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Bridging the prehospital communication gap: evaluating a smart glass-enabled telemedicine system

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Abstract

Introduction. Accurate and timely communication between emergency medical services (EMS) providers and remote physicians is vital for high-quality prehospital care, yet traditional phone or radio systems often fail to convey sufficient contextual information. Smart glasses offer a promising alternative by enabling real-time, first-person video and data sharing. This study evaluates a smart glass-based telemedicine system to understand how it is used in practice and perceived by emergency care providers.

Method. We conducted 16 near-realistic simulation-based evaluations involving EMS providers and emergency physicians. We analysed the system usage and user experience through multiple approaches, including video analysis, eye-tracking, interviews, and surveys.

Results. The smart glass-based telemedicine system was positively received by EMS and physician participants, who praised its effectiveness in enhancing communication and its ease of use. However, observations of actual usage—such as longer physician connection times and interaction challenges with the device—along with broader sociotechnical issues including infrastructure readiness, workflow integration, and ergonomic concerns, highlight the need for more thoughtful design to support successful adoption and deployment at scale.

Conclusion. Smart glasses hold significant promise for augmenting prehospital communication, but successful adoption will require careful integration into EMS workflows, ergonomic design refinements, and resilient technical infrastructure.

Introduction

Effective communication and coordination among distributed medical teams are critical for delivering safe, timely, and patient-centered care (McDonald et al., 2010). Communication breakdowns or delays are frequently cited as leading contributors to medical errors and adverse events (Katz et al., 2012; Schultz et al., 2013). These challenges are especially evident in time-sensitive medical settings, where providers operate under immense pressure and cognitive load, making communication even more difficult (Zhang et al., 2021). Prehospital care exemplifies such a setting. Emergency medical services (EMS) providers—including paramedics and emergency medical technicians (EMTs)—must often relay vital patient information to remote online medical control (OLMC) physicians for clinical guidance or to emergency department (ED) physicians and nurses to prepare for patient arrival (Ayub et al., 2017). This process, known as prehospital communication, is consistently reported in prior literature as being fraught with inefficiencies and misunderstandings (Reddy et al., 2009; Zhang et al., 2017). A key limitation lies in the continued reliance on traditional communication technologies such as radios and phones, which support only audio-based exchanges (Rowlands, 2003). These modalities inherently restrict the transmission of nuanced and contextual patient information—factors essential for informed medical decision-making—resulting in lengthy verbal report of EMS providers and misunderstanding of the real situation by remote care teams (English et al., 2022; Zhang et al., 2017).

Recognizing these immense challenges, ambulance-based telemedicine solutions have been developed to improve the prehospital communication process by enabling the transmission of vital signs and real-time video from EMS teams to remote care providers. These technologies have shown potential to support more informed decision-making and enhance care coordination (Yperzeele et al., 2014; Zhang et al., 2020). However, despite their promise, the adoption of such systems remains limited—primarily due to challenges related to portability, workflow compatibility, and usability in dynamic prehospital settings.

To better align with the hands-busy and mobile nature of EMS work, recent developments in smart glasses have begun to gain traction. These devices are lightweight head-worn displays equipped with a see-through screen and a video camera that can transmit first-person, point-of-view footage to a remote viewer. They can be operated hands-free, i.e., through voice control, minimizing their intrusiveness in hands-busy clinical environments (Zhang et al., 2025a). Additionally, smart glasses are often powered by augmented reality (AR) technologies to enable overlaying text, images, and annotations onto the wearer's field of view to guide the execution of clinical tasks. Given these advantages, smart glasses have increasingly been explored as a promising solution to facilitate prehospital communication (Broach et al., 2018; Cicero et al., 2015; Follmann et al., 2019; Schlosser et al., 2024). However, despite this growing body of work, existing research has often overlooked the user experience and how these systems are actually used (Grundgeiger et al., 2021).

To bridge these critical research gaps, our study investigates the holistic user experience of an integrated smart glass-assisted telemedicine system through near-real-life simulations, capturing both EMS providers' and physicians' perspectives after they used such a system. In particular, we analysed the system usage and user experience through multiple approaches, including video analysis, eye-tracking, interviews, and surveys. Our work makes the following contributions: 1) An empirical understanding of how a smart glass-based telemedicine system is used and experienced by EMS providers and physicians. 2) Design implications to support the use of smart glass in dynamic, time-critical medical settings.

Related work

Due to the limitations of voice-only communication mechanisms (e.g., radios, phones), researchers have explored technologies such as ambulance-based telemedicine systems to enable real-time video and data transmission during prehospital communication (Mitra et al., 2023; Sharifi Kia et al., 2023). While technically feasible and clinically beneficial, these systems face adoption barriers. Their bulky, vehicle-fixed hardware and reliance on manual input hinder use outside ambulances, where a significant portion of patient care typically occurs (Bergrath et al., 2011; Cho et al., 2015; Rogers et al., 2017). Moreover, the need for providers to keep their hands and eyes on the patient made interacting with laptops impractical in practice.

In recent years, researchers have advocated for portable, hands-free solutions to improve prehospital communication (Schlosser et al., 2021; Zhang et al., 2022). Smart glasses have emerged as a promising option due to their ability to stream first-person video and overlay information (e.g., text, images, annotations) onto the wearer's field of view, while enabling hands-free operation via gestures or voice commands (Dinh et al., 2023a; Dinh et al., 2023b; Zhang et al., 2023). These features have spurred growing interest in their use during emergency response. Studies have demonstrated the technical feasibility and effectiveness of smart glasses in supporting EMS patient care (Apiratwarakul et al., 2023; Apiratwarakul et al., 2025a; Apiratwarakul et al., 2022; Apiratwarakul et al., 2025b; Broach et al., 2018; Cicero et al., 2015; Drummond et al., 2017; Follmann et al., 2019). Reported benefits include improved diagnostic confidence for remote physicians and enhanced care performance (Broach et al., 2018; Demir et al., 2017; Noorian et al., 2019). A few studies have also examined smart glasses' role in communication and teamwork, showing benefits such as improved situational awareness and status visibility in search-and-rescue teams (Alharthi et al., 2018; Reuter et al., 2019), reduced need for verbal updates (Schlosser et al., 2024) and richer patient-focused discussion during prehospital care (Zhang et al., 2025b). Despite this growing body of work, existing research has often overlooked the user experience and how these systems are actually used in practice (Grundgeiger et al., 2021). Our study aims to bridge this gap.

Methodology

Study background

This study is part of a larger project to improve prehospital communication through an integrated telemedicine system, which includes two major components: (1) a smart glass application for EMS providers, capable of hands-free interaction (e.g., via voice commands or hand gestures), live video streaming, information overlays, and data sharing (Figure 1, Left); and (2) a web-based interface for physicians to view live video and information, take notes, and send text messages to EMS providers (Figure 1, Right). Both applications were iteratively designed using a user-centered, participatory approach (Bai et al., 2024; Zhang et al., 2024).

Study procedure and data collection

We conducted a total of 16 simulation studies across two EMS agencies in the United States: one fire-based agency located in a rural mountainous region, and another hospital-based agency in an urban area on the east coast. Each site hosted eight simulations. The simulations in the mountain region were conducted in an ambulance, while those in the urban area took place in a simulation lab. Of the 16 teams, 15 successfully completed the simulation; one team was unable to do so due to an overheated environment in the ambulance. A total of 35 unique EMS providers participated, including 25 paramedics and 10 EMTs. Their experience levels ranged from 2 months to over 30 years. In addition, 11 emergency physicians were involved in the simulations, two of whom had more than 10 years of clinical experience.

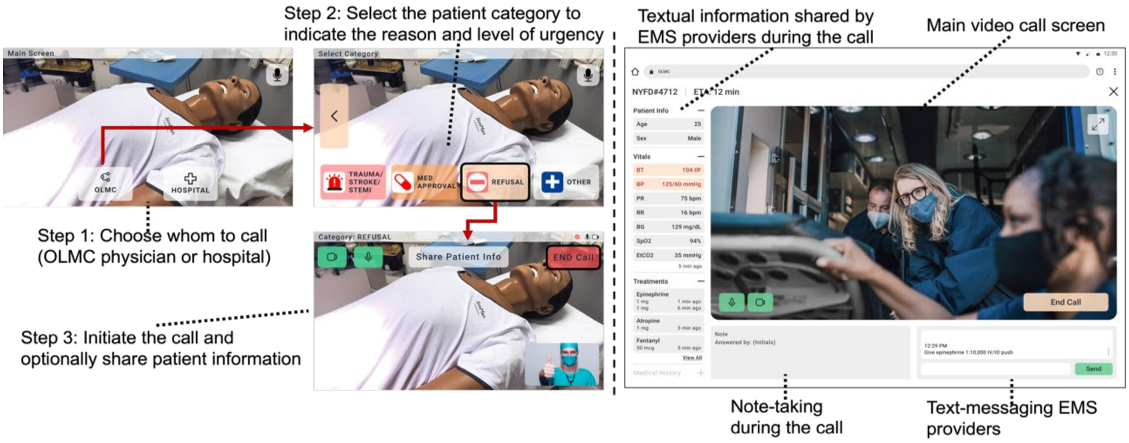

Figure 1. Left: The smart glass application used by EMS providers to contact OLMC physicians for medical guidance or the receiving hospital for patient arrival notification. Right: The web-based application used by remote physicians to connect with EMS providers.

Prior to the simulations, all participants were introduced to the system (Figure 2, Left) and trained to use it (e.g., using hand gestures to interact with the smart glass application (Figure 2, Right)). During the simulation, EMS providers were instructed to follow their typical workflow and use the smart glass application when seeking medical guidance or medication approval. Immediately following each simulation, participants completed a series of surveys composed of Likert-scale questions. These included the system usability scale (SUS) to assess overall usability (Brooke, 1996), the unified theory of acceptance and use of technology (UTAUT) to evaluate technology acceptance (Venkatesh et al., 2003), and a set of questions to assess the perceived usefulness of the designed system features. Additionally, EMS providers completed the NASA Task Load Index (NASA-TLX) to evaluate perceived workload associated with using smart glasses (Hart & Staveland, 1988). All surveys used a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree). After completing the surveys, participants engaged in semi-structured interviews designed to explore their general experiences. All simulations were video-recorded, and the interviews were audio-recorded.

Additionally, eye trackers were used to capture visual attention and system use. EMS providers wore Neon eye-trackers mounted on the smart glass frame, while physicians used Core eye-trackers mounted on the laptop; both devices were manufactured by Pupil Labs (Berlin, Germany). We used these data to quantify gaze time across interface elements and characterize interaction patterns.

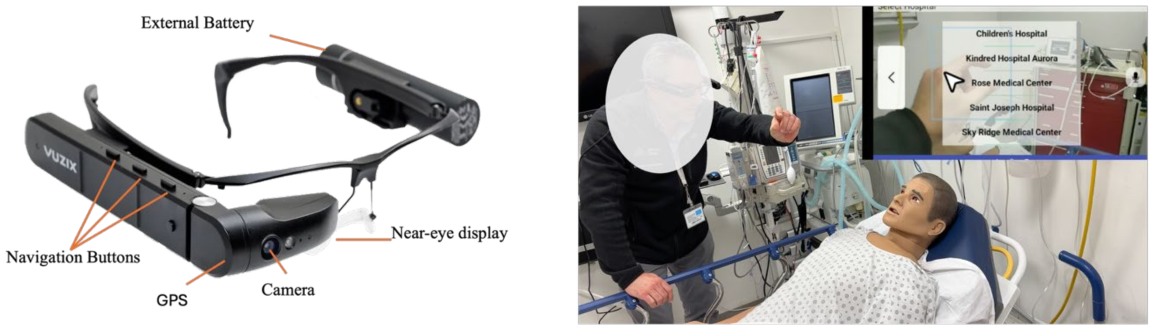

Figure 2. Left: The smart glass device (Vuzix M400) used in the project. Right: An illustration of interacting with the smart glass application using hand gestures.

Data analysis

We reviewed all video recordings and eye-tracking data collected during the simulations to analyze real-world user behavior and system usage patterns. Specifically, we examined: (1) where users looked and for how long, (2) what communication or interaction breakdowns occurred during teleconsultation, and (3) which interaction methods were used with the smart glasses (e.g., voice commands, gestures, or physical buttons).

Survey responses were compiled using Excel. We then calculated average scores for each item and survey construct (e.g., SUS). We also grouped the participants by agency type (urban vs. rural) and experience level (less than 1 year vs. more than 1 year). To assess whether there were statistically significant differences in perceptions between these groups, we conducted Mann-Whitney U tests.

We also conducted a qualitative thematic analysis of the interview transcripts using an abductive approach, which integrates both inductive and deductive coding (Vila-Henninger et al., 2024). The analysis focused on user experiences, perceived benefits and challenges, and sociotechnical factors influencing system adoption. Initially, two researchers independently coded a small subset of transcripts to generate an initial list of codes, which were then refined and consolidated into a preliminary codebook. This codebook served as a deductive framework to guide the analysis of the remaining transcripts, while we simultaneously allowed for the inductive emergence of new codes as they appeared in the data. Finally, all codes were grouped into overarching themes. Quotes included in the paper are labelled as 'EMS#' for EMS providers and 'P#' for physicians.

Results

Observations of system use in simulations

Smart glass usage patterns among EMS providers

We analysed the time EMS providers took to use the smart glass application to establish a call. The results showed substantial variation (M = 25 seconds, SD = 13.5 seconds; range = 14-65 seconds), indicating differences in how quickly providers adapted to the new technology, despite receiving the same amount of prior training.

To better understand these differences, we examined the issues and breakdowns encountered during use. As illustrated in Table 1, common challenges included difficulties with interaction methods—for example, providers either forgot or failed to perform hand gestures correctly (n = 7), pressed the wrong physical button (n = 2), or used an incorrect voice command (n = 2). Other issues involved confusion with the interface (n = 3), or technical glitches like device overheating or network disconnection (n = 2). Most breakdowns appeared to stem from limited familiarity with the system. Nevertheless, these errors were typically resolved quickly—specifically, all breakdowns except for technical glitches were resolved in under 6 seconds.

Observed Breakdown or Issue	Number of Occurrence	Average Recovery Time
Participant forgot correct voice command	2	0.5
Hand gesture was not successfully performed	7	3.6
User pressed a wrong button	2	5.0
User was confused about the interface	3	6.3
Technical glitches	2	22.5

Table 1. Types of observed interaction breakdowns during smart glass use, their frequency, and average time required for recovery from breakdowns (seconds).

We also examined the interaction methods used by providers when operating the smart glass device—voice commands, hand gestures, and physical buttons—to understand which methods were preferred and most likely to be used in practice (Table 2). Among the 15 teams who successfully completed the simulations, 8 used a single interaction method throughout, while 7 used a combination of two methods. Hand gestures were the most commonly attempted initial method, used by 10 out of 15 providers on their first attempt. However, 4 providers experienced issues such as the system failing to recognize their hand posture, prompting them to switch to physical buttons (n = 3) or voice commands (n = 1). Additionally, three providers began with buttons—one of whom later switched to voice commands—while two providers started with voice commands, and one of them later used hand gestures.

Finally, the average duration of teleconsultation (from call initiation to call termination) was 5 minutes and 15 seconds (range = 3 to 8 minutes). We also analyzed eye-tracking data to assess EMS providers' visual attention during the teleconsultation. Notably, participants frequently focused on the remote physician's video feed, with an average gaze time of 46.5 seconds (range = 2 seconds - 3 minutes; SD = 44 seconds).

First-Chosen Interaction Method	Sessions Using It	Failures	Switched To
Hand Gestures	10	4	Buttons (n=3), Voice Commands (n=1)
Voice Commands	2	1	Hand Gestures
Physical Buttons	3	1	Voice Commands

Table 2. Initial interaction methods selected by EMS providers, number of sessions using each method, observed failures, and alternative methods adopted.

Web application usage patterns among remote physicians

Our analysis of eye-tracking data revealed that physicians extensively engaged with the web application to view patient video streams and access textual data shared by EMS providers, including basic demographic information, vital signs, and administered treatments. On average, physicians spent 5 minutes and 7 seconds viewing the full interface, with 4 minutes and 37 seconds focused specifically on the video stream.

Demographic information was consistently shared with physicians in all sessions. Vital signs data were available in 13 sessions, but 6 physicians did not directly reference the shared information. Of those, 4 relied on viewing the vital signs monitor through the video feed, while 2 explicitly asked the EMS provider for the data. Treatment data were available in 12 sessions, but 5 physicians did not refer to them, even when accessible.

Three physicians used the note-taking feature to record treatment plans, dosages, and patient conditions—typically during conversations in which EMS providers were reporting information; but one participant took notes at the end of the simulation. Additionally, two physicians sent text messages to be displayed on the smart glass screen, primarily to confirm medication dosages that had been discussed and approved for administration.

User experiences

User experience of smart glasses

Overall Perception and Acceptance of the Smart Glass Technology. The overall average SUS score across all EMS providers was 73.2, which is considered above average usability (Table 3). While the difference was not statistically significant, providers from the urban agency reported slightly higher usability (M = 77.2, range = 52.5–100) compared to those from the rural agency (M = 68.6, range = 37.5–90). Years of experience did not significantly influence SUS scores, though providers with more than 10 years of experience tended to rate the system slightly lower (M = 72.7). More specifically, most participants reported that the system was straightforward to use (Q3: 4.3) and well-integrated (Q5: 4.0), with low levels of perceived complexity (Q2: 1.7) and awkwardness (Q8: 2.3). In terms of learnability, participants reported moderate confidence in using the system (Q9: 3.8) and believed that most users could learn it quickly (Q7: 4.1); they also indicated that minimal prior knowledge was needed (Q10: 2.1) and that reliance on technical support would be low (Q4:

2.3). However, participants' enthusiasm for frequent use was modest (Q1: 3.5), and this larger-than-most shortfall from the ideal is clearly visible in the radar chart (Figure 3A).

For the UTAUT questionnaire (Table 3), participants indicated that the application required little mental effort (Q2: 4.0) and that they could quickly become accustomed to using it (Q6: 4.0). Participants also reported high hedonic motivation, enjoying the experience of using the application (Q4: 4.1), and showed strong behavioral intention, expressing satisfaction with the trial (Q10: 4.2) and willingness to advocate for the application's use (Q9: 3.8). EMS providers gave moderately positive ratings for the system's value and reliability: they generally agreed that it improved communication efficiency (Q1: 3.8) and that benefits outweighed costs (Q5: 3.7), with only moderate trust in performance (Q8: 3.8) but relatively low concern about negative consequences (Q7: 2.5). However, facilitating conditions were weaker, with infrastructure readiness rated lowest (Q3: 3.3) and showing one of the largest gaps from the ideal in the radar chart (Figure 3B). Finally, no significant differences were observed in any construct between urban and rural providers, or between more experienced and less experienced providers.

As shown in Table 3, the workload assessments based on NASA-TLX scores indicated low cognitive demand (M = 2.0, SD = 1.29; Mdn = 1.0, IQR = 1.0–3.0), physical demand (M = 1.3, SD = 0.49; Mdn = 1.0, IQR = 1.0–1.5), and temporal demand (M = 1.4, SD = 0.79; Mdn = 1.0, IQR = 1.0–1.5), as well as low effort (M = 1.9, SD = 1.07; Mdn = 2.0, IQR = 1.0–2.0) and minimal feelings of discouragement, irritation, stress, or annoyance while using smart glasses (M= 1.6, SD=0.79; Mdn = 1.0, IQR = 1.0–2.0). Participants also rated their performance highly (M = 4.3, SD = 0.76; Mdn = 4.0, IQR = 4.0–5.0), suggesting that the system supported efficient task completion without introducing significant workload. These patterns are also visible in the radar chart (Figure 3C). Finally, no significant differences were observed between urban and rural providers, or between more experienced and less experienced providers.

Questionnaire	Average
System usability scale (SUS)	
Q1: I think that I would like to use this system frequently.	3.5
Q2: I found the system unnecessarily complex.	1.7
Q3: I thought the system was easy to use.	4.3
Q4: I think that I would need the support of a technical person to be able to use this system.	2.3
Q5: I found the functions in this system well-integrated.	4.0
Q6: I thought there was too much inconsistency in this system.	2.1
Q7: I would imagine that most people would learn to use the system very quickly.	4.1
Q8: I found the system very awkward to use.	2.3
Q9: I felt very confident using the system.	3.8
Q10: I needed to learn a lot of things before I could get going with this system.	2.1
Total Score	73.2
Unified theory of acceptance and use of technology (UTAUT)	
Q1: Using the smart glass app enhanced my ability to communicate with physicians efficiently.	3.8
Q2: Using the smart glass app required little mental effort.	4.0
Q3: I think the infrastructure will be readily available (e.g., network, technical support) to use the smart glass app.	3.3
Q4: I enjoyed using the smart glasses app during the testing.	4.1
Q5: I believe that the benefits of using the smart glass app would outweigh their costs and other issues.	3.7
Q6: I can see myself quickly getting used to using the smart glass app, based on my testing experience.	4.0
Q7: I worried about the negative consequences of using the smart glass app.	2.5
Q8: I trust that the smart glass app would perform as expected, based on my testing experience.	3.8
Q9: If I had the chance, I would advocate for using smart glasses based on my testing experience.	3.8
Q10: Overall, I am satisfied with my trial experience of using the smart glass app.	4.2
NASA task load index (NASA-TLX)	
Q1: How mentally demanding was the task (using smart glasses to establish a call)?	2.0
Q2: How physically demanding was the task?	1.3
Q3: How hurried or rushed was the pace of talking to the remote physician using smart glasses?	1.4
Q4: How successful were you in accomplishing the task?	4.3
Q5: How hard did you have to work to accomplish the task?	1.9
Q6: How discouraged, irritated, stressed, or annoyed were you during the use of the smart glass application?	1.6
Feature & design	
Q1: The ‘Choose Call Category’ step (e.g., ‘Trauma/Stroke/STEMI’, ‘Med Approval’, ‘Refusal’) is necessary and useful.	4.3
Q2: It is easy to figure out which call category to choose.	4.3
Q3: The ‘Video Call’ feature is useful.	4.3
Q4: It is easy to use ‘Video Call’ feature to communicate with physicians.	4.4
Q5: It is easy to use hand gestures to navigate this application.	3.6
Q6: It is easy to use voice commands to navigate this application.	4.2
Q7: It is easy to use tangible buttons (hard buttons on the side of the glass) to navigate this application.	3.8
Q8: The layout of the screen is intuitive and easy to navigate.	4.3
Q9: The smart glass does not block my vision.	3.3

Q10: The use of smart glasses does not interfere with my work.	3.5

Table 3: Survey results on EMS providers' user experience with smart glasses

<u>*Perceived impact on communication and teamwork*</u>. Participants emphasized that the '*see-what-I-see*' capability enabled by smart glasses improved communication with physicians by reducing ambiguity often associated with verbal-only communication methods. One participant described this feature as a potential '*game changer*' for managing complex or critical cases: '*With a live person, what they look like matters. Are they gasping for air? Is their skin blue?*' [EMS#26] Additionally, several providers described the experience as gaining an '*extra team member*', with physicians offering live mentorship during patient care—something rarely feasible via phone or radio: '*I gave it in the patient's arm, and [the doctor] saw it and said give it into the thigh. I was able to get a little bit more mentorship than I think I've ever had.*' [EMS#19] These perspectives were echoed in the survey results (Table 3): providers agreed that smart glass enhanced communication with physicians (UTAUT Q1: 3.8) and that the video call feature was useful (Feature and Design Q3: 4.3).

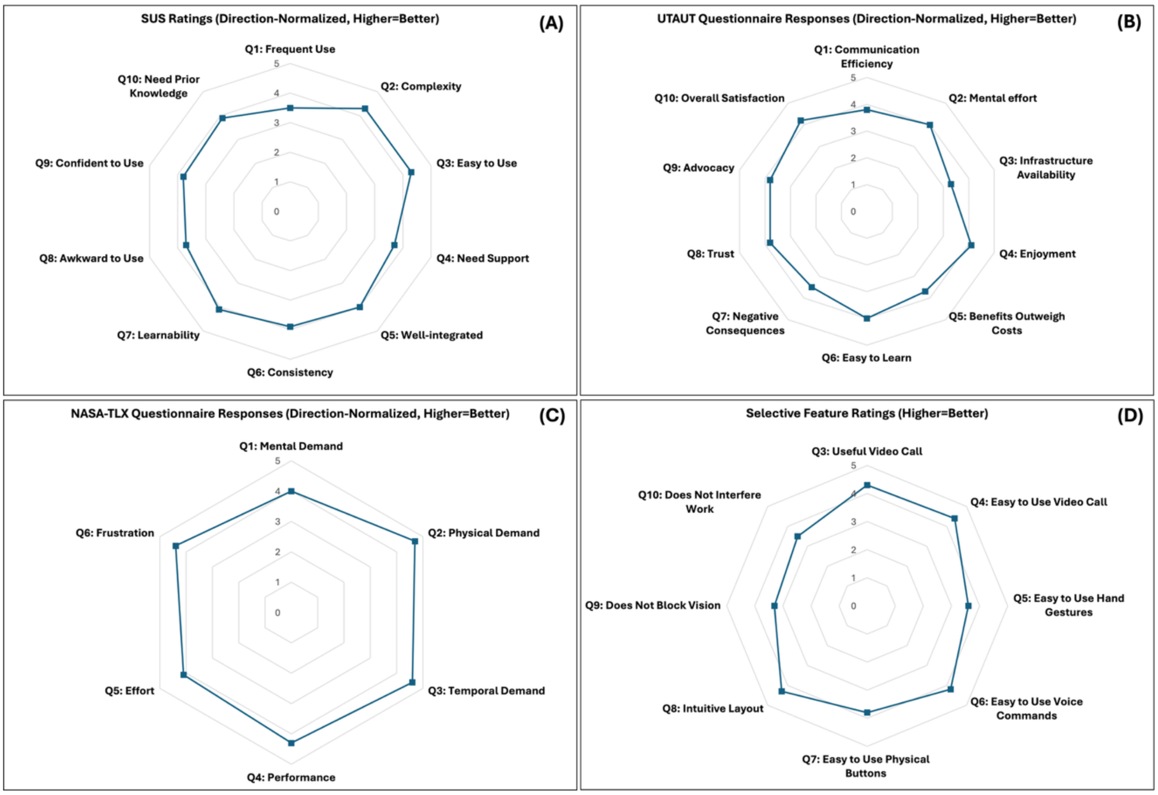

Figure 3. A): Direction-normalized SUS item ratings by EMS providers. Radar chart shows mean SUS responses after reverse-coding negatively worded items (Q2, Q4, Q6, Q8, Q10) so that higher values consistently indicate better usability (scale: 1–5; ideal = 5). B): Direction-normalized UTAUT item ratings by EMS providers. Radar chart shows mean UTAUT questionnaire responses from EMS providers on a 1–5 scale, with the negative-consequences item (Q7) reverse-coded. Larger values indicate higher user acceptance and better perceptions (scale: 1–5; ideal = 5). C): Direction-normalized NASA-TLX item ratings by EMS providers. Radar chart shows mean NASA-TLX responses recoded so that higher values consistently indicate lower perceived workload (i.e., lower mental/physical/temporal demand, effort, and frustration) and better perceived performance (scale: 1–5; ideal = 5). D): Feature and design ratings by EMS providers. Radar chart shows mean ratings for selected interface and interaction features, with higher values indicating more favorable perceptions (scale: 1–5; ideal = 5).

Beyond video communication, participants also highlighted the smart glass application's ability to receive textual information (e.g., instructions) from the remote physician as valuable for reducing ambiguity, preventing miscommunication, and avoiding potential medical errors: '*Having a screen that shows the actual dosage of it while talking to the physician is helpful.*' [EMS#32]

<u>Interface design and interaction</u>. Most EMS providers found the smart glass interface intuitive and easy to navigate, describing it as '*very user friendly, very simple to use*'. These opinions were also reflected in the survey results (see the '*feature and design*' questionnaire in Table 3): the question about layout and navigation (Q8) received an average rating of 4.3, and each step of the user flow for establishing the video call (Q1–Q4) also received high ratings, ranging from 4.3 to 4.4.

Regarding interaction with the smart glass, although hand gestures were the most frequently attempted initial method (as noted previously), they were not rated as easy to use (Q5: 3.6) compared to voice commands (Q6: 4.2), which received much higher ratings. As one participant reflected: '*The actual manipulation of objects [via hand gestures] takes some time to get used to. With proper training, I think it becomes easy. But for a first-time user, voice commands are probably the go-to. There's definitely a learning curve.*' [EMS#29] Nevertheless, several participants highlighted the importance of training to effectively use hands-free interaction and emphasized the value of offering multiple interaction methods to suit different preferences and real-world scenarios.

<u>Perceived impact on workflow</u>. Compared to phone or radio, the smart glass application allowed EMS providers to communicate with remote physicians with minimal disruption to hands-on patient care. Several participants noted that they could remain engaged in treatment tasks without needing to stop and handle the phone or radio: '*I like how I can just operate it with my hand or my voice, just do a quick little pinch and keep going, instead of pressing buttons on a radio and keeping hold of it.*' [EMS#30]

However, while workflow disruption was generally perceived as limited, some providers raised notable concerns. For instance, the use of smart glasses could potentially affect EMS providers' vision and situational awareness, which could be particularly problematic in unpredictable or high-risk environments, such as highways or unsafe neighborhoods: '*It's a little bit distracting. I found myself like not really looking around. I see it restricting my vision.*' [EMS#6] '*We need to hear what our surroundings are. Someone could be dangerous.*' [EMS#11] This concern was also reflected in the survey responses (see the '*feature and design*' questionnaire in Table 3), where participants only moderately agreed that the smart glass did not block their vision (Q9: 3.3), and this shortfall from the ideal score is also one of the most noticable gaps in the radar chart (Figure 3D).

Another major concern was the length of interaction with physicians. Unlike radio or phone calls, where doctors typically give quick orders and hang up, the use of smart glasses often led to longer conversations. A few EMS providers expressed concerns about being constantly observed when physicians stayed on the call longer, which they felt compromised their professional autonomy: 'I *feel like I'm being watched. We've always been a very doctor-hands-off system. And what this is doing is putting doctors back hands-on, like a 'mother, may I?' system.*" [EMS#6] These concerns may help explain why providers only slightly agreed that smart glasses did not interfere with their work (Q10: 3.3); this relatively large shortfall from the ideal score is also evident in the radar chart (Figure 3D).

Physician's experience about web-based application

<u>Overall perception of the web application</u>. The overall average SUS score across all physicians was 73.4, indicating above-average usability (Table 4). Participants rated the system as easy to use (Q3: 4.2) and not unnecessarily complex (Q2: 1.7), with minimal inconsistency (Q6: 2.0) and awkwardness (Q8: 1.7). Learnability was also positively evaluated, as most physicians believed people would be able to learn the system quickly (Q7: 3.9), and only minimal technical support would be needed (Q4: 2.6). The need for prior learning was low (Q10: 1.8) and the system's functions were viewed as well integrated (Q5: 3.9). In contrast, physicians' confidence (Q9: 3.5) and willingness to use the system frequently (Q1: 3.7) were only slightly above neutral, and these were among the largest gaps from

the ideal profile in the radar chart (Figure 4A). SUS scores were higher in urban areas (M = 78.1, range = 50–95) compared to rural areas (M = 60.8, range = 42.5–75). Urban users were significantly more willing to use the system (Q1: Mdn = 4) than rural users (Mdn = 3) ($p < 0.05$). They also perceived the system as more well integrated (Q5: Mdn = 4) and less inconsistent (Q6: Mdn = 2) than rural users (Mdn = 3 for both) (both $p < 0.05$).

Regarding the UTAUT ratings (Table 4), physicians agreed that the application improved communication efficiency (Q1: 4.5) and was easy to use (Q2: 4.5), enjoyable (Q4: 4.5), and quick to adopt (Q6: 4.5). Consistent with these perceptions, physicians reported low perceived risk (Q7: 2.1), high overall satisfaction (Q10: 4.4), and a willingness to advocate for the system's use (Q9: 3.9). However, trust in the system's reliability was only moderate (Q8: 3.5), perceived benefits were also moderate (Q5: 3.5), and infrastructure readiness received the lowest rating (Q3: 3.3). As shown in the radar chart (Figure 4B), these dimensions fall noticeably short of the ideal score, suggesting lingering uncertainty about whether current technical infrastructure and support can reliably sustain real-world use and integration.

Questionnaire	Average
System usability scale (SUS)	
Q1: I think that I would like to use this system frequently.	3.7
Q2: I found the system unnecessarily complex.	1.7
Q3: I thought the system was easy to use.	4.2
Q4: I think that I would need the support of a technical person to be able to use this system.	2.6
Q5: I found the functions in this system well-integrated.	3.9
Q6: I thought there was too much inconsistency in this system.	2.0
Q7: I would imagine that most people would learn to use the system very quickly.	3.9
Q8: I found the system very awkward to use.	1.7
Q9: I felt very confident using the system.	3.5
Q10: I needed to learn a lot of things before I could get going with this system.	1.8
Total Score	73.4
Unified theory of acceptance and use of technology (UTAUT)	
Q1: Using the application enhanced my ability to communicate with EMS providers efficiently.	4.5
Q2: Using the application required little mental effort.	4.5
Q3: I think I will have the necessary infrastructure readily available to use the application.	3.3
Q4: I enjoyed using the application during the testing.	4.5
Q5: I believe that the benefits of using the application would outweigh their costs and issues.	3.5
Q6: I can see myself quickly getting used to using the application, based on my testing experience.	4.5
Q7: I worried about the negative consequences of using the application during the testing.	2.1
Q8: I trust that the application would perform as expected, based on my testing experience.	3.5
Q9: If I had the chance, I would advocate for using the application based on my testing experience.	3.9
Q10: Overall, I am satisfied with my trial experience of using the application.	4.4
Feature & design	
Q1: The video call feature is useful.	4.8
Q2: The video call feature is easy to use in the current design.	4.5
Q3: It is useful to see patient information like administered medication and vital signs shared by EMS.	4.5
Q4: It is easy to find and read the shared patient information in the current design.	4.0
Q5: The note-taking feature is useful.	4.2
Q6: It is easy to take notes in the current design.	4.0
Q7: The feature of messaging EMS providers is useful.	4.3
Q8: It is easy to message EMS providers in the current design.	4.3
Q9: The layout on the screen is intuitive and easy to navigate.	4.6

Table 4: Survey results on physician’s user experience with the web application

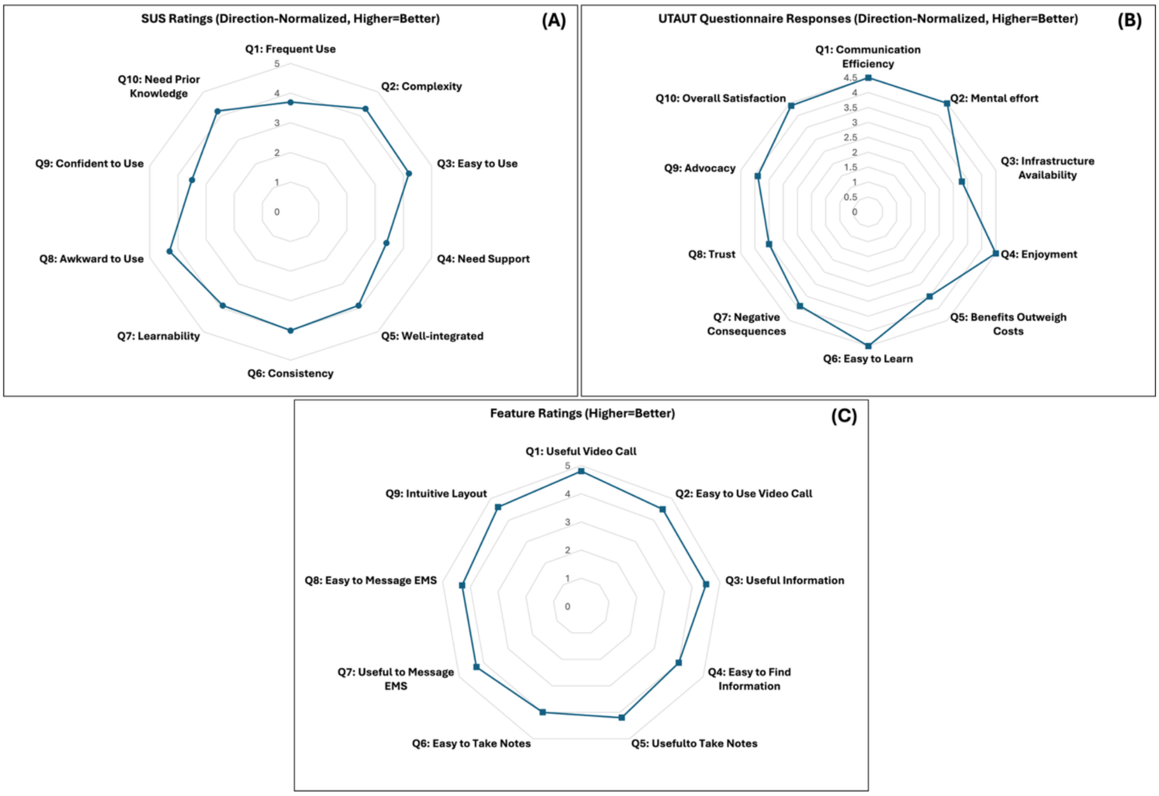

Figure 4. A): Direction-normalized SUS item ratings by physicians. Radar chart shows mean SUS responses after reverse-coding negatively worded items (Q2, Q4, Q6, Q8, Q10) so that higher values consistently indicate better usability (scale: 1–5; ideal = 5). B): Direction-normalized UTAUT item ratings by physicians. Radar chart shows mean UTAUT questionnaire responses from physicians on a 1–5 scale, with the negative-consequences item (Q7) reverse-coded. Larger values indicate higher user acceptance (scale: 1–5; ideal = 5). C): Feature and design ratings by physicians. Radar chart shows mean ratings for the system design and features, with higher values indicating more favorable perceptions (scale: 1–5; ideal = 5).

<u>Positive opinions about the system design and functionality</u>. As presented in Table 4 (see *the 'feature and design'* questionnaire) and illustrated in Figure 4C, emergency physicians reported positive perceptions of the system design. More specifically, physicians emphasized the value of being able to see the patient, as real-time video streaming allowed them to distinguish between cases that might otherwise sound identical over the phone—for example, whether an elderly patient with low blood pressure was simply dehydrated or severely septic. As one physician explained: '*The most important thing in medicine is just seeing the patient. I like being able to look down at the patient and see the patient and hear very clearly what the person is saying. I think it gave me a better sense of what's going on by seeing the patient.*' [P#3] Survey responses echoed this sentiment, with physicians rating the video call feature highly in terms of usefulness (Q1: 4.8) and ease of use (Q2: 4.5).

Beyond video calls, physicians could also view additional information shared by the EMS team. For instance, although EMS providers sometimes showed remote physicians the vital signs monitor while discussing patient parameters, physicians valued having these vital signs and other relevant patient information displayed in real time within the application. This appreciation was reflected in survey ratings for the usefulness of this feature (Q3: 4.5) and its ease of use (Q4: 4.0). Physicians further explained that being able to see such information in text format minimized the need for repeated verbal queries, especially in visually or acoustically challenging environments and when seeing vital signs monitor through smart glass is not feasible: '*It was great seeing where the vitals* *can automatically update into the feature that I'm looking at on the screen. I don't have to ask what's the oxygen now; I can see it on the screen in real time.*' [P#5]

The inclusion of a note-taking feature in the physician interface was also well received, as reflected in the survey responses (Q5: 4.2, Q6: 4.0) and in participants' follow-up interviews. As one participant noted: '*Having the opportunity to have that [in-app notetaking] would be really helpful.*' [P#4] To further enhance workflow efficiency, participants suggested integrating this note-taking functionality with existing electronic health record (EHR) systems, which could help reduce redundant data entry and ensure that key patient information captured during the call is directly accessible for documentation and follow-up care: '*I guess the question would be where the notes go. If this is integrated into your medical record or somewhere that this becomes part of their medical record, then I think that's a valuable tool.*' [P#8]

Finally, the in-app messaging system emerged as one of the most appreciated features for ensuring both clarity and discretion in communication. Physicians highlighted that the ability to send textual information to EMS providers not only reduced the risk of medication errors but also helped prevent potentially distressing verbal exchanges in the presence of patients or family members: '*I think the messaging is beneficial. It may help limit the risk of medication error, just because there's written confirmation in addition to verbal.*' [P#8] These sentiments were also reflected in participants' survey responses (Q7: 4.3, Q8: 4.3).

Concerns about the system design and functionality. Some physicians expressed concerns about the limitations of viewing through the EMS provider's perspective, particularly the lack of control over what they were able to see via the smart glass feed. At times, the shared view did not align with the physician's priorities: '*There's a fire and there's a patient here. I want to see the patient, not the fire.*' [P#1] Another concern involved communication limitations, that is, physicians sometimes wanted to speak directly with the patient, a family member, or EMS personnel performing hands-on tasks, but the current setup only allowed the smart glass wearer to hear them. As one physician explained: '*I didn't know if it was just the person with the glasses on that could hear me, or if it was everybody.*' [P#1]

In terms of ergonomics, dizziness emerged as a key concern when viewing the live feed. The motion of the camera, driven by the EMS provider's head movements, made the video difficult to follow: '*It was a little dizzying because the person was wearing the glasses, when they're looking around, the view bounces around a little bit.*' [P#6]

Discussion

Aligned with prior work (Broach et al., 2018; Demir et al., 2017; Noorian et al., 2019), our study revealed several benefits of using smart glasses, such as ensuring continuity of care, improving communication, and reducing ambiguity. Despite these advantages, our findings also surfaced several potential barriers that warrant careful consideration in future deployments, as discussed below.

Workflow and infrastructure integration

Integrating the smart glass system into prehospital workflows was identified as critical for successful adoption (Zhang et al., 2024; Zhang et al., 2022). EMS teams already manage multiple devices—radios, tablets, monitors—and adding a new system could potentially increase cognitive load unless well integrated. More specifically, both EMS and OLMC providers in our study expressed uncertainty about the readiness of current infrastructure, i.e., how to effectively integrate old phone-based devices and the new smart glass telemedicine system to ensure smooth coexistence and transitions.

Moreover, we found that the average physician call duration was 5.3 minutes with a few physicians stay connected throughout the entire call. Some EMS providers, especially experienced paramedics, expressed concerns that longer physician presence could make them feel be monitored or supervised, which they felt undermined their autonomy and potentially slowed down field operations. One possible reason for physicians remaining on the call for extended periods is the absence of standardized guidelines as to when it was appropriate to disengage, leading some to err on the side of staying connected. Future system deployments would benefit from establishing clinical guidelines or communication protocols that define appropriate criteria for ending remote consultations—balancing physician availability with EMS autonomy and workflow efficiency.

Finally, eye-tracking data also highlight a tension between richer visual context and on-scene attention demands. During teleconsultation, EMS providers frequently fixated on the remote physician's video feed, suggesting that the "see-what-I-see" channel can become a salient focal point during active care. While this visibility can strengthen shared situational awareness, sustained monitoring may compete with hands-on patient care—consistent with participants' concerns that smart glasses could interfere with workflow. Future designs could consider context-aware user interfaces for the smart-glass display that temporarily downplay or minimize noncritical visuals (e.g., the remote physician's video feed) while still enabling rapid re-access when needed.

Real system usage pattern

Our study also revealed several interesting observations about how the system was used in near-real-life simulations, offering insights into how such systems may function in actual practice once deployed. For example, when interacting with the smart glass device, while hand gestures were the most common initial choice, several providers encountered issues, prompting them to switch modalities. Voice commands were generally preferred for being fast and intuitive but occasionally faltered in noisy environments. Physical buttons offered the highest reliability but were viewed as less convenient during patient care. Many participants appreciated the flexibility to switch between modalities, emphasizing that the system must support near-effortless interaction to avoid disruption to care.

Another observation is that while most physicians actively engaged with the video feed, the use of supplemental features such as digital notetaking and text messaging was limited. Feedback on the notetaking feature was mixed—some physicians found it helpful for recording key treatment plans, while others questioned its usefulness without integration into the hospital's EHR systems. Furthermore, despite the availability of on-screen textual information (e.g., treatment details, vitals), eye-tracking data showed that physicians sometimes did not check those elements and instead asked EMS providers for the same information. This may be due to either overlooking discreetly displayed data or preferring real-time updates over potentially outdated on-screen values. To address these issues, future system iterations could: (1) integrate with vital sign monitors to stream live physiological data directly to physicians; (2) enhance the visibility of newly displayed information (e.g., pulsing upon available); and (3) connect notetaking features with EHR systems to avoid duplicative documentation and streamline clinical workflows.

User acceptance and usability concerns

While overall reception of the smart glass system was positive, user acceptance varied across settings and experience levels. Urban EMS teams—often operating with fewer personnel (two members in an ambulance unit) and tighter time constraints—reported higher usability and appreciation for physician input. In contrast, rural providers, who typically had more on-scene staff and longer transport times, showed greater ambivalence toward the system's added value. Similarly, experienced providers were also more skeptical overall. These differences underscore the importance of tailoring deployment strategies to local EMS agencies, team composition, and provider experience (Schuster & Nathan-Roberts, 2017).

Although smart glasses were generally rated as easy to use, several usability and ergonomic concerns emerged that may impact long-term acceptance. On the EMS side, a few providers reported minor vision obstruction—similar to what has been noted in prior literature (Mitrasinovic et al., 2015; Zhang et al., 2023). Though not dealbreakers, these issues suggest the need for improved adjustability in future hardware designs. On the physician side, some participants noted that the video feed could occasionally induce dizziness or visual fatigue. This was typically attributed to rapid head movements by EMS providers wearing the glasses, which caused the video to become shaky or blurry on the receiving end (Munusamy et al., 2021). These findings emphasize the importance of stabilizing video capture (e.g., through software-based smoothing) and making EMS users aware of how head movements can affect video quality during streaming.

Conclusion

Our study demonstrates the potential of smart glasses to meaningfully enhance prehospital communication and offers an important step toward translating this technology from controlled simulations to real-world clinical use. At the same time, successful adoption will require more than favorable usability—it depends on robust infrastructure, seamless integration into existing EMS workflows, and careful consideration of provider roles, autonomy, and contextual practices. Addressing these sociotechnical challenges is critical to ensuring that smart-glass-assisted telemedicine improves care delivery without adding unintended burden. Future research should focus on large-scale deployment strategies, integration with existing EMS systems, and policy and training frameworks that support sustainable adoption of this emerging technology.

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