AHRQ Grant Final Progress Report

- **Title of Project:** A novel approach for supporting care coordination across distributed emergency care teams
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- **Inclusive Dates of Project:** 9/30/2021-09/29/2024 (with 1-year no cost extension)
- **Project Officer:** Dr. Roland Gamache
- **Grant Award Number:** 1R21HS028104-01A1

Report Components

Abstract

Purpose: This study aimed to design, develop, and evaluate a smart glass application for EMS providers and a web-based application for remote emergency care physicians to enhance prehospital care coordination.

Scope: In this study, our goal is to understand how to design smart glass applications and novel interaction mechanisms to improve prehospital care coordination while accounting for the limited capacity of emergency care teams to interact with handheld computing devices

Methods: Using a user-centered design approach, we conducted participatory design workshops, usability evaluations, and simulation-based assessments with 78 EMS providers and 33 emergency physicians across multiple hospital and EMS sites. We also conducted summative evaluation through simulations to assess the impact of smart glasses on prehospital care performance and communication effectiveness.

Results: The iterative design process identified key features for both the smart glasses used by EMS providers and the web-based telemedicine application used by remote physicians. Our study also uncovered socio-technical challenges in implementing smart glasses in emergency settings. The simulation-based summative evaluation demonstrated that smart glasses facilitated more frequent and in-depth discussions, increased task prompts, and improved task completeness during prehospital care.

Conclusions: Smart glasses enhance EMS communication and care coordination but require workflow integration strategies. Findings inform future adoption and policy considerations for hands-free telemedicine in prehospital settings.

Key Words: Smart glasses, emergency medical services, telemedicine, prehospital communication, user-centered design

I. Purpose

The goal of this project is to design, develop, and evaluate a smart glass application for emergency medical services (EMS) providers and a web-based application for remote emergency care physicians to improve prehospital care coordination. The study also aims to gain an in-depth understanding of the socio-technical challenges associated with implementing technology in the fast-paced prehospital care environment. There are two specific aims for this study: Aim 1) To design and develop technologies that support real-time prehospital care coordination. Aim 2) To evaluate the impact of technology solutions on prehospital care coordination.

II. Scope

Background

Care coordination is a critical component of safe, efficient, and patient-centered care delivery. Failures in coordinated care are one of the root causes of adverse events, such as delays in patient care, deviations from standard medical procedures, and missed opportunities for shared decision making, all yielding potential harm to patients. However, how to optimize coordination in emergency care has received little attention so far. Management of critically ill patients (e.g., trauma, myocardial infarction, and stroke) during ambulance transport requires fast care coordination and shared decision making between prehospital and hospital teams. That is, prehospital care providers in the field need to access expert knowledge and specialties from a more experienced physician at the receiving facility regarding a specific health issue or how to perform an advanced or even invasive medical procedure. Despite its critical role, care coordination and communication between prehospital and hospital teams remain ineffective and challenging. Current coordination mechanisms (e.g., radio and phone) are not optimal for information sharing and care coordination in prehospital encounters, often leading to confusion and miscommunication, and consequently, adversely affecting patient outcome. Technology solutions such as ambulance-based telemedicine systems have been developed to improve prehospital care coordination. These systems, however, have intrinsic limitations

which lead to a low adoption rate. One root cause is that emergency medical professionals need to keep their eyes and hands on their patient, leaving them with limited abilities to interact with handheld computing devices. Furthermore, the physical handling of computing devices increases the likelihood of cross-contamination and patient infections. Therefore, novel technologies (e.g., smart glass) and modes of interactions (e.g., voice command, hand gesturing, Augmented Reality) are needed for supporting prehospital care coordination. Smart glasses have high potential for serving as an unobtrusive technological conduit between prehospital and hospital care providers because they promise advantages such as hands-free operation and context-aware user interaction. In this study, our goal is to understand how to design smart glass applications and novel interaction mechanisms to improve prehospital care coordination while accounting for the limited capacity of emergency care teams to interact with handheld computing devices.

Setting

The studies were conducted in collaboration with Children's Hospital Colorado (Aurora, Colorado), Aurora Fire Rescue (Aurora, Colorado), Interfaith Medical Center (New York), Mount Sinai Hospital (New York), and Maimonides Medical Center (New York). The user-centered design studies (e.g., participatory design workshops and formative evaluations) were conducted in controlled settings (e.g., a private office) while the summative evaluations (e.g., simulations) were conducted in simulation centers.

Participants

Our participants included both EMS personnel and emergency care physicians. They were recruited from Children's Hospital Colorado (Aurora, Colorado), Aurora Fire Rescue (Aurora, Colorado), Interfaith Medical Center (New York), Mount Sinai Hospital (New York), and Maimonides Medical Center (New York). In total, 78 unique EMS providers and 33 unique emergency care physicians participated in this study. It is worth mentioning that eight of EMS providers and four of emergency care physicians (18.2%) attended two or more sessions. The recruited EMS providers held different roles (e.g., paramedic vs EMT) and had a wide range of experience (from <1 year to >40 years). More specifically, 20 (47%) participants were paramedics, while the rest (23/43, 53%) were EMTs; 13 (30%) were recruited from the rural area-based agency, with the rest (30/43, 70%) from the urban-based agencies. Similarly, emergency care physicians also had a wide range of experience, from 1 year to 30 years, and 11 of them (50%) had over 10 years of experience. The various characteristics of these medical sites (e.g., rural vs. metropolitan area, pediatric vs. adult

medical center, fire-based vs. hospital-based) helped improve the generalizability of this research.

III. Methods

Study Design

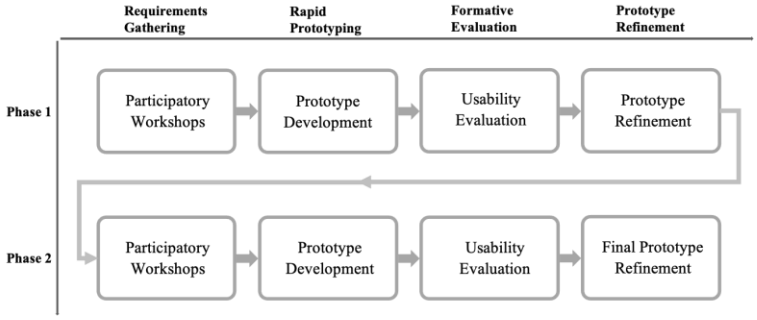

Figure 1: Study Design for Research Aim 1.

This study consists of two aims. The first aim (Aim 1) focused on designing and developing a technological coordinating mechanism to support prehospital care coordination while taking into consideration the workflow of emergency care professionals. In this aim, we used an iterative user-centered design approach, combining participatory design (PD) with usability evaluation. This research aim comprised 2 phases, each including design requirement gathering, rapid prototyping, usability evaluation, and prototype refinement (Figure 1). The second aim (Aim 2) focused on conducting simulations to assess the impact of the proposed technology solution on care coordination and teamwork efficiency during fast-paced prehospital care. In total, we conducted 16 simulations at two EMS agencies: 8 simulations were conducted with a fire-based agency in a mobile simulation lab that resembles the back of an ambulance, while the other 8 simulations were conducted with a hospital-based agency in a simulation lab within the affiliated hospital (Figure 2).

Figure 2: Conducted simulations for Research Aim 2.

Intervention

We designed and developed two interventions in this study. The first intervention is the smart glass application (Figure 3) designed for EMS providers. It was prototyped using the Vuzix M400 platform (Vuzix Corporation; Figure 4A). This application has five crucial system features, including 1) establishing video calls with OLMC physicians, 2) indicating call priority for expeditious OLMC contact, 3) enabling direct communication between EMS providers and receiving emergency department (ED)

providers, 4) sharing multimedia patient information with remote care teams, and 5)

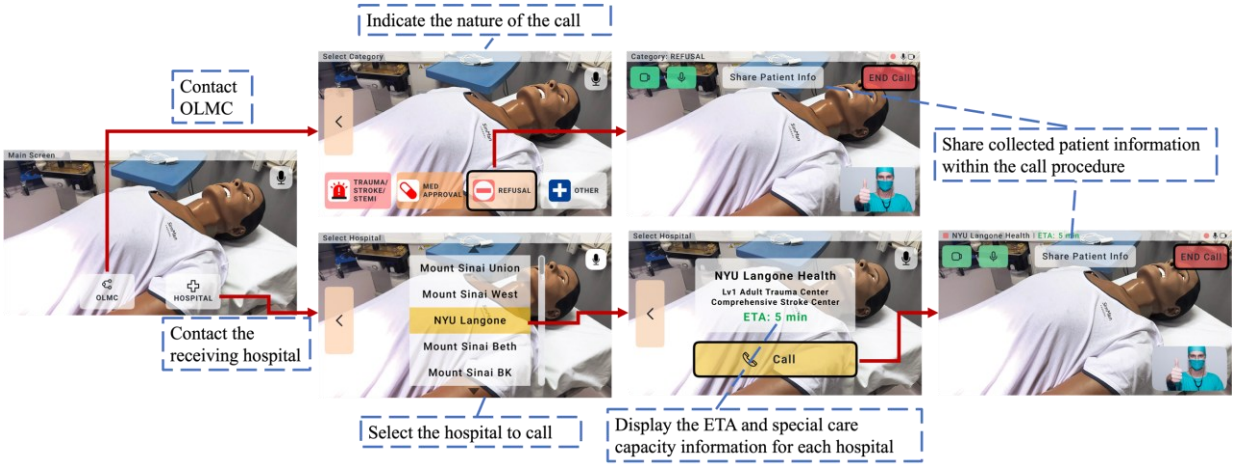

Figure 3: Smart glass application interface.

enabling touchless device operation.

The second intervention is a web-based application for the remote emergency care physicians (Figure 5). This application has four major features that were desired by remote emergency care providers (e.g., physicians) for addressing the challenges in pre-hospital communication, including video streaming of patient situation, receiving textual information from EMS providers, taking notes, and sending messages to EMS providers.

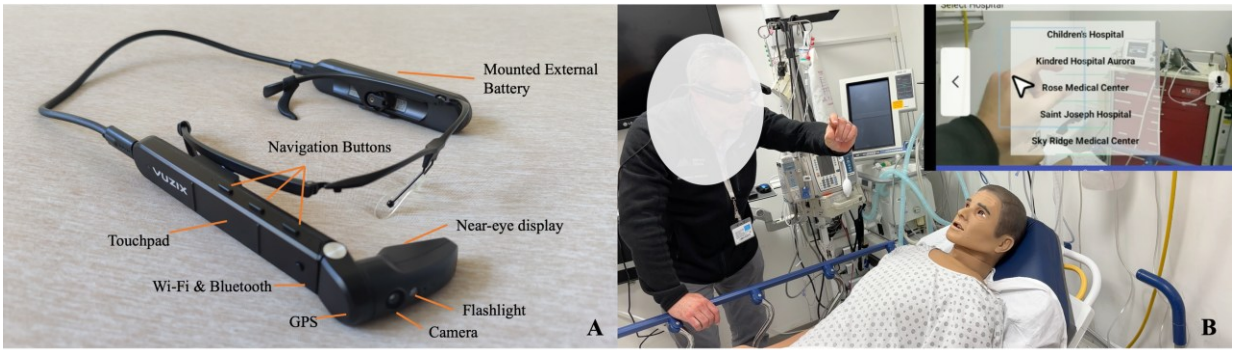

Figure 4: (A) The smart glass device (Vuzix M400) used in the study. (B) A study participant interacting with the application using hand gestures.

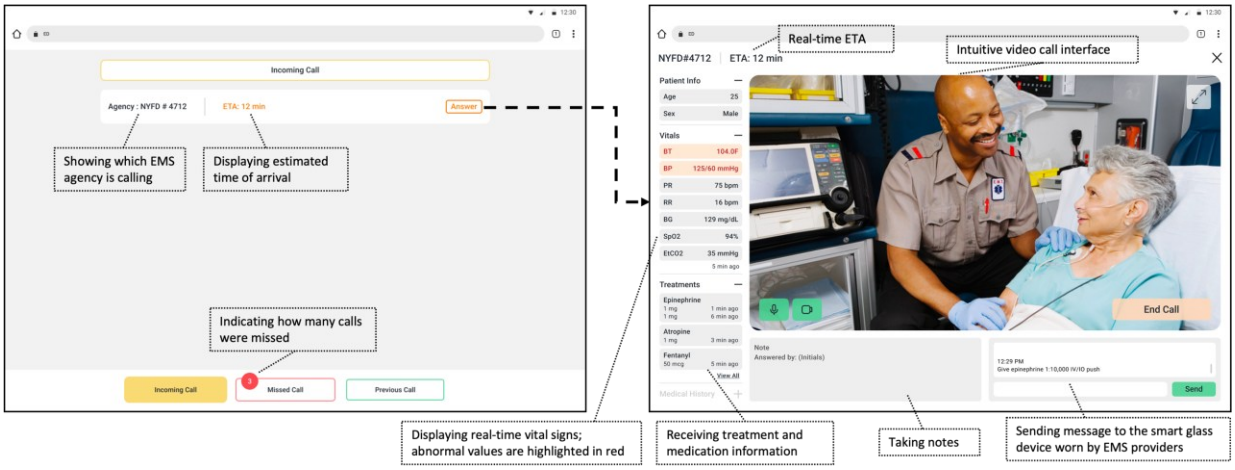

Figure 5: The web-based application for the remote emergency care physicians.

Measures/Data Collection/Analysis

Aim 1

In Aim 1, we conducted two phases of participatory design (PD) workshops, rapid prototyping, usability evaluation, and prototype refinement. Each workshop included 3-4 participants and lasted up to 2 hours. The general activities conducted in PD workshops included: (1) group discussions, where participants engaged in group discussions to share their requirements and suggestions for creating an integrated telemedicine system; (2) individual sketching, where each participant had the opportunity to either create different design concepts through paper sketching and explain their design rationale or critique an existing prototype created in a previous phase, (3) group-based design, where participants collectively refined and developed design concepts that everybody agreed upon, and (4) wrap-up discussion, where participants shared their insights regarding sociotechnical challenges in the effective adoption and use of the designed telemedicine system in their workflow.

In each phase, we also created prototypes by iteratively creating low-fidelity prototypes using paper and medium-fidelity prototypes using Figma (Figma Inc), based on the findings and user insights collected from preceding design or evaluation studies. Once the design (e.g., system features) was finalized, we implemented functional prototypes.

After we successfully developed a functional system prototype, we conducted individual usability evaluations in a controlled environment, such as an office or a simulation laboratory. The purpose of this activity was to both gather design requirements and evaluate the designs. In particular, we were interested in finding out whether the

application's designs and features could effectively address the needs of providers and current challenges in the prehospital communication process. At the beginning of each testing session, we provided training to the participants about system features and how to use the application. Once participants were confident enough to use the application independently, they were guided to complete various tasks corresponding to the major features of our application. We used both objective and subjective measures to evaluate the system's usability. Objective measures included task completion time, task success rate, and errors encountered. Subjective measures were administered through a survey, which consisted of a modified version of the System Usability Scale (SUS) and a section of Likert-scale questions for participants to rate the usefulness of different system features and interaction methods on a scale of 1 to 5 (1 representing not useful at all and 5 representing very useful), as well as a poststudy interview to elicit participants' perceived benefits and challenges associated with using the application in practice. Feedback and responses from participants informed the prioritization of design modifications and prototype refinements in subsequent steps.

To facilitate data analysis, all research activities were both audio-recorded and video-taped. Photographs of the created artifacts (e.g., design/drawings) were also be taken for the purposes of data analysis. All discussions were transcribed, iteratively coded and analyzed using descriptive, thematic analysis. All artifacts and design feedback collected throughout the design process (i.e., design sketches, photographs) were used to analyze the desired features and interaction modalities. Descriptive statistical approaches were used to analyze quantitative data (e.g., questionnaire, rating of interface design).

Aim 2

In Aim 2, we conducted 16 simulations. During each simulation, EMS providers were asked to perform two different medical scenarios back to back (a five-year-old pediatric patient with asthma and a five-year-old pediatric patient with anaphylaxis). We chose these two medical scenarios to minimize their impact on task performance because they had an equivalent level of complexity, and most EMS providers were expected to have the necessary knowledge to handle such cases. In each scenario, the EMS provider was instructed to contact OLMC via either radio/phone (control group) or the smart glasses application (treatment group) to discuss the patient's status and obtain medical approval for certain treatments and medications. For the control group, the EMS teams in the mountain region agency used a mobile phone for communication, as that is their commonly used method for contacting the OLMC physician, while the EMS teams in the east coast agency used a radio as their communication method. We randomized the order of scenarios and the communication technology used for each team to ensure that the

number of teams using smart glasses or radio/phone for each medical scenario was balanced.

Before each simulation session, the research team trained EMS providers to use the smart glass application and the OLMC physician to use the web-based application until they felt comfortable and confident using the system independently. During the simulation, EMS providers used the equipment and medications normally available to them to complete the two scenarios. They were also instructed to contact the OLMC physician for decision support and medical approval. After each simulation, both EMS providers and OLMC physicians first completed a survey with Likert-scale questions to assess the system's usability and their perceived usefulness of the integrated telemedicine system for communication. This was followed by a semi-structured interview to discuss any problems participants felt the system introduced, the hindrances it created, the support it provided, and its acceptability and potential for adoption.

We also used eye-tracking devices from Pupil Labs to track EMS providers' and OLMC physicians' visual attention while they were using their respective applications. We used the Neon model to track EMS providers' eye movement, as it can be mounted on wearable glasses, and the Pupil Core model for tracking OLMC physicians' visual attention, as this model is more suitable for desktop applications. The eye-tracking data helped us investigate the visual attention alignment of both EMS providers and OLMC physicians during communication via smart glasses.

Each simulation lasted about one hour and was both video- and audio-recorded. The communication process between EMS providers and OLMC physicians was also recorded (communications that occurred via radio/phone were only audio-recorded, while those that occurred via smart glasses were both video- and audio-recorded).

We employed both subject and objective evaluation methods. We measured the time to completion of a task, the success rate of each task (e.g., completion of a specific task within a defined time), and the communication length. We also asked 6 expert raters to assess care performance, and its impact on patient outcome. After each scenario, we administered brief surveys, containing both quantitative and qualitative questions, to assess two aspects: 1) perceptions of the system prototype and 2) the effects of using the system on providers' workload. The assessment of the former aspect allowed us to identify problems that participants felt the system introduced, the hindrances it created, the support it provided, and its acceptability and potential for adoption. Questionnaires were designed using Likert-type scales, including the following categories: 1) user's overall feelings about the usefulness of the system; 2) challenges in adopting the system; 3) the time and effort required for using the system; 4) the amount of attention the system

attracts away from user's primary task; 5) comparison with and improvement over current coordination mechanisms (e.g., radio); 6) user's reaction to and recovery from system breakdowns; and 7) timely feedback on errors. The evaluation of the latter aspect allowed us to assess whether the proposed system can significantly lower emergency care professionals' workload when coordinating with their counterparts. To do this, participants were asked to complete the NASA-TLX questionnaire, a subjective workload assessment tool that has been validated in experimental and real-world settings.

Limitations

This study has several limitations that should be considered when interpreting the findings. First, our simulations took place in controlled environments, which may not fully capture the complexities and unpredictability of real-world prehospital scenarios. Although we aimed to replicate typical EMS conditions, factors such as environmental noise, unpredictable patient reactions, and varying network connectivity could impact the actual use of smart glasses in field settings. Additionally, we relied on 5G network technology to support video streaming, but network availability may vary significantly across rural or remote areas, potentially affecting the performance of smart glasses in under-resourced settings.

IV. Results

Principal Findings & Outcomes

Our study has yielded several interesting and impactful findings, most of which have been reported in our publications (see the 'List of Publications'). In this report, we highlight three major findings: system requirements, socio-technical considerations, and the effectiveness and impact of smart glasses.

System Requirements:

We identified five crucial system features for the smart glass application used by EMS providers, including 1) establishing video calls with OLMC physicians, 2) indicating call priority for expeditious OLMC contact, 3) enabling direct communication between EMS providers and receiving emergency department (ED) providers, 4) sharing multimedia patient information with remote care teams, and 5) enabling touchless device operation. The design process for the smart glass application has been reported in our JMIR 2024 paper (please see reference [6]).

(1) Establishing video calls with OLMC physicians: Smart glasses could be invaluable for consulting with OLMC physicians through a video call, enabling physicians to see exactly what EMS providers see. This feature could significantly enhance physicians'

understanding of the patient's condition and needs, leading to more informed decision-making.

(2) Indicating call priority for expeditious OLMC contact: Given the persistent issue of lengthy waiting times to connect with OLMC physicians, we designed a feature that allows EMS providers to indicate the urgency of the call.

(3) Enabling direct communication between EMS providers and receiving emergency department (ED) providers: Through our research, it became evident that smart glasses can act as a valuable tool to facilitate direct communication between EMS and ED providers via video calls. EMS providers can conveniently select a hospital from a list organized by proximity to the current location of the EMS team. Using embedded GPS, the smart glasses can automatically calculate and display the ETA to the chosen hospital.

(4) Sharing multimedia patient information with remote care teams: Our participants emphasized the importance of sharing pivotal, textual, and visual patient information (e.g., vital signs and photos) with remote care teams to facilitate their conversations. Therefore, we designed a feature that allows EMS providers to share patient information after the call is established.

(5) Enabling touchless device operation: Given the nature of EMS work, which often requires the use of hands and entails a risk of cross contamination, participants expressed a strong preference for touchless interaction methods to operate the smart glass device over using the default tangible buttons. We integrated both voice commands and hand gestures into our system prototype. More specifically, we used the Vuzix Software Development Kit to program a set of simple voice commands corresponding to text labels on the virtual buttons. To implement the hand gesture–based interactions, we used third-party gesture-sensing software (CrunchFish). This interaction method allows users to perform a pinch gesture by tapping their thumb and index finger together to choose an option on the interface (Figure 4B).

We also identified four major features that were desired by remote emergency care providers (e.g., physicians) for addressing the challenges in pre-hospital communication, including video streaming of patient situation, receiving textual information from EMS providers, taking notes, and sending messages to EMS providers. The design process for the physician telemedicine application has been reported in our AMIA 2024 paper (please see reference [7]).

(1) Video streaming of patient situation: Physicians recognized the great potential of video communication for enhancing pre-hospital communication, especially in critical cases such as those involving pediatric patients where EMS providers might lack familiarity, or in

instances related to trauma, stroke, and respiratory distress where less experienced EMS providers might not have the required expertise. The home screen displays different types of calls—incoming, missed, and completed calls—allowing physicians to easily track both completed and missed EMS calls. Additionally, the system displays which EMS agency is calling as knowing such information sometimes provides insights into the nature of the call. We adopted an intuitive interface similar to those of prevalent video conferencing software (e.g., Zoom). The interface design included only three buttons to control the video and audio functions and to end the call.

(2) Receiving textual information from EMS providers: Physicians mentioned that receiving key patient data in text format from EMS providers could address miscommunication issues, which were often caused by communication delays, noisy background, and potential human errors in articulation and comprehension. Through two phases of design and evaluation, we identified several critical information physicians would like to receive in text format, including real-time vital signs, medication administration, estimated time of arrival (ETA), and basic demographics (e.g., age).

(3) Taking notes: Physicians mentioned that they would use a paper sheet to document brief information shared by EMS providers during the call. Therefore, we included a freeform text field for note-taking, which allows physicians to document efficiently, keeping pace with the conversation with EMS providers.

(4) Sending messages to EMS providers: Prehospital is a noisy environment, which may hinder effective and accurate communication between EMS providers and remote physicians. To prevent potential misunderstandings, the text-based chat channel could be used to convey precise medical guidance (e.g., medication name and dosage) to EMS providers. This information can be displayed on the platform used by EMS providers (e.g., smart glasses) so that EMS providers can visually see the medical guidance. Considering that smart glasses have a limited display size, to ensure that messages are easy to read and do not overwhelm EMS providers, we limited the number of characters in messages to 30.

Socio-Technical Considerations for Adopting Smart Glasses in EMS Care:

In addition to the design requirements, we also gained an in-depth understanding of socio-technical considerations about adopting the smart glass application. More details about these findings can be found in our JAMIA Open paper (please see the reference [2]). In summary, smart glasses were recognized as a useful tool to improve EMS workflow given their hands-free nature and capability of processing and capturing various patient data. Out of the eight dimensions of Sittig and Singh's sociotechnical framework, we found that

hardware and software, human-computer interface, workflow, and external rules and regulations were cited as the major factors that could influence the adoption of this novel technology. Users highlighted several requirements that are necessary for ensuring successful implementation in the EMS context, such as durable devices, steady network connectivity, minimal interface design, seamless integration with workflow, and secure data management.

Effectiveness and Impacts of Smart Glasses:

Through simulations, we assessed the impact of the integrated telemedicine system consisting of smart glasses on communication and care performance during prehospital care.

We found that smart glasses could significantly mitigate communication breakdowns, and enhance communication and situational awareness between EMS providers and remote physicians by enabling hands-free, first-person video streaming, allowing for more in-depth, multi-model (video, audio, implicit visual cues, and gesture) discussions on patient care. However, challenges like visual alignment issues, extended communication duration, privacy concerns, and reliance on high-speed networks highlight the need for careful integration of smart glasses into prehospital workflows.

Regarding the impact on care performance, we observed that smart glasses enabled remote physicians to prompt EMS providers more frequently during critical procedures compared to radios. Specifically, the average number of physician prompts per session was 2.6 with smart glasses, compared to 1.8 with radio or phone communication. Additionally, smart glasses achieved a significantly higher completeness rate (96%) compared to radio (90.48%) ($p < 0.05$). These results indicated that smart glasses could enhance EMS providers' patient care performance.

Discussions

To the best of our knowledge, this study represents the first of its kind that uses a user-centered design approach to explore the appropriate design of smart glasses in facilitating communication and care coordination between prehospital and remote care providers. Our approach is deeply rooted in participatory design, which promises to create user-friendly clinical systems and thoroughly addresses user needs. Our iterative design approach is beneficial, as it can effectively identify and address various user needs and ensure that providers with different roles and occupations can equally voice their needs and concerns.

The co-design process with end-users (e.g., EMS providers and emergency care physicians) helped us identify key features deemed necessary to enhance prehospital communication.

In addition to video calls, which are evidently the most critical and useful feature of any telemedicine system, EMS providers emphasized that the smart glass should have (1) a video call functionality to contact OLMC physicians, allowing them to convey contextual patient information; (2) an option to indicate the call severity and priority to expedite the connection with OLMC physicians; (3) a direct video-based communication link with the ED team at the receiving hospital, supplemented with essential information such as ETA and the hospital's special care capabilities, facilitating effective communication and aiding in patient destination decision-making; (4) an option to share critical, multimedia patient information (e.g., photos, demographics, treatments, and vital signs) with remote care teams, augmenting the video call and providing comprehensive details for more informed medical decisions; and (5) integration of touchless interaction methods, enabling hands-free operation and reducing the likelihood of cross contamination, a crucial aspect given the nature of EMS work. On the other hand, emergency care providers expressed interest in the ability to take notes, receive textual information, and send messages to EMS providers, among other functionalities for the web-based telemedicine application designed for them.

Designing and implementing telemedicine systems for the prehospital setting is a complex and challenging socio-technical endeavor. It involves not only collaborating with end-users and domain experts to iteratively design and create a user-friendly system that aligns with the fast-paced prehospital workflows and meets care providers' needs, but also adhering to internal and external policies and regulations that address critical issues such as data security, HIPAA compliance, privacy, and standardization. There are certainly other factors, such as cost, technical support, and maintenance, which we did not explore extensively in our study, that are also critical for the adoption of telemedicine technology.

Regarding the effectiveness of smart glasses, our study demonstrates that they facilitated more frequent and in-depth discussions, enabled more task prompts, and improved task completeness. These benefits are significant, as they have the potential to enhance prehospital care substantially. For example, with smart glasses, remote physicians could visually observe the preparation and administration of medications and other treatments, providing real-time feedback on positioning and adjustments, such as syringe alignment or the designated treatment area on the patient's body. This capability fostered more in-depth discussions around these tasks. In contrast, with radio or phone communication, remote physicians could not observe medication preparation or administration, limiting the depth of discussion on this topic.

However, these benefits come at a cost. While smart glass-based communication took a comparable amount of time to phone-based communication, the ability to visually observe the patient and task performance (e.g., medication administration) often led remote

physicians to remain on the call longer. One possible explanation is that remote physicians wanted to ensure that the approved treatments were performed correctly and to observe the patient's response to the treatment plan. On one hand, this new paradigm of care coordination enabled by smart glasses can enhance shared understanding and facilitate more in-depth discussions. On the other hand, it may also extend communication times, potentially impacting current workflows. For instance, EMS providers may have limited time for extended discussions, and remote physicians' availability could be constrained, leading to delays in responding to other EMS calls. These findings highlight the need for additional training or the establishment of protocols for video-based telecommunication, clarifying when a call should be concluded (e.g., after providing medical approval or guidance, rather than remaining on the call to observe treatment execution)

Significance

This research is significant because it is an essential early step toward developing novel "hands-free" technologies that can be seamlessly integrated into hands- and eyes-busy medical contexts, and in turn, decreasing the workload of care professionals in coordinating patient care across geographical boundaries, and improving care coordination in prehospital and other critical care settings (e.g., tele-surgery, telemedicine triage, etc.).

Conclusions

Rooted in user-centered design, the study has yielded invaluable insights into leveraging smart glasses for enhancing communication and care coordination in the dynamic prehospital environment. Our study highlighted that our smart glass application created for EMS providers and the web-based application developed for remote physicians could facilitate more frequent and in-depth discussions, enable more task prompts, and improve task completeness, having the potential to enhance prehospital care substantially. The findings and lessons learned from our study are poised to guide future work on the implementation and integration of smart glasses into prehospital care.

V. List of Publications and Products

We have published seven articles in top health informatics venues. In addition, we have three papers under review or in preparation.

Published Articles

[1] Zhang, Z., Joy, K., Harris, R., Ozkaynak, M., Adelgais, K., & Munjal, K. (2022). Applications and user perceptions of smart glasses in emergency medical services: semistructured interview study. JMIR Human Factors, 9(1), e30883.

[2] Zhang, Z., Ramiya Ramesh Babu, N. A., Adelgais, K., & Ozkaynak, M. (2022). Designing and implementing smart glass technology for emergency medical services: a sociotechnical perspective. JAMIA open, 5(4), ooac113.

[3] Zhang, Z., Bai, E., Joy, K., Ghelaa, P. N., Adelgais, K., & Ozkaynak, M. (2023). Smart glasses for supporting distributed care work: systematic review. *JMIR Medical Informatics*, *11*(1), e44161.

[4] Zhang, Z., Bai, E., Stepanian, A., Jagannath, S., & Park, S. Y. (2024). Touchless interaction for smart glasses in emergency medical services: user needs and experiences. *International Journal of Human–Computer Interaction*, 1-20.

[5] Zhang, Z., Joy, K., Bhadani, A. S., Joshi, T. D., Adelgais, K., & Ozkaynak, M. (2024, January). Information seeking and sensemaking in Emergency Medical Service through simulation video review. In *AMIA Annual Symposium Proceedings (Vol. 2023, p. 804)*.

[6] Zhang, Z., Bai, E., Xu, Y., Stepanian, A., Kutzin, J. M., Adelgais, K., & Ozkaynak, M. (2024). A smart glass telemedicine application for prehospital communication: User-centered design study. *Journal of Medical Internet Research*, *26*, e53157.

[7] Bai, E.Z., Zhang, Z., Xu, N., Ozkaynak, M., and Adelgais, K. (2024). User-centered design of an Emergency Department telemedicine application for prehospital communication. In *Proceedings of the American Medical Informatics Association Annual Symposium (AMIA'24)*.

Under Review/In Preparation

[8] Zhang, Z., Bai, E., Xu, Y., Ozkaynak, M. and Adelgais, K. Can you see what I see? Examining the impact of smart glasses on communication dynamics in distributed emergency medical teams. Under Review by ACM Computer Supported Collaborative Work and Social Computing (CSCW 2025).

[9] Zhang, Z., Bai, E., Xu, Y., Kutzin, J. M., Ozkaynak, M. and Adelgais, K. The impact of smart glasses on care performance in prehospital settings.

[10] Zhang, Z., Bai, E., Xu, Y., Ozkaynak, M. and Adelgais, K. User perceptions of smart glasses for prehospital communication: Insights from EMS providers and remote physicians.