Information Seeking and Sensemaking in Emergency Medical Service through Simulation Video Review

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Abstract
Emergency medical services (EMS) providers often face significant challenges in their work, including collecting, integrating, and making sense of a variety of information. Despite their criticality, EMS work is one of the very few medical domains with limited technical support. To design and implement effective decision support, it is essential to examine and gain a holistic understanding of the fine-grained process of sensemaking in the field. To that end, we reviewed 25 video recordings of EMS simulations to understand the nuances of EMS sensemaking work, including 1) the types of information and situation that are collected and made sense of in the field; 2) the work practices and temporal patterns of EMS sensemaking work; and 3) the challenges in EMS sensemaking and decision-making process. Based on the results, we discuss implications for technology opportunities to support rapid information acquisition and sensemaking in time-critical, high-risk medical settings such as EMS.

Introduction

Clinical decision-making is anchored by a set of many small sensemaking activities that clarify patient conditions and recognize critical events. Sensemaking is an integral part of medical work.[1] This notion represents a sociotechnical process of collecting, analyzing, interpreting, and communicating data that comes from various resources (e.g., environment, artifacts) to make sense of the past, present, and future events that often lead up to a major clinic decision.[2] Several studies have highlighted the critical role of sensemaking in teamwork and decision-making in hospital settings, such as emergency department and intensive care unit.[3,4] However, the examination of sensemaking work in out-of-hospital settings, such as emergency medical services (EMS) or prehospital care, has been limited.

EMS providers face great challenges in their work due to uncertainties in patient conditions, the fast-paced and dynamic work environment, and the lack of technology support.[5,6] These issues could significantly affect the quality and safety of patient care in the field.[7] Prior work has attempted to design and develop clinical decision support systems (CDSS) for EMS providers to improve prehospital care; however, their implementations encountered many barriers and faced low user adoptions.[8,9] One primary reason is the lack of consideration of work context and user needs.[10,11] To that end, it is critical to understand what data EMS providers are collecting and sensemaking, how they make sense of "messy" patient data, what work practices and tools they adopt, and what challenges in sensemaking and information seeking they currently face. These details can inform user-centered design and evaluation of CDSS that could be used to improve patient outcomes and teamwork in the field. Additionally, understanding the nuances of EMS sensemaking can also facilitate the integration of CDSS into EMS workflow for more effective use and better user adoption.

The examination of the information seeking and sensemaking of EMS is inherently challenging given the dynamic work environment. Traditional methods such as interviews or observations may not be effective or even feasible to capture the subtle details of EMS work. Video review of simulations can be a valid and efficient way to analyze the data offline and capture fine-grained, essential details of fast-paced EMS work, which are otherwise challenging to study in real-world settings.[5,6] In this study, we reviewed 25 video recordings of a series of EMS simulations on pediatric patient care. We focused our analysis on categorizing the information-seeking and sensemaking activities, understanding work practices and patterns in sensemaking, and examining challenges and issues in the EMS sensemaking and decision-making process. Our analysis revealed a total of 25 major types of sensemaking activities that were grouped into 8 high-level categories. We also found that the EMS sensemaking work was often conducted collaboratively and concurrently. Role differentiation in EMS sensemaking was also observed. Challenges in this process included incomplete or unsuccessful sensemaking attempts, situation recall and awareness issues, and failed recognition of critical events and patient needs.

Our study makes the following contributions to the medical informatics field: First, we provided a detailed account of EMS work practices and faced challenges in information seeking and sensemaking, which remain understudied in literature. Second, we detailed the approach of utilizing video review of simulations to examine highly dynamic, complex, context-specific medical work. Lastly, our study informs design implications for technology solutions that support rapid information acquisition and sensemaking in time- and safety-critical medical settings such as EMS.

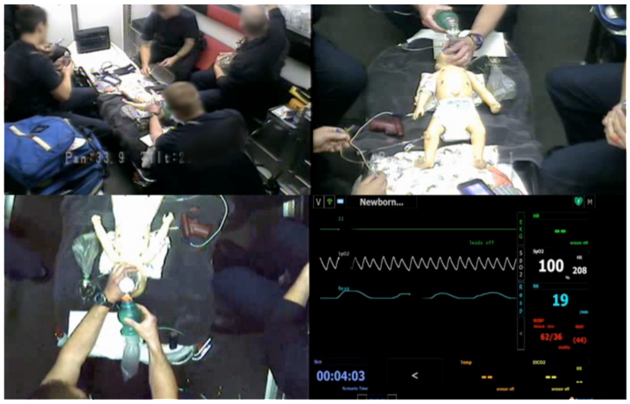

Figure 1. Screenshot of a video recording, showing four views of the simulation: a) top left: zoom-out view of the mock ambulance, b) top right: patient's foot view, c) bottom left: patient's overhead view, and d) bottom right: view of vital signs monitors.

Methods

Study Design and Dataset

In this study, we performed a secondary analysis of a series of videotaped simulations conducted within a fire-based EMS agency in the mountain region of the U.S.[12] The simulations were performed by EMS providers recruited from the agency, consisting of paramedics, emergency medical technicians (EMTs), and advanced emergency medical technicians (AEMTs), who met the state licensure requirement for their scope of practice. Most of the participants have more than 10 years of experience. The teams of EMS providers who participated in the simulations were consistent with their typical composition when responding to emergencies. No roles were removed during the scenarios. In general, each simulation team had 3-5 members with one paramedic serving as the team leader.

The simulations focused on evaluating team-based care of pediatric emergencies following medical training. The simulation scenarios included a 15-month child in hypotensive shock and seizures, a 1-month-old infant with hypoglycemia and shock, and a 4-year-old child experiencing clonidine ingestion. All these scenarios required intravenous (IV) fluid, medication administration, and airway management. For example, in the scenario of hypoglycemia, the mannequin was set to have seizure activity if it was not treated with dextrose within 5 minutes of the simulation starts. Each simulation used a high-fidelity pediatric mannequin with advanced features, such as simulated ECG rhythms and real-time tactile and auditory feedback. A simulation operator used a tablet to remotely control the mannequins to provide real-time responses (e.g., changes in sounds and vital signs) to providers' interventions. EMS teams used their training equipment organized in the manner of their pediatric bags used in the field. They were oriented to the mannequin and other training materials and asked to provide normal care following their protocols as they would in the field. The length of simulations varies, ranging between 9 and 14 minutes, with an average length of 11 minutes.

All simulations were conducted in a mock ambulance interior environment. The simulation environment was equipped with video cameras and microphones, allowing the simulation team to capture visual and auditory data. More specifically, four views of the simulation activities were obtained: 1) a zoom-out view of the entire interior of the mock ambulance (Figure 1a), 2) a patient's foot view (Figure 1b), 3) a patient's overhead view (Figure 1c), and 4) the view of vital signs monitors (Figure 1d). In total, 135 simulations were performed in a 6-month period. The present study randomly selected 25 simulation video recordings from this large dataset. The selected sample has an almost even number of video recordings for each scenario. This secondary analysis was approved by Pace University IRB.

Data Analysis

Since most representations of the patient status and team activities are managed using observable social (e.g., EMS providers' inquiries and verbal reports) and physical elements (e.g., paper and computerized artifacts), it is feasible for us to analyze these data for a detailed analysis of EMS sensemaking work practices. Our data analysis process consisted of multiple steps, as illustrated in Figure 2.

As the first step, one researcher (R2) transcribed all the videos (n=25) while another two researchers (R3 and R4) performed quality control to ensure the transcription was correct. The transcript of each video recording included a set of fields, including time stamps, conversations, speaker (who was speaking), subject (whom the speaker was tabling to), performing tasks and actions, and artifacts used. These researchers have extensive training in video analysis, while also being trained by the senior authors (R1, R5, and R6) to interpret medical procedures and terminologies in the context of EMS. An excerpt of the transcript is shown in Table 1.

In the second step, two researchers (R2 and R4) first reviewed four videos randomly selected to develop a coding scheme. The analysis focused on what information was asked for, what things were made sense of, who initiated the sensemaking activity, what artifacts were used, what decisions were made, and what barriers or challenges were observed. The initial list of codes was discussed among researchers to determine which codes to keep, merge, or discard. After the coding scheme was set, we created a codebook defining each code to standardize the coding process.

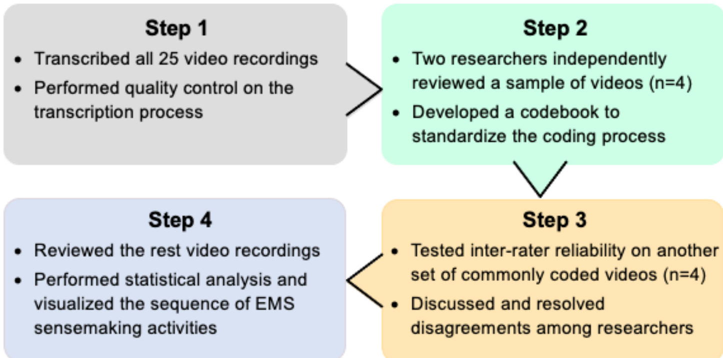

Figure 2. Data analysis procedures.

An example of data analysis is illustrated in Table 2. In this example which represents the coding process for the transcript excerpt shown in Table 1, we documented the time for a decision made, what that decision was (administering IV fluid), and who made that decision. In addition, we also recorded the start time, end time, and duration for the sensemaking activity, the high-level (level 1) and low-level (level 2) category of the sensemaking activity, and who initiated the sensemaking activity. Other types of information, such as artifacts used and observed challenges, were also recorded but excluded from Table 2 due to space limits.

In the third step, we used Cohen's Kappa coefficient to test the inter-rater reliability by asking the same two researchers (R2 and R4) independently coded another 4 video transcripts using the developed codebook and compared their codes on sensemaking activities, decision-making points, and observed challenges. The coders presented a "substantial" agreement on the codes (Kappa value is 0.72). After this step, R2 coded the rest video transcripts to complete the video review process. As a verification step, R1 and R3 reviewed all the data analyses to ensure the correctness and appropriateness of coding. Disagreements on the analysis were discussed and resolved during weekly group meetings among all researchers.

Once the coding process was completed, we performed a descriptive statistical analysis of the coded data. For example, we calculated the number of occurrences of different types of sensemaking activities over 25 simulation events, the number of information requests and initiated sensemaking activities for each role, and the frequency of observed challenges and issues (e.g., incomplete sensemaking attempts). In addition, we also visualized the sequence of sensemaking activities in a timeline for each video to identify temporal patterns of EMS sensemaking work.

Table 1. An excerpt from the transcript of a simulation recording.

Time	Speaker	Subject	Dialogue	Action
05:06	Team Leader	Team	Let's start with the fluid. Yes, Let's go with glucose. We will do D10W. What's my number on D10?	
05:29	Med Paramedic	Team Leader	D10W?	
05:31	Team Leader	Med Paramedic	Hmm. [*confirmation*]	
05:33				Med paramedic checked the medication chart
05:36	Med Paramedic	Team Leader	It's going to be 20ML.	
05:38	Team Leader	Med Paramedic	20ML? Okay.	

Table 2. An example of data analysis for the excerpt illustrated in Table 1.

Start Time	End Time	Duration	Sensemaking Activity (Level-1 Code)	Sensemaking Activity (Level-2 Code)	Who Initiated?	Decision-Making Point
05:06					Team Leader	Treatment-IV fluid
05:06	05:38	32s	Treatment	Appropriate dosage of IV fluid	Team Leader	

Results

In this section, we report the following major findings of our analysis: 1) the types of information and situation that are made sense of by EMS providers, 2) temporal patterns of EMS sensemaking activities, 3) role-based analysis of EMS sensemaking, 4) artifacts used for sensemaking in the field, and 5) challenges in effective sensemaking and decision making in EMS.

Types of Information Sought and Made Sense of in EMS

As shown in Table 3, EMS team members made sense of a variety of information and patient status. More specifically, we identified 25 major types of sensemaking activities and grouped them into 8 high-level categories, including demographics, patient's medical history, mechanism of injury, physical findings, treatments, equipment, teamwork, and communication with the receiving hospital. Below we describe each category in detail.

Demographics: Commonly discussed demographic information included patient age, name, and weight. In particular, the age of the patient was inquired by EMS providers in a total of 24 occurrences in 18 simulations, while the patient's name was asked in 8 instances. In comparison, it is surprising to see that the patient's weight was only assessed using broselow tape in 2 instances given this information was often needed for the calculation of medication dosage.

Patient's Medical History: Typically, EMS providers would talk to the patient's parents or guardians at the beginning of patient care to gather all the information pertaining to the patient's medical history. In the simulations, two types of information—medication taken and the patient's ongoing/previous medical conditions—were often asked about. The former information was requested in a total of 24 occurrences across 15 simulations, while the latter was asked 17 times in 10 simulations. Additionally, we also found inquiries about other types of information concerning the patient's medical history (n=28), such as diaper condition or recent checkup results.

Mechanism of Injury (MOI): To come up with an appropriate patient management plan, it is critical for EMS providers to know how the patient got injured or what type of incident occurred. EMS providers specifically asked for this information from the patient's parents or guardians in all simulations. Detailed MOI information asked by EMS providers included what happened (n=49) and when/where the incident happened (n=16).

Treatments: Most commonly sensemaking activities related to treatments included the appropriate dosage of IV fluid (n=54) and type of medications (n=52) given to the patient. While administering treatment to the patient, the EMS providers also discussed the appropriate ways to establish IV access on the patient (n=18). For example, they often discussed the needle size for establishing IV access ("*Do you want to use the 60 CC syringe behind you?*") and which body part of the patient to use for IV access ("*Should we do the line on his left side? Hands or forearm?*"). It is also worth mentioning that the whole team frequently discussed the effectiveness of the given treatment (n=24), based on the vital signs and patient's reactions after treatment administration. Finally, EMS teams also discussed what specific treatment to perform in 10 out of 25 simulations (e.g., "*Do you want to do an IV or IO? Which one is easier?*").

Physical Findings: This category contains perhaps the most prominent and frequent sensemaking activities compared to other categories. For example, throughout the simulations, EMS providers often checked and requested to measure the vital signs of the patient (n=159), including blood pressure, temperature, pulse ox, respiratory rate, heart rate, etc. In addition, the patient's breathing status (n=55), consciousness (n=26), symptoms (n=25), and airway (n=10) were other important aspects of the patient's physiological status that were discussed during many simulations. Regarding symptoms, EMS providers not only attempted to understand what present symptoms indicated but also discussed any changes in patient status and their possible causes ("*Baby stopped crying. How is she doing? Is she alert? Can you wake her up? Give me a good listen. Let's make sure we haven't flooded her up at all.*").

Equipment: While administering treatment, the EMS providers discussed the right way to use a piece of equipment in 12 occurrences, where to find a piece of equipment in 16 occurrences, and if the equipment is working properly in 20 occurrences. Reasons for EMS providers to discuss how to appropriately use a piece of equipment included 1) they never used a particular piece of equipment before, or 2) they lacked experience using a piece of equipment on pediatric patients. For example, in one simulation, the medication paramedic asked the team how to connect a particular type of IV tube to the bag: "*I don't think I've ever used this type before. How should I use it*?"

Teamwork: During most of the simulations (n=22), EMS providers would ask each other about what tasks or treatments they have completed, are working on, or are planning to perform. In particular, co-workers' ongoing or intended activities were asked about and discussed in a total of 50 instances. In addition, they also asked for information about what tasks or treatments have been done (n=20). Such kinds of information could help EMS providers maintain awareness of the whole team's work status to inform the next steps.

Communication with Hospital: EMS teams were aware of the importance of communicating accurate and essential patient information to the receiving hospital. Even though contacting the hospital was not required in simulations, they simulated providing a verbal report to the receiving hospital in 22 out of 25 simulations. Before the verbal report, they spent time discussing which hospital they should contact (n=14) and the estimated time of arrival to the hospital (n=3).

Table 3. Category, frequency, and duration of identified sensemaking activities.

High-Level Category	Low-Level Category	Total Number of Occurrences	Number of Simulations an Activity Occurred	Average Number of Occurrences	Max Duration (seconds)	Average Duration (seconds)
Demographics	Patient name	8	8	1	2	1.75
	Patient weight	2	2	1	33	30.5
	Patient age	24	18	1.33	20	6.38
Patient's Medical History	Medication taken	24	15	1.6	48	10.85
	Previous or ongoing medical conditions	17	10	1.7	31	13.57
	Other	28	15	1.87	42	11.01
Mechanism of Injury	What happened	49	25	1.96	80	20.14
	When and/or where the incident happened	16	14	1.14	25	8.63
Physical Findings	Consciousness	26	17	1.53	36	15.16
	Vital Signs	159	25	6.36	62	11.08
	Breathing	55	23	2.39	50	16.24
	Airway	10	7	1.43	20	8.36
	Symptoms	25	19	1.32	57	14.95
Treatments	The type of treatment to perform	10	10	1	56	25.2
	Appropriate dosage of IV fluid	54	22	2.45	92	20.88
	Medication type and dosage	52	22	2.36	83	22.12
	The appropriate way for establishing IV access	18	14	1.26	53	17.59
	Effectiveness of treatment	24	14	1.71	60	24.07
Equipment	The right way to use an equipment	12	9	1.33	34	13.89
	Where to find an equipment	16	12	1.33	28	9.26
	Whether the equipment is working	20	19	1.05	68	28.93
Teamwork	Co-worker's ongoing task	50	22	2.27	42	16.16
	Tasks that the co-workers have done so far	20	16	1.05	57	24.66
Communication with Hospital	Which hospital to contact	14	14	1	45	19.64
	ETA to hospital	3	3	1	6	4.33

Note: "Total Number of Occurrences" represents the total number of times a low-level category of sensemaking activity was successfully carried out in simulations. "Number of Simulations an Activity Occurred" represents the total number of simulations during which a low-level category of sensemaking activity was performed. "Average Number of Occurrences" was measured using "Total Number of Occurrences" divided by the "Number of Simulations an Activity Occurred". "Max Duration" represents the longest time for conducting a sensemaking activity. "Average Duration" was measured using the sum of the duration for a specific sensemaking activity divided by the "Total Number of Occurrences".

Temporal Patterns of EMS Sensemaking

As shown in Table 3, on average, EMS providers spent more than 20 seconds making sense of a few categories of information and patient status, including patient weight (30.5s), whether the equipment is working (28.93s), co-worker's task progress (24.66s), the type of treatment to perform (25.2s), the effectiveness of performed treatment (24.07s), medication dosage (22.12s), IV fluid dosage (20.88s), and what happened to the patient (20.14s). A few interesting things are worth noting. First, whether the equipment is working not only occurred relatively frequently (n=20), but also took a relatively long time. This might be because EMS providers were not familiar with the equipment provided during simulations. Second, co-workers' task progress (e.g., what tasks have been done so far) usually took a great amount of time to discuss, indicating that EMS providers relied on verbal communication to confirm and keep track of past activities to inform future tasks. Finally, among these categories that lasted relatively longer, four of them were related to treatments. This finding revealed that treatment-related sensemaking activities often required a lot of EMS providers' cognitive resources and efforts.

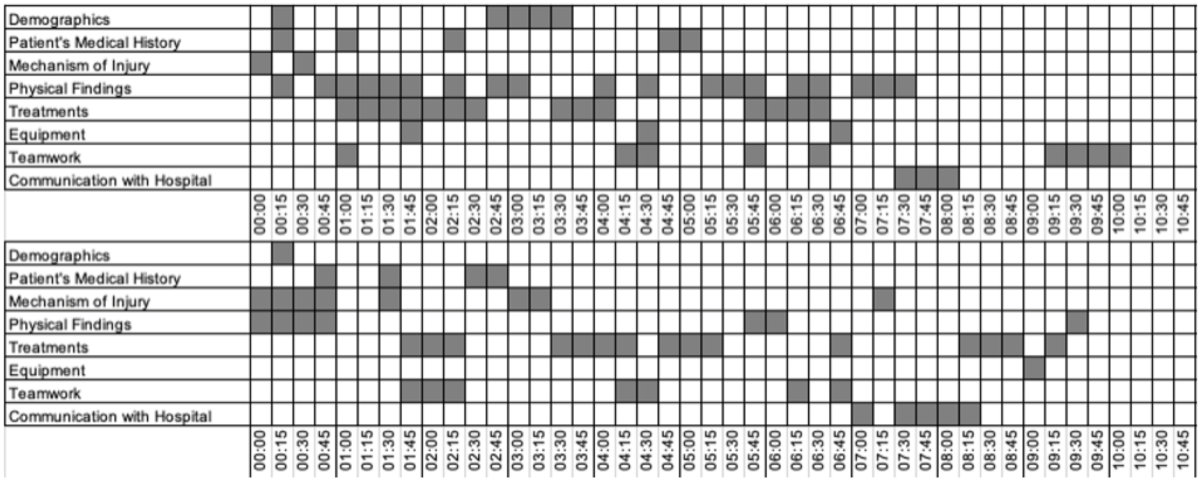

Figure 3. Temporal Visualization of Sensemaking Activities in Two Randomly Sampled Simulations.

We also visualized the sensemaking activities on a timeline for all 25 simulations to identify temporal patterns of EMS sensemaking work. Due to space restrictions, we only show a sample of this analysis, containing two simulations randomly selected from the dataset (Figure 3). The analysis revealed that the information about demographics, mechanism of injury, and medical history was made sense of first in most simulations. Other information categories, such as physical findings, treatments, and equipment, did not follow any specific order. Additionally, we also found that *concurrent sensemaking* activities were very common. For example, in the top visualized scenario in Figure 3, the sensemaking activities related to physical findings and treatments highly overlapped. These findings highlight the multitasking nature of EMS work.

Role-based Analysis of EMS Sensemaking

We were also interested in understanding teamwork and role differentiation in EMS sensemaking. As such, we analyzed who initiated which sensemaking activity in each simulation. As shown in Figure 4, the EMS sensemaking work is a *collaborative* effort. That is, all the EMS providers were involved in collecting information from various sources and making sense of what is going on.

However, there exists role difference in the type and amount of sensemaking activities. More specifically, the team leader role initiated more sensemaking activities than other roles in almost all the categories, with only one exception (equipment). In particular, on average, team leaders asked questions about physical findings almost six times per simulation, followed by treatments (averaged 3.1 times per simulation), patient medical history (averaged 2.67 times per simulation), and mechanism of injury (averaged 2.25 times per simulation). Medication paramedics, who were responsible for administering medications and other treatments, also contributed significantly to the sensemaking work. Similar to team leaders, this role also initiated many discussions about physical findings (averaged 4.67 times per simulation), patient medical history (averaged 2.5 times per simulation), and treatments (averaged 2.29 times per simulation). In particular, their sensemaking of equipment was more often than that of other roles; a possible explanation is that they were the roles preparing and using equipment to perform treatments. In contrast, the airway paramedics had initiated the least sensemaking activities and mainly focused on physical findings (averaged 2 times per simulation) and treatments (averaged 2.33 times per simulation), while paying less attention to other categories (e.g., demographics, equipment, teamwork, and communication with the hospital).

Artifacts Used during EMS Sensemaking

Throughout the simulations, we noticed that EMS providers rarely used any computing device or technology for sensemaking and cognitive support. The only two artifacts commonly used during EMS sensemaking were the vital signs monitor and medication chart. The vital signs monitor—a tool for monitoring the patient's physiological status—was used by EMS providers frequently to check the patient's status, especially after performing a treatment. A medication chart was also used in many simulations to determine the most appropriate medication dosage for the pediatric patient based on the patient's age and weight. These tools could help EMS providers make more accurate decisions regarding medication or IV fluid dosage given to patients.

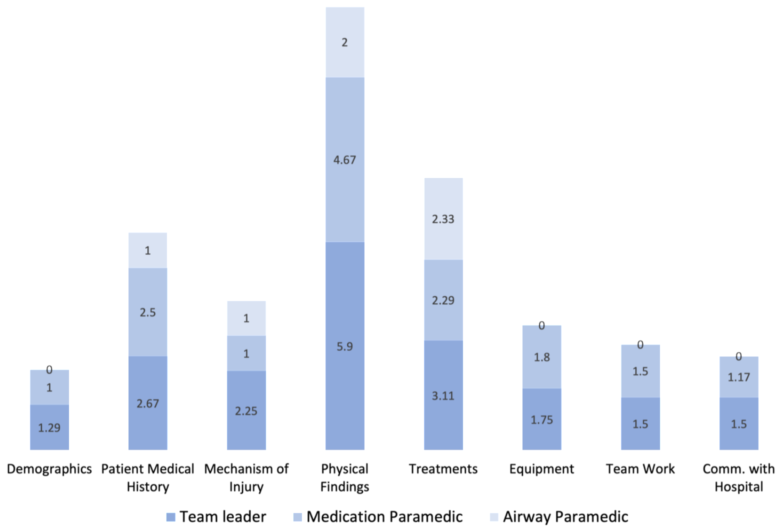

Figure 4. Role-based Sensemaking Activity Analysis. The number represents the average frequency of initiating a high-level category of sensemaking activity by each role.

Challenges in EMS Sensemaking

Incomplete Sensemaking Attempts: Across all 25 simulations, we observed a total of 40 instances where the sensemaking activity was initiated (e.g., a question asked by one EMS provider) but never got completed. A typical example of this issue is that a provider who asked about patient status received no response from other members. These issues might be caused by the lack of closed-loop communication, which could lead to failure of sensemaking and inefficient information flow among EMS providers. Among the low-level categories, 19 inquiries about vital signs went unanswered. Sometimes, when an inquiry got no response, the asker might choose to repeat his/her question at a later time. For instance, in the excerpt below (excerpt#1), we observed that at the beginning of the simulation, the team leader asked for the patient's pulse, but he did not get a response. About one minute later, the team leader interrupted the patient's guardian who had been talking about the patient's medical history, and asked the team to assess the patient's pulse.

#Excerpt 1

Time Stamp	Speaker	Subject	Dialogue and Action
00:29	Team Leader	Team	Can I get a quick pulse?
[*The query about the patient's pulse was unanswered. After that, the patient's guardian started briefing the team about what happened to the patient and pertinent medical history information.*]			
01:48	Team Leader	Team	Apologies for one second here. What is our pulse ox at?

Situation Recall Issues: Even though EMS providers verbally requested a lot of information to make sense of patient situations, sometimes they couldn't remember or recall them at a later time. These issues often led to repeated questions about the same information, which could affect efficient team communication. For example, in the following excerpt (excerpt#2), the medication paramedic verbally reported that he was giving 40 milliliters of fluid and the team leader acknowledged that. About three minutes later, the patient's heart rate dropped slightly; the team leader thus asked the amount of fluid that was given to the patient ("*you gave 20*?"). The medication paramedic responded that he gave 40 instead of 20 milliliters.

#Excerpt 2

Time Stamp	Speaker	Subject	Dialogue and Action
06:07	Med Paramedic	Team	I'll go ahead and give 40 milliliters for the fluid challenge.
06:10	Team Leader	Med Paramedic	Okay.
[*3 mins later*]			
09:15	Team Leader	Med Paramedic	You gave 20?
09:16	Med Paramedic	Team Leader	I gave 40.

Situation Awareness Issues: In some cases, EMS providers, especially team leaders, may not be aware of what tasks their team members had performed (e.g., the dosage of fluids given to the patient) or what is going on with the patient (e.g., a change of vital signs or patient symptoms). Two reasons could be accounted for the occurrence of such issues: 1) Team leaders were busy with other tasks (e.g., talking to the parent to understand what happened to the patient) and didn't pay attention to his/her team members' verbal reports or actions. 2) EMS providers did not verbally report the task they were performing, causing other team members to lack awareness of the past and ongoing events. These situations could lead EMS providers to ask questions about the information they missed. For example, in excerpt#3, while one medication paramedic (med paramedic#1) was reporting that the intraosseous (IO) vascular access had been established, the team leader was discussing the patient's vital signs with another team member (med paramedic#2). Apparently, the team leader didn't hear the updated status about establishing IO access. Later when med paramedic#2 recommended a medication treatment, the team leader said that they needed to wait until the fluid was administered before performing any further treatment. At this time, med paramedic#1 overheard this conversation and informed the team leader that the IO was in.

#Excerpt 3

Time Stamp	Speaker	Subject	Dialogue and Action
05:05	Med Paramedic#1	Team	IO is in.
[*Team leader and med paramedic#2 were discussing the changes in vital signs*.]			
05:40	Med Paramedic#2	Team Leader	Rate at 200. Our rate should normally be at about 150. I feel like we should do adenosine.
05:46	Team Leader	Med Paramedic#2	Let's wait just a second for the fluid.
05:51	Med Paramedic#1	Team Leader	IO's in, [team leader's name].

<u>Failed Recognition of Patient Needs</u>: Given the low frequency of pediatric patient encounters for many EMS providers, we observed that EMS providers sometimes couldn't accurately and timely recognize critical events in treating pediatric patients. A key example is that EMS providers might not be able to recognize the need to perform the required treatments. For instance, simulated scenarios in this study (e.g., hypovolemic shock) required the EMS team to administer IV fluid for treatment. To make that decision, EMS providers must first recognize the patient is in shock, which is usually indicated by the vital signs and the patient's condition. However, we noticed that EMS providers sometimes didn't measure vital signs in a timely fashion or even missed obtaining them. Another problem we identified is that EMS providers sometimes had trouble finding and using the correct equipment. For instance, they used adult equipment on the pediatric patient in several simulation sessions.

Discussion

Decision-making during EMS encounters has been found challenging due to various factors (e.g., workflow issues and the chaotic nature of prehospital care); as such, prior work has highlighted the necessity of providing decision support to EMS providers to reduce patient safety events.[13,14] A few research efforts have attempted to develop CDSS for EMS teams.[15,16] However, these CDSS interventions have inherent limitations. For instance, many of the developed CDSS did not consider EMS workflow, leading to many barriers that prevent user adoption, such as cognitive overload of using CDSS and unexpected impacts on patient interaction and teamwork.[17] To understand how to better design CDSS for prehospital care, we performed video analyses of simulations to examine the nuanced, fine-grained EMS sensemaking activities that often lead to major clinic decision-making.

Our study revealed that EMS providers collected, integrated, communicated, and made sense of a variety of information and patient status in the field, which could be grouped into 8 high-level categories. Most of these sensemaking activities were related to patient information or status, such as the mechanism of injury, physiological status, and treatments, while a few others were pertinent to teamwork (e.g., what task has been completed) and equipment (e.g., where to find or how to use a particular equipment). These findings revealed that CDSS should not only be designed to support making a one-time diagnosis or a prognosis.[18] Instead, our findings prompt CDSS designers to consider *combining CDSS and other informatics tools with various functions to support many small sensemaking activities that eventually lead up to a major decision point*.

We also found both retrospective (e.g., what was done) and prospective (e.g., what is likely to happen) sensemaking activities. The former type of sensemaking implies that people look back on what has happened to make sense of the current situation,[2] while the latter type represents the prediction of future events.[4] An example of retrospective sensemaking is asking about completed tasks; in the simulations, we observed a significant number of teamwork-oriented sensemaking activities (e.g., what task has been completed). This finding indicates the criticality of maintaining awareness of completed tasks for EMS providers, a work practice that was also observed in other fast-paced medical teams.[19] Future integrated CDSS interventions should *track, record, and present past and ongoing task status to alleviate EMS providers' mental efforts in remembering all forms of task-oriented and teamwork information*. For the prospective sensemaking work practice, CDSS could be designed to *support predicting and alerting providers about possible future events*. For example, in one of our scenarios, the mannequin could have seizure activity if it was not treated with dextrose within 5 minutes of the simulation starts; CDSS can be designed to predict and alert the probability of such patient safety events so EMS providers can coordinate among themselves to be prepared both practically and mentally to handle possible future events in a timely fashion. While designing such alerting features, CDSS designers should conduct a comprehensive assessment of the impact of different alert types (e.g., video versus audio, repeated versus one-time) on the cognitive load and attention of EMS providers. This evaluation is essential to identify the most effective method of alerting EMS providers, ensuring that it aids their situational awareness while also mitigating the risk of alert fatigue.[20]

Another interesting finding is that the EMS sensemaking work is a collaborative effort with all team members working together to collect and integrate a variety of critical information from different sources to make sense of what is going on with the patient. In addition, we also found role-based differences in information-seeking and sensemaking. For example, airway paramedics mainly focused on physical findings and treatments while paying less attention to other sensemaking activities. In contrast, medication paramedics initiated more equipment-related sensemaking activities. Given these findings, we suggest that future CDSS interventions for prehospital care should *not only enhance individual sensemaking by accommodating each role's information needs but also enable articulation and communication among EMS team members*. Future work could delve into examining the influence of employing CDSS on EMS teamwork dynamics. This exploration is particularly pertinent as previous studies have highlighted that the implementation of CDSS interventions can potentially alter communication patterns among care providers and even reshape team roles, structure, and overall dynamics.[21,22]

Aligned with prior studies,[23] our work also found concurrent EMS sensemaking activities, which could be attributed to the multitasking nature of prehospital care. Even though such work practice allows EMS teams to carry out patient care tasks in a timely fashion, it could potentially lead to human error and patient safety issues.[24] In particular, this work practice could easily overwhelm care providers, making them lose track of past, ongoing, or pending tasks.[5] More effective strategies and team-based interventions are necessary to better support EMS multitasking, such as leveraging natural language processing and artificial intelligence techniques to *automatically track and capture EMS workflow and visualize completed and ongoing tasks in information systems in an easy-to-absorb format*. By doing so, EMS providers can take a glance at the task information to maintain a good level of situational awareness.

Our study also revealed several challenges in the EMS sensemaking process. For example, we noticed that EMS teams had experienced incomplete sensemaking attempts, lack of closed-loop communication, and situation recall issues. These problems were more likely to happen when EMS providers worked on multiple threads and lacked effective mechanisms to keep track of past and ongoing events. To address these issues, it might be useful to *provide training on communication and teamwork to improve EMS care performance*. The training curriculum can be simulation-based and incorporate core principles and strategies of team communication. Additionally, the simulation-based training scenario should reflect the complicating and multitasking nature of prehospital care so that EMS providers can use these opportunities to not only practice patient care skills but to learn how to manage and overcome barriers in communication and teamwork.

Several limitations of this study should be noted. First, we solely relied on video review of simulations to investigate the research questions. The findings can be strengthened by corroborating with other types of research data, such as interviews or in situ observation. Despite this limitation, it is worth noting that video analysis allowed us to analyze the data in great detail by playing the video back and forth. Second, there may exist bias in the video analysis. To limit this bias, at least two researchers were involved in coding the video data and their analyses were discussed as a group until reaching a consensus. Third, our data only had three pediatric emergency care scenarios. As such, the findings might not be fully generalizable to other care scenarios or adult care. Future work can investigate additional medical scenarios to confirm and even extend our findings.

Conclusion

In this study, we analyzed information-seeking and sensemaking activities during EMS encounters through video review of pediatric emergency care simulations. Our work reveals fine-grained patterns and work practices of EMS sensemaking, as well as challenges facing EMS providers in making informed decisions. We utilized the results to discuss implications for designing effective decision support for EMS providers and highlight the necessity of providing tailored training to enhance team-based communication and collaboration.

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