UiA University of Agder

Master

User-Centered Design and Evaluation of an Augmented Reality-based Decision Support Prototype for Ambulance Workers

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Abstract

Background: The demand for healthcare services is increasing globally, and there is a need for improved, sustainable health services. The Norwegian Ministry of Health and Care Services highlights the need for improved coordination between the various healthcare providers to ensure a cohesive patient journey. Ambulance services play an important role in the early phases of the patient journey. There is an increasing demand for performing clinical tasks in ambulance services while having limited support.
Objective: The main objective of this study is to investigate how technological solutions can increase information availability and decision support for ambulance workers while they are providing emergency care. Five research questions were formulated, looking into how Augmented Reality (AR) can potentially support ambulance workers in providing emergency care.
Methods: In this mixed-method study, a Design Science Research Methodology (DSRM) was used. In addition, the Human-Centered Design approach was utilized, to ensure user involvement throughout the process. A co-design workshop with ambulance workers was conducted to assess the users' needs and to gather requirements for the conceptual design and prototype development. Furthermore, a prototype demonstration and user feedback workshop was performed to receive user feedback on the proposed concept.
Results: Based on the needs assessment and requirement specification, a solution concept has been designed, and a corresponding Proof of Concept (PoC) prototype was developed using Microsoft HoloLens 2 glasses. The prototype contains four main components: a video communication tool, visualization of the patient's vital parameters, presentation of clinical practice guidelines, and visualization of the patient's medical history. In the prototype demonstration and user feedback workshop, all participants unanimously agreed that the use of video communication with remote physicians would increase decision support, and that the use of the prototype system based on AR-technology would increase patient safety. However, both technical and usability challenges were discovered, highlighting the need for further refinements of the design, and user testing.
Conclusion: AR technology can potentially be applied in prehospital emergency care, but the technology must be developed further and adopted to the emergency care context. In addition, a lack of research on the use of AR technology in prehospital emergency care was identified, emphasizing the need for further research.

Keywords:
Prehospital emergency care, Ambulance workers, Clinical decision support, Augmented reality, User involvement

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University of Agder, 2021
Annika Irslinger

Contents

List of Figures

List of Tables

Abbreviations

AR Augmented Reality

CDS Clinical Decision Support

DSR Design Science Research

DSRM Design Science Research Methodology

ECG Electrocardiogram

ED Emergency Department

EMDC Emergency Medical Dispatch Center

EMS Emergency Medical Service

GP General Practitioner

HCD Human-Centered Design

ICT Information and Communication Technology

IDE Integrated Development Environment

MTU Medical-Technical Unit

PEPJ Prehospital Electronic Patient Journal

PoC Proof of Concept

SUS System Usability Scale

TRL Technology Readiness Levels

UCD User-Centered Design

UI User Interface

UWP Universal Windows Platform

Definition of Terms

Augmented Reality
«Augmented Reality (AR) technologies project virtual information onto real world environments» [1].

Clinical practice guidelines
«Clinical practice guidelines are systematically developed statements to assist practitioner and patient decisions about appropriate health care for specific clinical circumstances» [2].

Clinical decision support
«Clinical Decision Support (CDS) provides clinicians, staff, patients, or other individuals with knowledge and person-specific information, intelligently filtered or presented at appropriate times, to enhance health and health care» [3].

Emergency care chain
According to the Norwegian National Advisory Unit on Prehospital Emergency Medicine (NAKOS), [4] the emergency care chain mainly consists of General Practitioner (GP), out-of-hours medical service and call center, Emergency Medical Dispatch Center (EMDC), ambulance vehicle, boat, and helicopter, and hospital emergency department.

Emergency Medical Dispatch Center
The Emergency Medical Dispatch Center (EMDC) receives the emergency calls and gives instructions and support to the caller, while coordinating and dispatching ambulance resources [4].

Prehospital Electronic Patient Journal
The phrase Prehospital Electronic Patient Journal (PEPJ) refers to the electronic ambulance record system that is used in Norway.

Proof of Concept
Kendig [5] refers to Oxford English Dictionary, defining a proof of concept as follows: «Evidence (usually deriving from an experiment or pilot project) demonstrating that a design concept, business idea, etc., is feasible» [6].

Prototype
«A prototype is an early sample, model or release of a product created to test a concept or process» [7].

Smart glasses

The following definition of smart glasses is given by Hofmann et al. [8]:

> "Smart-glasses," "digital eye glass," "eye glass display," or "personal imaging systems" are wearable devices that display images to the visual field of a user. They are designed to add visual elements to the visual experience of a person without significantly distorting or disturbing the person's ordinary vision.

Summary care record

Defined by Helse Norge [9]: «A Summary care record («Kjernejournal») provides healthcare professionals with fast access to certain important health information about you, regardless of where you are receiving treatment.»

Technology Readiness Levels

«Technology Readiness Levels (TRL) are a type of measurement system used to assess the maturity level of a particular technology» [10].

Chapter 1

Introduction

1.1 Background

A growing population and an increasing elderly population extend the demand for health care services globally, and emphasize the need for an improved and sustainable health service [11, 12]. The Norwegian Ministry of Health and Care Services established a strategy for the development of healthcare services in the National Health and Hospital Plan 2020-2023, with an aim of achieving a sustainable, patient-centered health service in Norway [13, 14]. The importance of coordination between municipalities and hospitals to achieve a cohesive patient journey is highlighted, which is in line with The Coordination Reform [15]. Furthermore, the government wants to facilitate more use of technology, such as ICT systems that support coordination between healthcare personnel, and points out that the possibility for two-way communication between health professionals will benefit the patients. One of the main goals is to achieve a coordinated chain of emergency care [14], and as seen in Figure 1.1, technology is suggested to play an important role in accomplishing this.

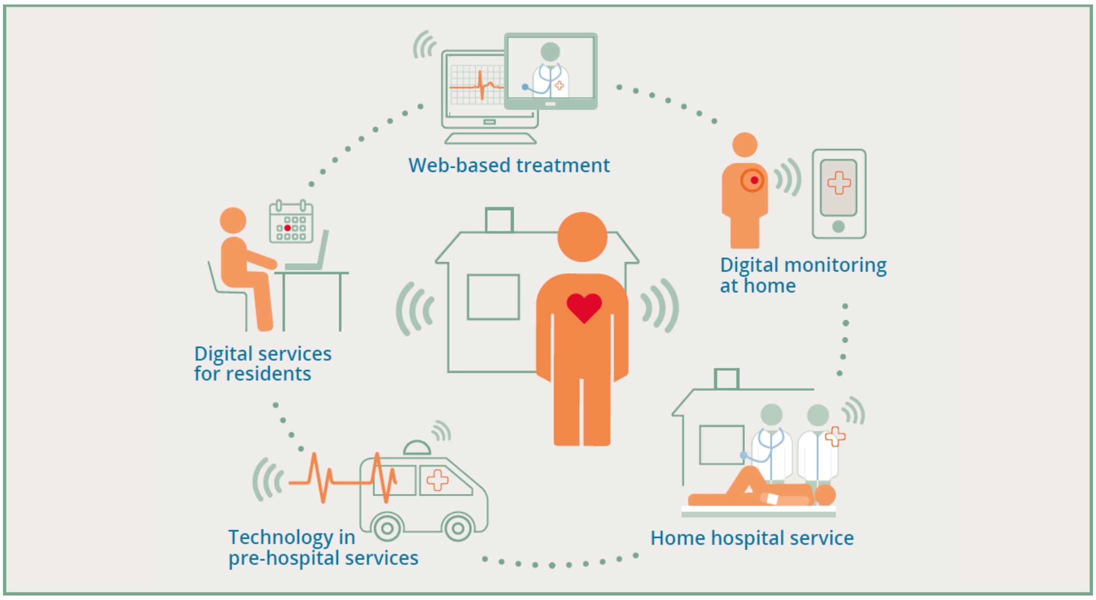

Figure 1.1: Technology in prehospital services is one of the main focus areas [14]

Prehospital emergency services are the citizens' safety net when experiencing critical situations, and the ambulance service plays an important role in starting patient treatments and bringing patients to correct care facilities for further treatment. In acute situations, time can be crucial for the patient outcome [16]. Technology, such as medical technical devices and patient records have been developed, but ambulance services are still behind on the digitization process. Many ambulances are still using paper-based systems and there are limited coordination and data sharing between the care facilities in the emergency care chain [17].

Emergency Care Context

According to the Norwegian National Advisory Unit on Prehospital Emergency Medicine (NAKOS), [4] the emergency care chain mainly consists of General Practitioner (GP), out-of-hours medical service and call center, Emergency Medical Dispatch Center (EMDC), ambulance vehicle, boat, and helicopter, and hospital emergency department. The figure below, Figure 1.2, shows different actors of the emergency care chain in Norway [18]. The EMDC receives the emergency calls and gives instructions and support to the caller, while coordinating and dispatching ambulance resources. The ambulance service has an important role in the early stages of the patient journey, by starting early clinical examinations and treatments until arrival at the receiving care facility. For the whole emergency care service to function properly, each actor in the emergency care chain must perform well independently and also together as a team [4].

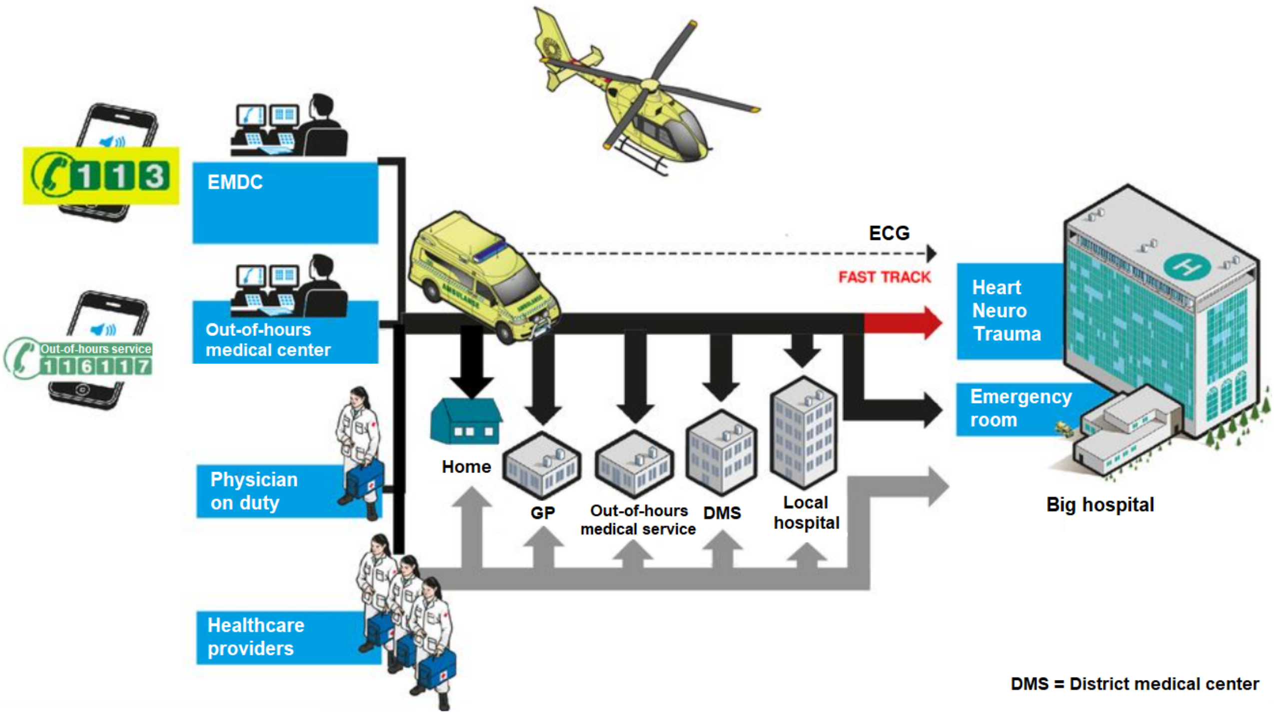

Figure 1.2: The Norwegian emergency care chain (translated to English) [18]

1.2 Problem Statement

Ambulance services have moved from solely being a patient transportation service, to being the hospitals' extended arm to start early patient treatments [17]. An increasing demand for the ambulance workers to execute clinical examinations and start early treatment and preparations in demanding scenarios increases the need for extended knowledge and decision support in the ambulance services. Complex and vague missions can be challenging to handle, and ambulance workers sometimes struggle to find the correct level of care and where to transport the patient [17, 19]. Due to limited coordination with other care facilities in the emergency care chain, the ambulance workers can experience a feeling of being alone in demanding situations[1].

1.2.1 Scope

In this research, the main objective is to investigate how technological solutions can increase the information availability and clinical decision support for the ambulance workers while they are providing emergency care. Other stakeholders, such as physicians, specialists, and patients are also relevant for this project, but will not be the main focus in this study. The user perspective is essential for this research, and therefore the technical focus is mainly concentrated on the top layer in the seven-layered OSI model [20]. Others have researched how video communication tools, such as ceiling-mounted cameras or smart phones can be used to increase decision support in ambulance services [12, 16, 19, 21, 22], while in this study the use of augmented reality is investigated. Hence, the following research questions were created.

1.2.2 Research Questions

RQ1: How can Augmented Reality (AR) support ambulance workers in providing emergency care?
RQ2: How do ambulance workers need information and decision support to be presented to them while providing emergency care?
RQ3: How do ambulance workers prefer to request information and decision support on-demand while providing emergency care?
RQ4: How can bi-directional support between ambulance workers and care facilities be provided?
RQ5: What are the main usability challenges with AR technology used in prehospital emergency care?

[1]Based on findings in the authors pre-project, ICT442 Seminar 3. Not published report, can be provided on request. Title: Use of ICT/eHealth in prehospital care: in-vehicle system to support ambulance workers

1.3 Project Context

The author of this study is employed at Bliksund AS and has been involved in an innovation project in the company. The innovation project investigates how state-of-the-art technology can be used to support ambulance workers in providing emergency care. Knowledge gained in the innovation project has been valuable in the execution of the author's planned activities in this study. When preparing the user involvement activities, an expert panel from Bliksund supported the author in constructing scenarios with correct terminology to present to involved ambulance workers. The expert panel consisted of the chief medical officer, the ambulance record product owner, and a customer contact from Bliksund. The author has gained valuable insight into the prehospital emergency care field, and has acquired important contacts and easy access to target users for this study. Thus, quality assurance and validity of studied questions were improved.

1.4 Disclaimer

Due to the Covid-19 pandemic, parts of the planned activities for this project were not possible to perform in the intended way. The user involvement of the ambulance workers had to be done in digital online workshops via video collaboration tools, rather than meeting physically as intended. Since the user involvement was performed digitally, the developed concepts could not be systematically tested and evaluated in the academic institution's test facilities as initially planned.

Chapter 2

State-of-the-Art

Based on the research questions formulated for this study, two main areas were investigated to get an overview of the state-of-the-art: 1) decision support via video technology and 2) augmented reality applied in prehospital emergency care or related environments. Due to limited existing research on augmented reality in prehospital emergency care, literature targeting other environments, such as medicine, education, disaster management, and the military were also included.

Decision Support via Video Technology

Several studies have identified benefits by using video technology in prehospital care [12, 16, 19, 21–23]. Ambulance workers can communicate (audio + video) with remote physicians, such as specialists at the hospital, and receive advice regarding the patient treatment. Winburn et al. [23] present a systematic review of the utilization of telehealth in prehospital care, stating that real-time video conferencing is the most common way of delivering telehealth in Emergency Medical Services (EMS). Potential for improved critical decision making by using advanced technology was addressed. Furthermore, real-time video seemed to be especially beneficial when used in potential stroke situations. However, a shortage of research on the use of telehealth in the prehospital environment was discovered, implying that the utilization of telehealth in prehospital care could be expanded [23].

Wu et al. [16] proposed a cloud-based real-time data sharing solution for automatic streaming of the gathered data, such as vital signs, ECG, and image/video from the emergency scene to the hospital prior to arrival. The system is a tablet-based Android application used over broadband cellular network. Wu et al. [16] state that the offering of a video-based telemedicine platform enhances the prehospital care quality, by expanding the medical care that can be given in the ambulance vehicle. However, when testing the solution, connectivity issues were discovered. The live video had up to 40% frame loss when driving on the highway, when exceeding 40 mph (approximately 64 km/h), and had almost 1 second latency. Weerakkody et al. [12] also highlighted challenges regarding data loss when delivering video over the internet, leading to poor video quality. High video quality is essential in time-critical decision making. Nevertheless, the study [12] presents several benefits using video in prehospital care, such as improved quality of healthcare by improving decision making and increased diagnostic accuracy.

Stated by Thelen et al. [21], the single most important factor for successful bi-directional video communication between ambulance workers and physicians is usability, including such factors as ease of use, reliability, and robustness. Vicente et al. [19] also highlight the importance of good usability, since unreliable technology and poor usability reduce the benefit of video communication. The solution presented by Thelen et al. [21] is a ceiling-mounted camera that can be controlled (tilt and zoom) by the remote physician. Bergrath et al. [22] also investigated the feasibility of prehospital video communication with physicians with a ceiling-mounted camera in the ambulance vehicle. The physicians mainly gave diagnostic support and delegated medication administration to the ambulance workers remotely, which could increase patient safety. The study [22] concluded that the provision of vital signs, ECG, and video streaming to the hospital can shorten the time before advanced treatment can be provided. In addition, there is a need for a larger study to investigate possible complications and patient outcome.

Kim et al. [24] indicated that the diagnosis made prehospitally, when being supported remotely using telemedicine was made accurately, since the diagnosis was in accordance with the in-hospital diagnosis. Even though the study identified benefits of using telemedicine in emergency prehospital care, Kim et al. [24] claim that a majority of the articles investigating the use of remote support from experts do not provide quantitative data from long-term studies, thus identifying a lack of quality assurance and documentation on patient outcomes. Kim et al. also address technical challenges when using video communication in prehospital care, such as network failures and limited processing power.

Vicente et al. [19] address that the ambulance workers can receive support via video communication with physicians in deciding if the patient is healthy enough to stay at home with self-care. Both the patients and the ambulance workers were more confident in the decisions and believed the support increased patient safety. Moreover, [24] and [12] indicate that the use of video communication helps in deciding the correct level of treatment and where to transport the patient.

Augmented Reality in Related Environments

When browsing relevant literature, a lack of research was discovered relating to the use of AR in prehospital emergency care and ambulance services. Therefore, related environments were researched, such as medicine, the military, and disaster and mass causality incidents.

Mainly, AR has been used for training or educational settings in the reviewed literature [25–31]. Munzer et al. [25] executed a scoping review of the use of AR technology in emergency medicine. The prehospital care category only contained eight articles, which were mainly looking into training or educational applications.

[26, 30] and [31] use AR technology to provide contextual content such as displaying an

overlay of internal organs on manikins or cadavers or by setting the scene by simulating real-life scenarios. Ingrassia et al. [30] present an AR self-instruction training system that visualized 3D objects anchored to a manikin and the environment.

Wilson et al. [26], Glick et al. [28] and Follmann et al. [32] state that the use of AR applications increased the accuracy when performing clinical tasks. In Follmann's study [32], paramedics carried out a triage of patients, where one group used smart glasses and the other group did not. The participants using smart glasses had an accuracy of 92%, while the control group only reached an accuracy of 58%. However, the triage took much more time when using the AR application.

[25, 27, 28, 32–34] investigate AR solutions for providing remote guidance and decision support. Glick et al. [28] found that the use of AR glasses with guidance from a remote mentor increased the quality of performance and self confidence when performing a chest thoracotomy. In addition, the duration of the procedures was not significantly affected when using the AR glasses. Broach et al. [34] look into the use of smart glasses during mass causality incidents. The study highlights that AR glasses can provide incident commanders and the receiving care facility with valuable information from the scene. The information exchange can help the incident commanders and physicians get an overview of the incident and plan the allocation of resources. The possibility for hands-free communication when taking care of patients was highlighted, especially in mass causality incidents [32, 33, 35]. The scoping review by Munzer et al. [25] suggest that AR technology should have a role in telehealth after finding that the use of AR to provide healthcare over distances is feasible.

Although several possibilities have been found with AR technology, usability challenges have been identified in the literature [29, 31, 35]. Martinez-Millana et al. [35] state that the literature highlights technical limitations with Google Glass, such as connectivity failure, challenges with receiving images, and that the device automatically reboots. Furthermore, Leuze et al. [31] tested the use of voice commands using the HoloLens 1 and found that high background noise strongly affected the voice recognition negatively. Demir et al. [33] suggest that a user-centered design approach should be utilized to achieve high user acceptance and satisfaction when developing such complex interactive systems.

According to the state-of-the-art, there is a wide range of possibilities using AR technology in emergency care. Studies [25, 30, 32] claim that there is huge potential for AR technology in healthcare education, disaster scenarios, and in prehospital and telemedicine settings. Nevertheless, the literature emphasizes that research on AR technology applied in clinical settings is in its early stages and that further research is required [25, 28, 36].

Chapter 3

Theoretical Background

In this chapter, background information relevant to this thesis is briefly presented, describing the methodology used and giving a brief introduction to augmented reality.

3.1 Design Science Research

The Design Science Research Methodology (DSRM) presented by Peffers et al. [37] gives an overview of principles, practices, and procedures required to carry out design science research in information systems. Design science is important to create successful artifacts. The design science process consists of six main steps: problem identification and motivation, definition of the objectives for a solution, design and development, demonstration, evaluation, and communication. Figure 3.1 illustrates the steps in the DSR process [38].

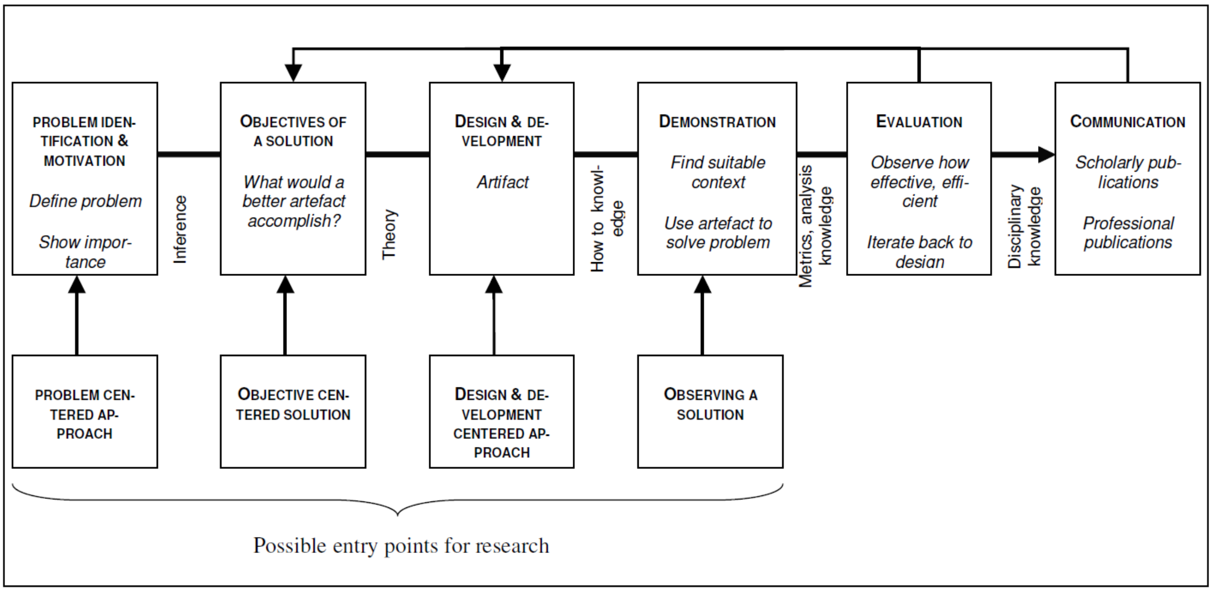

Figure 3.1: Design science research process model [38]

3.2 Human-Centered Design

Human-Centered Design (HCD) [39] is an approach that emphasizes the importance of user involvement throughout the design of interactive systems. The approach encourages participatory engagement from the stakeholders throughout the process to ensure high user satisfaction. The approach is an iterative process with four main activities: understanding and specifying the context of use, specifying the user requirements, producing design solutions, and evaluating the design, as seen in Figure 3.2.

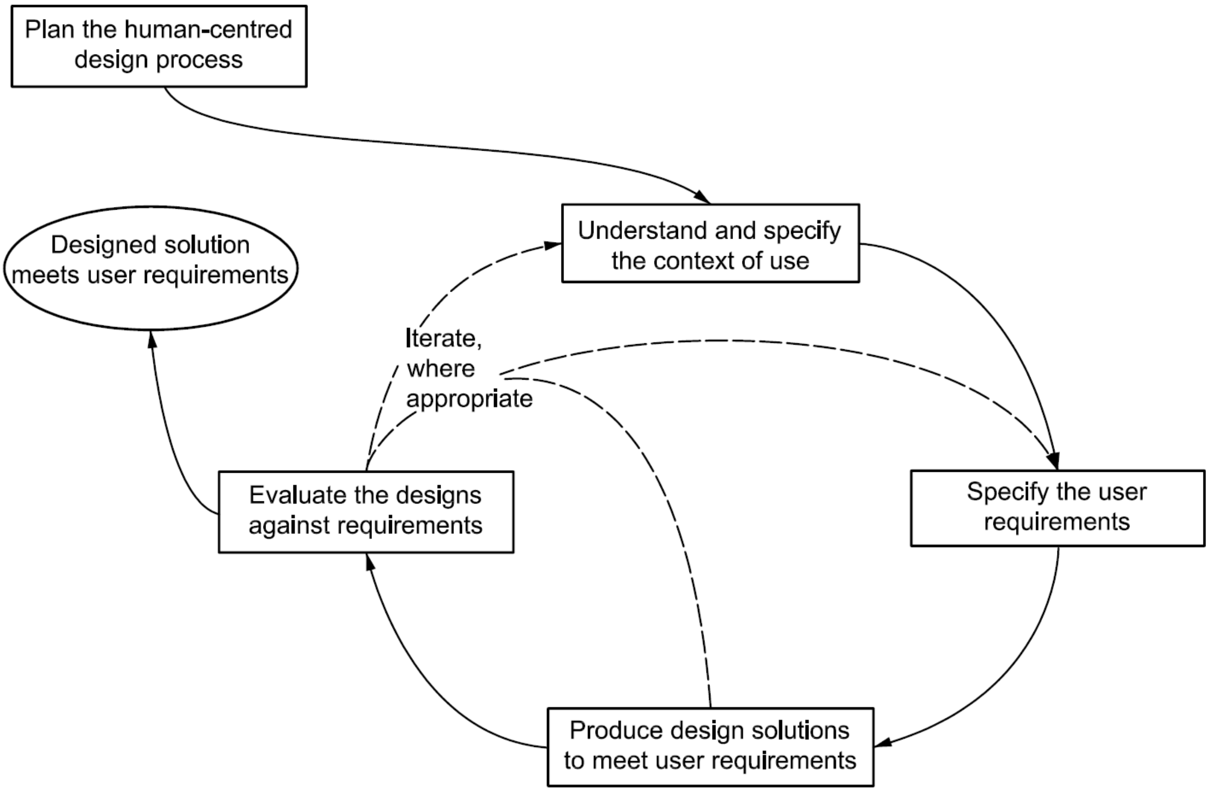

Figure 3.2: Human-centred design activities [40]

3.3 Augmented Reality

Augmented Reality (AR), simply put, is technology that links the physical and virtual world together [41]. Figure 3.3 gives an overview of mixed reality, ranging from the real world on the left side to the completely virtual world on the right side. With AR technology, the physical world is enhanced by virtual elements and 3D objects through platforms such as smart phones or head-mounted displays. From the definition, AR solutions are interactive systems that can be navigated in real-time. Schmalstieg and Höllerer [41] state that AR systems require at least three components: a tracking component, a registration component, and a visualization component.

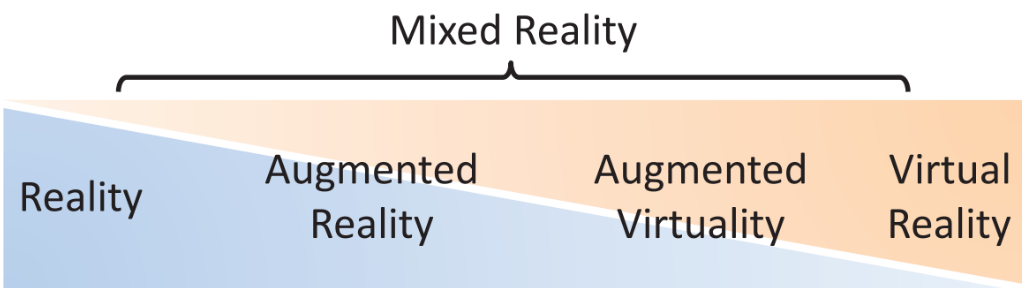

Figure 3.3: Mixed Reality: combinations of real and virtual environments [41]

Chapter 4

Methodology

In this mixed-method research, a Design Science Research Methodology (DSRM) [37] was used to gain a deeper understanding of the prehospital emergency care field, and to design an artifact that could potentially improve ambulance workers' work conditions. Based on activities in the DSR methodology, a Proof of Concept (PoC) [5, 6] prototype was developed, increasing knowledge of the research and problem area. In addition to the DSR methodology, a Human-Centered Design approach [39] was used to ensure user involvement throughout the process. Ambulance workers were included in initial steps of the research to gain knowledge about ambulance workers' challenges and needs. Furthermore, ambulance workers were involved to gather user feedback on the prototype to provide recommendations for further development.
The following steps were conducted to investigate ambulance workers needs, establish requirements, develop a prototype, and gather user feedback:

a) Literature review of the state-of-the-art to investigate the existing literature and solutions relevant to the focus area in this study

b) Co-design workshop to gather qualitative results to specify the user needs and user requirements

c) Proof of concept prototype development

d) Prototype demonstration and user feedback workshop to gather feedback and input for recommendations for further development

The following sections will describe the methods used in detail.

4.1 State-of-the-Art (step a) above)

A literature review was conducted to investigate the state-of-the-art related to the research area in this study. The field of prehospital emergency care related to decision support using various technology was investigated. Additionally, the use of Augmented Reality (AR) in both prehospital care and other related environments was examined to get an overview and status of the research field. The literature was explored by searching the databases Oria, Google Scholar, and the Journal of Medical Internet Research, using and combining the following search terms:

- prehospital care/service

- emergency care
- ambulance service
- ambulance/emergency vehicle
- decision support
- information availability
- video technology
- video consultation
- augmented reality
- smart glasses

The articles' title and abstract were screened for eligibility. Studies published before the year 2010 or studies written in languages other than English were discarded. In order to be included in the literature review, the studies had to target prehospital emergency care or Augmented Reality applied in other related scenarios. Search terms, title, date found, date published, journal, and a short summary of the article's content were entered into an excel sheet to get an overview. A total of 19 articles were included in this study.

The following sub-chapters address the main phases in the DSR methodology [37] with a description of how HCD activities [39] have been applied throughout the study.

4.2 Problem Identification and Motivation

Based on identified challenges in the pre-project, ICT442 Seminar 3[1], regarding the use of ICT/eHealth solutions in the ambulance services, a problem statement was formulated. The following activities in Section 4.3 were undertaken to further investigate the users' needs and how to potentially overcome some of the identified challenges.

4.3 Definition of the Objectives for a Solution

4.3.1 Co-Design Workshop (step b) above)

Initially in the project, a three-hour digital co-design workshop [42, 43] with five ambulance workers was carried out, to map the needs and understand the challenges of ambulance services in more depth. The mapping served as a basis for creating the needs assessment and requirement specification needed for the prototype development. The inclusion criteria to participate in the workshop were that the participants had to have experience as a paramedic or ambulance worker from the ambulance services.

[1]Not published report, can be provided on request. Title: Use of ICT/eHealth in prehospital care: in-vehicle system to support ambulance workers

Recruitment of Participants

Participants were recruited in collaboration with a company developing an electronic ambulance record system where the author of this study is employed. A contact person in the Hospital of Southern Norway (Sørlandet Sykehus HF) was contacted by phone by the author, and an invitation e-mail with further information about the project was sent as a follow-up. After one week, a second follow-up was done by phone to confirm participation. One week prior to the workshop, an information e-mail with the agenda for the workshop was sent to the five confirmed participants. A consent form and a guide of how to connect to Teams without a user-profile were attached. Additionally, an introduction to Bliksunds innovation project was given in an introductory video attached in the information e-mail, to shorten the participants passive time during the workshop.

Data Collection

Prior to the co-design workshop, a test-run was performed for the main facilitator and moderators to practice the execution plan and the technology to be used. The author of this study had the role as the main facilitator of the workshop, while the supervisors acted as moderators.

Initially in the workshop, a presentation of the innovation project including the aim for the workshop was presented to the participants by the main facilitator. Two scenarios from the emergency care context had been created in advance, in collaboration with an expert panel in Bliksund. The scenarios were presented to the participants with related tasks for the participants to solve. The scenarios are presented in chapter (5?). Thereafter, the participants were divided into two separate break-out rooms to work on the tasks, where the author's supervisors facilitated one break-out room each, guiding the participants through the tasks. Miro[2], a collaboration tool was used throughout the group work to sort and refine the participants' ideas. After working in groups, all participants were gathered together to discuss and elaborate on each of the group's ideas. Lastly, a brief summary and description of the continuation of the innovation project were given, encouraging the ambulance workers to participate in the next workshop as well.

The recordings from the workshop were stored securely in the academic institution's storage platform (MS OneDrive) and used for transcribing the recorded material. Afterwards, the material was summarized and anonymized.

Privacy Considerations

Before carrying out the co-design workshop, the project was approved by the Norwegian Centre for Research Data (NSD) [44], reference number 450054. All participants were

[2]https://miro.com/

informed both verbally and in writing that the workshop would be recorded. Additionally, the participants received the following information about the workshop: participation was voluntary, answers would be anonymized, contact information was provided in case the participants wanted to see, change, or delete the material, and their consent could be withdrawn at any time. All participants signed the consent form prior to the workshop. The consent form is provided in Appendix A in the Norwegian language.

4.3.2 Needs Assessment and Requirement Specification

After the workshop, the recordings were transcribed and summarized for use in the needs assessment. Activities described by Watkins et al. [45] were used as inspiration for creating the needs assessment. The needs and suggestions from the participants were gathered in a table, followed by a prioritization process based on the importance of the input and whether it was in or out of scope. To be in-scope, the idea/need had to meet the following criteria:

- Targeting prehospital emergency care and ambulance workers
- Targeting the need for information and/or decision support
- Targeting the environment in the ambulance vehicle or the patient's home
- The needed information/support is not available at the present time

Additionally, ideas/needs related to the following aspects were also regarded as in-scope:

- Increasing communication/collaboration between ambulance workers and care facilities
- Addresses how ambulance workers want needed information/support to be presented to them
- Addresses how the ambulance workers want to request the information/support

The importance/magnitude of the need was assessed by considering the following:

- How many participants/groups addressed a similar need in the co-design workshop
- Was the need strengthened by being mentioned by the participants in the pre-project
- Was the need strengthened by other relevant projects or research

Next, a requirement specification was created, based on the results from the needs assessment. Functional and non-functional requirements were formed, using the Volere shell provided in the Volere Requirement Specification Template [46]. Figure 4.1 gives a description of the parameters in the Volere shell. The originator of the requirement has been kept anonymous in this study, to ensure the participant's privacy. Finally, the requirements were prioritized based on the impact the requirement would have for the end-user and the effort needed to realize the requirement.

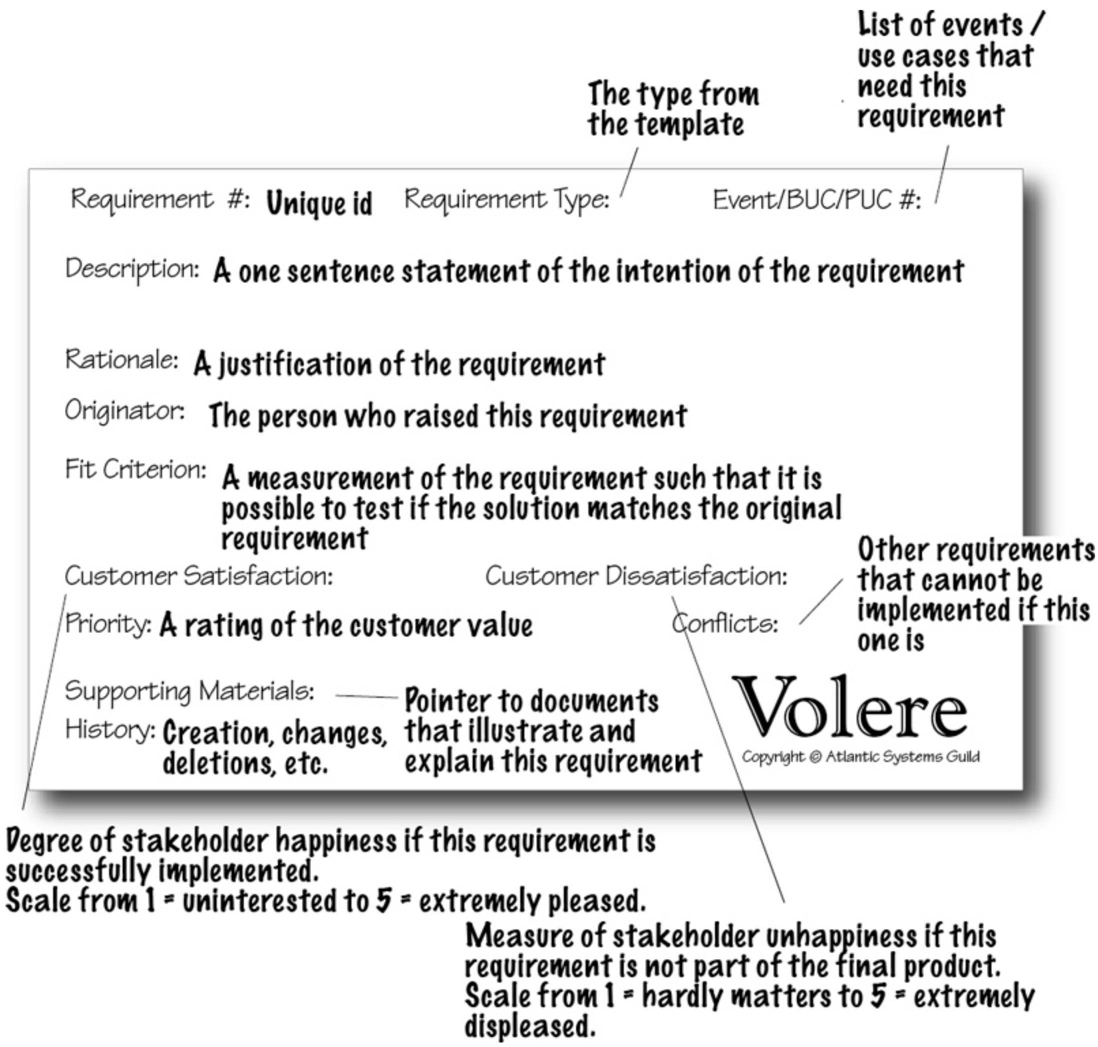

Figure 4.1: The Volere shell for specifying requirements [46]

4.4 Design and Development

Conceptual Design

The design and development phase started with designing the concept. Based on the requirement specification a conceptual model [47] was created, giving a high-level description of how the prototype would operate. System actions and user actions based on the user tasks were specified in the model. Next, several low-fidelity paper prototypes [48, pp. 426–434] of potential solutions to realize the concept were created and reviewed by the supervisors and coworkers. After deciding on the concept, a story board was created to visualize one possible sequence of user and system actions.

4.4.1 Proof of Concept Prototype Development (step c) above)

After refining and reviewing the ideas, a higher-fidelity prototype [48, pp. 428–434] was developed. The prototype design process was mainly done horizontally, meaning that the focus was on providing the users with a wide range of functionality but with less detail [48, p. 433]. Horizontal prototyping was used to give the ambulance workers an impression of the concept and possibilities of the technology, rather than focusing on time-consuming details.

The aim was to create a semi-functional PoC [5, 6] prototype with a Technology Readiness Level (TRL) in the low-to-mid range of the TRL scale [49], Table 4.1, and to get user feedback on the concept.

Table 4.1: Technology Readiness Levels (TRL) [49]

TRL Level	Description
TRL 1	basic principles observed
TRL 2	technology concept formulated
TRL 3	experimental proof of concept
TRL 4	technology validated in lab
TRL 5	technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)
TRL 6	technology demonstrated in relevant environment (industrially relevant environment in case of key enabling technologies)
TRL 7	system prototype demonstration in operational environment
TRL 8	system complete and qualified
TRL 9	actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)

4.5 Demonstration

To communicate the prototype design and to collect user feedback for potential further development, a prototype demonstration and user feedback workshop was performed. The workshop was held digitally and lasted for two hours.

4.5.1 Prototype Demonstration and User Feedback Workshop (step d) above)

The prototype demonstration and user feedback workshop was intended to be executed physically in the academic institution's test facilities, but due to Covid-19, the workshop had to be performed online. Therefore, a demonstration video was made for the ambulance workers in the workshop, so they could get an impression of how the system operates.

Recruitment of Participants

To gather feedback on the prototype, based on the requirements from the co-design workshop, the same people were recruited to participate in the prototype demonstration and user feedback workshop. The participants were contacted both by e-mail and phone prior to the workshop. A Teams invitation with the agenda enclosed, was sent to the participants two weeks prior to the workshop. Additionally, a reminder was sent the day before the workshop. Four out of the five participants from the co-design workshop joined the second workshop.

Data Collection

Initially in the workshop, a short presentation was given by the author, summarizing the key findings from the co-design workshop and giving the participants an introduction to AR technology and the prototype concept. The presentation was followed by a prototype demonstration video, a questionnaire, and a discussion at the end.

Prototype Demonstration Video

A demonstration video was created in advance of the workshop, to demonstrate the main functionalities and give the participants an impression of the possibilities with the technology. Firstly, the video gave a short introduction to the smart glasses used, followed by four main video elements, showing each of the prototype's buttons in the main menu and their corresponding functionalities. With help from two co-workers, a scenario involving an ambulance worker, a patient, and a physician was acted out to set the right context. After giving the participants an introduction to the main features in the prototype, two additional video clips with examples of different use cases were shown.

Questionnaire

After watching the demonstration video, the participants were asked to answer a digital questionnaire. The questionnaire was created in the SurveyXact tool[3], inspired by the System Usability Scale (SUS) template for usability testing [50]. Since the participants could not physically test the prototype, the questionnaire was modified to suit the prototype demonstration. The questionnaire can be found in Appendix B. After the participants had answered the questionnaire, everyone gathered together for a discussion, so that the participants could elaborate and discuss their thoughts with each other and with the facilitators.

Privacy Considerations

The consent form from the co-design workshop was also valid for the prototype demon-

[3] https://www.surveyxact.com/

stration and user feedback workshop, underlying the same NSD project, reference number 450054. At the beginning of the workshop the participants were asked verbally, as a reminder, if the meeting could be recorded. All participants consented. The recordings from the second workshop were also stored securely in the academic institution's storage platform. The questionnaire was made anonymous.

4.6 Evaluation

After demonstrating the artifact to the users, an evaluation of how well the prototype fulfills the user requirements would have been the next step in the DSRM. Since it was not possible to perform a physical testing of the prototype in this study, a complete evaluation was not performed. Nevertheless, the prototype demonstration and user feedback workshop provided some indications of how the prototype could potentially support the ambulance workers.

4.7 Communication

After completing the practical activities in this study, the problem area, prototype, and research results will be communicated to colleagues, fellow students, and researchers at the academic institution through this report and a thesis presentation. Additionally, the author presented the prototype and main findings at a digital conference in *Ambulanseforum*, a forum for the prehospital emergency care environment in Norway[4].

[4] https://ambulanseforum.no/konferanser/ambulanseforum-digital-konferanse

Chapter 5

Needs Assessment and Requirement Specification

In this chapter, the process of analyzing the ambulance workers' needs for creating the requirement specification necessary for the conceptual design and prototype development is described. Before going through the process, a brief description of two scenarios used to set the context in the co-design workshop will be given.

Scenarios

The expert panel from Bliksund supported the author in creating realistic scenarios with correct terminology that the ambulance workers would easily recognize and relate to. Based on findings in the author's pre-study and recommendations from the expert panel, a scenario involving an unresolved issue and a scenario regarding suspicion of stroke were chosen. These scenarios can be complex and demanding for the ambulance workers who may need support.

Unresolved Issue

This scenario addresses a call for an ambulance in a rural area with two hours drive to the nearest hospital. The ambulance workers received the following information from the EMDC: 85 year old woman, lives alone far up in the valley, called the EMDC herself saying that she could not stand up, and that she was in the hospital three months ago with a small heart attack. When the ambulance arrives, the woman is awake, pale, has dry skin, and denies having pain. The ambulance workers try to help her stand up, but she is unable to stand upright and must be helped back to bed. A municipal doctor is available at the office, which is approximately a one hour drive in the opposite direction of the hospital. The EMDC has received information that the on-call municipal doctor will not leave the office, but can be consulted over the phone/radio if needed.

Suspicion of Stroke

In this scenario, the ambulance service has received a mission marked as potential stroke. The patient's husband called the EMDC, saying that his wife did not come down for breakfast as normal this morning, and when he went to check in on her, he found her on the floor. The woman could not stand up and her speech was incoherent. The 78 year old woman is normally healthy and uses no regular medication. The incident occurred in the eastern part of southern Norway, with a few minutes drive from the nearest ambulance station to the patient. When the ambulance workers arrive, they find the lady on the floor by the bed. The patient is awake, worried, and tries to reach for the ambulance worker's hand with her left hand. She has an irregular pulse, follows the instructions given by the ambulance workers, but is not able to speak and has reduced strength in her right leg. The ECG measurement shows atrial fibrillation. The on-call physician is at the nearest hospital, approximately a 20 minute drive away, and has decided to await further information from the ambulance. The ambulance workers perceive the patient's condition as a stroke and start examinations according to the corresponding clinical practice guideline. Time-usage is considered as highly important, and the ambulance workers therefore start the transportation from the patient's home, and have to decide which hospital to bring the patient to. The ambulance workers have to decide whether to drive west or east depending on time-usage and which hospital provides the proper treatment. Further examinations, gathering of information, and consulting with physicians/specialists will be done from the ambulance vehicle.

Based on the aforementioned scenarios, the workshop participants worked on tasks that would give the author insight in the challenges and the needs related to the scenarios. Furthermore, possible solutions to provide the ambulance workers with support were discussed.

5.1 Needs Assessment

After completing the co-design workshop with ambulance workers, a needs assessment was done. The assessment started by gathering all the suggestions/needs and summarizing them in a table. Table 5.1 and Table 5.2 summarize the ideas regarding scenario one, and Table 5.3 and Table 5.4 summarize the ideas regarding scenario two.

Next, the needs were prioritized by examining the importance/magnitude and scope of the input. Table 5.5 and Table 5.6 show the prioritization of the needs, where the green-colored identification numbers correspond to the included needs, and the red-colored were not included further in the assessment.

Table 5.1: User needs (scenario 1, part 1)

	Current situation	**Desired situation**	**Potential solution**
1 **Video communication with physician (mentioned by all participants and for both scenarios)**	Phone call/radio with physicians/ specialists	Physicians/specialists being able to see the patient while the patient is being examined by the ambulance workers. Possibility to communicate (audio + video) with more than one physician/specialist at the same time (e.g. hospital physician, municipal doctor, and ambulance worker)	- Camera solution - Camera on glasses/head - Could have a tile in the PEPJ system to select if you wanted to communicate with the physician using the smart glasses or camera in the vehicle - Video using the tablet (PEPJ system) - Video from the patient's home: smart glasses At least the audio should be recorded
2 **Medical history (previous admissions, allergies, medication) mentioned by both groups**	No standard way of getting this information, sometimes from relatives, EMDC, or hospital, or not at all	Access to the summary care record, DIPS, epicrisis, or other relevant information from hospitals	Access in PEPJ on tablet
3 **Presenting all relevant information in one view to the remote physician**	Not standardized, mainly the physicians do not see the patient or vital parameters. ECG can be sent to the hospital. Relies on what is being presented by the ambulance worker by phone/radio	physicians being able to see and hear the patient, and see vital parameters and measurements taken with medical-technical units, all in one view/system. Would decrease errors due to current poor description of symptoms over telephone	- Camera solution - Camera on glasses/head
4 **Emergency room opening hours**	Think they have to contact by phone the nearest health institution to ask about availability	Being able to see which nearby emergency rooms are open at the given time, and contact information	A tile in the PEPJ system showing which nearby emergency rooms are open at the given time, and contact information
5 **Mission message from EMDC over speaker**	Ambulance worker reads the message to his/her partner while driving to the patient	The message being presented digitally over speaker	Speakers

Table 5.2: User needs (scenario 1, part 2)

	Current situation	**Desired situation**	**Potential solution**
6 **Gathering all the information in one joint system/view (video, medical history, vital signs, clinical practice guidelines, etc.)**	Some ambulance stations still use paper-based patient records. Receive information from different MTUs which must be manually filled into the record (ex. CRP, Hb), receive information via phone/radio etc.	Gather all this information in one view	Develop integration between MTUs and PEPJ tablet, and gather procedures and clinical practice guidelines, video, medical history etc. in one system/view
7 **Voice command**	Large amounts of information must be manually registered into the PEPJ system, typing is time-consuming	Being able to use voice commands to enter for ex. notes into the PEPJ system ("Hei Bliksund") and also to send a message to physicians/ specialists. Especially relevant/important during the pandemic	Smart glasses, PEPJ tablet system, some kind of speakers
8 **Easy access to clinical practice guidelines in one system/view**	Uses mobile phone to enter a different application (Bliksund Grid) to read the guidelines	Easy access to clinical practice guidelines in one joint system/view	Easy access directly in the PEPJ system. Ex. when taking an ECG measurement, there would be easy access to the ECG guideline or when giving the patient medication. Could show the guidelines in the smart glasses
9 **Notice of dangers (threatening patient)**	Do not get information about threatening behavior unless being told so by the EMDC	A warning system, warning triangle or similar, to warn the ambulance workers of dangerous behavior	Displaying warning symbol in the PEPJ

Table 5.3: User needs (scenario 2, part 1)

	Current situation	**Desired situation**	**Potential solution**
10 Support to decide which care facility to transport the patients to	Ambulance workers spend a lot of time finding out where to transport the patient, using much time on the phone/radio to communicate with physicians/specialists. This steals time which could be used on the patient	Ambulance workers giving physicians/specialists all the information they have regarding the patient, and after the physicians have made a decision it would be displayed in the system, clearly indicating the destination without spending much time on the phone	Chat function or a destination tile in the system where physicians/ specialists can register where the patient should be transported, as well as the physicians being able to access all relevant information regarding the patient in one system (maybe voice command)
11 Time to arrival, calculation of driving and flight time	physicians ask how much time there is left until arrival at the care facility, which can be difficult for the ambulance workers to determine. According to clinical guidelines regarding stroke, the ambulance workers are obligated to call for the air ambulance service if 15 or 20 minutes (or more) can be saved by using helicopter, which can be very challenging to calculate	A functionality/tile in the system calculating (based on GPS signals) how much time is left until arrival. For stroke patients: time savings using ambulance vehicle vs helicopter	Automatic calculations based on current GPS position
12 Prioritized landing sites for air ambulance		A functionality for the air ambulance to see the ambulance workers/vehicle location (GPS coordinates) and get advice on prioritized nearby landing sites. And the EMDC also seeing the same information	A button/tile in the PEPJ system; when the ambulance workers enter information into this tile, the air ambulance will receive the location of the vehicle and prioritized landing sites for the helicopter. Could use voice command to do this "Hello, Bliksund, show landing sites"

Table 5.4: User needs (scenario 2, part 2)

	Current situation	**Desired situation**	**Potential solution**
13 NIHSS (neurological examination)	Triage system (RETTS, NEWS, SATS)	A more extensive neurological scoring system (ex. NIHSS) that is used in every step of the care chain (e.g. from home care service -> ambulance service -> hospital). Could also help the neurologist to give advice and prepare themselves before the patient arrives at the hospital	Combined with the abovementioned chat function? With voice command. Check lists where you easily answer for ex. paralysis -> yes/no, and get a total score that helps in the decision-making
14 Trigger points	Today the system relies on the ambulance workers' knowledge and communication skills, regarding the explanation of the patient's status to the neurologist. If the patient's condition is not explained highlighting the important information, valuable time can be lost and negatively influence the decision making and patient outcome	The ambulance workers get warnings/notifications on important/critical information that must be highlighted in the conversation with the physician/specialist and/or that could be important for further treatment	A program/system that gives a warning when certain criteria are met, ex. atrial fibrillation -> warning of possible stroke (possible clot rather than bleeding) (Ex. using artificial intelligence)
15 Recording of interview/ conversation with relatives	Today they must try to remember what the relatives have told them regarding the patient's medical condition and history and rarely having time to write it down. After the mission they try to write down what they can remember, into the patient record, especially challenging during the pandemic (covid) as relatives rarely can participate in the patient transportation. Also difficult to reproduce what they were told when registering the information into the record	Functionality to record the conversation with relatives at the patient's home (or other location)	

Table 5.5: User needs, prioritization part 1 (green) = Included (red) = Not included

	ID	Importance/magnitude	Scope
Video communication with physician (mentioned by all participants and for both scenarios)	**1** (Included)	HIGH Mentioned by all participants and also confirmed by other sources (e.g. Sykehuset Innlandet [51] and the authors pre-study)	In-scope: RQ4 and RQ2 Bi-directional support between ambulance workers and care facilities. How can AR help them; e.g. video, using glasses
Medical history (previous admissions, allergies, medication) mentioned by both groups	**2** (Included)	RELATIVELY HIGH Mentioned by participants in the pre-study and by both workshop groups	In-scope: Important for the ambulance workers to get needed support, can be related to RQ1, RQ2
Presenting all relevant information in one view to the remote physician	**3** (Included)	RELATIVELY HIGH Mentioned by both workshop groups	In-scope: Important to answer RQ4 regarding how the bi-directional support between ambulance workers and physicians could be provided
Emergency room opening hours	**4** (Not included)	RELATIVELY LOW Mentioned by one person in one of the workshop groups, and the effect of developing this could be rather low, but could be added to the system later as a further minor improvement	In-scope: Could be interesting and relevant in this scope, but since the importance and effects are relatively low, this suggestion will not be considered for this project
Mission message from EMDC over speaker	**5** (Not included)	LOW Mentioned by one person in one of the workshop groups, and the effect of developing this world be quite low, but could maybe be added to the system later as a further minor improvement	Out-of-scope: Not giving ambulance workers increased decision support or information availability. This could easily be done with minor changes to the current system
Gathering all the information in one joint system/view (video, medical history, vital signs, clinical practice guidelines, etc.)	**6** (Included)	HIGH Mentioned both in the pre-study and by both workshop groups	In-scope: Relevant for the design of a concept, should be presented as much as possible in one coherent solution
Voice command	**7** (Included)	RELATIVELY HIGH Mentioned several times by one of the workshop groups and also confirmed by Sykehuset Innlandets project [51], important for the ambulance workers to have their hands free	In-scope: Relevant for RQ3, but also RQ1 and RQ4
Easy access to clinical practice guidelines in one common system	**8** (Included)	RELATIVELY HIGH Mentioned by one workshop group and as important for all three group members, also correlates to the need for gathering as much as possible in one common system. Also confirmed by the pre-study	In-scope: Relates to RQ2 regarding how the ambulance workers need the information to be presented to them

Table 5.6: User needs, prioritization part 2 (green) = Included (red) = Not included

	ID	Importance/magnitude	Scope
Notice of dangers (threatening patient)	9	RELATIVELY HIGH Mentioned by one participant in one of the workshop groups, and confirmed in the pre-study. Further work?	Out-of-scope: Not in the scope of this study since this does not directly address decision support and information accessibility to improve patient care. Rather addresses the ambulance personnel's safety
Support to decide which care facility to transport the patients to	10	HIGH Mentioned by all workshop participants and one participant stated that this issue is almost a daily discussion amongst ambulance workers	In-scope: Relates to needed decision support that can have huge impact on time-usage, which is especially important in acute situations and can hugely affect the patient outcome, RQ1 and RQ2
Time to arrival, calculation of driving and flight time	11	RELATIVELY LOW Only mentioned by one workshop participant, but can potentially affect the time-savings in critical situations such as stroke and could affect the patient outcome positively. Further work?	In-scope: Could help the decision-making process regarding transportation methods in acute situations such as stroke
Prioritized landing sites for air ambulance	12	RELATIVELY LOW Mentioned by one participant. Could be helpful for the air ambulance, making it easier for them to find a landing site near the incident	Out-of-scope: Regarding other stakeholder: air ambulance is not a target stakeholder for this project
NIHSS (neurological examination)	13	RELATIVELY HIGH Mentioned by both workshop groups. Confirmed by another project in Oslo. Further work?	Out-of-scope: Looking at other examination tools is not in the scope of this study
Trigger points	14	HIGH Mentioned several times by one workshop group and is already used to some degree in the PEPJ system. Could for instance use AI to give warnings/notifications when certain behavior/symptoms occur to help the ambulance workers detect important signs more easily.	In-scope: Highly relevant to give ambulance workers decision support, but addresses a different direction of providing decision support (e.g. Artificial Intelligence)
Recording of interview/ conversation with relatives	15	RELATIVELY LOW Mentioned by one workshop group. Could be helpful, at least to ease the documentation process of the information given by relatives. Maybe further work?	Out-of-scope: Relates more to documentation than the current scope

After prioritizing the needs and ideas, a priority matrix was made to easily visualize which needs would be included and which would not. As shown in Figure 5.1, input 1, 2, 3, 6, 7, 8, 10, and 14 corresponded to the «High importance - In-scope» section and were therefore included further in this study. Table 5.7 displays the ID number and a brief description of the included needs.

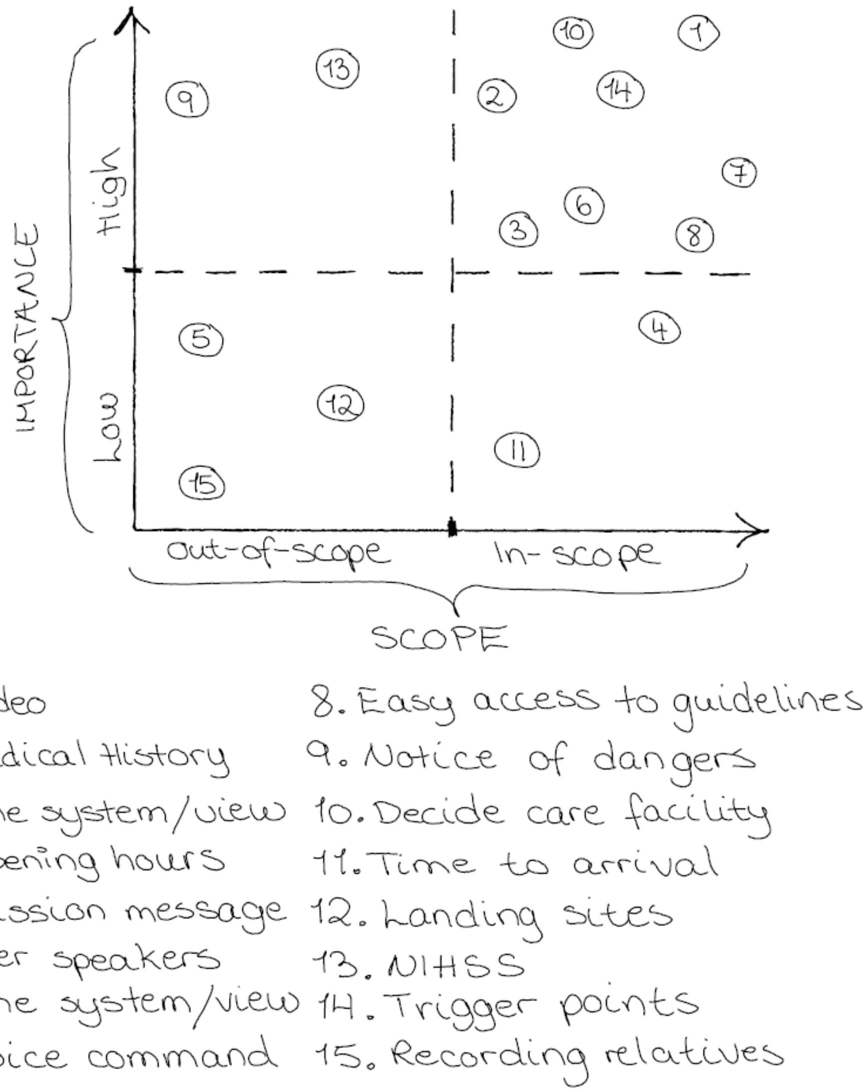

Figure 5.1: User needs, priority matrix

Table 5.7: Included user needs

ID number	Description
1	Video communication with physician
2	Medical history (previous admissions, allergies, medication etc.)
3	Presenting relevant information in one view to the physician
6	Gathering all the information in one system/view
7	Voice command
8	Easy access to clinical practice guidelines in one system/view
10	Support to decide which care facility to transport the patients to
14	Trigger points

5.2 Requirements Specification

Based on the needs assessment, a requirement specification was created by investigating the main requirements necessary to fulfill the ambulance workers' needs. After examining the co-design workshop transcriptions in more depth regarding the included needs, a total of 18 functional and non-functional requirements [46] were created. Pages 27 to 36 show the Volere shells [46] specifying the requirements.

Functional requirement:

Requirement #: **1** Requirement Type: **9** Event/BUC/PUC #: **ID 1**

Description: **The system should give the possibility for the ambulance worker to communicate with physicians/specialists by using both audio and video**

Rationale: **Both audio and video are needed for the physician to see the patient and give advice when communicating with the ambulance worker. Audio and video combined can increase the physician's decision basis when giving the ambulance worker advice for further patient treatment**

Originator: **Chief ambulance worker and ambulance worker**

Fit Criterion: **Both the ambulance worker and the physician/specialist should be able to see and listen to each other clearly**

Customer Satisfaction: **5** Customer Dissatisfaction: **5**

Priority: **Highest priority** Conflicts: **0**

Supporting Materials: **Needs Assessment**

History: **Created February 21th 2021**

Functional requirement:

Requirement #: **2** Requirement Type: **9** Event/BUC/PUC #: **ID 1**

Description: **The system should give the ambulance worker the possibility to communicate (audio + video) with more than one physician/specialist at a time**

Rationale: **In cases such as stroke patients, it is important to be able to communicate (audio + video) with more than one physician/specialist at a time, such as physicians/specialists from two different hospitals, to determine the way forward**

Originator: **Ambulance worker**

Fit Criterion: **Three, or more, people should be able to communicate with each other in one conversation using both audio and video**

Customer Satisfaction: **3** Customer Dissatisfaction: **2**

Priority: **Medium** Conflicts: **0**

Supporting Materials: **Needs Assessment**

History: **Created February 23ed 2021**

Non-functional requirement:

Requirement #: **3** Requirement Type: **13a** Event/BUC/PUC #: **ID 1**

Description: **It must be possible for the ambulance worker to communicate (audio + video) with a remote physician/specialist while in the ambulance vehicle**

Rationale: **Ambulance workers spend a lot of time in the ambulance vehicle, and if support is needed while driving to the hospital, the system should support video communication (audio + video) in the vehicle**

Originator: **Chief ambulance worker and ambulance worker**

Fit Criterion: **The system has internet connection in the ambulance vehicle and it is possible to communicate (audio + video) with a remote physician while in the vehicle**

Customer Satisfaction: **5** Customer Dissatisfaction: **5**

Priority: **High** Conflicts: **0**

Supporting Materials: **Needs Assessment**

History: **Created February 23ed 2021**

Non-functional requirement:

Requirement #: **4** Requirement Type: **13a** Event/BUC/PUC #: **ID 1**

Description: **It must be possible for the ambulance worker to communicate (audio + video) with a remote physician/specialist while in the patient's home**

Rationale: **Ambulance workers make important decisions regarding treatment and transportation of the patient in the patient's home. Therefore the system should support video communication in the patient's home**

Originator: **Ambulance worker**

Fit Criterion: **The system has internet connection in the patient's home and it is possible for the ambulance worker to communicate (audio + video) with remote physicians while in the patient's home**

Customer Satisfaction: **5** Customer Dissatisfaction: **5**

Priority: **High** Conflicts: **0**

Supporting Materials: **Needs Assessment**

History: **Created February 23ed 2021**

Functional requirement:

Requirement #: **5** Requirement Type: **9** Event/BUC/PUC #: **ID 1**

Description: **It must be possible for the ambulance workers to have their hands free when communicating with a physician/specialist**

Rationale: **It is necessary for the ambulance workers to have their hands free so they can continue the patient care while communicating with physicians/specialists**

Originator: **Chief ambulance worker and ambulance worker**

Fit Criterion: **The ambulance workers have their hands free while communicating with a physician/specialist**

Customer Satisfaction: **4** Customer Dissatisfaction: **3**

Priority: **High** Conflicts: **0**

Supporting Materials: **Needs Assessment**

History: **Created February 23ed 2021**

Functional requirement:

Requirement #: **6** Requirement Type: **9** Event/BUC/PUC #: **ID 2**

Description: **Medical history such as previous admissions (epicrisis), allergies, medication, and chronic diseases from the summary care record and hospital EPJs, such as DIPS, via Norwegian Health Net, should be accessible in the system**

Rationale: **Medical history is important for the ambulance workers to make informed decisions about further patient treatment**

Originator: **Ambulance worker**

Fit Criterion: **The ambulance workers can easily access medical history using the system**

Customer Satisfaction: **4** Customer Dissatisfaction: **4**

Priority: **High** Conflicts: **0**

Supporting Materials: **Needs Assessment**

History: **Created February 23ed 2021**

Functional requirement:

Requirement #: **7** Requirement Type: **9** Event/BUC/PUC #: **ID 6, ID 3**

Description: **The video conferencing tool, medical history, vital parameters, and clinical practice guidelines should be presented in one view to the ambulance worker**

Rationale: **To use different types of equipment to access needed information is time-consuming for the ambulance workers, which takes important time away from the patient. Therefore the required information and support should me gathered in one view/screen**

Originator: **Chief ambulance worker and ambulance worker**

Fit Criterion: **The needed information can be accessed in one single view**

Customer Satisfaction: **4** Customer Dissatisfaction: **5**

Priority: **High** Conflicts: **0**

Supporting Materials: **Needs Assessment**

History: **Created February 23ed 2021**

Functional requirement:

Requirement #: **8** Requirement Type: **9** Event/BUC/PUC #: **ID 6, ID 3**

Description: **Vital parameters should be displayed to the ambulance worker in real-time in the system**

Rationale: **Vital parameters are highly important for the ambulance workers to decide the course of treatment for the patient**

Originator: **Chief ambulance worker and ambulance worker**

Fit Criterion: **Vital parameters are displayed in real-time to the ambulance worker**

Customer Satisfaction: **3** Customer Dissatisfaction: **5**

Priority: **High** Conflicts: **0**

Supporting Materials: **Needs Assessment**

History: **Created February 23ed 2021**

Functional requirement:

Requirement #: **9** Requirement Type: **9** Event/BUC/PUC #: **ID 7**

Description: **The ambulance workers should be able to navigate the system using voice commands**

Rationale: **Typing and physically navigating the system with their hands is time-consuming for the ambulance workers. Voice command would allow the ambulance workers to have their hands free to focus on the patient**

Originator: **Chief ambulance worker and ambulance worker**

Fit Criterion: **The ambulance worker can request needed support/information (e.g. video call) using voice commands**

Customer Satisfaction: **4** Customer Dissatisfaction: **2**

Priority: **Medium** Conflicts: **0**

Supporting Materials: **Needs Assessment**

History: **Created February 23ed 2021**

Functional requirement:

Requirement #: **10** Requirement Type: **9** Event/BUC/PUC #: **ID 7**

Description: **It should be possible to register free-text notes into the ambulance record system using voice command**

Rationale: **Typing and physically navigating the system with their hands is time-consuming for the ambulance workers. Voice command would allow the ambulance workers to have their hands free to focus on the patient**

Originator: **Chief ambulance**

Fit Criterion: **The ambulance worker can register a free-text note in the ambulance record system using voice commands**

Customer Satisfaction: **4** Customer Dissatisfaction: **2**

Priority: **Medium** Conflicts: **0**

Supporting Materials: **Needs Assessment**

History: **Created February 23ed 2021**

Functional requirement:

Requirement #: **11** Requirement Type: **9** Event/BUC/PUC #: **ID 8**

Description: **The system should be able to display clinical practice guidelines to the ambulance worker**

Rationale: **Ambulance workers use clinical practice guidelines when providing emergency care. Easily accessible clinical practice guidelines presented in a format that gives them the possibility to have their hands free would allow them to treat the patient at the same time as reading the guidelines**

Originator: **Ambulance worker**

Fit Criterion: **Ambulance workers can read clinical practice guidelines while giving patient care**

Customer Satisfaction: **3** Customer Dissatisfaction: **4**

Priority: **Medium** Conflicts: **0**

Supporting Materials: **Needs Assessment**

History: **Created February 23ed 2021**

Functional requirement:

Requirement #: **12** Requirement Type: **9** Event/BUC/PUC #: **ID3, ID 10**

Description: **The ambulance worker should be able to provide the physician/specialist with the patient's vital parameters and ECG while communicating with the physician/specialist via audio and video**

Rationale: **The physician/specialist could potentially make quicker and more informed decisions regarding how the ambulance workers should continue the patient treatment and transportation**

Originator: **Chief ambulance worker and ambulance worker**

Fit Criterion: **The ambulance worker can make vital parameters, ECG, and audio + video available to the physician/specialist**

Customer Satisfaction: **4** Customer Dissatisfaction: **3**

Priority: **Medium High** Conflicts: **0**

Supporting Materials: **Needs Assessment**

History: **Created February 25ed 2021**

Functional requirement:

Requirement #: **13** Requirement Type: **9** Event/BUC/PUC #: **ID 10**

Description: **The ambulance worker should be able to communicate (audio + video) with more than one physician/specialist at the same time**

Rationale: **Gathering more of the stakeholders together in one communication channel could give the ambulance workers more insight and possibility to influence the decision-making process. Stakeholders can discuss and decide the course of treatment together and potentially save time, e.g. neurologist, medical doctor, and ambulance worker**

Originator: **Ambulance worker**

Fit Criterion: **Three or more people are able to communicate with each other in one conversation using both audio and video**

Customer Satisfaction: **3** Customer Dissatisfaction: **2**

Priority: **Medium** Conflicts: **0**

Supporting Materials: **Needs Assessment**

History: **Created February 25ed 2021**

Functional requirement:

Requirement #: **14** Requirement Type: **9** Event/BUC/PUC #: **ID 10**

Description: **The ambulance worker should be able to receive messages from physicians/specialist directly in the ambulance record system**

Rationale: **It is time-consuming to talk on the phone while taking care of the patient. If the physician/specialist could access the needed information (vital parameters, ECG, and video communication) about the patient, the physician/specialist could enter a message directly in the system when the destination is decided**

Originator: **Chief ambulance worker**

Fit Criterion: **The ambulance worker can receive a message from the physician/specialist directly in the ambulance record system**

Customer Satisfaction: **3** Customer Dissatisfaction: **2**

Priority: **Medium** Conflicts: **0**

Supporting Materials: **Needs Assessment**

History: **Created February 25ed 2021**

Non-functional requirement:

Requirement #: **15** Requirement Type: **11a** Event/BUC/PUC #: **General**

Description: **The interaction with the system should be easy and intuitive for the ambulance workers**

Rationale: **The system should be easy and intuitive for the ambulance worker to use so that the interaction is not time-consuming, as this would take important time from the patient care**

Originator: **Ambulance worker**

Fit Criterion: **The ambulance worker gives positive feedback regarding the ease-of-use of the system, or based on a performance indicator the time spent on a task is satisfactory**

Customer Satisfaction: **4** Customer Dissatisfaction: **5**

Priority: **High** Conflicts: **0**

Supporting Materials: **Needs Assessment**

History: **Created February 22nd 2021**

Non-functional requirement:

Requirement #: **16** Requirement Type: **11c** Event/BUC/PUC #: **General**

Description: **The ambulance worker should be able to learn to use the system easily**

Rationale: **The system should be easy to learn so that the ambulance worker can easily use the system, even when they do not use it regularly**

Originator: **Ambulance worker**

Fit Criterion: **The ambulance worker gives positive feedback regarding the learnability of the system, or based on a performance indicator the time spent on learning a task is satisfactory**

Customer Satisfaction: **3** Customer Dissatisfaction: **5**

Priority: **High** Conflicts: **0**

Supporting Materials: **Needs Assessment**

History: **Created February 22nd 2021**

Non-functional requirement:

Requirement #: **17** Requirement Type: **13a** Event/BUC/PUC #: **General**

Description: **The system should not require any additional cables when in use**

Rationale: **The ambulance workers' work environment can be very hectic, and cables or other items can be both in the way and harmful**

Originator: **Chief ambulance worker**

Fit Criterion: **No extra cables or other items are needed when using/interacting with the system**

Customer Satisfaction: **2** Customer Dissatisfaction: **5**

Priority: **Medium** Conflicts: **0**

Supporting Materials: **Needs Assessment**

History: **Created February 22nd 2021**

Functional requirement:

Requirement #: **18** Requirement Type: **9** Event/BUC/PUC #: **ID 14**

Description: **The system should give the ambulance worker a warning or heads-up if there are possible dangers to the patient's health, such as a potential stroke, by displaying a warning. The warning should be based on the vital parameters, ECG, examinations, etc. registered into the ambulance record system**

Rationale: **That the ambulance workers detect critical conditions, such as heart attack, stroke, etc., as soon as possible can be crucial for the patient outcome. In some cases it can be challenging to detect early signs and symptoms, and a system giving warnings could help the ambulance workers detect critical conditions at an earlier stage**

Originator: **Ambulance worker**

Fit Criterion: **The system gives a warning when a potential critical condition may occur, based on vital parameters, ECG, and examinations registered into the ambulance record system**

Customer Satisfaction: **4** Customer Dissatisfaction: **2**

Priority: **Medium** Conflicts: **0**

Supporting Materials: **Needs Assessment**

History: **Created February 26th 2021**

After creating the Volere shells, the requirements were inserted into a table and prioritized. The prioritization was based on the impact that the requirement would potentially have on the ambulance workers and the effort it would require to realize the requirement. Table 5.8 and Table 5.9 show all 18 requirements, and how they were prioritized.

Table 5.8: Prioritization of requirements, part 1

Req. #	Description	Impact	Effort	Priority
1 (ID 1)	The system should give the possibility for the ambulance workers to communicate with physicians/specialists by using both audio and video	High	High	1
2 (ID 1)	The system should give the ambulance worker possibility to communicate (audio + video) with more than one physician/specialist at a time	Medium	High	11
3 (ID 1)	It must be possible for the ambulance worker to communicate (audio + video) with a physician/ specialist while in the ambulance vehicle	High	Medium	2
4 (ID 1)	It must be possible for the ambulance worker to communicate (audio + video) with a physician/ specialist while in the patient's home	High	High	14
5 (ID 1)	It must be possible for the ambulance workers to have their hands free when communicating with a physician/specialist	High	Medium	7
6 (ID 2)	Medical history such as previous admissions (epicrisis), allergies, medication, and chronic diseases from the summary care record via the Norwegian Health Net (and hospital EPJs such as DIPS), should be accessible in the system	High	High	4
7 (ID 6)	The video conferencing tool, medical history, vital parameters, and clinical practice guidelines should be presented in one screen/view to the ambulance worker	High	Medium	6
8 (ID 6)	Vital parameters should be displayed to the ambulance worker in real-time in the system	High	Medium	3
9 (ID 7)	The ambulance workers should be able to navigate the system using voice commands	Medium	Medium	12
10 (ID 7)	It should be possible to register free-text notes into the ambulance record system using voice command	Medium	High	13
11 (ID 8)	The system should be able to display clinical practice guidelines	High	High	5
12 (ID 10, ID 3)	The ambulance worker should be able to provide the physician/specialist with the patient's vital parameters and ECG while communicating with the physician/specialist via audio and video	High	High	15

Table 5.9: Prioritization of requirements, part 2

Req. #	**Description**	**Impact**	**Effort**	**Priority**
13 (ID 10)	The ambulance worker should be able to communicate (audio + video) with more than one physician/specialist at the same time	Medium	High	11
14 (ID 10)	The ambulance worker should be able to receive messages from physicians/specialists directly in the ambulance record system	Medium	High	17
15 (General)	The interaction with the system should be easy and intuitive for the ambulance workers to use	High	High	9
16 (General)	It should be easy for the ambulance worker to learn to use the system	High	High	10
17 (General)	The system should not need any additional cables when in use	High	Medium	8
18 (ID 14)	The system should give the ambulance workers a warning or heads-up if there are possible dangers to the patient's health, such as a potential stroke, by displaying a warning triangle. The warning should be based on the vital parameters, ECG, examinations, etc. registered into the ambulance record system	High	High	16

After prioritizing the requirements, a priority matrix for the requirements was created, see Figure 5.2. The requirements that corresponded to the «Medium Impact - Medium Effort» and «Medium Impact - High Effort» sections were not included further in this study. All requirements in the «High Impact - Medium Effort» were included. Additionally, some of the requirements in the «High Impact - High Effort» section were included further. Requirements 4, 12, and 18 were not included. The main target environment to investigate in this research was the ambulance vehicle, and requirement 4 targeted the environment of the patient's home, and was therefore not included. Requirement 12 focuses on information provided to the physician, and was not included in this study, due to the main focus being the ambulance workers. Furthermore, requirement 18, regarding trigger points (in the artificial intelligence direction) was not in the scope of this study.

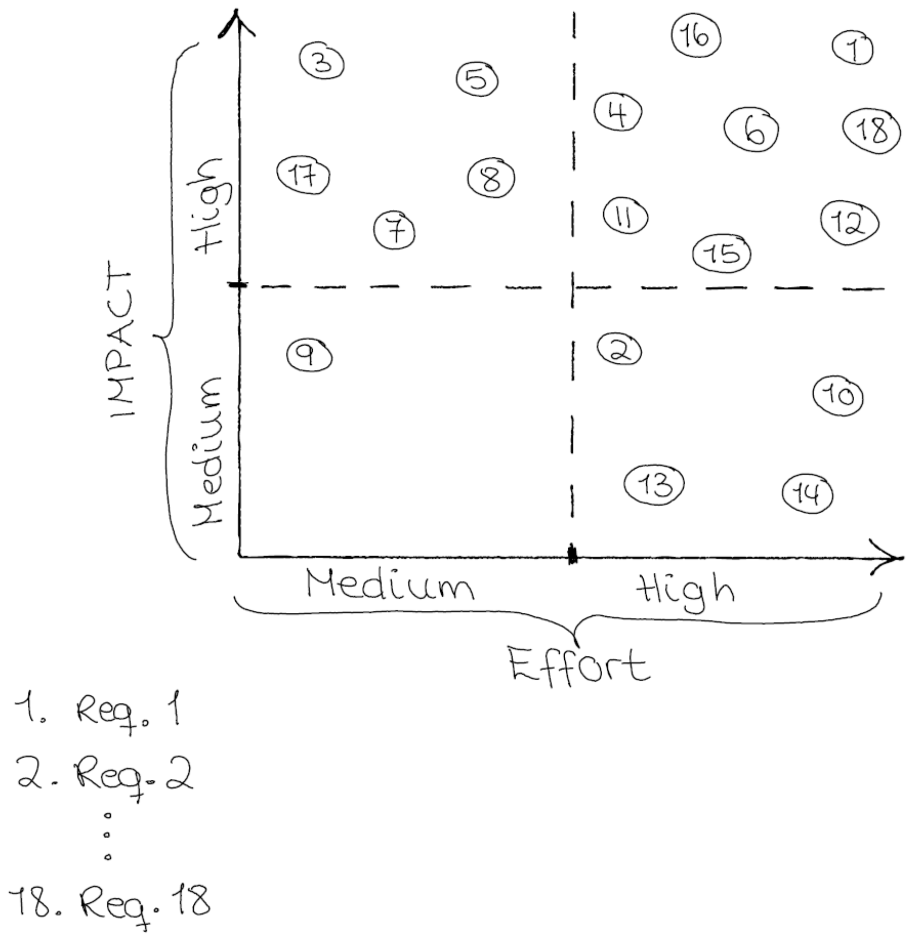

Figure 5.2: Requirements, priority matrix

The following list presents the requirements in prioritized order, where the green-colored requirements represent the requirements that had to be included in the solution, the yellow requirements represent the requirements that would be nice to have included, and the red ones represent requirements for potential further work.

= **Must have** = **Nice to have** = **Further work**

1: Req. 1 (ID 1) Video communication
2: Req. 3 (ID 1) Communicate (audio + video) in vehicle
3: Req. 8 (ID 6) Vital parameters
4: Req. 6 (ID 2) Medical history
5: Req. 11 (ID 8) Clinical practice guidelines
6: Req. 7 (ID 6) One view
7: Req. 5 (ID 1) Hands free
8: Req. 17 (General) No cables
9: Req. 15 (General) Ease-of-use
10: Req. 16 (General) Learnability
11: Req. 2 (ID 1) and 13 (ID 10) Communicate with more than one physician
12: Req. 9 (ID 7) Navigate by voice
13: Req. 10 (ID 7) Register free-text notes by voice
14: Req. 4 (ID 1) Communicate (audio + video) in patient's home
15: Req. 12 (ID 10) Provide the physician with needed information
16: Req. 18 (ID 14) Trigger points
17: Req. 14 (ID 10) Receive message from physician

Chapter 6

Solution Design and Proof-of-Concept Development

In this chapter, the process of creating the conceptual design based on the needs assessment and requirement specification is presented, followed by describing the main components of the prototype and how it was realized.

6.1 Conceptual Design

The design and prototyping phase of the research started by creating a concept based on the needs assessment and requirement specification. A video communication tool, vital parameters, clinical practice guidelines, and medical history were the main features to be included, related to requirements 1, 3, 8, 6, 11, 7, and 5. To get an overview of the main elements needed for the PoC prototype, a simple figure, Figure 6.1, was created. Additionally, requirement 5 regarding being able to work with the hands free, and the usability related requirements 15 and 16 were to be considered.

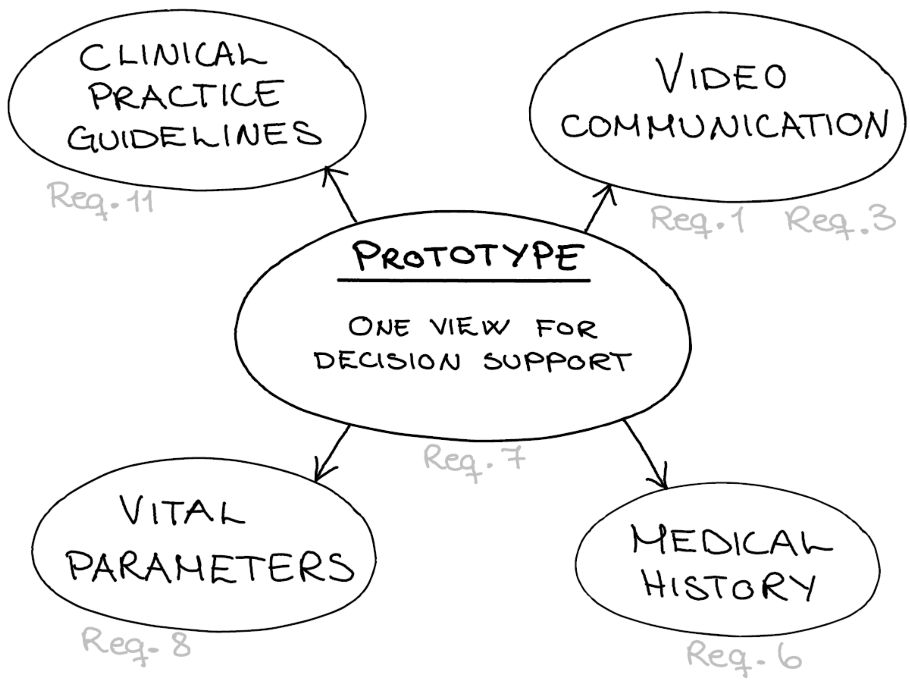

Figure 6.1: Main elements to be included in the concept

Conceptual Model

Figure 6.2 gives a high-level overview of the concept and how it would operate. The blue-colored boxes in the conceptual model refer to the actions performed by the user, and the orange-colored boxes correspond to the actions that the system must do to support the user tasks [47, 48]. When the user enters the application, the system displays a main menu consisting of four buttons with the option to activate a video communication tool, display vital parameters, clinical practice guidelines, or medical history. Depending on the chosen option, the system will display the requested information. The main menu will be displayed at all times, to give the user the possibility to activate the needed information at any given time, and to be able to display more than one feature at the same time. Initially in the conceptual design, instructing was the main interaction type intended for the prototype. According to Sharp et al. [48, p. 81], instructing is:

> Where users issue instructions to a system. This can be done in a number of ways, including typing in commands, selecting options from menus in a windows environment or on a multi-touch screen, speaking aloud commands, gesturing, pressing buttons, or using a combination of function keys.

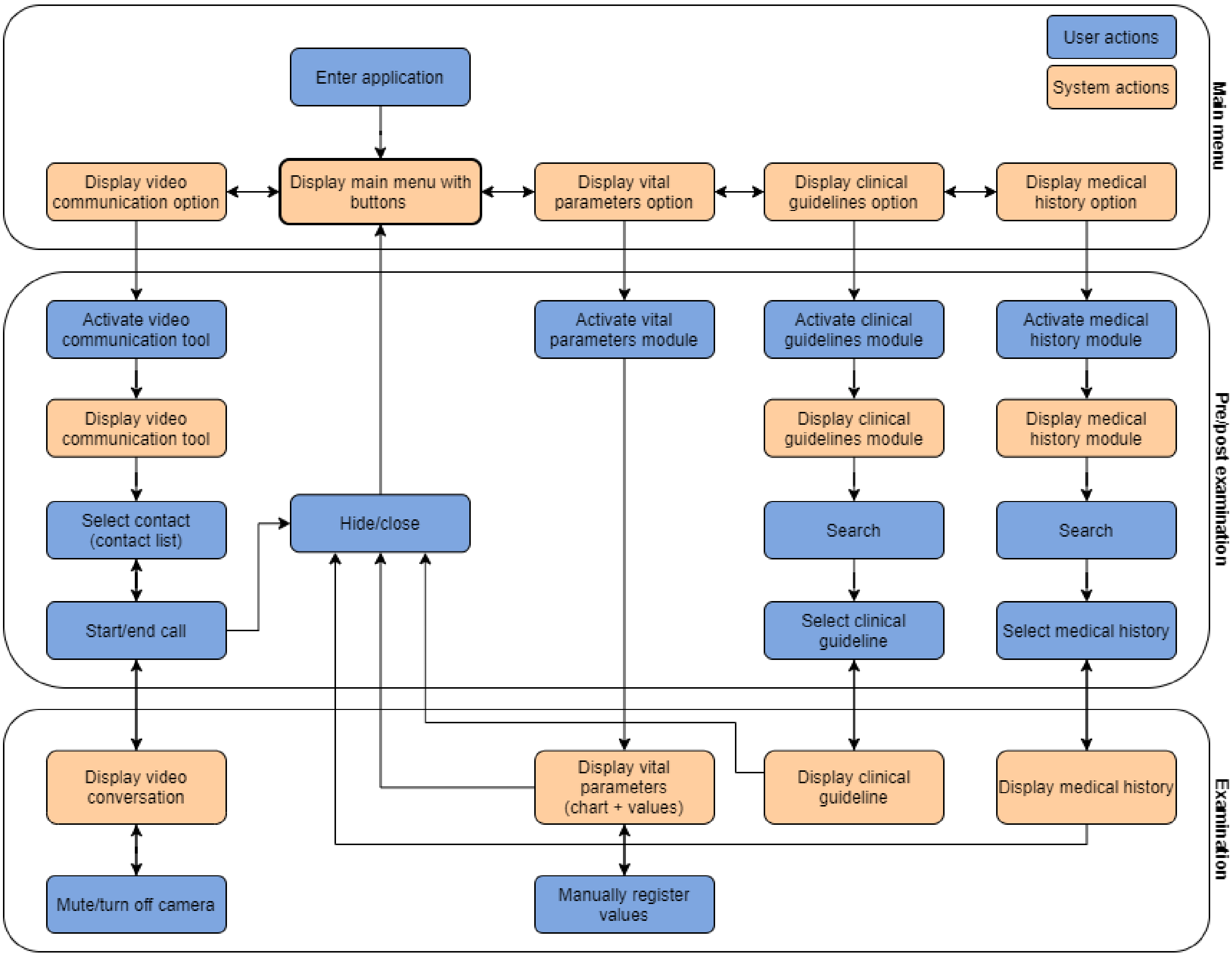

Figure 6.2: Conceptual model

Concept Sketches and Storyboard

After reviewing the conceptual model with the supervisors and after refining it, several sketches of potential solutions to realize the concept were created. Three of the different sketches for a potential design solution were compared to each other in collaboration with the supervisors and co-workers. The three concept ideas are shown and the positives and negatives of each solution are given, as follows:

Concept One

The sketch of concept one, Figure 6.3, shows the initial idea of a way to display the required information while letting the ambulance worker have their hands free to focus on the patient in the ambulance vehicle. One window would be displayed for the video communication tool, one for the vital parameters, one for the clinical guidelines, and one for the medical history. For the initial concept, the idea was not refined enough, not including any information about how to navigate the system. The idea was for the ambulance worker to be able to activate the relevant information when it was needed.

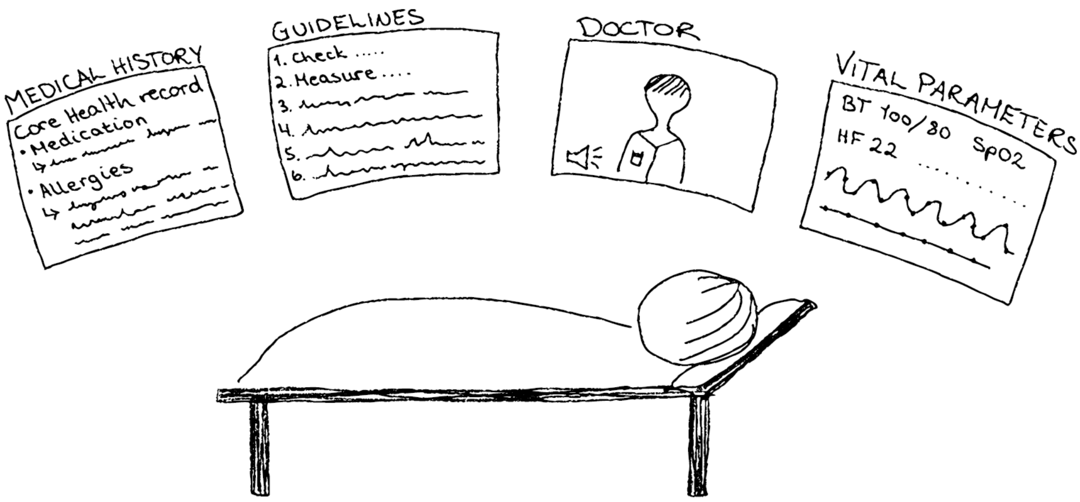

Figure 6.3: Sketch of concept one

Positives:

- The user can select what information is needed at any given time, and only select the specific information needed. E.g., if only video communication is needed, the user can activate only the video communication functionality
- Hands are free while being able to see the needed information

Negatives:

- Can potentially lead to overload of information
- Could be challenging to navigate and maneuver all the different components, with a risk for errors when interacting with the system

Concept two

Figure 6.4 shows concept two, where the video communication tool, vital parameters, clinical practice guidelines, and medical history, are all visualized in one window. The four main menu buttons are positioned on the left side of the window, with the option to activate the needed information.

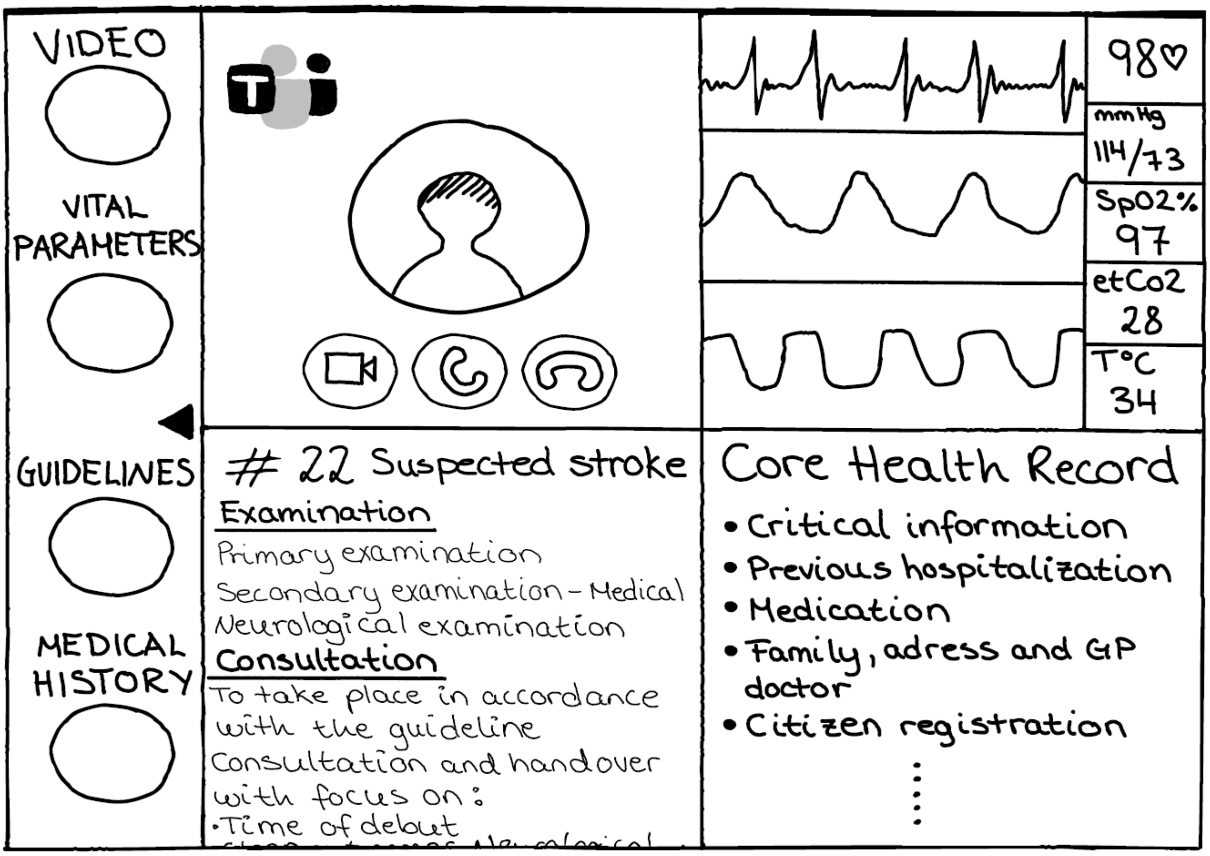

Figure 6.4: Sketch of concept two

Positives:

- The user can select the information that is needed at any given moment, and only select the specific information. E.g., if only video is needed, the user can activate only the video functionality
- Hands are free while being able to see the needed information
- The user only needs to interact with one window. When the single window is adjusted, the user is finished and can continue with other tasks

Negatives:

- Can potentially lead to overload of information
- Can be challenging to adjust the window to display all four elements properly
- Can be challenging to read the clinical guidelines and medical history in this format

Concept three

The third concept, Figure 6.5, shows the environment in the ambulance vehicle, with a patient lying on a stretcher. Only three of the main menu buttons are displayed at a fixed position at the top of the view. The vital parameters are displayed on the side at a fixed position in the ambulance worker's view. In Figure 6.5, the video communication tool feature is activated as an example.

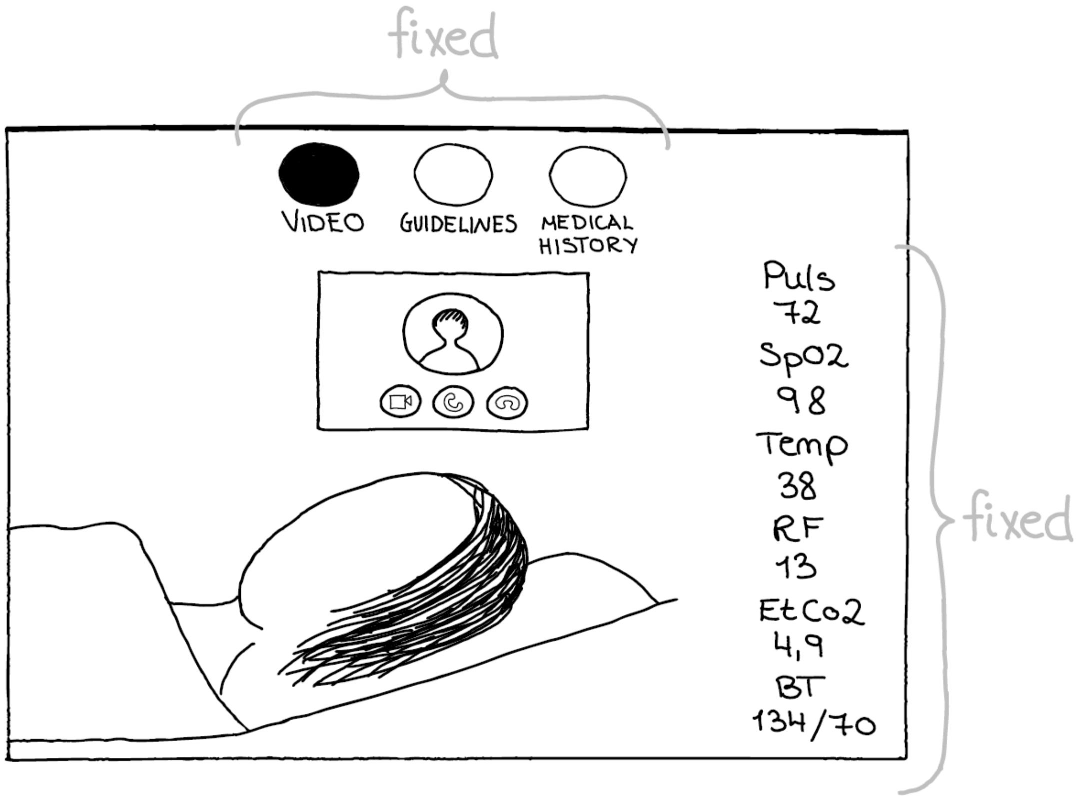

Figure 6.5: Sketch of concept three

Positives:

- The user can select the information that is needed at any given time, and only select the specific information needed (except for vital parameters). E.g., if only video communication is needed, the user can activate only the video communication functionality
- Hands are free while being able to see the needed information
- Vital parameters are visible to the ambulance worker and also the physician at any time, because of the fixed position

Negatives:

- Can potentially lead to overload of information
- Could be challenging to navigate and maneuver the three components: video, guidelines, and medical history

After comparing the three concepts, a mix between the first and third concept was chosen. Concept one had the advantage of being able to select exactly the information needed, and the possibility to position the information where it is suitable for the user. In concept two, it seemed to be too challenging to read and navigate through all the information in one single window. By combining concept one with the main menu buttons from concept three, the final concept was chosen.

To be able to create the concept of displaying the different windows of information in one view, with the possibility for the ambulance workers to take care of the patient with their hands free at the same time, AR glasses were chosen for the prototype development. The use of AR glasses can be one possible way of realizing the requirements. The video communication tool, vital parameters, clinical practice guidelines, and medical history can be displayed in one view to the ambulance worker, with the possibility to have their hands free. Additionally, AR glasses with no need for cables when in use are available on the market. The usability requirements regarding ease-of-use and learnability would also have to be considered, since AR technology is a relatively new technology, especially for being used in ambulance services.

Figure 6.6 shows the chosen concept in a storyboard where the ambulance worker wears smart glasses to display virtual elements in the ambulance vehicle while taking care of a patient. In the first image in the storyboard, the main menu consisting of the four buttons is displayed to the ambulance worker. In the second image, the ambulance worker selected the video button and therefore gets a video communication tool presented. In the third image, the ambulance worker additionally selected the vital parameters button, and can therefore also see the patient's vital parameters. In the fourth image, the ambulance worker additionally selected the guidelines button and can therefore see a clinical guideline being displayed. Lastly, in image five, the ambulance worker has activated all four buttons, meaning that also the medical history is displayed to the ambulance worker.

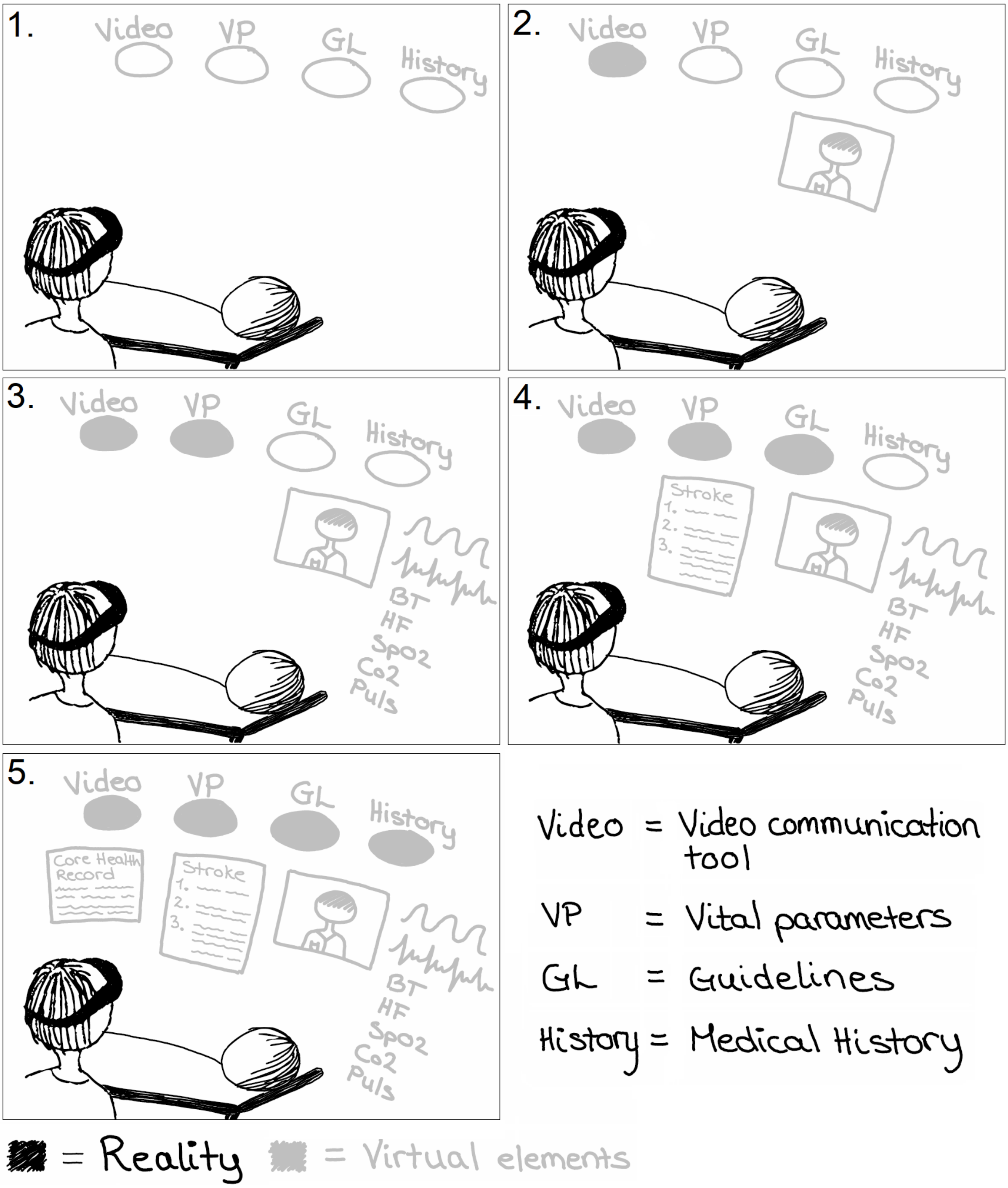

Figure 6.6: Storyboard of final concept

To visualize the chosen concept more clearly in the proper context-of-use, a low-fidelity prototype was made by superimposing the four components onto a picture of the inside of an ambulance vehicle[1]. Figure 6.7 shows the main menu buttons in the ambulance vehicle and Figure 6.8 shows how it would look if all components were activated by the ambulance worker.

[1]Using the MediBang Paint tool: https://medibangpaint.com/en/

Figure 6.7: The concept inside an ambulance vehicle [52] from the ambulance worker's AR view

Figure 6.8: The concept inside an ambulance vehicle [52] from the ambulance worker's AR view, part 2

6.2 Solution Architecture

In order to provide ambulance workers with the information included in the concept, integration with several other eHealth solutions must be secured. For the vital parameters, an integration with Bliksund's ambulance record system or directly with the monitoring device via Bluetooth must be established. To gain access to clinical practice guidelines, the prototype system could be integrated with Bliksund Grid, which is an application that contains clinical practice guidelines. Furthermore, to access patients' medical history, the prototype system could have an integration with the summary care record (Norwegian «Kjernejournal») via the Norwegian Health Network [53].

When integrating with national eHealth solutions, the vendor is required to follow the Norwegian Health Network's established processes for testing and approval [54]. Furthermore, a reference architecture should be used, such as the HL7/FHIR-based reference architecture presented by the Norwegian Directorate for eHealth [55], as shown in Figure 6.9. Even though the overall solution architecture is relevant, it is not within the scope of this project, and therefore the integration of the prototype solution in the national reference architecture and the verification will be work for the future.

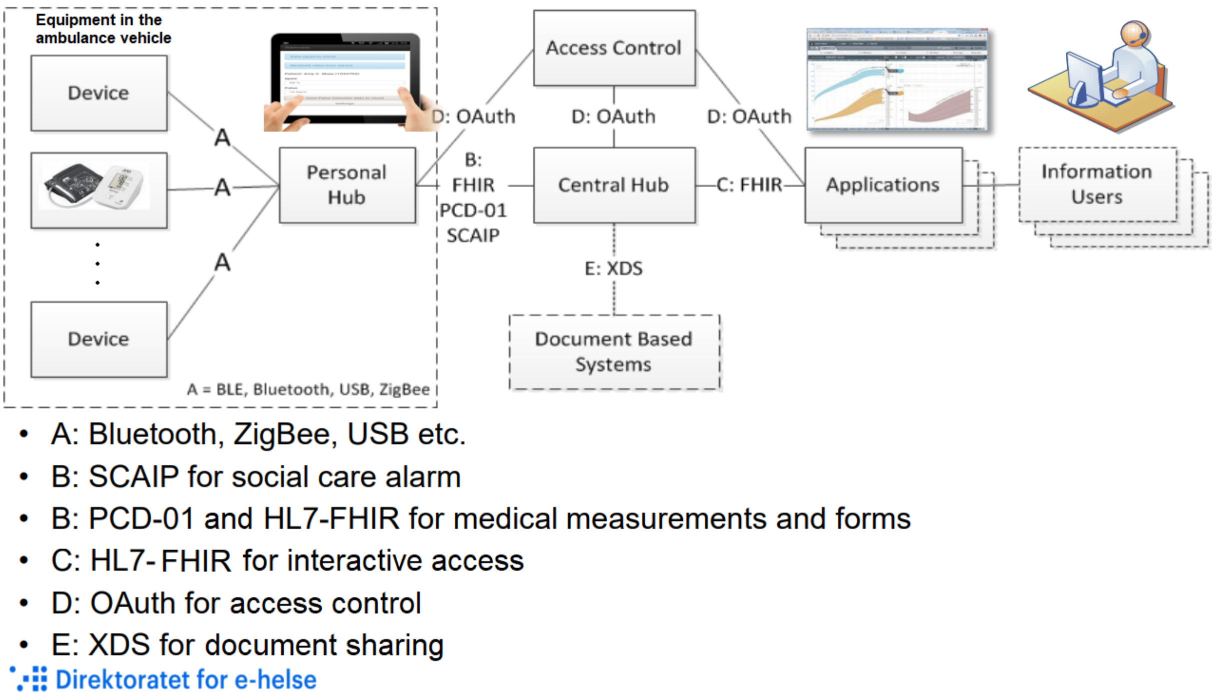

Figure 6.9: Reference architecture, by the Norwegian Directorate for eHealth [55]

6.3 Prototype

After having finalized the concept idea for the prototype, it was decided that the Microsoft HoloLens 2[2] would be used for the prototype development. The HoloLens 2 are the leading AR glasses on the market and employ the Windows Holographic operating system [57]. The glasses give a wide range of possibilities to display and manipulate virtual elements in the real environment, with built in functionality for head, hand and eye tracking, depth sensing, voice commands, and more [57].

Figure 6.10: HoloLens 2 [56]

Microsoft Visual Studio, an integrated development environment (IDE) for developing windows applications [58], was used to develop the prototype application in this study. Visual Studio is used by the developers in Bliksund, and the author could therefore easily receive guidance and support from co-workers when developing the prototype. The Unity tool [59] was also considered as a tool to use for the prototyping, but was not selected because the author, supervisors, and co-workers did not have prior experience using the tool. Additionally, Unity is primarily used for game development, and is also recommended for developing 3D elements for VR/AR applications [59]. As 3D elements were not necessary for this prototype, Visual Studio was sufficient for this project.

XAML[3] and the C#[4] programming language were used in Visual Studio version 2019 for the prototype and User Interface (UI) implementation. Additionally, the Windows 10 SDK[5], version 10.0.19041.0 was used. To be able to run the application on the HoloLens 2 device, an Universal Windows Platform (UWP)[6] application was developed, with the ARM64 architecture selected.

When deploying the application to the HoloLens 2, the guide described in Microsoft's documentation [60] was followed. The main steps were to activate developers mode on both the PC and HoloLens and to activate the Device Portal option on the HoloLens, followed by selecting the ARM64 architecture and Remote Machine in Visual Studio, and connecting to the Hololens by the IP-address. Additionally, the PC and HoloLens were connected to each other using the Windows Device Portal [61] and the Microsoft HoloLens companion application [62] installed on the PC to easily live stream the content or transfer photos and videos from the glasses directly to the PC. In general, Microsoft's

[2]https://www.microsoft.com/en-us/hololens/hardware
[3]https://docs.microsoft.com/en-us/windows/uwp/xaml-platform/
[4]https://docs.microsoft.com/en-us/dotnet/csharp/tour-of-csharp/
[5]https://developer.microsoft.com/en-us/windows/downloads/windows-10-sdk/
[6]https://docs.microsoft.com/en-us/windows/uwp/get-started/universal-application-platform-guide

Mixed Reality documentation [63] was widely used throughout the prototype development for gaining knowledge about mixed reality and HoloLens.

Initially, in the prototype development, four main menu buttons were created in Visual Studio, Figure 6.11, with the purpose of activating the video communication tool, vital parameters, clinical practice guidelines, and medical history. After creating the main menu UI and reviewing it with the supervisors, it was decided to improve the buttons for a better user experience in the AR environment.

Figure 6.11: Initial main menu buttons

The buttons in the first prototype version were not satisfactory. The text on the buttons was hard to read and it was challenging to accurately press the correct button when using the glasses. The Windows Mixed Reality documentation recommends using a dark or colored back plate with white text for the best user experience in mixed reality. Additionally, it is recommended to use semi-bold or bold font weight with minimum font size of approximately 34pt when the distance to the hologram is two meters [64, 65]. Figure 6.12 shows the improved main menu buttons. The following changes were made:

- Increased font size and changed to bold
- Increased the size of the buttons and rounded the corners
- Changed to a stronger background color on buttons
- Added borders in contrasting color
- Added more space between the buttons

Figure 6.12: Improved main menu buttons

Video Communication Tool

When selecting the Video button, the idea was for a video communication tool to open in a new window. For the video communication, Microsoft Dynamics 365 Remote Assist [66] was used. This application provides a solution for calling Microsoft Teams users directly from the glasses. The remote physician can then see everything that happens in the glasses from a PC or smartphone, and can additionally draw and make arrows directly in the HoloLens user's view [66].

Since the Remote Assist application is an immersive application [67], all other virtual windows are hidden when Remote Assist is opened. This was a drawback, as the author intended to have the prototype menu open all the time for the user to be able to activate the needed information at any given moment. The author therefore tried other solutions, such as browser-based Teams and Telegram, and tried to find other application such as Skype and Zoom, with no success. Video call using browser-based Teams was not possible, since the current browser in the HoloLens did not support audio and video. Therefore, the author tried an Insider preview build [68], which provided a chromium-based browser with support for audio and video. However, the insider build had some technical issues that led to the prototype not functioning properly. Hence, the HoloLens was reset to the last stable build and the Remote Assist application was used after all. The Remote Assist application was launched through the prototype menu by using the Uniform Resource Identifier (URI) [69] as shown in the following code:

```
private async void VideoButton_Click(object sender, RoutedEventArgs e)
        {
            await this.LaunchExternal(new Uri("ms-voip-video:"));
        }
//for launching external URI
private async Task LaunchExternal(Uri uri)
        {
            await Windows.System.Launcher.LaunchUriAsync(uri);
        }
```

Figure 6.13 shows how the Remote Assist application looks when opened in the glasses. The Hololens user can easily call the desired person by clicking the person's photo, given that the person is in the contact list or belongs to the same organization.

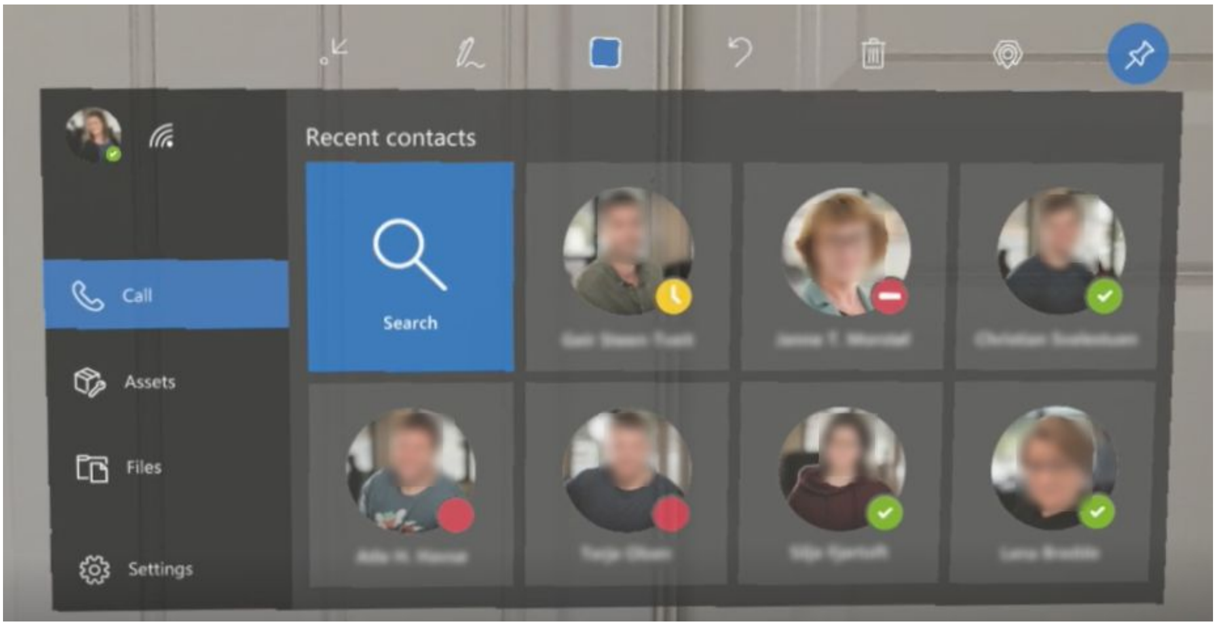

Figure 6.13: Dynamics 365 Remote Assist

Vital Parameters

Vital parameters *(Vitalia = Vitals)* were included into the prototype by utilizing parts of Bliksunds ambulance record system. The ambulance record is an UWP application that can run on the HoloLens. By integrating the ambulance record system into the prototype, both simulated and live vital parameters could be shown in the glasses. The CEO in Bliksund helped in adapting the ambulance record application to fit the purpose. Irrelevant information was removed, thus having only the vital signs module left. Additionally, adjustments were made by the CEO to the Medical Unit Broker program needed to fetch the vital parameters via Bluetooth from the medical-technical unit. After installing the ambulance record application on the HoloLens and running the Medical Unit Broker on an external PC, the ambulance record application was launched through the prototype by using a similar URI method, as follows:

```
private async void VitalsButton_Click(object sender, RoutedEventArgs e)
{
    await this.LaunchExternal(new Uri("bewa:"));
}
```

Figure 6.14 shows how the vital parameters were presented in the glasses when launched through the prototype. The ambulance worker can see both a graph and values of the vital parameters, and additionally enter measurements manually into the system. The presentation of the vitals graph and values would have to be optimized for the HoloLens, to improve the usability and readability.

Figure 6.14: Vital parameters shown in HoloLens

Clinical Practice Guidelines

Bliksund also provides an UWP application containing clinical practice guidelines *(Prosedyrer = Guidelines)*. This application was installed on the HoloLens and tested, but because of poor readability in the glasses, a PDF document of a clinical guideline was made with larger font to illustrate the functionality. To open the PDF document by clicking the «Prosedyrer» button in the prototype, the aforementioned URI method was used, by entering the url link to the document in Bliksund's SharePoint. Figure 6.15 shows how the clinical practice guideline was displayed in the prototype in the glasses.

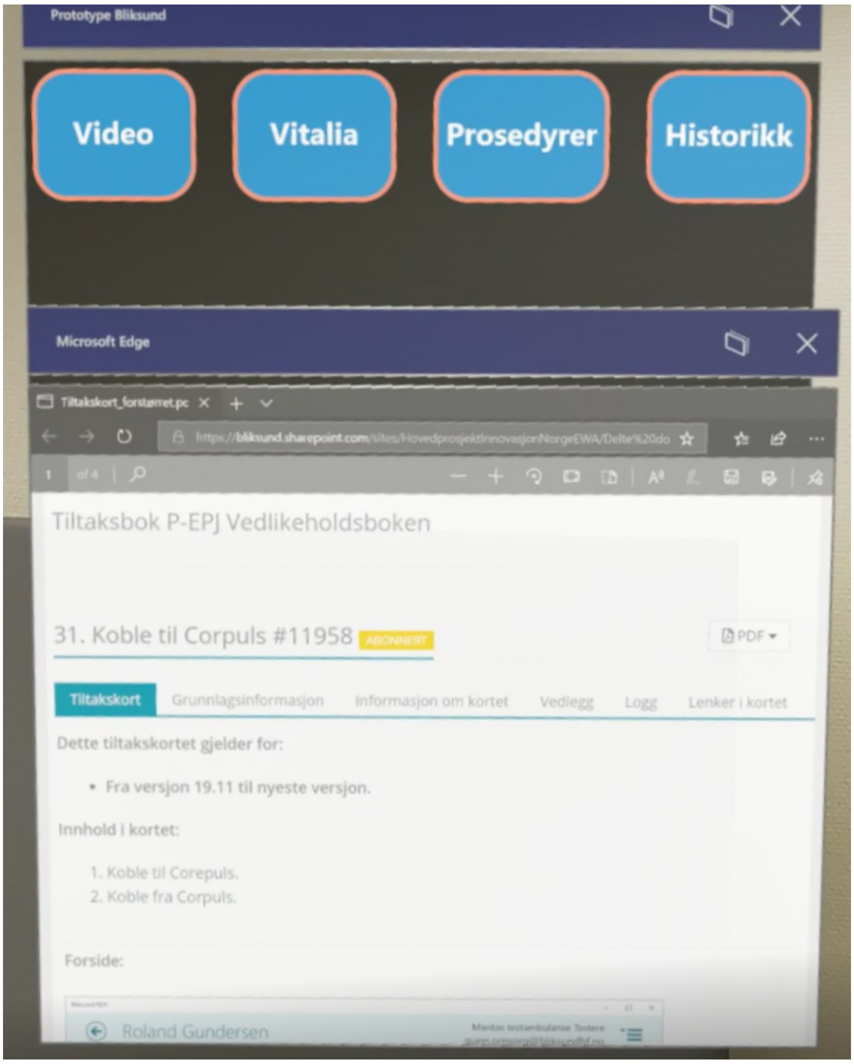

Figure 6.15: Clinical practice guideline shown in HoloLens

Medical History

Based on the ambulance workers needs', medical history should also be included in the prototype. Medical history, such as the summary care record, is not accessible in the ambulance services today, but there is ongoing work to make it available. Since there is no solution for this yet, an imitation of the summary care record was made by creating a PDF document based on information found about the summary care record on Helse Norge's pages [9] and the Norwegian Directorate of eHealth's document regarding critical information in the summary care record [70]. Additionally, the author checked her own summary care record to look at the layout and main content. The imitated summary care record document can be found in Appendix C. The aforementioned URI method was also used here, entering the url to the PDF document into the code. Figure 6.16 shows how the imitated summary care record was displayed in the glasses.

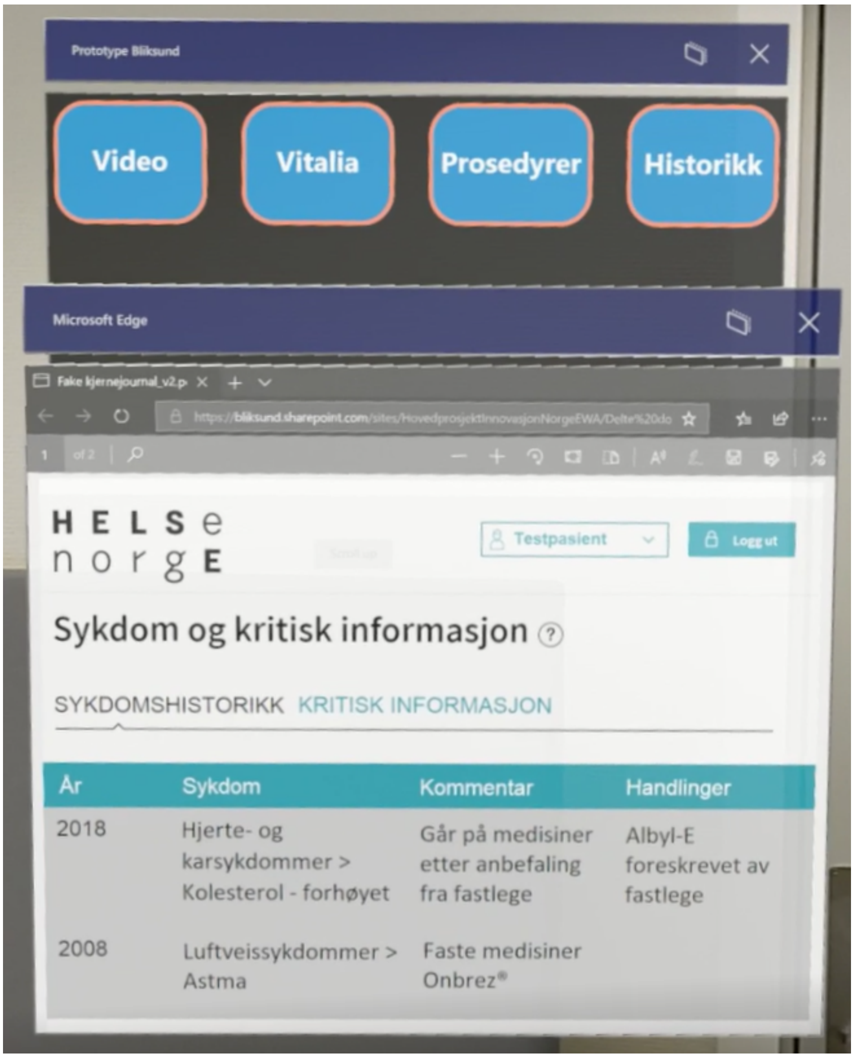

Figure 6.16: Medical history shown in HoloLens

Combining information

For the ambulance workers to access the relevant information at the needed time, and to gather the information in one view, as described in the requirement specification in Section 5.2, different combinations of the information were tested in the glasses. Figure 6.17 shows how vital parameters, a clinical guideline, and medical history are presented at the same time by activating the three corresponding buttons from the menu.

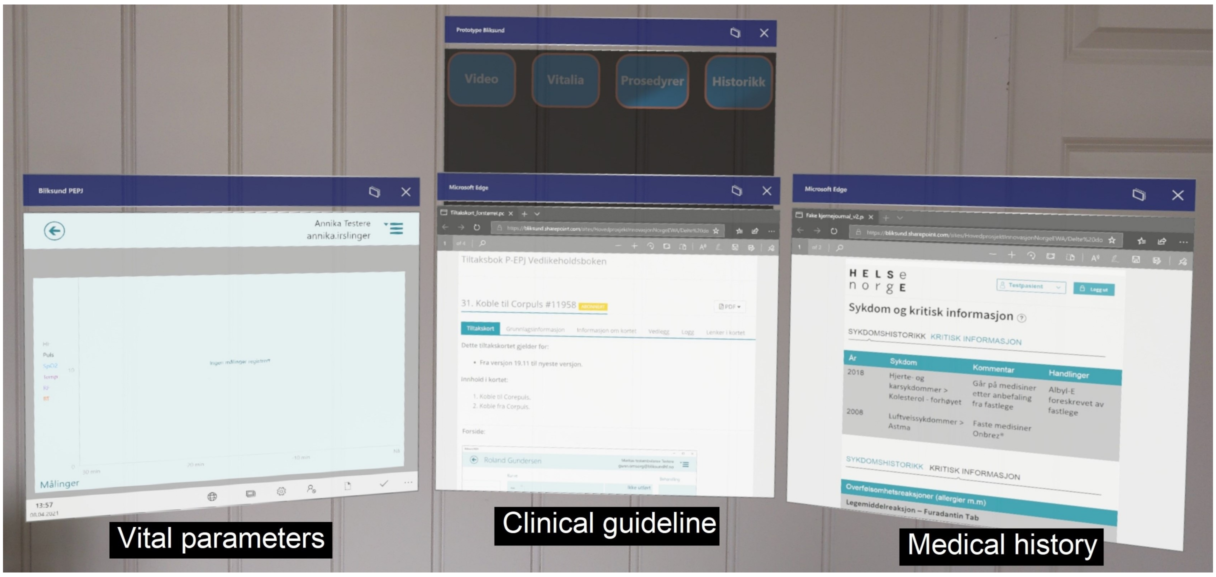

Figure 6.17: Combining vital parameters, clinical guidelines, and medical history in one view

Interacting with mixed reality

After completing the main functionalities in the prototype, a logo and splash screen were added to the prototype to get a more coherent solution. Figure 6.18 shows the HoloLens menu and how to enter the prototype application. When interacting with the HoloLens glasses, mainly the hands are used for navigating the system, but voice can also be used. There are several gestures that the user must learn in order to navigate the system [71], and a quick introduction to the main gestures is given when a new user signs into the HoloLens for the first time. Since navigating by voice was one of the «Nice to have» requirements in this study, different voice commands were tested. The buttons in the prototype menu could be activated both by using the hands, or by saying the button name out loud. When browsing the clinical guideline or medical history documents, voice can be used to scroll up and down, by saying «scroll up/scroll down». Additionally, the user can zoom in or out by saying «zoom in/zoom out» and can also close the documents by saying «close».

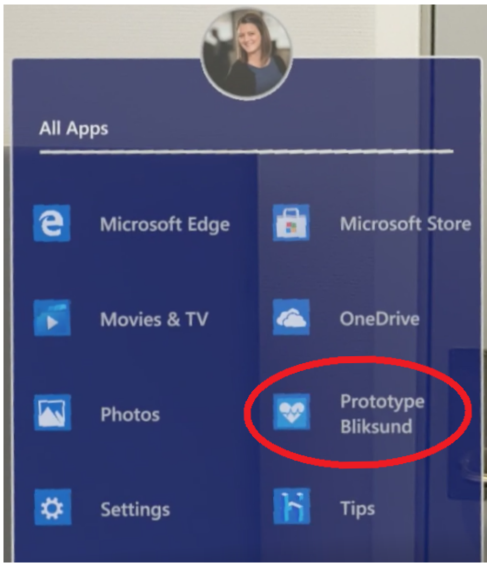

Figure 6.18: HoloLens menu for opening the prototype application

Chapter 7

Prototype Demonstration and User Feedback

After completing the conceptual design and prototype development, a prototype demonstration and user feedback workshop was performed with ambulance workers. In this chapter, the prototype demonstration is described, followed by the user feedback that was gathered in the workshop. In addition, some learnings from the prototype development are presented at the end.

7.1 Prototype demonstration

After finishing the prototype development, a demonstration and user feedback workshop was prepared by creating a presentation and a demonstration video. Since the workshop could not be held physically as initially intended, the author focused on creating a demonstration video of the prototype showing the functionalities and possibilities with the technology.

At first, the HoloLens glasses were presented to the participants, showing that the glasses have cameras, speakers, and buttons for adjusting the volume and brightness, and an adjustable strap. Furthermore, the functionalities corresponding to the four prototype buttons were shown. For the participants to easily recognize the intended context-of-use while showing the video functionality, a scenario including an ambulance worker with a patient, while communicating with a remote physician was planned and filmed with help from two co-workers, Figure 7.1.

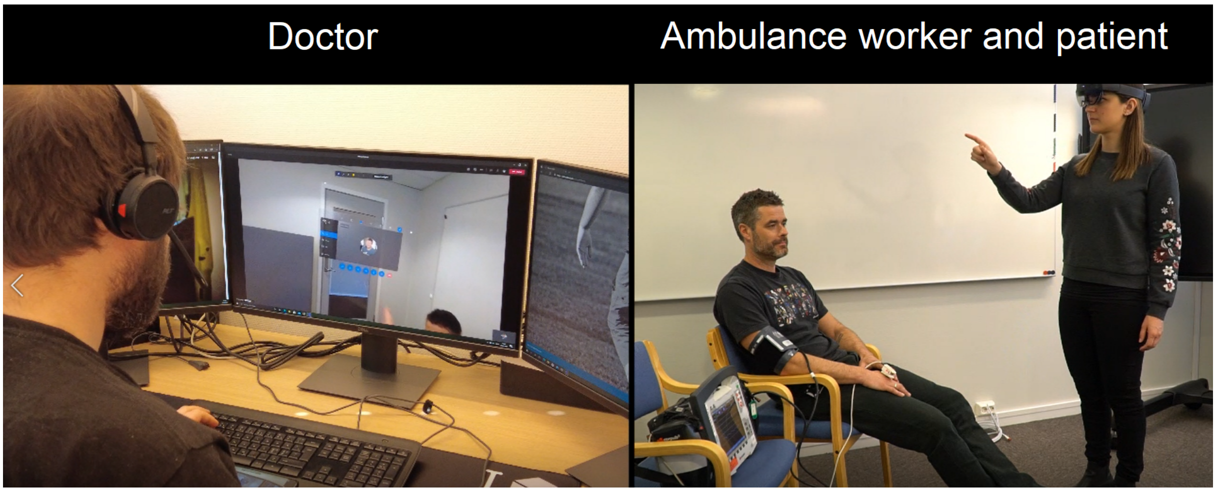

Figure 7.1: Demonstration video: video functionality

Next, the vital parameters were shown by displaying a video of both the view from inside the glasses, and also the view from the outside when using the glasses, as shown in Figure 7.2. By showing the different views, the workshop participants could more easily understand how the navigation of the system works. The clinical guidelines and medical history functionalities were shown in a similar way.

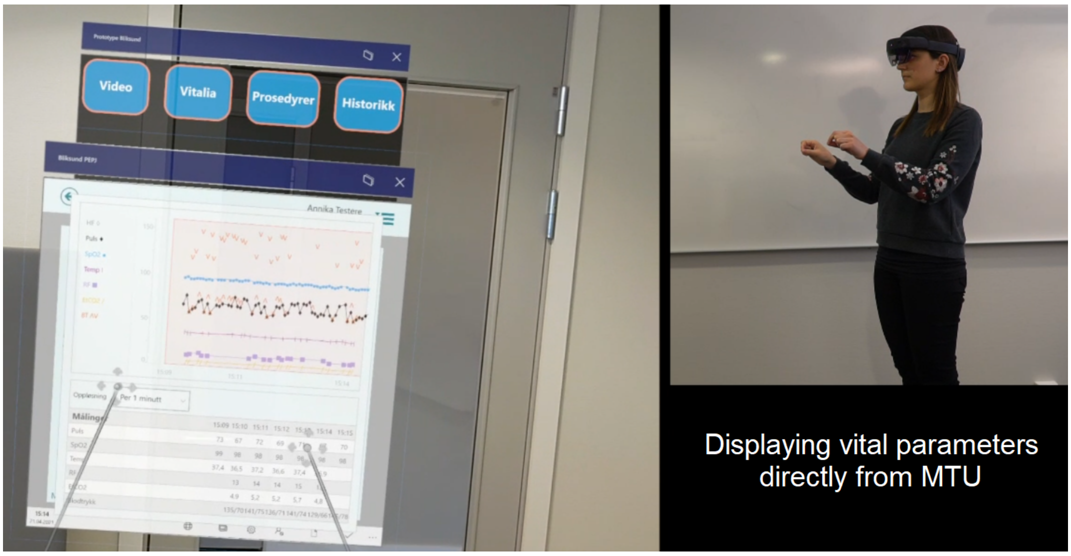

Figure 7.2: Demonstration video: vital parameters

After showing the participants the four main functionalities of the prototype, two examples of different use cases were presented. The first use case was that the ambulance worker communicated by video with the physician while displaying the medical history in the glasses at the same time, as shown in Figure 7.3. Both the ambulance worker and the physician can then see the medical history while communicating with each other. The second use case shown in the demonstration video was that the ambulance worker opened the vital parameters, clinical guidelines, and medical history and displayed them at the same time in the glasses.

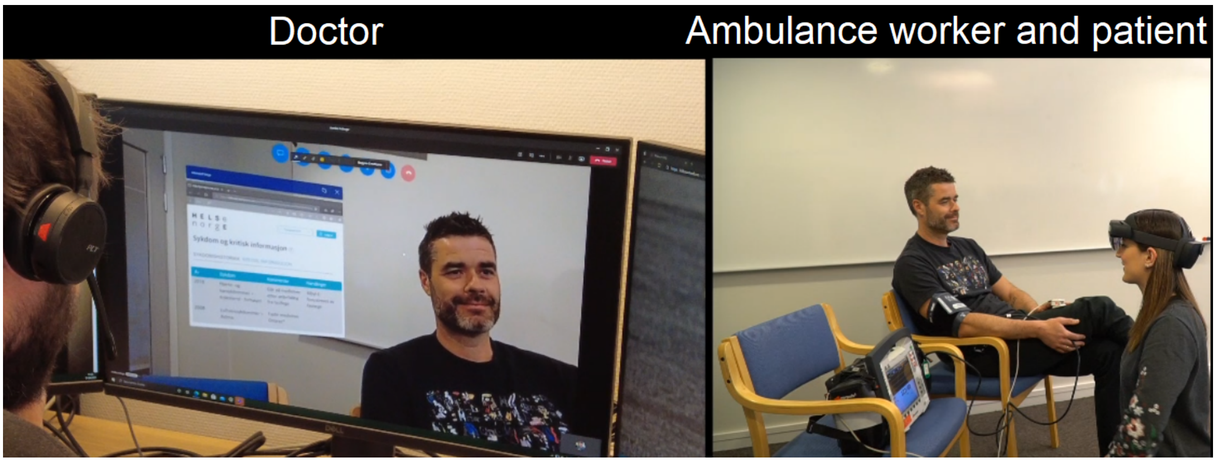

Figure 7.3: Demonstration video: video communication with physician and displaying medical history

7.2 User Feedback

After watching the demonstration video, the participants answered an online questionnaire regarding the prototype. The questionnaire addressed aspects regarding the information presented in the prototype and usability related questions. Figure 7.4 shows the participants answers for the questions related to the usefulness of the information and functionalities included in the prototype.

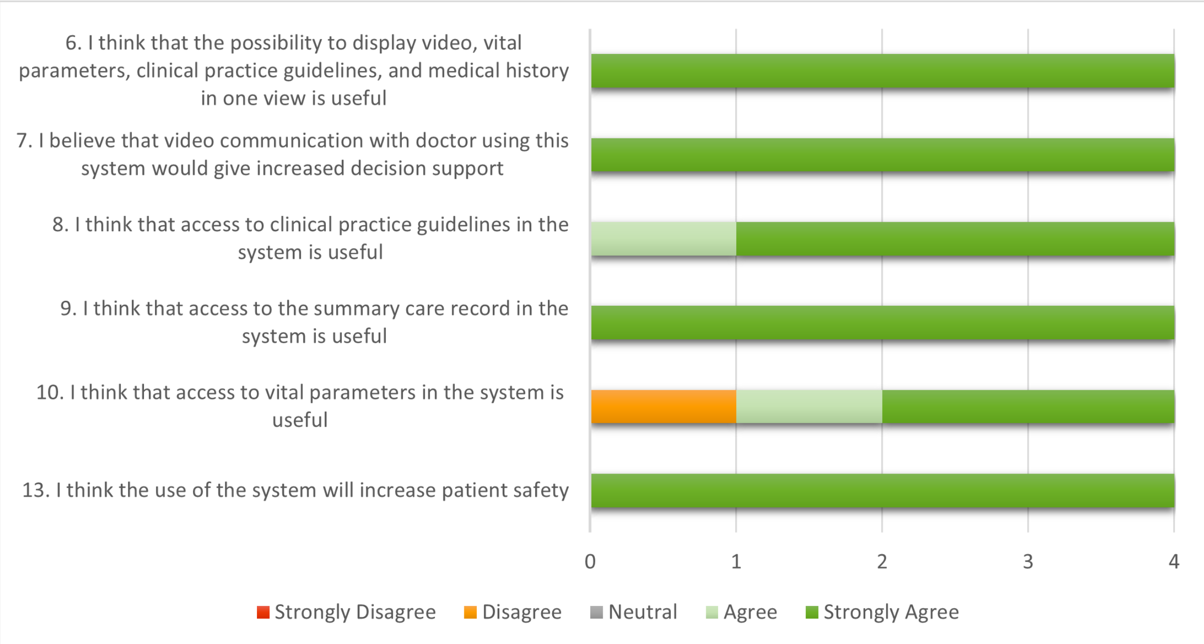

Figure 7.4: Questionnaire answers related to usefulness of included information and functionalities

As seen in Figure 7.4, the participants unanimously agree that it is useful to display the video communication tool, vital parameters, clinical practice guidelines, and medical history in one view. Furthermore, all the participants agree that video communication with a physician would increase decision support, and that the use of the prototype system would increase patient safety. Access to the summary care record and clinical practice guidelines is also stated to be useful by the participants; while on the other hand there is some variance regarding if it is useful for vital parameters to be included in the system.

Figure 7.5 shows the participants' answers related to the usability of the prototype. The participants would like to use the prototype system, and three out of four participants like the way of accessing the information and the way it is presented. Regarding the complexity, learnability, and ease of use of the system, the participants have divided opinions.

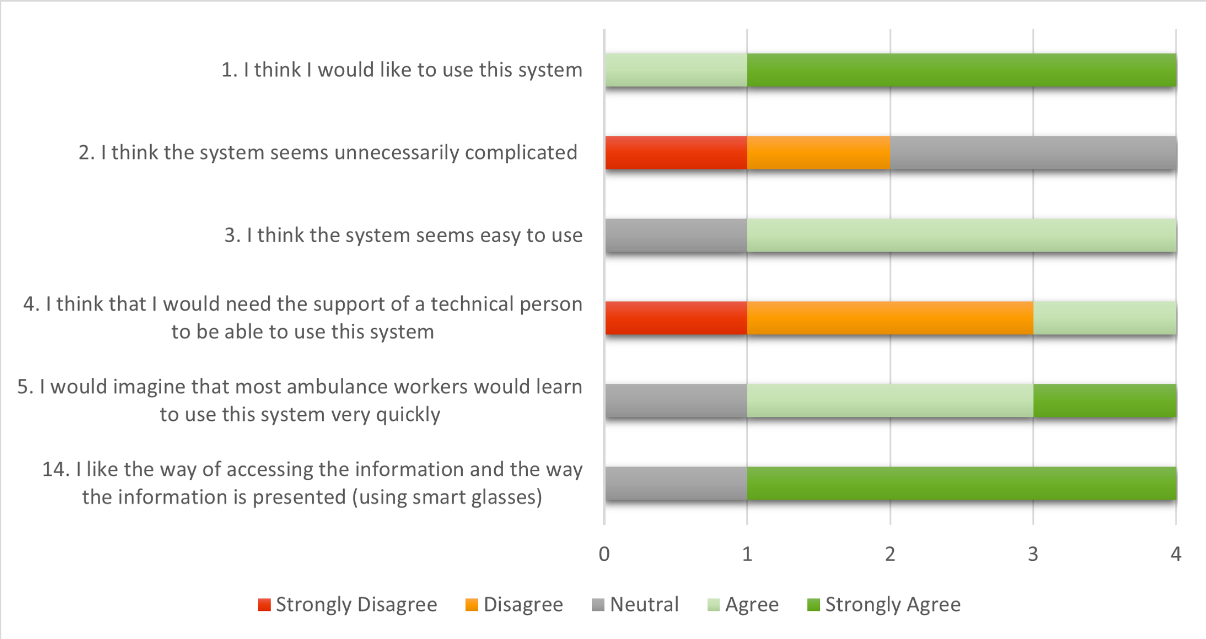

Figure 7.5: Usability related questionnaire answers

After the participants answered the questionnaire, everyone gathered together in the digital meeting for a discussion about the prototype. In the discussion, the participants could elaborate on the different aspects addressed in the questionnaire, and could ask the author and supervisors questions. The author asked the participants questions regarding opportunities or challenges with the prototype system, other potential use cases, the need for training, usefulness of the information included, and how to navigate the system.

All participants saw potential with the prototype system, but highlighted the need to test the system in the context of an ambulance vehicle. Additionally, the participants stated that the prototype has to be developed further and adapted to the ambulance workers' work environment. One participant stated the following:

"*I think that this is very exciting and I believe that this can be something someday, if it continues to be researched and further developed and adapted to our usage. But it is a bit difficult to know without having tried the glasses in practice.*"

In accordance with the findings from the co-design workshop, the ambulance workers think that video communication with physicians would give increased decision support. All four participants stated that the possibility to communicate by voice and video with physicians would give the most added value and should be the first thing to focus on in further development. Furthermore, it was mentioned by one participant that it would be useful to use the glasses to open catalogs or reference books when needing to double check documentation, and that this would save time compared to scrolling through books and other paper-based material.

It was stated by two out of the four participants that the highest added value of video communicating with physicians would be when used in the patient's home, as explained by one participant:

"*I think that the use of video communication with physicians is most useful in the patient's home. It is in the patients' homes that the most difficult decisions are made; decisions related to whether the patient can be left at home or not. It is also in these cases that we get the most complaints, whether the patient can stay at home or not.*"

The participants highlighted that when consulting with a physician using the glasses, it is important that the video conversation can be logged for documentation. If there are any incidents or complaints later on, the logged video conversation can be investigated. Additionally, it was stated to be important that the glasses can communicate with the ambulance record system, so that the ambulance workers would not have to document the same information twice. For instance if the glasses were used to document something by taking a photo of the incident, the photo should automatically be registered in the ambulance record system for documentation. Furthermore, legal aspects regarding what kind of information is allowed to be included in a photo/video of the patient was also brought up. One participant stated the following:

"*There are ongoing discussions regarding the use of photos as documentation, related to privacy considerations. This is already an issue with the ambulance record system today, regarding what we are allowed to take photos of and whether it should be included in the patient's ambulance record or not. If we start to use glasses, and collect information in them, it must be possible to transfer the information directly to the tablet to avoid having to register the same information twice.*"

Even though the participant addressed challenges that must be considered, the participant stated that the prototype system has potential to ensure the quality of the ambulance workers' work. One participant suggested another use case for the glasses, to display small video clips in the glasses, showing how different procedures are done:

"*It could be helpful with tutorial videos giving instructions of how, for example, restart of equipment in the vehicle is done. Or guidance on how to use the radio for some special cases, such as setting up communication equipment in a tunnel. Then the ambulance worker could look at these instruction videos directly in the glasses.*"

Other use cases such as getting an overview of a mass injury incident or car accident by streaming the video from the glasses to the incident commander or emergency department at the hospital was mentioned. Furthermore, one participant suggested that integrating other MTUs into the glasses, such as C-Reactive Protein (CRP) measurement devices could be useful.

One of the participants mentioned that more information will be available in the future in the digital ambulance record system on the tablet, and raised the question whether it is necessary to have access to for instance the pharmaceutical product compendium (felleskatalogen)[1] and the summary care record in the glasses when available on the tablet. The participant highlighted the need to investigate what kind of information the remote physicians need to see. The physicians' input should also be considered when deciding which information should be included in the glasses.

Regarding how the information can be requested by the ambulance workers when needed, voice commands were mentioned several times both in the co-design and demonstration and user feedback workshop. It was clearly stated that the voice commands have to be very simple, so that the ambulance workers can only say a short command and get the needed information presented right away. Challenges regarding high noise levels in the ambulance vehicle, especially on acute missions with high speed, were raised, regarding the system understanding the voice commands in the noisy environment. Furthermore, one participant stated that the system has to be able to distinguish between which voices are regular conversations and what are commands to the system. Additionally, a functionality should be created for selecting who to call via the system, as stated by one participant:

"*We have a calling system that we use in our vehicle today, in which we can press a few buttons to enter a pre-defined contact list with the calling information to the various hospital clinics in the region, and with different sub-categories. Something similar could be applied in the glasses for selecting the person to call.*"

Several usability related aspects were discussed in the demonstration and user feedback workshop, and it was strongly highlighted on more than one occasion that the system must be as simple as possible to use. Even people with moderate to low technical skills must be able to use the system. The participants stated that it should require as few clicks as possible to navigate the system, and that it should be easy to get started using the glasses when the ambulance worker decides to use them. One participant stated that the hand gestures to interact with the system look relatively simple, but that the keyboard seems difficult to use. Furthermore, the benefits of using the system must be so high that even though it requires some effort, it is still worth it. One participant stated the following:

"*The glasses must understand the difference between regular conversation and commands to the system, and I think that some kind of command, such as «Hi, Google» could work for the system to understand the difference. The navigation must be so simple that you can say for instance «pharmaceutical product compendium (felleskatalogen) - Morphine»*

[1] https://www.felleskatalogen.no/medisin/

and then the system opens the corresponding information. If the system would understand such simple commands, I think it would be an amazing tool. "

The participants also mentioned aspects regarding that the glasses must withstand being cleaned with strong detergents, and wondered about how the ambulance workers would react to using smart glasses regarding car sickness. Furthermore, one participant was worried about the distance such glasses potentially could create between the ambulance workers and the patients. All participants agreed that the prototype was interesting and that it has potential, but that the glasses must be tested in the real environment of the ambulance services. When the participants were asked what was the most important feature to develop further and implement, all participants agreed that the single most important feature was the video communication tool.

7.3 Learnings from the use of HoloLens

During the prototype development and testing of the HoloLens, several discoveries were made. The author identified usability challenges, but also possibilities. In the initial testing of the HoloLens, the author found it tiring for the eyes when using the glasses for longer periods. However, after discovering how to change the brightness in the glasses, the eye strain decreased. Large, bright areas displayed in the glasses increased the eye strain, while dark or colored elements were more pleasant for the eyes. Additionally, text documents with white background could both be tiring for the eyes and difficult to read.

Several times, the author misclicked buttons or clicked buttons unintentionally which could be frustrating. Furthermore, it took some time getting used to the ways of navigating the system in the glasses and learning the different gestures. After learning the gestures and after having tested the glasses for a while, the interaction became more effortless and fewer unintentional actions were done. When interacting with several virtual windows in the glasses, it can be challenging to position them as intended, and elements that are positioned very close can be challenging to interact with. When clicking the close elements, one can experience that the hand goes through the virtual window rather than clicking the intended button. Interacting with the virtual keyboard can also be challenging and time consuming, and when used for signing in, it can be challenging to know if the right characters were entered. On the other hand, the functionality for signing in by iris recognition is very quick and easy.

Another challenge is that when using immersive applications [67] in the glasses, such as the Remote Assist application, then all other applications are hidden. This was a challenge in the prototype development, as the intention was to be able to display the prototype menu at all times, and for the user to activate relevant information whenever needed; meaning that when the user clicks the video button, the prototype menu will be hidden, and the user would have to enter the HoloLens menu to open the prototype again. Additionally, the author once experienced that the HoloLens hardware was overheated and had to be switched off. Another drawback is that when four or more virtual windows are open at the same time in the HoloLens glasses, the first application that was opened becomes inactivated. Inactive applications are darkened and will become active as soon as the user interacts with the application window again.

If the applications that have been used in the glasses are not closed before shutting down the device, the applications will reappear in the same position as last time. This can be an advantage, but also a disadvantage. When trying to re-open the application the next time using the glasses, the application window sometimes will not appear in front of you, because it is already opened. One example of this is when the author had used the Remote Assist application in the hallway without closing the application. The next time the author intended to use the Remote Assist application in the living room, but when trying to open the application, it would not appear. After a while, it was discovered that the Remote Assist application was already opened, and that the hologram was still positioned in the hallway.

The HoloLens glasses give the possibility to interact with the system by using voice commands. When testing voice commands to interact with the glasses, it was discovered that the system does not always understand the commands given. In some cases it seems like the system does not react at all, even though the command is repeated. Other times, the system responds right away. In other words, the voice control is not always reliable. However, when the voice control is working, it is very efficient and the user has their hands free for other tasks.

Chapter 8

Discussion

8.1 Research Questions

In this study, five research questions were created to investigate the use of state-of-the-art AR technology for increasing collaboration and decision support in prehospital emergency care, with ambulance workers in focus.

RQ1

How can Augmented Reality (AR) support ambulance workers in providing emergency care?

When reviewing the state-of-the-art literature, Chapter 2, it was discovered that there is limited existing research on the use of AR technology in prehospital emergency care [25, 28]. Therefore, related environments, such as the military and disaster management were researched. Although no literature was found addressing the exact same use cases as in this study, some studies showed promising results with the use of AR technology for remote guidance and decision support that are relevant for the current scope. Studies found that, with the use of AR technology, accuracy when performing clinical tasks increased, as well as self confidence [26, 28, 32].

The ambulance workers that participated in the workshops of this study highlighted that the possibility for video communication with physicians during ambulance missions would be very helpful, see Chapter 5 and 7. Situations that are vague and complex are often challenging for the ambulance workers. It can be a time-consuming process, to decide about the correct level of treatment and which care facility to transport the patient to. When communicating by voice and video with remote physicians, the ambulance workers can receive recommendations and advice for further patient treatment and transportation, and potentially save valuable time. The HoloLens 2 glasses provide a functionality allowing the remote physician to interact with the ambulance worker directly in a video call, by augmenting arrows and drawings directly into the ambulance worker's view for guidance.

In addition, information such as vital parameters, clinical practice guidelines, and information about the patient's medical history can be presented to the ambulance workers using AR glasses. This information is also available to the remote physician, who can follow what the ambulance worker is doing from a PC or smartphone. All participants in the prototype demonstration and user feedback workshop, Chapter 7, unanimously agreed that it is useful to gather the aforementioned information in one view. However, there was not complete agreement on whether the vital parameters were useful to include in the glasses. From an ambulance worker's point of view, that is understandable, since the vital parameters are clearly displayed to the ambulance workers on the monitor in the vehicle. However, it is important for the remote physician to be able to see the vital parameters. By providing the physicians with the possibility to see the patient, see vital parameters, and other relevant information, physicians can make more informed decisions, signaling that improved decision support can be provided to the ambulance workers with AR technology. Additionally, other relevant information and functionalities could be displayed in the AR glasses, such as warnings based on triggers, as mentioned in the co-design workshop.

On the other hand, the state-of-the-art review showed that there also are benefits using other, simpler technologies, such as ceiling-mounted cameras in the ambulance vehicle or simpler smart glasses [16, 19, 21, 22]. The benefit of the physician seeing the patient would also be accomplished with ceiling-mounted cameras, but the possibility for the physician to augment elements into the ambulance worker's view and see vital parameters or other relevant information would not be achieved with ceiling-mounted cameras alone.

All workshop participants believed that the AR prototype could give improved decision support and increase patient safety. The findings in this study and in the reviewed literature imply that AR glasses have the potential to support ambulance workers while they are providing emergency care. However, the workshop participants pointed out that the prototype would have to be developed further, and that the system must be adapted to the ambulance workers' context of use.

RQ2

How do ambulance workers need information and decision support to be presented to them while providing emergency care?

In the co-design workshop, the participants suggested that video communication with physicians could be done by using the ambulance record tablet or smart glasses. Furthermore, one participant stated that many ambulance vehicles already have cameras installed inside. Another participant suggested that a tile for activating video communication could be added in the ambulance record application on the tablet, and that the user could select whether to use either the in-vehicle camera or for instance smart glasses. A need for video communication with physicians in the patient's home was raised, and in regards to that, an in-vehicle camera would not be sufficient. Therefore, the tablet or glasses were highlighted by the participants.

Regarding text-based information such as clinical practice guidelines and medical history, the participants had slightly different opinions on whether this should be presented in smart glasses or on the tablet. One participant found it best to gather as much as possible in the ambulance record system on the tablet, whereas another participant liked the possibility of viewing the information in smart glasses. The ambulance workers would not necessarily have to choose either/or, since the information shown in this study's prototype in the glasses is based on integration with existing UWP applications. This means that the ambulance worker could potentially choose to use AR glasses or the tablet following individual preferences for each mission. Either way, it is important that when the ambulance worker first has decided which option to use, the needed information must be possible to display in the chosen solution. Participants in both workshops highlighted that switching between devices can be challenging and time-consuming.

Both in the reviewed literature, see Chapter 2, and in this study, the need for the ambulance workers to have their hands free while providing emergency care was addressed [32, 33, 35]. Therefore, the technology used to provide information and decision support should allow the ambulance workers to have their hands free to take care of the patients. AR glasses fulfill this requirement, but if many interactions with the glasses are required when displaying the information, such as button presses, scrolling, and zooming, the hands would not really be free to take care of the patient. Thus, voice commands were raised as a possible solution for navigating the technology in question.

RQ3

How do ambulance workers prefer to request information and decision support on-demand while providing emergency care?

In the co-design workshop, the participants stated that voice control could be used for navigating the system and for requesting needed information. Furthermore, it was suggested to use voice control to enter notes into the ambulance record system. In the second workshop, the participants stressed that the voice commands would have to be short and easy, otherwise the system would not be used. Additionally, the smart glasses would have to be reliable, because the system has to perform accurately, especially when used in emergency situations. One participant asked how the voice commands on the HoloLens would work in regards to background noise. This has not been tested yet. In the reviewed literature, Chapter 2, Leuze et al. [31] found that background noise strongly affected the voice recognition negatively when using the HoloLens 1, indicating that there could be similar challenges with the HoloLens 2. The author also found challenges using voice commands, Section 7.3. The HoloLens 2 glasses did not always respond to the voice command, and the command had to be repeated several times. The voice control would have to be tested further to evaluate if the technology is developed far enough to be used in such a time-critical environment as emergency care.

In the demonstration and user feedback workshop, one participant suggested that a similar calling system to what is used today could be used to request a video call with a physician/specialist. The ambulance workers can select who to call through a pre-defined list of relevant care facilities and departments. The video call could be initiated from the ambulance record tablet or directly in the smart glasses, and potentially by using voice commands.

RQ4

How can bi-directional support between ambulance workers and care facilities be provided?
As found in both the state-of-the-art review [19] and in this study, the ambulance workers can receive support by two-way communication with physicians using both audio and video. The ambulance workers can receive advice and recommendations that can help in decision making regarding the correct level of treatment and transportation. Additionally, the physicians receive more information, such as seeing the patient and patient specific information, allowing them to make informed decisions. Potentially, video support can increase the confidence of both the physician, ambulance worker, and patient in decisions about whether to leave the patient at home with self-care. In the co-design workshop, the participants stated that it would be important to be able to communicate with more than one physician/specialist at the same time, since it can be challenging to come to an agreement between the different care facilities regarding where the patient should be transported to.

The use of smart glasses is one potential solution to provide the physicians with needed information, but there are also other options. For instance, a ceiling-mounted camera or simpler smart glasses could be used for the video communication, while other patient specific information could be provided directly through the ambulance record system to the physician's computer. In this case, the physician does not rely on the ambulance worker showing the needed information. The physician could then look at vital parameters etc. independent of what the ambulance worker is doing. However, from the ambulance workers' perspective, this solution would not provide them with the needed information in one view. Furthermore, the possibility for the ambulance workers to display relevant information in front of themselves while having their hands free to treat the patient would be removed.

RQ5

What are the main usability challenges with AR technology used in prehospital emergency care?
Several usability challenges regarding the use of smart glasses were found in the literature [29, 31, 35], Chapter 2, and also in this study, Section 7.3. Technical limitations, such as connection failure, readability issues, error-prone interaction, and unreliable voice control were discovered. All participants in the demonstration and user feedback workshop

stressed that the systems must be easy to use and reliable, otherwise the system would not be used. Furthermore, if the system is too cumbersome to set up or if initiating a video conversation or finding the needed information takes a long time, the ambulance workers would not use the system either. These findings strengthen the importance of user involvement in the design process and highlight the need for testing the technology in the intended context-of-use. All participants addressed the need for testing the technology in the real context and mentioned this several times throughout the demonstration and user feedback workshop.

One participant in this study, Chapter 7, addressed the potential human contact distance that could arise between the ambulance workers and patients by using smart glasses. The acceptability for the technology, both by the ambulance workers and the patients should be investigated further. Including the users in the design process can potentially increase the acceptability of new technology, and the solution is likely to be better adapted to the intended context-of-use.

8.2 Research Limitations

This research has some limitations. The main limitation was that the proof-of-concept prototype could not be tested and evaluated properly by the users themselves because the workshops had to be executed digitally, due to Covid-19. The limited assessment of the prototype led to the research questions related to system navigation and presentation of information and decision support not being answered as thoroughly as intended. Furthermore, due to the limited sample size used in this study, the findings do not have statistical relevance. However, in spite of the small sample size, the findings do give relevant qualitative results about how AR technology can support ambulance workers when providing emergency care.

8.3 Design Limitations

A limitation of the conceptual design in this study is that not all user needs and requirements could be included in the current concept. The prioritization of included requirements and the requirements to be considered for future work was decided on and explained by the author.

Chapter 9

Conclusion and Future Work

9.1 Conclusion

The state-of-the-art review and findings in this study have shown the potential for using AR technology to support ambulance workers in providing emergency care. Decision support from remote physicians can be provided to the ambulance workers using AR glasses. Ambulance workers can receive guidance from remote physicians who are able to see both the patient and patient specific information, while augmenting elements directly into the ambulance workers view. Additionally, AR glasses can provide the ambulance workers with relevant information for decision support, such as clinical practice guidelines and the patient's medical history, while having their hands free to take care of the patient. However, both technical and usability limitations with AR glasses were discovered, such as connection failure, readability issues, unreliable voice control, and error-prone interaction with the system. In conclusion, AR technology can potentially be applied in prehospital emergency care, but the technology must be developed further and adapted to the emergency care context. Since a lack of research on the use of AR technology in the emergency care context was identified, further research is encouraged.

9.2 Future Work

Further iterations of the conceptual solution design, prototype refinement and testing in the intended context-of-use should be performed, to evaluate the use of AR glasses in more depth. The main aspects that could be considered for future improvements of the prototype are:

- Creating a calling system for the ambulance workers to be able to select the relevant physician or specialist to video-call
- Functionality for searching for, or at least selecting, the relevant clinical practice guideline in the smart glasses
- Adapting the vital parameters feature for improved usability in smart glasses. Potentially display the vital parameters in a different way in the glasses, such as fixating them on the side of the user's view
- General usability improvements

As mentioned above, the AR glasses should be tested in the real environment and with the target users. The following could be considered for further testing:

- Test the video quality, especially when driving at high speed
- Test the internet connectivity in rural areas
- Test the internet connectivity outside of the ambulance vehicle (portable 4G/5G router)
- Test navigating the system by voice commands, especially when there is background noise
- Test the general reliability of the technology

Outlook

In general, for a system such as the AR prototype presented in this study, there are several aspects that must be considered. Other relevant stakeholders, such as the physicians/specialists should also be involved in the design process. The physicians' perspective would be valuable in designing the system, to decide how to present important information needed for physicians to support the ambulance workers. Furthermore, legal aspects should be considered, such as investigating if the system would be classified as a medical device, hence being subject to the Medical Device Regulation (MDR) [72]. In addition, as mentioned in Section 6.2, further considerations of the solution architecture should be included in future work.

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Appendices

A Consent Form

Vil du delta i forskningsprosjektet

Prehospital elektronisk pasientjournal

Dette er et spørsmål til deg om å delta i et forskningsprosjekt hvor formålet er å avdekke og forstå problemstillinger ambulansearbeidere står ovenfor, i forbindelse med informasjonstilgjengelighet og beslutningsstøtte. Dette skrivet gir deg informasjon om målene for prosjektet og hva deltakelse vil innebære for deg.

Formål
Prosjektet inngår som del av masterutdannelsen Informasjons- og Kommunikasjonsteknologi ved Universitetet i Agder. Prosjektet omhandler bruken av elektronisk pasientjournal i prehospital tjeneste, med fokus på informasjonstilgjengelighet og beslutningsstøtte. Ambulansearbeidere står på mange måter alene om å ta viktige beslutninger om pasientbehandling i akutte situasjoner. Målet med dette prosjektet er å identifisere og forstå problemstillinger ambulansearbeidere står ovenfor, med fokus på hvordan ulik teknologi kan være et hjelpende verktøy. Det vil videre undersøkes hvordan ambulansearbeidere vurderer brukeropplevelsen av teknologien for å avdekke utfordringer, forbedringspotensialer og muligheter.

Hvem er ansvarlig for forskningsprosjektet?
Universitetet i Agder er ansvarlig for prosjektet, hvor førsteamanuensis Martin Gerdes er hovedveileder for prosjektet.

Hvorfor får du spørsmål om å delta?
Du blir forespurt om å delta på digital workshop basert på din arbeidserfaring fra prehospital tjeneste. Det er en forutsetning at deltagerne har jobbet eller jobber i ambulansetjenesten, slik at virkelighetsnære problemstillinger kan kartlegges og diskuteres.

Hva innebærer det for deg å delta?
Hvis du velger å delta i prosjektet, innebærer det deltakelse på digital workshop en eller to ganger og med en varighet på ca. 2 timer hver gang. Workshopen inneholder spørsmål om dine erfaringer fra ambulansetjenesten om situasjoner hvor du opplevde å ikke ha tilgang til den informasjonen eller støtten/bistanden du trengte for å ta viktige beslutninger. Dine svar fra workshopen blir registrert elektronisk ved lyd/bilde-opptak. Opptaket vil deretter transkriberes og anonymiseres, og opptaket vil slettes ved prosjektets slutt.

Det er frivillig å delta
Det er frivillig å delta i prosjektet. Hvis du velger å delta, kan du når som helst trekke samtykket tilbake uten å oppgi noen grunn. Alle dine personopplysninger vil da bli slettet. Det vil ikke ha noen negative konsekvenser for deg hvis du ikke vil delta eller senere velger å trekke deg.

Ditt personvern – hvordan vi oppbevarer og bruker dine opplysninger
Vi vil bare bruke opplysningene om deg til formålene vi har fortalt om i dette skrivet. Vi behandler opplysningene konfidensielt og i samsvar med personvernregelverket.

- Det er kun studenten som utfører workshopen og respektive veiledere ved Universitetet i Agder som vil ha tilgang til workshop-materialet.
- Lyd/bilde-opptaket vil bli utført med en enhet utlevert av Universitetet i Agder og lagret adskilt fra annen data.
- Dersom prosjektrapporten skal publiseres vil alle opplysninger anonymiseres slik at det ikke vil være mulig å identifisere deltakere.

Hva skjer med opplysningene dine når vi avslutter forskningsprosjektet?
Opplysningene anonymiseres når prosjektet avsluttes, noe som etter planen er ved utgangen av desember 2021. Ved prosjektslutt vil lyd/bilde-opptaket slettes.

Dine rettigheter
Så lenge du kan identifiseres i datamaterialet, har du rett til:
- innsyn i hvilke personopplysninger som er registrert om deg, og å få utlevert en kopi av opplysningene,
- å få rettet personopplysninger om deg,
- å få slettet personopplysninger om deg, og
- å sende klage til Datatilsynet om behandlingen av dine personopplysninger.

Hva gir oss rett til å behandle personopplysninger om deg?
Vi behandler opplysninger om deg basert på ditt samtykke.
På oppdrag fra Universitetet i Agder har NSD – Norsk senter for forskningsdata AS vurdert at behandlingen av personopplysninger i dette prosjektet er i samsvar med personvernregelverket.

Hvor kan jeg finne ut mer?
Hvis du har spørsmål til studien, eller ønsker å benytte deg av dine rettigheter, ta kontakt med:
- Universitetet i Agder ved førsteamanuensis Martin Gerdes, prosjektansvarlig, tlf: +47 90 79 89 73, e-mail: martin.gerdes@uia.no
- Vårt personvernombud: Ina Danielsen, tlf: +47 38 14 81 40, e-mail: personvernombud@uia.no

Hvis du har spørsmål knyttet til NSD sin vurdering av prosjektet, kan du ta kontakt med:
- NSD – Norsk senter for forskningsdata AS på epost (personverntjenester@nsd.no) eller på telefon: 55 58 21 17.

Med vennlig hilsen

Martin Gerdes
(Forsker/veileder)

Annika Irslinger
(Student)

Samtykkeerklæring

Jeg har mottatt og forstått informasjon om prosjektet Elektronisk prehospital pasientjournal, og har fått anledning til å stille spørsmål. Jeg samtykker til:

☐ å delta på digital workshop

Jeg samtykker til at mine opplysninger behandles frem til prosjektet er avsluttet

----
(Navn i blokkbokstaver) (Telefonnummer)

(Signert av prosjektdeltaker) (Dato)

B Questionnaire

Spørreundersøkelse, workshop 2

Vennligst fyll ut det alternativet som passer best til din opplevelse etter å ha sett demo av prototypen. Spørreundersøkelsen er helt anonym.

Dersom det skulle oppstå problemer kontakt:
Annika Irslinger, tlf: +47 95 49 89 85 eller e-post: anniki15@uia.no

1. Jeg tror jeg ville likt å bruke dette systemet

Helt uenig	Delvis uenig	Nøytral	Delvis enig	Helt enig
(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

2. Jeg synes systemet virker unødvendig komplisert

Helt uenig	Delvis uenig	Nøytral	Delvis enig	Helt enig
(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

Hvis relevant: Hvilke elementer er det som gjør at systemet virker komplisert å bruke? (Valgfritt)

3. Jeg synes systemet virker lett å bruke

Helt uenig	Delvis uenig	Nøytral	Delvis enig	Helt enig
(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

Hvis relevant: Hvilke faktorer kan bidra til å gjøre systemet lettere å bruke? (Valgfritt)

4. Jeg tror jeg ville trenge hjelp fra person med teknisk kunnskap for å bruke dette systemet

Helt uenig	Delvis uenig	Nøytral	Delvis enig	Helt enig
(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

Hvis relevant: Hva tror du at du ville trenge hjelp til og når? (Valgfritt)

5. Jeg vil anta at de fleste ambulansearbeidere kan lære seg dette systemet veldig raskt

Helt uenig	Delvis uenig	Nøytral	Delvis enig	Helt enig
(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

Hvis relevant: Hvilken type opplæring kunne være nødvendig? (Eks. digitalt kurs, fysisk kurs, brukerveiledning, teknisk assistanse, etc.) (Valgfritt)

6. Jeg mener at muligheten for å vise video, vitalparametere, prosedyrer og pasienthistorikk i ett felles system er nyttig

Helt uenig	Delvis uenig	Nøytral	Delvis enig	Helt enig
(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

Hvorfor/hvorfor ikke? (Valgfritt)

7. Jeg tror videokommunikasjon med lege ved bruk av dette systemet vil bidra til økt beslutningsstøtte

Helt uenig	Delvis uenig	Nøytral	Delvis enig	Helt enig
(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

Hvorfor/hvorfor ikke og eventuelt med hvilken type lege? (Valgfritt)

8. Jeg mener at tilgang til prosedyrer i dette systemet ville være nyttig

Helt uenig	Delvis uenig	Nøytral	Delvis enig	Helt enig
(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

9. Jeg tror tilgang til kjernejournal i dette systemet ville være nyttig

Helt uenig	Delvis uenig	Nøytral	Delvis enig	Helt enig
(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

10. Jeg mener vitalparametere er viktig å ha tilgjengelig i dette systemet

Helt uenig	Delvis uenig	Nøytral	Delvis enig	Helt enig
(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

11. Jeg tror det blir for mye informasjon å vise i systemet

Helt uenig	Delvis uenig	Nøytral	Delvis enig	Helt enig
(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

Hvis relevant: Hvilken informasjon er ikke relevant å inkludere i dette systemet? (Valgfritt)

12. Jeg mener det er nyttig at jeg selv kan velge hvilken informasjon (video, vitalparametere, prosedyrer, pasienthistorikk) som er nødvendig å vise i systemet til hvilken tid

Helt uenig	Delvis uenig	Nøytral	Delvis enig	Helt enig
(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

13. Jeg tror bruken av dette systemet vil kunne øke pasientsikkerheten

Helt uenig	Delvis uenig	Nøytral	Delvis enig	Helt enig
(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

Hvorfor/hvorfor ikke? (Valgfritt)

14. Jeg likte måten å få tilgang til informasjon på og måten den ble presentert (ved bruk av smartbriller)

Helt uenig	Delvis uenig	Nøytral	Delvis enig	Helt enig
(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑

Hvorfor/hvorfor ikke? (Valgfritt)

15. Har du noen forslag til annen informasjon som kunne være nyttig å vise i dette systemet? (Valgfritt)

16. Ser du noen andre potensielle bruksområder for dette systemet? (Valgfritt)

Tusen takk for din besvarelse!

C Summary Care Record Example

HELSe norgE

Testpasient | Logg ut

Sykdom og kritisk informasjon ?

SYKDOMSHISTORIKK KRITISK INFORMASJON

År	Sykdom	Kommentar	Handlinger
2018	Hjerte- og karsykdommer > Kolesterol - forhøyet	Går på medisiner etter anbefaling fra fastlege	Albyl-E foreskrevet av fastlege
2008	Luftveissykdommer > Astma	Faste medisiner Onbrez®	

SYKDOMSHISTORIKK KRITISK INFORMASJON

Overfølsomhetsreaksjoner (allergier m.m)

Legemiddelreaksjon – Furadantin Tab

Reaksjon	Blodtrykksfall
Alvorlighetsgrad	Alvorlig
Sannsynlighet	Sannsynlig
Kilde	Hentet fra tidligere journal
Tidspunkt for hendelse	05.03.2014
Sist oppdatert	27.04.2017
Oppdatert av	Ola Nordmann

Komplikasjoner ved anestesi (narkose og bedøvelse)

Ingen gjeldende

Kritiske medisinske tilstander

Ingen gjeldende

Pågående behandling og implantater

Ingen gjeldende

Endringer i behandlingsrutiner

Ingen gjeldende

Smitte

Ingen gjeldende