sequence: Mono-trauma with Suspected Dislocation Fracture of the Left Ankle

The following case study was taken from Koppenberg et al. [2024].

Case Study Metadata (case_study)

- id: fracture_osg
- title: „Monotrauma mit V.a. Luxationsfraktur OSG links“
Translation: „Monotrauma with suspected dislocation fracture of the left ankle“
- patient_name: Herr Müller
- patient_age: 24
- patient_gender: m
- patient_weight: 80
- vitals_enabled: true

Sequential Simulation Flow

1. Comment

- text: „Kapitel 4: Sweet dreams are made of this“
Translation: „Chapter 4: Sweet dreams are made of this“

2. Comment

- text: „Researcher: Verify medication and fake arm is ready before starting this scenario.“
Translation: „Researcher: Verify medication and fake arm is ready before starting this scenario.“

3. Text Block

- text: „Sie werden zu einem Mountainbike Sturz alarmiert.“
Translation: „You are dispatched to a mountain bike crash.“

4. Text Block

- text: „Am Unfallort befinden sich zwei junge Mountainbiker. Der Patient klagt über stärkste Schmerzen (NRS 8) und hält sich den schmerzverzerrten linken Knöchel.“
Translation: „There are two young mountain bikers at the scene. The patient complains of severe pain (NRS 8) and is holding his left ankle in agony.“

5. Text Block

- text: „Orientierende Untersuchung: 24-jähriger Patient (80 kg). Monotrauma des linken OSG im Sinne einer Luxationsfraktur mit deutlicher Fehlstellung. Er klagt über Parästhesien (Taubheitsgefühl / Kribbeln) im Vorfuß. Keine Bewusstlosigkeit, erinnert sich an das Sturzereignis.“
Translation: „Primary assessment: 24-year-old patient (80 kg). Monotrauma of the left upper ankle joint, indicative of a dislocation fracture with significant malalignment. He complains of paresthesia (numbness / tingling) in the forefoot. No loss of consciousness, remembers the fall.“

6. Vital Change

- hf: 110
- spo2: 98
- af: 22
- sys_bp: 140

7. Step (type: prompt)

- icon: ic_medication
- text: „Fentanyl zur Analgesie (in 0,05 mg Schritten i.v.)“
Translation: „Fentanyl for analgesia (in 0.05 mg steps IV)“

- action: next

8. **Step** (type: medication)

- drug: Fentanyl
- dosage: „in 0,05 mg Schritten zu 0,15 mg rantasten“
Translation: „titrate in 0.05 mg steps up to 0.15 mg“
- medication_id: fentanyl
- application_form: iv

9. **Vital Change**

- af: 18
- hf: 100
- delay: 5000 (*in milliseconds*)

10. **Step** (type: prompt)

- text: „Procedural Sedation and Analgesia (PSA) vorbereiten“
Translation: „Prepare Procedural Sedation and Analgesia (PSA)“
- action: next

11. **Step** (type: medication)

- drug: Midazolam
- dosage: „2 mg“
- medication_id: midazolam
- application_form: iv
- warning_text: „Langsam spritzen!“
Translation: „Inject slowly!“
- warning_type: yellow

12. **Step** (type: medication)

- drug: Esketamin
- dosage: „20 mg“
- medication_id: esketamin
- application_form: iv
- **Nested Element: Vital Change**

- hf: 90
- spo2: 95
- af: 12
- sys_bp: 110
- delay: 10000

13. **Comment**

- text: „Überprüfung der peripheren Durchblutung, Motorik und Sensibilität!“
Translation: „Check peripheral perfusion, motor function, and sensation!“

14. **Step** (type: alert)

- alert_type: green
- title: „pDMS“
Translation: „CMS (Circulation, Motor function, Sensation)“
- message: „Überprüfung der peripheren Durchblutung, Motorik und Sensibilität!“
Translation: „Check peripheral perfusion, motor function, and sensation!“

15. **Step** (type: prompt)

- text: „Repositionierung durchführen“
Translation: „Perform reduction“
- action: next

16. **Text Block**

- text: „Nach einem beherzten ‚Schuhausziehgriff‘ erfolgt die Reposition des OSG links, was mit einem deutlichen ‚Klacken‘ quittiert wird. Der Vorfuß wird prompt rosig, der Puls ist wieder tastbar und die Rekap.-Zeit liegt bei < 2 s.“
Translation: „After a firm ‘boot removal maneuver’, the left ankle is reduced, accompanied by a distinct ‘clunk’. The forefoot immediately turns pink, the pulse is palpable again, and capillary refill time is < 2 s.“

17. **Step** (type: alert)

- `alert_type`: green
- `title`: „Erfolgskontrolle“
Translation: „Success check“
- `message`: „Puls tastbar? Recap < 2s? Schwellung rückläufig?“
Translation: „Pulse palpable? Cap refill < 2s? Swelling subsiding?“
- `action`: next

18. Step (type: prompt)

- `text`: „Samsplint und elastischen Verband anlegen“
Translation: „Apply SAM splint and elastic bandage“
- `action`: next

19. Text Block

- `text`: „Anamnese: Der Patient ist beim Downhill-Fahren mit dem linken Fuß an einem Stein hängengeblieben. Durch die Fixierung in den Klickpedalen kam es zur Luxation. Er sei nicht auf den Kopf gefallen und habe keine weiteren Verletzungen außer Schürfwunden.“
Translation: „History: While downhill riding, the patient caught his left foot on a rock. Due to being locked into clipless pedals, the dislocation occurred. He did not hit his head and has no other injuries apart from abrasions.“

20. Step (type: prompt)

- `text`: „Re-Analgesie vor Abtransport überprüfen“
Translation: „Check need for re-analgesia prior to transport“
- `action`: next
- **Nested Element: Step** (type: medication)
 - `drug`: Fentanyl
 - `dosage`: „0,1 mg“
 - `medication_id`: fentanyl
 - `application_form`: iv

21. **Step** (type: handover)

- mode: minimal
- identifikation: „männlich, Müller, 24J, 80kg“
Translation: „male, Müller, 24yo, 80kg“
- prioritäet: „A: frei | B: AF 16, SpO₂ 96 % | C: HF 86 | D: | E: Sturz beim MTB“
Translation: „A: clear | B: RR 16, SpO₂ 96 % | C: HR 86 | D: | E: MTB crash“
- handlung: „C: 18-G i.v. | D: Fentanyl, PSA (Midazolam, Esketamin) | E: Reposition, Sam-splint“
Translation: „C: 18-G IV | D: Fentanyl, PSA (Midazolam, Esketamine) | E: Reduction, SAM splint“
- anamnese: „Keine Vorerkr., keine Meds, Allergie: Pollinosis, Letzte Mahlzeit: vor 2h“
Translation: „No prior conditions, no meds, allergy: pollen, last meal: 2h ago“

B.3 Detailed Case Sequence: ST-elevation myocardial infarction (STEMI) with shock

The following case study was taken from Koppenberg et al. [2024].

Case Study Metadata (case_study)

- id: stemi_shock
- title: „Hinterwand-STEMI mit kardiogenem Schock“
Translation: „Inferior STEMI with cardiogenic shock“
- patient_name: Herr Ziegler
- patient_age: 56
- patient_gender: m
- patient_weight: 85

Sequential Simulation Flow

1. Comment

- text: „Kapitel 10“
Translation: „Chapter 10“

2. Comment

- text: „Alarmierung und Anfahrt“
Translation: „Dispatch and approach“

3. Text Block

- text: „An einem Dienstagmorgen um 05:15 Uhr geht ihr Melder: Häuslicher Sturz. Die Anfahrt führt sie in eine gepflegte Einfamilienhaussiedlung in einem Vorort.“
Translation: „On a Tuesday morning at 05:15, your pager goes off: domestic fall. The drive takes you to a neat single-family housing estate in a suburb.“

4. Comment

- text: „Eintreffen“
Translation: „Arrival“

5. Text Block

- text: „Beim Eintreffen öffnet ihnen eine besorgte Ehefrau die Tür. Sie ruft ihnen zu: Kommen Sie, mein Mann der ist im Schlafzimmer. Er hat so starke Schmerzen.“
Translation: „Upon arrival, a worried wife opens the door. She calls out to you: Come in, my husband is in the bedroom. He is in so much pain.“

6. Text Block

- text: „Sie folgen der Frau ins Schlafzimmer. Der Patient sitzt leicht nach vorne gebeugt auf der Bettkante.“
Translation: „You follow the woman into the bedroom. The patient is sitting slightly bent forward on the edge of the bed.“

7. Text Block

- text: „In Augenschein fällt sofort, dass der Patient kaltschweißig ist und über starke Schmerzen in beiden Händen klagt.“
Translation: „It is immediately apparent that the patient is cold and sweaty and complaining of severe pain in both hands.“

8. Text Block

- text: „Die Ehefrau erzählt Ihnen, dass Ihr Mann gegen 5 Uhr auf die Toilette wollte. Auf dem weg zur Toilette sei er nach wenigen Schritten wie ein Baum nach vorne umgefallen und mit den Händen voran gegen den Schlafzimmerschrank gestürzt. Nach ca. einer Minute habe der Mann über extrem starke Schmerzen in den Handgelenken geklagt.“
Translation: „The wife tells you that her husband wanted to go to the toilet around 5 o'clock. On the way to the toilet, after a few steps, he fell forward like a tree and crashed hands first into the bedroom wardrobe. After about a minute, the man complained of extremely severe pain in his wrists.“

9. Text Block

- text: „Diese sind inzwischen stark angeschwollen.“
Translation: „These are now severely swollen.“

10. Comment

- text: „erstes xABCDE“
Translation: „first xABCDE“

11. Step (type: prompt)

- text: „Initiales xABCDE“
Translation: „Initial xABCDE“

12. Text Block

- text: „AF 25/min, SpO₂ 85 %, RR 85/43, Rekap. Zeit 3s, GCS 15, Schwellung der Handgelenke“
Translation: „RR 25/min, SpO₂ 85 %, BP 85/43, Cap. refill time 3s, GCS 15, swelling of the wrists“

13. Comment

- text: „Sauerstoff“
Translation: „Oxygen“

14. Step (type: prompt)

- icon: ic_medication
- text: „Sauerstoffgabe (6 l/min)“
Translation: „Oxygen administration (6 L/min)“

15. Comment

- text: „Volumengabe 500ml“
Translation: „Volume administration 500ml“

16. Step (type: prompt)

- text: „i.v. Zugang legen und Volumengabe 500ml“
Translation: „Establish IV access and administer 500ml volume“

17. Text Block

- text: „Der Patient berichtet nun, nachdem er sich langsam beruhigt, dass er zur Toilette habe gehen wollen weil ihm übel geworden sei. Er hatte ein starkes Völlegefühl im Oberbauch.“
Translation: „The patient now reports, after slowly calming down, that he wanted to go to the toilet because he felt nauseous. He had a strong feeling of fullness in his upper abdomen.“

18. Comment

- text: „nach erstem xABCDE folgende Meldung:“
Translation: „following message after first xABCDE:“

19. Comment

- text: „Falls nach einem EKG bereits gefragt wurde, nicht anzeigen.“
Translation: „If an ECG has already been asked for, do not display.“

20. **Step** (type: alert)

- alert_type: yellow
- title: „Diagnose“
Translation: „Diagnosis“
- message: „Mögliche kardiologische Ursache überprüfen!“
Translation: „Check for possible cardiological cause!“
- action: next

21. **Comment**

- text: „spätestens jetzt 12-Kanal EKG“
Translation: „at the latest now 12-lead ECG“

22. **Step** (type: prompt)

- text: „12-Kanal EKG“
Translation: „12-lead ECG“

23. **Step** (type: alert)

- alert_type: red
- title: „EKG Auswertung“
Translation: „ECG evaluation“
- message: „EKG STEMI der Hinterwand erkannt“
Translation: „ECG inferior STEMI detected“

24. **Comment**

- text: „if not happened previously then prompt Vollelektrolytlösung“
Translation: „if not happened previously then prompt balanced crystalloid solution“

25. **Step** (type: medication)

- drug: Vollelektrolytlösung
Translation: Balanced crystalloid solution
- dosage: „500 ml“
- application_form: iv

26. **Comment**

- text: „— hier diesen Fall abbrechen —“
Translation: „— abort this case here —“

B.4 Detailed Case Sequence: Cardiopulmonary resuscitation (CPR)

The following case study was taken from Jahn et al. [2025].

Case Study Metadata (case_study)

- id: reanimation_supermarket
- title: „Herz-Kreislauf-Stillstand (Basic)“
Translation: „Cardiac Arrest (Basic)“
- patient_name: Frau Bauer
- patient_age: 75
- patient_gender: f
- patient_weight: 70
- vitals_enabled: false

Sequential Simulation Flow

1. Comment

- text: „Fallbeispiel 3.1 Herz-Kreislauf-Stillstand (Basic) - Reanimation“
Translation: „Case study 3.1 Cardiac Arrest (Basic) - Reanimation“

2. Text Block

- text: „Um 11:20 Uhr geht ein Alarm für den RTW ein. Einsatzstichwort: 'Kreislaufprobleme einer älteren Dame in einem Supermarkt; vermutlich bewusstlos'. Der Supermarkt liegt nur 500m von der Rettungswache entfernt.“
Translation: „At 11:20 am, an alarm goes off for the ambulance. Dispatch keyword: 'Circulatory problems of an elderly lady in a supermarket; presumably unconscious'. The supermarket is only 500m away from the ambulance station.“

3. Text Block

- text: „Am Notfallort führt eine Angestellte Sie zur Damentoilette. Dort ist eine ältere Dame in einer WC-Kabine eingeschlossen. Sie hatte zuvor über Druck in der Brust und Übelkeit geklagt. Eine Reinigungskraft hörte stöhnende Geräusche, die Dame antwortete jedoch nicht mehr, sondern 'schnarchte' nur noch.“

Translation: „At the scene, an employee leads you to the women's restroom. An elderly lady is locked in a toilet stall there. She had previously complained of chest pressure and nausea. A cleaner heard groaning noises, but the lady no longer answered, only 'snored'.”

4. Text Block

- text: „Das Team findet eine verschlossene Kabinentür vor. Die Füße der Dame sind seltsam verdreht unter der Tür sichtbar. Auf lautes Klopfen und Rufen erfolgt keine Reaktion.“

Translation: „The team finds a locked stall door. The lady's feet are visible under the door, strangely twisted. There is no reaction to loud knocking and calling.”

5. Step (type: action_prompt)

- icon: ic_warning
- title: „Notarzt alarmieren!“
Translation: „Alert emergency physician!”
- subtitle: „Bewusstlosigkeit“
Translation: „Unconsciousness”
- action_button: „NACHFORDERN“
Translation: „REQUEST”

- auto_execute: 5s

- **Nested Element: Step** (type: feedback)

- text: „Notarzt wurde alarmiert. Anfahrt ca. 7 Minuten.“

Translation: „Emergency physician was alerted. Arrival in approx. 7 minutes.”

6. Text Block

- text: „Sie verschaffen sich Zugang zur Kabine. Die Patientin ist blass, nicht kontaktierbar und zeigt keine Regung.“
Translation: „You gain access to the stall. The patient is pale, unresponsive and shows no reaction.“

7. Comment

- text: „nur falls der Proband es nicht von alleine anspricht“
Translation: „only if the test subject does not address it independently“

8. Step (type: prompt)

- text: „Initiales xABCDE & Bewusstseinslage prüfen“
Translation: „Initial xABCDE & check level of consciousness“

9. Text Block

- text: „Es wird eine tiefe Bewusstlosigkeit (GCS 3) festgestellt. Atmung und Kreislauf sind nicht vorhanden. Sichere Todeszeichen sind nicht feststellbar.“
Translation: „Deep unconsciousness (GCS 3) is determined. Respiration and circulation are absent. Sure signs of death are not detectable.“

10. Step (type: alert)

- alert_type: red
- title: „Patientenverfügung“
Translation: „Advance healthcare directive (DNR)“
- message: „Patientin erkannt. KEINE Reanimation gewünscht.“
Translation: „Patient recognized. NO resuscitation desired.“
- action: next

11. Text Block

- text: „Hier schauen ob Proband trotzdem reanimiert oder nicht.“
Translation: „Observe here whether the test subject resuscitates anyway or not.“

12. Text Block

- `text: „ENDE DES FALLBEISPIELS“`
Translation: „END OF CASE STUDY“

B.5 Detailed Case Sequence: Febrile Seizure in a Toddler

This use case presents a 1 year old child with a febrile seizure. It was not part of the three use cases actively used in the study. Instead, this use case was shown to explain the functions of the AsR glasses. This includes the hardware and interaction methods (swiping forward / backward on glasses frame) as well as possible UI elements.

This case study was taken from Jahn et al. [2025].

Case Study Metadata (case_study)

- `id: febrile_seizure`
- `title: „Fieberkrampf bei einem Kleinkind“`
Translation: „Febrile seizure in a toddler“
- `patient_name: Lukas`
- `patient_age: 1`
- `patient_gender: m`
- `patient_weight: 10`

Sequential Simulation Flow

1. Comment

- `text: „Fallbeispiel von 80 Fälle Rettungsdienst – Fallbeispiel 7.6 Atemnot beim Kind (Basic)“`
Translation: „Case study from 80 Cases EMS – Case study 7.6 Dyspnea in a child (Basic)“

2. Text Block

- **text:** „Um 00:24 Uhr erhalten Sie einen Einsatz über Funk mit dem Einsatzstichwort Kind mit Atemnot. Nach der Einsatzübernahme informiert die Leitstelle Sie, dass es sich um ein ca. einjähriges Kind handle, das laut Aussage der Eltern plötzlich blau angelaufen sei. Sie erreichen den Einsatzort im ländlichen Bereich nach siebenminütiger Anfahrt. Bei dem Notfallort handelt es sich um ein Einfamilienhaus.“

Translation: „At 00:24 you receive a radio dispatch with the keyword child with dyspnea. After accepting the assignment, dispatch informs you that it is about an approximately one-year-old child who, according to the parents, suddenly turned blue. You reach the scene in a rural area after a seven-minute drive. The emergency location is a single-family home.“

3. Text Block

- **text:** „Ein aufgeregter ca. 30-jähriger Mann öffnet die Tür. Er empfängt Sie mit den Worten: ‚Kommen Sie schnell, mein Sohn bekommt keine Luft mehr; und führt Sie in das angrenzende Wohnzimmer.“

Translation: „An excited approx. 30-year-old man opens the door. He greets you with the words: ‚Come quickly, my son can’t breathe anymore; and leads you into the adjacent living room.“

4. Text Block

- **text:** „Dort befindet sich eine Frau mit einem Säugling auf dem Arm. Sie erheben den Erstbefund gemäß pädiatrischem Beurteilungsdreieck (PBD): Das Kind erscheint schläfrig und reagiert nicht auf Ihr Eintreffen. Die Atemfrequenz ist regelmäßig, aber leicht erhöht. Sie bemerken eine leichte Lippenzyanose bei ansonsten normalem Hautkolorit.“

Translation: „There is a woman holding an infant in her arms. You assess the initial findings according to the Pediatric Assessment Triangle (PAT): The child appears drowsy and does not react to your arrival.

The respiratory rate is regular but slightly elevated. You notice slight cyanosis of the lips with otherwise normal skin color."

5. Step (type: prompt)

- text: „Primary Survey (ABCDE) durchführen“
Translation: „Perform Primary Survey (ABCDE)“

6. Text Block

- text: „A: Atemwege frei. B: Atemgeräusche unauffällig, SpO₂ 96 %. C: Rekap-Zeit < 2s, Puls schnell und regelmäßig. D: Kind schläfrig, reagiert auf Reize mit Abwehrbewegungen, Pupillen isokor. E: Temperatur 39,6°C (Ohr).“
Translation: „A: Airway clear. B: Breath sounds unremarkable, SpO₂ 96 %. C: Capillary refill time < 2s, pulse fast and regular. D: Child drowsy, reacts to stimuli with defensive movements, pupils isocoric. E: Temperature 39.6°C (ear).“

7. Step (type: prompt)

- text: „SAMPLER-Anamnese mit den Eltern durchführen“
Translation: „Perform SAMPLER history with the parents“

8. Text Block

- text: „Die Mutter berichtet: Lukas ist seit gestern krank (Husten, Abgeschlagenheit, Fieber). Sie wurde durch ein ‚komisches Grunzen‘ wach und fand das Kind blau angelaufen und am Körper zuckend vor. Bisher wurden Wadenwickel und Globuli angewandt. Letzte Mahlzeit: Fläschchen am Abend. Bekannt sind nur rezidivierende Infekte.“
Translation: „The mother reports: Lukas has been sick since yesterday (cough, fatigue, fever). She woke up to a ‚weird grunting‘ and found the child turned blue and twitching all over. So far, calf compresses and homeopathic globules have been used. Last meal: bottle in the evening. Only recurrent infections are known.“

9. **Step** (type: prompt)

- text: „Blutzuckermessung durchführen“
Translation: „Perform blood glucose measurement“

10. **Step** (type: alert)

- alert_type: green
- title: „Diagnose“
Translation: „Diagnosis“
- message: „V.a. Fieberkrampf (postiktale Phase).“
Translation: „Suspected febrile seizure (postictal phase).“
- action: next

11. **Step** (type: medication)

- drug: Paracetamol
- dosage: „125 mg“
- medication_id: paracetamol
- application_form: rectal
- warning_text: „Maximaldosierung (75mg/kg/d) -> 750mg/d beachten!“
Translation: „Note maximum dosage (75mg/kg/d) -> 750mg/d!“
- warning_type: yellow

12. **Step** (type: prompt)

- text: „Diazepam-Rektiole (5 mg) für Rezidivfall bereitlegen“
Translation: „Prepare Diazepam rectal tube (5 mg) in case of recurrence“
- action: next

13. **Step** (type: prompt)

- text: „Wadenwickel zur Fiebersenkung erneuern“
Translation: „Renew calf compresses to lower the fever“
- action: next

14. **Step** (type: prompt)

- text: „Transport in Kinderklinik vorbereiten (Monitoring: Pulsoxymetrie)“
Translation: „Prepare transport to children’s hospital (Monitoring: pulse oximetry)“
- action: next

15. **Step** (type: handover)

- mode: minimal
- identifikation: „männlich, Lukas, 1J, 10kg“
Translation: „male, Lukas, 1yo, 10kg“
- ereignis: „Kind plötzlich blau angelaufen und am ganzen Körper zuckend aufgefunden. Aktuell postiktale Phase.“
Translation: „Child suddenly turned blue and found twitching all over. Currently postictal phase.“
- prioritäet: „A: frei | B: AF 25, SpO₂ 96 % | C: HF 140, Recap < 2s | D: schläfrig, reagiert auf Reize | E: Temp 39,6°C“
Translation: „A: clear | B: RR 25, SpO₂ 96 % | C: HR 140, Cap refill < 2s | D: drowsy, reacts to stimuli | E: Temp 39.6°C“
- handlung: „C: Monitoring | E: 125mg Paracetamol supp. | D: Diazepam bereitgelegt“
Translation: „C: Monitoring | E: 125mg Paracetamol supp. | D: Diazepam prepared“
- anamnese: „Rezidivierende Infekte, keine Allergien, letzte Mahlzeit: Fläschchen am Abend.“
Translation: „Recurrent infections, no allergies, last meal: bottle in the evening.“

Appendix C

User Study

C.1 Study Procedure

Studienablauf

1. Datenschutz unterschreiben
 - a. Aufklärung
 - b. Fragen klären
2. Fragebogen Ausfüllen lassen
 - a. Dabei Unterschied von VR, AR, AsR erklären
3. Brille kennenlernen lassen
 - a. Hardware und Eingabemöglichkeiten erklären
4. Erstes Beispielfallbeispiel (zusammen mit Probanden durchgehen)
 - a. Nur Funktionen und Screens erklären
5. Erklären was erwartet wird bei den Fallbeispielen
 - a. Probanden sollen fiktive Patienten behandeln (und Maßnahmen oder Untersuchungen, die sie nicht durchführen können (aufgrund fehlenden Materials oder Menschen), erklären).
 - b. Disclaimer:
 - i. Das Ziel der Studie ist nicht die konkrete Brille zu bewerten, sondern das allgemeine Konzept. Das Konzept ist, visuell Informationen über eine AsR/AR-Brille im Einsatz einzublenden. Dazu gehören auch die Interaktionsmöglichkeiten.
 - ii. Unser Ziel ist es daher nicht genau dieses Modell im Einsatz später zu verwenden, da bereits bessere Modelle in Aussicht stehen. (Leichter, bessere Auflösung, längere Laufzeit)
6. Fallbeispiele
 - a. Nach jedem Fallbeispiel einen Fragebogen ausfüllen lassen
 - b. Fallbeispiele:
 - i. (A): Herz-Kreislauf REA
 - ii. (B): fracture_osg
 - iii. (C): stemi_shock
7. Semi-Structured Interview

C.2 Privacy Information and Consent Form

Einwilligung und Information zur Erhebung und Verarbeitung personenbezogener Daten für eine Studie im Rahmen der Bachelorarbeit „Konzeptentwicklung geeigneter Nutzer-Schnittstellen für ein nicht-intrusives Assistenzsystem in der prähospitalen Notfallmedizin“

1. Forschungsprojekt

Konzeptentwicklung geeigneter Nutzer-Schnittstellen für ein nicht-intrusives Assistenzsystem in der prähospitalen Notfallmedizin (Bachelorarbeit).

2. Beschreibung des Forschungsprojektes

Im Rahmen dieser Studie wird der Einsatz einer AR-Brille im Rettungsdienst evaluiert. Mittels simulierter Fallbeispiele wird untersucht, wie Head-up-Displays (HUDs) gestaltet sein müssen, um als nicht-intrusives Assistenzsystem in der präklinischen Notfallmedizin optimal zu funktionieren.

3. Projektleitung

Jonas Boxler, RWTH Aachen, jonas.boxler@rwth-aachen.de

4. Gegenstand und Zweck der Verarbeitung personenbezogener Daten

Die Daten werden im Rahmen von Fragebögen, der Aufzeichnung von Fallbeispielen und einem Interview erfasst. Die pseudonymisierten Ergebnisse werden in die Abschlussarbeit aufgenommen und im akademischen Rahmen veröffentlicht. Es erfolgt keine anderweitige Nutzung.

5. Art der personenbezogenen Daten der Betroffenen/besondere Kategorien von personenbezogenen Daten

Es werden persönliche Angaben (Geschlecht, Alter, Qualifikation, Berufserfahrung im Rettungsdienst) sowie potenziell Audio- und Videoaufzeichnungen zur Verhaltens- und Interaktionsanalyse während der Fallbeispiele angefertigt. Außerdem werden Audioaufzeichnungen eines Interviews verwertet.

6. Empfänger der Daten

Die Rohdaten werden intern von Jonas Boxler ausgewertet. Betreuer der Bachelorarbeit erhalten Zugriff auf die Daten. Anonymisierte Ergebnisse fließen in die Abschlussarbeit ein.

7. Rechtsgrundlage

Für die Verarbeitung der personenbezogenen Daten im Zusammenhang mit dem oben genannten Forschungsprojekt ist eine Einwilligung gem. Art. 6 Abs. 1 S. 1 lit. a) DSGVO erforderlich und dient als Rechtsgrundlage.

Sofern besondere Kategorien personenbezogener Daten betroffen sind, werden die von Ihnen erhobenen personenbezogenen Daten auf Basis Ihrer Einwilligung gemäß Art. 9 Abs. 2 lit. a) DSGVO verarbeitet.

8. Datenlöschung und Speicherdauer

Die Daten werden gespeichert, bis der Zweck erlischt (Abschluss und Begutachtung der Bachelorarbeit sowie Ablauf gesetzlicher Aufbewahrungsfristen) oder der Nutzer die Verarbeitung seiner Daten widerruft.

9. Rechte der betroffenen Person

Werden personenbezogene Daten von dem Unterzeichnenden verarbeitet, ist er Betroffener i.S.d. DS-GVO und es stehen ihm folgende Rechte gegenüber dem Verantwortlichen zu.

Er hat gemäß Artikel 15 ff. DS-GVO dem Verantwortlichen gegenüber unter den dort definierten Voraussetzungen das Recht auf **Auskunft** über die betreffenden personenbezogenen Daten sowie auf **Berichtigung** oder **Löschung** oder auf **Einschränkung** der Verarbeitung, ein **Widerspruchsrecht** gegen die Verarbeitung sowie das Recht auf **Datenübertragbarkeit**. Auch hat er gemäß Artikel 77 DS-GVO das Recht der Beschwerde bei der Datenschutz-Aufsichtsbehörde (<https://www.ldi.nrw.de/>), wenn der Betroffene der Ansicht ist, dass die Verarbeitung der ihn betreffenden personenbezogenen Daten gegen diese Verordnung verstößt. Wenn die Verarbeitung auf einer Einwilligung des Betroffenen beruht (vgl. Art. 6 Abs. 1 lit. a, Art. 9 Abs. 2 lit. a DSGVO), hat er ferner das Recht, die Einwilligung jederzeit zu widerrufen, ohne dass die Rechtmäßigkeit der aufgrund der Einwilligung bis zum Widerruf erfolgten Verarbeitung berührt wird; dieser entfaltet seine Wirkung erst für die Zukunft.

Zur Ausübung der vorgenannten Rechte sendet der Unterzeichner eine E-Mail an jonas.boxler@rwth-aachen.de.

- ☐ Ich willige in die Verarbeitung der personenbezogenen Daten im Rahmen der Bachelorarbeit zu den oben genannten Zwecken ein. Mir ist bekannt, dass ich nicht verpflichtet bin, obige Einwilligung zu erteilen und ich diese jederzeit widerrufen kann.
- ☐ Ich möchte freiwillig an der Studie teilnehmen. Mir ist bewusst, dass ich jederzeit ohne Konsequenzen die Studie abbrechen kann.

Name, Vorname

Ort, Datum

Unterschrift

Studienleitung

Ort, Datum

Unterschrift

C.3 Questionnaire

Id:

Fragebogen

Auszufüllen vor Studie

Allgemein zu Ihrer Person

Nr	Frage
1	Welches Geschlecht haben Sie? ☐ männlich ☐ weiblich ☐ divers
2	Wie alt sind Sie? _____ Jahre alt

Ausbildung und Qualifikationen

3	Welche ist Ihre höchste medizinische Qualifikation? ☐ Keine ☐ EH (Erste-Hilfe-Kurs) ☐ San (Sanitätshelfer/in) ☐ RH (Rettungshelfer/in) ☐ RS (Rettungssanitäter/in) ☐ Rettungsassistent/in ☐ Notfallsanitäter/in ☐ Arzt/Ärztin ☐ Andere (z.B. OTA, MFA, ATA, Pflegefachkraft): _____
4	Welche zusätzlichen rettungsdienstbezogenen Qualifikationen haben Sie? ☐ Praxisanleiter/in ☐ Desinfektor/in ☐ Organisatorischer Leiter/in Rettungsdienst ☐ Leitender Notarzt (LNA) ☐ Luftrettung ☐ Disponent für die integrierte Leitstelle ☐ Ausbilder, für: _____ ☐ Sonstige: _____
5	Üben Sie Ihre medizinische Qualifikation hauptamtlich und/oder ehrenamtlich aus? ☐ Hauptamtlich, seit _____ Jahren ☐ Ehrenamtlich, seit _____ Jahren

Id:

Augen und Sehvermögen

6 Tragen Sie im Einsatz eine Brille? (z.B. als Sehhilfe)

- ☐ Ja
☐ Nein
-

Erfahrungen mit AR / Smart-Brillen

7 Haben Sie schon einmal eine **VR**-Brille benutzt? (z.B. Meta Quest, PlayStation VR, Apple Vision Pro, HTC Vive)

- ☐ Jeden Tag
☐ Regelmäßig
☐ Ein paar Mal
☐ Einmal
☐ Noch nie
-

8 Haben Sie schon einmal eine **AR**-Brille benutzt? (z.B. Microsoft HoloLens, Apple Vision Pro, Meta Quest)

- ☐ Jeden Tag
☐ Regelmäßig
☐ Ein paar Mal
☐ Einmal
☐ Noch nie
-

9 Haben Sie schon einmal eine **AsR**-Brille benutzt? (z.B. Google Glass, Meta Display, Rayneo, Rokid)

- ☐ Jeden Tag
☐ Regelmäßig
☐ Ein paar Mal
☐ Einmal
☐ Noch nie
-

10 Haben Sie schon einmal ein Heads-Up-Display benutzt? (z.B. Geschwindigkeitsanzeige im Auto auf der Frontschuttscheibe)

- ☐ Jeden Tag
☐ Regelmäßig
☐ Ein paar Mal
☐ Einmal
☐ Noch nie
-

11 In welchem Kontext haben Sie schon einmal eine **VR**-Anwendung verwendet?

- ☐ Gaming zuhause
☐ Gaming extern
☐ Kunst / Museum
☐ Schulung / Übung / Lehre
☐ Sonstiges, und zwar: _____
-

Id:

12 In welchem Kontext haben Sie schon einmal eine **AR**-Anwendung verwendet?

- ☐ Gaming zuhause
- ☐ Gaming extern
- ☐ Kunst / Museum
- ☐ Schulung / Übung / Lehre
- ☐ Sonstiges, und zwar: _____

13 In welchem Kontext haben Sie schon einmal eine **AsR**-Anwendung verwendet?

- ☐ Gaming zuhause
 - ☐ Gaming extern
 - ☐ Kunst / Museum
 - ☐ Schulung / Übung / Lehre
 - ☐ Sonstiges, und zwar: _____
-

Ihre bisherigen Erfahrungen mit XR (Falls zutreffend)

14 Wie waren Ihre bisherigen Erfahrungen mit XR-Anwendungen?

				
Sehr schlecht	Schlecht	Okay	Gut	Sehr gut

Rettungsdienst

16 Welche Merkhilfen verwenden Sie im Einsatz?

- ☐ Checklisten
 - ☐ Schablonen (z.B. für die Notfallnarkose)
 - ☐ Taschenkarten
 - ☐ SOPs (Standard Operating Procedures)
 - ☐ Algorithmen
 - ☐ Sonstige, und zwar: _____
 - ☐ Keine
-

Id:

Assistenzsysteme für den Rettungsdienst

- 17 In **welchen Bereichen** würden Sie sich eine digitale Unterstützung wünschen? / **Welche Informationen** sollte Ihnen ein Assistenzsystem zur Verfügung stellen?

Ich würde mir bei ... digitale Unterstützung wünschen.

	1 Stimme überhau pt nicht zu	2 Stimm e nicht zu	3 Stimm e eher nicht zu	4 Weder noch	5 Stimm e eher zu	6 Stimm e zu	7 Stimm e voll und ganz zu
Medikation (Auswahl)							
Medikation (Dosierung)							
Medikation (Dosierung Kinder)							
Wechselwirkungen mit Dauermedikatione n							
Vitalparameter- überwachung							
Patientenübergabe							
Diagnosefindung							
Auswahl von Behandlungs- schritten							
Scores (und deren Berechnung)							
Dokumentation							
Einsicht in Patientenakte/ Vorgeschichte							
Vorerkrankungen							
Patientenverfügun g							
Navigation (Auto)							
Navigation (Zu Fuß)							

Id:

Potenzielle Eintreffzeiten von Einsatzmitteln (z.B. nächster freier Notarzt, RTH, Drehleiter)							
Krankenhauskapazitäten							
Live-Übersetzung							
Allergien							
SOPs, Algorithmen und Leitlinien							
Gefahrenstoffe							
Kontakte (Angehörige, Hausarzt)							

In folgenden weiteren Bereichen oder Situationen:

28 Wollen Sie mir noch etwas mitteilen?

C.4 Post-Scenario Questionnaire

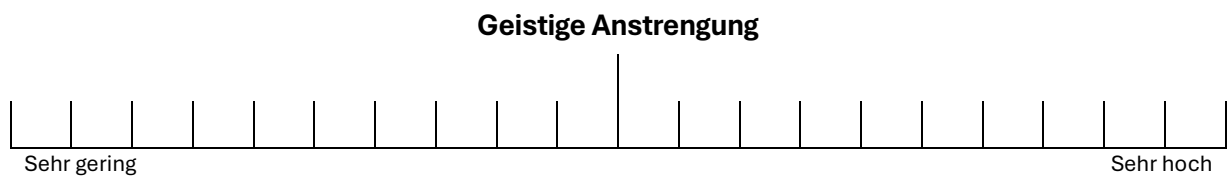
Id:
Fallbeispiel Nr:

Fragebogen

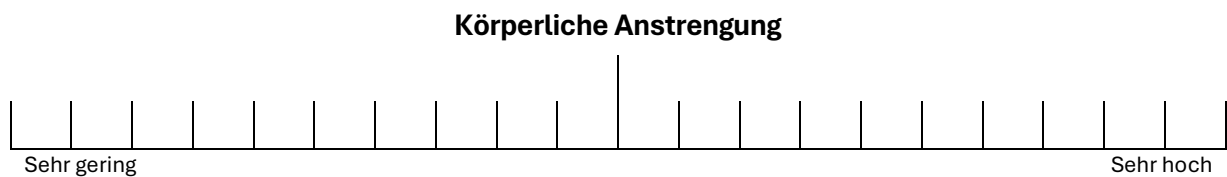
Auszufüllen nach jedem Fallbeispiel

Bitte bewerten Sie die soeben durchgeführte Aufgabe anhand der folgenden sechs Kriterien. Setzen Sie ein Kreuz (X) in das Kästchen, das Ihre Erfahrung im Fallbeispiel am besten widerspiegelt.

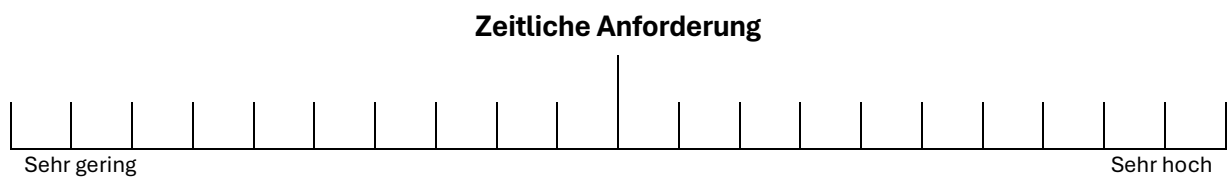
1. Wie viel **geistige Anstrengung** war im Fallbeispiel erforderlich?



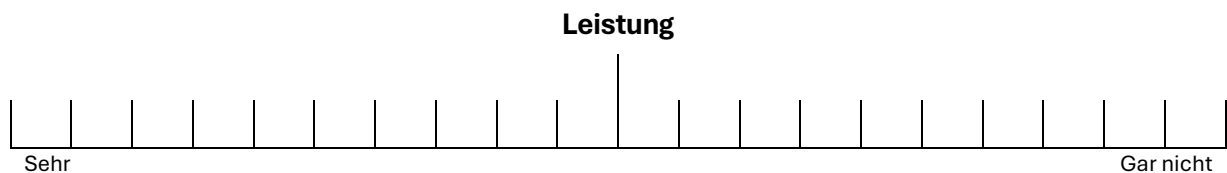
2. Wie viel **körperliche Anstrengung** war erforderlich?



3. Wie viel **Zeitdruck** empfanden Sie während des Fallbeispiels?



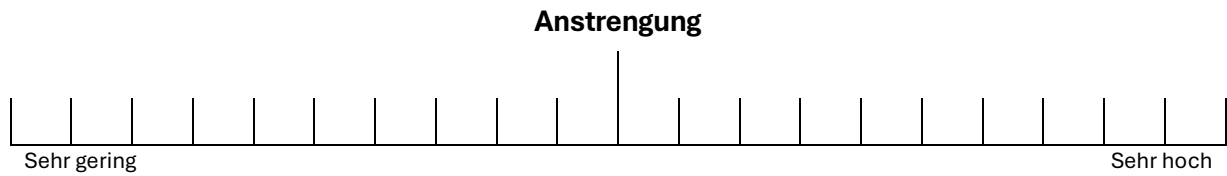
4. Wie zufrieden waren Sie mit Ihrer **Leistung** im Zusammenhang mit diesem Fallbeispiel?



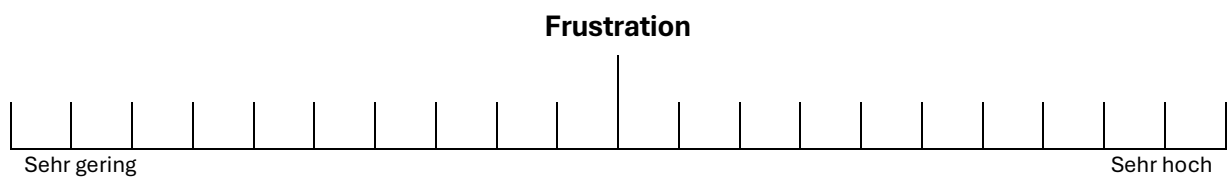
Id:

Fallbeispiel Nr:

5. Insgesamt betrachtet: Wie groß war die von Ihnen empfundene **Anstrengung** bei diesem Fallbeispiel?



6. Wie **frustriert** fühlten Sie sich während des Fallbeispiels?



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

	1	2	3	4	5	6	7	
behindernd	☐	☐	☐	☐	☐	☐	☐	unterstützend
kompliziert	☐	☐	☐	☐	☐	☐	☐	einfach
ineffizient	☐	☐	☐	☐	☐	☐	☐	effizient
verwirrend	☐	☐	☐	☐	☐	☐	☐	übersichtlich
langweilig	☐	☐	☐	☐	☐	☐	☐	spannend
uninteressant	☐	☐	☐	☐	☐	☐	☐	interessant
konventionell	☐	☐	☐	☐	☐	☐	☐	originell
herkömmlich	☐	☐	☐	☐	☐	☐	☐	neuartig

Wollen Sie mir noch etwas mitteilen?

C.5 Interview Questions

Id:

Interview Fragen

Allgemein (Bewertung des Prototyps)

1. Haben Sie mit der Nutzung des Assistenzsystems anders gehandelt, als Sie normalerweise handeln würden?
2. Welche Einblendung fanden Sie am hilfreichsten?
 - a. Warum? (Darstellungsart, Timing, Inhalt, Notwendigkeit, Ablenkungsfaktor)
 - b. Fanden Sie noch weitere Einblendungen hilfreich?
3. Welche Einblendung fanden Sie am wenigsten hilfreich?
 - a. Warum? (Darstellungsart, Timing, Inhalt, Notwendigkeit, Ablenkungsfaktor)
 - b. Fanden Sie noch weitere Einblendungen nicht hilfreich?

Darstellungsart und Formfaktor (visuell)

4. Könnten Sie sich vorstellen im Einsatz eine AsR-Brille zu tragen?
 - a. Falls nein: Welche Eigenschaften stören Sie?

Ideales Assistenz System

5. In welchen Situationen im Einsatz würden Sie sich eine Unterstützung wünschen?
(In der Form eines Assistenzsystems)
 - a. Beispiele: Fragebogen
 - b. Wie müsste die Unterstützung gestaltet sein, damit Sie diese verwenden würden?
 - i. In Hinsicht auf die Informationen, die angezeigt werden (*Was?*)
 - ii. In Hinsicht auf die Darstellungsart – d.h. wie diese Informationen angezeigt werden (*Wie?*)
 - iii. Welche Interaktionsmöglichkeiten würden Sie sich wünschen?
 1. D.h. Eingabemöglichkeiten oder manuelle Eingriffsmöglichkeiten

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