Collaborative Information Seeking during a 911 Call Surge: A Case Study

Rob Grace
Texas Tech University
rob.grace@ttu.edu

Aurélie Montarnal
IMT Mines Albi
aurelie.montarnal@mines-albi.fr

Eva Petitdemange
IMT Mines Albi
eva.petitdemange@mines-albi.fr

Juliette Rutter
IMT Mines Albi
juliette.rutter@mines-albi.fr

Guillermo Romera Rodriguez
Pennsylvania State University
gkr5144@psu.edu

Michelle Potts
Chandler Police Department
michelle.potts@chandleraz.gov

ABSTRACT

This case study examines collaborative information seeking in a public-safety answering point during a 911 call surge that occurred when a man fired an assault rifle at police officers and evaded capture for nearly an hour in March 2020. Overwhelmed by questionable and imprecise reports from 911 callers, telecommunicators and on-scene responders began working together to conduct broad and deep searches for the shooter. Whereas broad searches improved the scope of information gathering by identifying multiple, albeit questionable and imprecise, reports of the suspect's location, deep searches improved the quality of information gathering by investigating 911 callers' reports using drone, helicopter, and patrol units. These findings suggest requirements for collaborative information seeking in public-safety answering points, including capabilities to conduct broad and deep searches using next-generation 911 technologies, and command and control requirements for triaging these search tasks within inter-organizational emergency response systems.

Keywords

Emergency communications, information seeking, emergency management, crisis informatics.

INTRODUCTION

Emergency communications work in public-safety answering points (PSAP) is historically overlooked in studies of emergency response and management (Gardner & McEntire, 2003; Gillooly, 2021). However, ongoing changes to the sociotechnical infrastructure and work practices of PSAPs motivates research on *collaborative information seeking* (CIS): activities in which multiple people work together to seek information needed to accomplish a shared goal (Karunakaran et al., 2013). In the context of emergency communications, CIS focuses attention on emerging practices of team-based emergency call taking and supplemental information seeking that can enhance the timeliness and quality of situational awareness information dispatched to first responders during an emergency.

Studies of CIS in PSAPs are needed for two reasons. First, emergency communications work increasingly requires telecommunicators to seek information from multiple sources, including traditional telephone calls and supplemental, Next-Generation 911 (NG911) reporting and situational awareness channels. Telecommunicators now answer non-voice reports received from emergency (e.g., text-to-911) and non-emergency text messages (Grace & Sinor, 2021). Early adopter PSAPs also access supplemental situational awareness information from traffic and building cameras, advanced location services such as RapidSOS, personal safety devices (i.e., Apple watch), vehicle telematics (i.e., OnStar), building alarms (i.e., ASAP-to-PSAP), various restricted and public databases, and open sources such as social media.

Second, seeking information from multiple, NG911 sources requires telecommunicators to work as teams during mass emergencies. Some PSAPs now assign telecommunicators to work as communication specialists alongside telecommunicators working as traditional call takers and dispatchers (Grace & Potts, 2022). Communication specialists are responsible for gathering information from NG911 sources to provide situational awareness information that fills gaps in information gathered from 911 callers. Consequently, work practices inside PSAPs involve CIS when cross-functional teams of call takers, dispatchers, and communications specialists seek information from multiple sources to improve the efficiency and effectiveness of emergency communications and response operations.

Despite changes to the infrastructure and work practices of PSAPs, existing research focuses on traditional voice communication between call takers and 911 callers for emergencies involving a single person or small group (e.g., home burglary) that are reported by an involved party (e.g., homeowner who calls 911). While these studies highlight the critical role call takers play in extracting, interpreting, and classifying information from 911 callers that shapes subsequent citizen-responder interactions (Gillooly, 2021; Gillooly et al., 2020; Lum et al., 2020), they do not examine how teams of telecommunicators gather information during mass emergencies that generate a surge of 911 calls from multiple involved and non-involved parties, as well as streams of supplemental data from multiple NG911 sources. As a result, gaps persist in our understanding of CIS in emergency communications work inside PSAPs and, more broadly, command-and-control centers in crisis management. Specifically, we do not understand the triggers and tasks of team-based CIS during 911 call surges, or the sociotechnical requirements for supporting CIS during mass emergencies.

To address these gaps in the literature, this paper presents a case study of CIS during a 911 call surge generated when a man fired an assault rifle at police officers and evaded capture for nearly an hour in Chandler, Arizona. The case study shows that an overload of noisy, unverified, inconsistent, and imprecise 911 calls triggered CIS among telecommunicators who shifted from working as a co-acting group to a collaborative team capable of performing interdependent search tasks. Working as a collaborative team, telecommunicators and on-scene responders performed broad and deep searches to efficiently discover suspect locations reported across incoming 911 calls and improve the quality of location information reported by callers, respectively, These findings suggest that CIS in command-and-control centers like PSAPs requires sociotechnical systems that support the performance and coordination of broad and deep search tasks among members of intra- and inter-organizational teams.

THEORETICAL FRAMEWORK

Studies of *collaborative information seeking* (CIS) focus on the *i*) domain-specific triggers that motivate people to work together to seek information, *ii*) interdependent information search, retrieval, and sharing tasks people perform to address an information need, and *iii*) coordination of these tasks within work groups or teams. Whereas studies often examine information seeking among citizens during disasters such as earthquakes and floods (Rivera, 2021), studies of CIS among professional responders have mostly focused on the work of doctors and nurses in hospital emergency departments (Karunakaran et al., 2013; Reddy et al., 2009).

Triggers of Information Seeking

Information seeking is triggered by events that arise in work contexts. Whereas individual information seeking (IIS) is triggered by a lack of information, studies observe that IIS shifts to CIS when people encounter the following triggers (Reddy et al., 2008):

- *Complex, time-critical information needs* that require people to gather multiple information objects in short periods of time.
- *Lack of domain expertise* that requires people to seek information from other actors within or outside an organization.
- *Lack of accessible information* that requires people to work together to locate and access sources of needed information.
- *Fragmented information* that require people to work together to seek information from multiple, distributed systems and disconnected datasets.

These "triggers" characterize actors' information needs, capabilities, and environments, and, at a high level, define the situations in which CIS is required to accomplish work objectives.

Although there exists a "wide variety of triggers depending on the domain and context" (Reddy et al., 2008), triggers of CIS have not been examined in emergency communications work during mass emergencies. Prior studies focus on the IIS of call takers who follow question-and-answer scripts to gather information from 911

callers. For example, research investigates characteristics of 911 caller behavior that can indicate deception, such as when a person makes a false police report (Miller et al., 2020), or health conditions, such as the onset of a stroke, that require an emergency medical response (Buck et al., 2009). Identifying these triggers for IIS can improve the procedures and decision-support systems that help call takers efficiently gather information from callers or supplemental sources that can improve emergency response outcomes (Spangler et al., 2020). However, as PSAPs adopt new systems and new personnel (i.e., communications specialists) to use these systems, it is necessary to understand the needs, capabilities, and environments that trigger call takers, dispatchers, and communications specialists to work together to seek information during an emergency, and the requirements for systems that can support team-based emergency communications work.

Tasks of Information Seeking

Like triggers, information seeking tasks are intrinsic to work practices and vary widely depending on the work domain and context. In general, Karunakaran et al. (2013) understand CIS as consisting of search, retrieval, and sharing tasks, where "search" is often understood as a low-level task in comparison to the high-level activity of information seeking (Wilson, 2000). However, concepts of search emerge in various literatures that offer insight into the information seeking tasks of emergency communications work.

First, frameworks of information seeking distinguish between what we will refer to as broad and deep searches. A *broad search* gathers diverse information required to refine a general need by expanding the scope of relevant sources and information. Examples of broad search tasks appear in studies that examine information workers' (scientists, engineers, analysts, etc.) practices of surveying (e.g., identifying key people in a field), chaining (e.g., following chains of citations) and browsing (e.g., scanning abstracts or tables of contents) (Ellis & Haugan, 1997).

In contrast, a *deep search* gathers precise or high-quality information required to address a specific need by narrowing the scope of relevant sources and information. Rather than browsing, deep searches find actors using well-defined search queries to filter results and retrieve specific information (objects) (Ellis & Haugan, 1997). Importantly, actors' understanding of the information need changes across the information seeking process, such that broad, "exploratory" searches help refine the scope of relevance for conducting deep or "focused" searches for information (Kuhlthau, 2004). Simply put, while broad searches help actors refine general questions, deep searches answer specific questions.

Second, Hertzum and Simonsen (2019) distinguish between search tasks performed be healthcare professionals in *uncertain situations* and equivocal or *ambiguous situations* inside emergency departments. Some search tasks, such as patient triage, often occur in uncertain situations in which team members seek new information to answer well-defined questions, i.e., reduce uncertainty. In contrast, in ambiguous situations, such as when diagnosing a rare disease, teams must first define the situation and information needs by reviewing existing information and sharing differing interpretations. Consequently, uncertain situations involve forward-looking searches guided by known questions, whereas ambiguous situations require information gathering that supports sensemaking and coordination to define questions for subsequent searches (Pirolli & Card, 2005).

Together, these concepts offer insight into the evolving information seeking tasks of emergency communications. Typically, call taking is highly structured around procedures for uncertain situations: telecommunicators ask 911 callers incident-specific "where", "what", and "who" questions and relay their answers to emergency responders (Kropczynski et al., 2018). However, when a 911 caller fails to provide requested information, communication specialists using NG911 sources stand to conduct deep searches for missing information that can reduce uncertainty during an emergency (Grace & Potts, 2022). Additionally, mass emergencies reported by numerous involved and non-involved 911 callers can create ambiguous situations in which telecommunicators must determine the nature of the incident so they can then follow procedures for addressing "where," "what," and "who" information needs. Here broad searches across numerous 911 calls and supplemental NG911 sources are likely necessary to make sense of the emergency so that telecommunicators can refine information needs and perform (deep) search tasks required during the response.

Teamwork and Information Seeking

In emergency communications, CIS can involve call takers, dispatchers, communications specialists, and first responders who work together to accomplish (inter-)organizational emergency dispatch and response objectives. Such work groups or teams have been conceptualized in different ways (Kozlowski & Bell, 2013), but are commonly understood as consisting of two or more people who perform interdependent tasks in pursuit of a common goal (Baker et al., 2006). Additionally, studies distinguish between two types of teams: *Co-acting groups* involve members who work in parallel and independently to contribute aggregate outputs, while members of *collaborative teams* perform interdependent tasks that contribute to synthetic outputs (Hackman & O'Connor,

2004). Although both accomplish organizational work objectives, they differ in the interdependence and required coordination of work tasks (i.e., loosely coupled vs tightly coupled) and the nature of their collective outputs.

Factors related to team performance and effectiveness have been frequently studied (Salas & Rosen, 2008), especially in high-reliability organizations like PSAPs (Baker et al., 2006). These include the knowledge, skills, and attitudes of team members, as well as factors such as composition, context, and organizational culture that influence how teams work together (Salas et al., 2015). Related to the triggers of CIS, studies of teamwork highlight individual cue recognition during situation assessment—information gathering and interpretation that informs situation awareness—as the precondition for adaptive team performance. That is, teams can change how they work together if team members recognize and communicate threats to the team's mission (Burke et al., 2006). In the following case study, we examine triggers recognized by telecommunicators during a 911 call surge that led to adaptive team performance.

Research Questions

To address gaps in the literature related to the triggers and tasks of CIS in emergency communications during mass emergencies, this paper addresses the following research questions:

1. What triggers CIS among telecommunicators during a 911 call surge?
2. What CIS tasks do telecommunicators perform during a 911 call surge?

RESEARCH DESIGN

This paper presents a case study of CIS during a 911 call surge that occurred when a man in Chandler, Arizona fired an assault rifle at police officers and evaded capture for nearly an hour in March 2020. The paper therefore follows the research design appropriate for an "in-depth inquiry into a specific and complex phenomenon (the 'case'), set within its real-world context" (Yin, 2013, p. 321). Below we describe the phenomenon of inquiry or "case" and describe the methods of data collection and analysis that resulted in the thick description of the relationship between the case and its context presented in the Results section (Yin, 2013).

Incident Summary

The "case" examined in this case study involves an incident that occurred at approximately 23:45 on March 23, 2020, when a man using an AR-15 rifle began firing into the air outside his apartment building in Chandler, Arizona, a city southeast of Phoenix (Curtis, 2020). Responding to a surge of 911 calls received by the Chandler Police Department Emergency Communications Center (hereafter the Chandler PSAP), police officers arrived at the scene near the intersection of E. Commonwealth Avenue and S. Hamilton Street. The suspect fired on the first police vehicle that entered the apartment parking lot, striking the passenger-side body and windshield of the vehicle.

The Chandler PSAP continued to gather reports from 911 callers and dispatch updates to the on-scene incident commander (IC) who coordinated an air and ground search for the shooter. Unable to quickly locate the suspect in the dark, the IC directed police officers to establish a perimeter and launch an uncrewed aerial vehicle (UAV). A police helicopter arrived and, based on reports from 911 callers, located the suspect with its searchlight around 500 meters east from the apartment complex. At approximately 00:45, the suspect surrendered to police after firing over 100 rounds from two weapons. No one was injured during the incident.

Data Collection and Analysis

In partnership with the Chandler PSAP, we gathered audio data for 911 calls (n=136) and the radio traffic that occurred between dispatchers and police units over the one-hour period of the incident. These data were transcribed, anonymized, and call metadata was recorded to describe the call time, approximate caller location, number of call taker questions and concurrent calls, and information extracted for each call. This research received institutional review board approval. Overall, the incident generated 136 calls lasting approximately 184 minutes (avg. = 64.8 seconds per call) during which call takers asked a total of 534 questions (avg. = 3.9 questions per call) which resulted in dialogues in which 19,883 words were spoken (avg. = 146.2 words per call).

Additionally, we examined and classified the quality and accuracy of information gathered from 911 callers. First, we classified 911 calls as *informative* if callers provided any "who" information related to the whereabouts and/or description of a potential suspect (Kropczynski et al., 2018). Calls were classified as *uninformative* if callers only reported hearing shots fired, i.e., "what," and their location, i.e., "where." These classifications align with general call handling standards published by the Association of Public-Safety Communications Officials (APCO, 2018),

and specific instructions for call handling during shots fired, assault, and active shooter incidents (IAED, 2012). As we describe in the results, informative (i.e., high quality) calls were rare: most people called 911 to report the sound of gunshots.

Second, we classified informative 911 calls as *accurate* if the "who" information reported the whereabouts and/or description of the correct suspect. Calls were classified as *inaccurate* if callers reported information about persons other than the correct suspect. Determining accuracy was possible using the radio communications of first responders and media reports about the incident (Curtis, 2020). In the former, police officers confirm or deny the accuracy of 911 information dispatched from the PSAP throughout the emergency response.

RESULTS

The following describes four stages—dispatch, surge, lull, and capture—of CIS performed by responders during the incident. Across these stages, telecommunicators shifted from working as a co-acting group to a collaborative team in response to the overload of information from 911 callers. At the same time, telecommunicators worked together with on-scene ground and aerial units to investigate questionable and imprecise information gathered from callers.

Dispatch (11:45-11-46 PM)

At approximately 11:45 PM, a call taker in the Chandler PSAP answers the first of 136 calls reporting gunshots near the intersection of East Commonwealth Avenue and North Hamilton Street:

> 911, where is your emergency?
>
> *Hi, it's on the crossroads of Commonwealth Avenue and Hamilton Street.*
>
> Do you need the police or paramedics there, ma'am?
>
> *We heard some shots and there's a man screaming.*
>
> How many shots did you hear?
>
> *Uh, probably I heard like 3 to 4.*
>
> Ok, you heard 3-4 gunshots and a man screaming?
>
> *Yes, there's a man still screaming. Oh my gosh. He's nearby, he's nearby.*
>
> He's near your house?
>
> *He's outside. He's outside of our home.*
>
> What do you see, ma'am? What do you hear?
>
> *He is on Commonwealth Avenue. We are in apartment [#].*
>
> Can you tell what he is wearing?
>
> *No, no, no, we can't. It's right behind us. We hear it really close.*
>
> Ok, just stay there. We have a lot of officers on the way…

Telecommunicators work as normal to answer seven more calls over the first minute of the incident. As in most PSAPs, telecommunicators work as a co-acting group by independently entering gathered information from 911 callers into a Computer-Aided Dispatch (CAD) system which a separate telecommunicator, the dispatcher, then radios to on-scene first responders.

Also as normal, the PSAP's call routing system assigns incoming 911 calls reporting gunfire to available telecommunicators who are responsible for answering each call within 20 seconds and gathering priority "where" and "what" information for dispatch within 60 seconds (APCO, 2018). To efficiently gather this information, telecommunicators follow a standardized question-and-answer script which, for reports of gunfire, includes questions about the description and precise location of the shooter. So, when Call 6 arrives 46 seconds after Call 1, it is routed to another telecommunicator who answers with the same questions:

> [Call taker] 911, where is your emergency?
>
> *[Caller] Yes, there is a gun shooting outside in my apartment complex.*
>
> Where do you live? Where do you live?

I live at 651 E. Commonwealth Avenue…

Ok, is it in your complex or nearby?

Yes. It is in my complex downstairs.

What unit do you live in?

I live in apartment [#]. It's like at apartment [#], I think.

And you think it's near apartment [#]?

Yes. I think it's the guy downstairs… he was banging on one of the cars and he was yelling and cussing and screaming and banging on the hood of the car like crazy.

Do you know what he looks like?

I'm not exactly sure. I was asleep and it woke me…

Are you hearing gunshots right now?

Yes.

Does it sound like it's directly downstairs from you?

It is. I know where he's at. He is right downstairs…

Can you tell me anything at all about his description, scruffy hair, beard? Anything? Dark or light clothing??

He has dark clothing on.

Could you tell if he had a gun in his hand like a handgun? Shotgun?

I didn't see the gun. I just know he was banging on the car.

Ok, you guys stay as safe as you can. I have more calls coming in, so I have to answer those but call if you hear anything else or if you know of anyone that gets hurt.

Ok.

Ok, we've got help on the way, ok?

Thank you.

Although the details are sparse—male, dark clothing, screaming—this call provides the only eyewitness account of the suspect out of 136 calls the PSAP will receive over the next hour. In contrast, and in response to the identical call handling script followed by call takers, most 911 callers provide redundant "where" and "what" information about the sound of gunfire at the apartment complex at 651 E. Commonwealth Avenue.

The CAD system aggregates incident-related information entered by call takers for the dispatcher to radio to police units in the area:

> Sound of shots heard in the area of Commonwealth and Hamilton… 3-4 shots heard then a male screaming. RP [reporting party] said they also heard tires screeching after the sound of shots was heard.

Police units in the area acknowledge the dispatch and begin radio communications while en route to the scene. "In the area and didn't hear anything," radios the nearest police officer who, seconds later, confirms "shots fired. Lots of shots going off."

After information from Call 6 is entered into CAD, the dispatcher radios police officers the update:

> We have somebody in unit [#] at 651 E..Commonwealth Ave. stating she thinks someone is near unit [#] shooting. This RP is positive. We have someone who is banging on a door near unit [#] prior to hearing the gunshots.

The first police car that enters the apartment complex comes under fire: "We're getting shot at, someone from the south just hit the vehicle." The dispatcher immediately drops a tone over the radio to report shots fired and multiple police units begin converging on the apartment complex, including the officer who assumes command of the response. The incident commander (IC) instructs arriving officers to put on helmets and body armor and, via the dispatcher, requests ground and aerial units, including a Phoenix Police Department helicopter and UAV that will launch from a patrol car near the scene.

After the first minute of the incident, telecommunicators in the PSAP have gathered redundant "where" and

"what" information from Calls 1-8, and the above "who" details from Call 6 (Figure 1). With police units at the apartment complex under fire and establishing a perimeter around the block, telecommunicators urgently need to identify and locate the shooter.

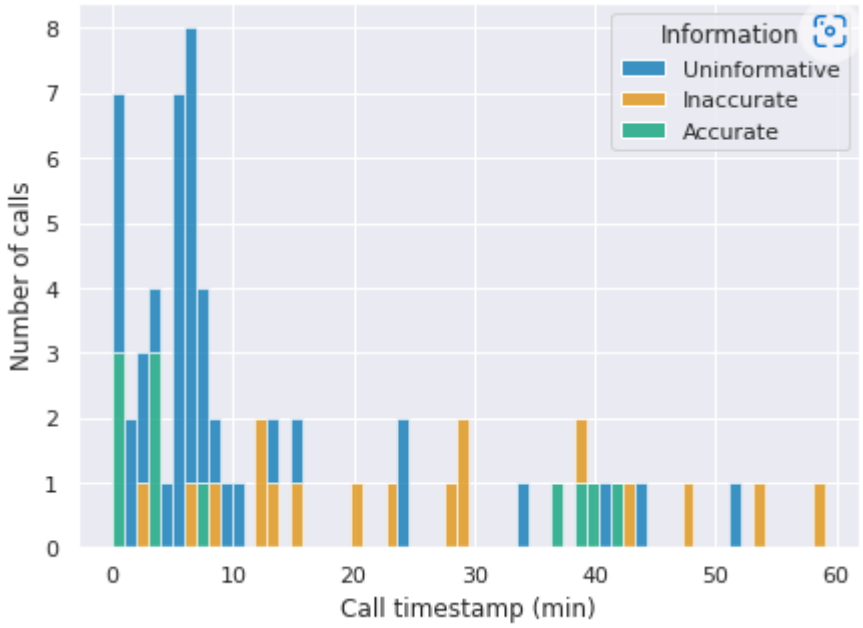

Figure 1. Information gathered from 911 calls received by the PSAP during the incident.

Surge (11:46-11:55 PM)

Over the next nine minutes, 66 incoming 911 calls overwhelm telecommunicators at the Chandler PSAP and overflow to PSAPs in the neighboring cities of Mesa and Phoenix. Inundated by callers reporting only the sound of gunfire (Figure 2), telecommunicators begin working as a collaborative team to efficiently gather reports from people who can see the shooter or possible victims. To do so, telecommunicators monitor CAD for information already gathered by telecommunicators working in the PSAP and adapt the call handling script to prioritize questions that address police officers' remaining information needs: the location and description of the suspect.

While continuing to answer calls on a first come, first served basis, call takers now immediately ask 911 callers if they can see the shooter. Call 15, answered at 11:47 PM, is illustrative:

> 911, where is your emergency?
>
> *Yes, there is, I believe, like twenty gunshots coming from around Folley Park off of Arizona [Avenue].*
>
> Commonwealth and Hamilton?
>
> *Yeah.*
>
> Ok, do you see anything ma'am or are you only hearing it?
>
> *No, I am hearing it and it's gunshots.*
>
> Ok, we are already there. Thank you so much.
>
> *Alright, thank you.*

When a telecommunicator adapts the call handling script in response to information gathered by another call taker, work inside the PSAP shifts from independent tasks performed by individual members of a co-acting group to interdependent tasks performed among telecommunicators working together as a collaborative team. Although call takers continue to answer calls on a first-come, first-served basis, seeking information from callers to address dynamic information needs represents a shift to CIS triggered by the 911 call surge.

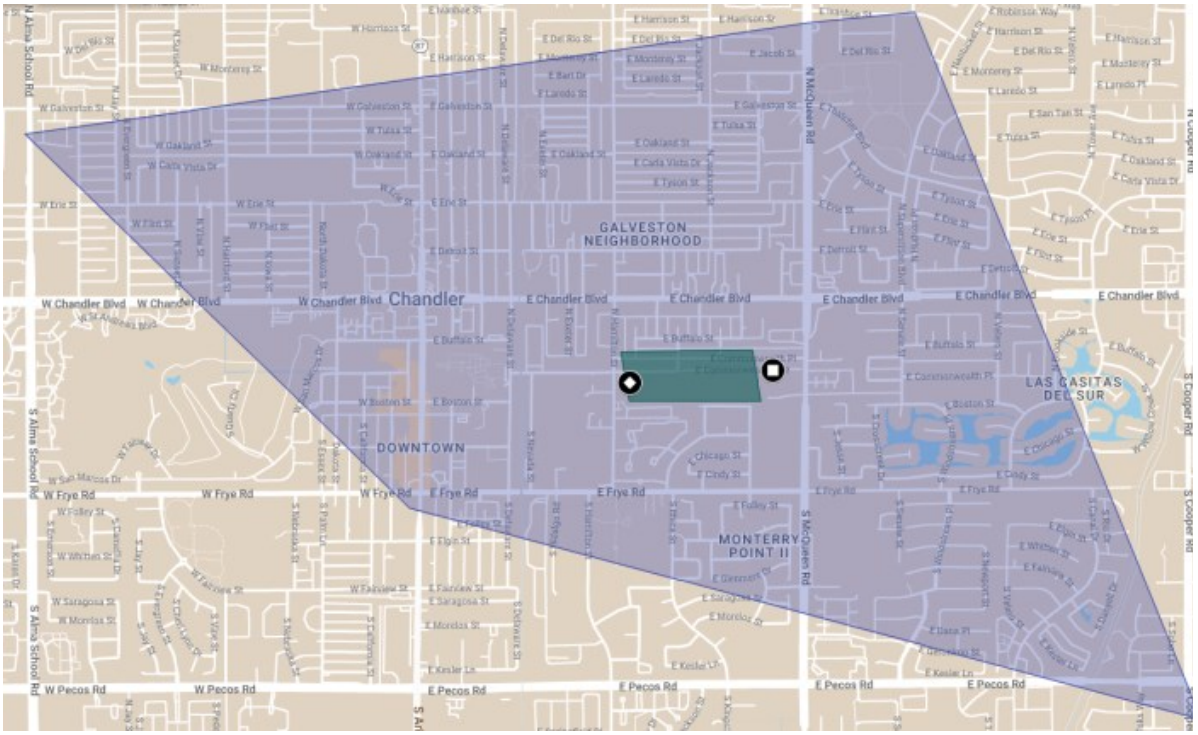

Figure 2. Locations of 911 callers reporting the sound of gunfire (blue) and details about the shooter (green). The diamond and square represent locations where the suspect started shooting and was captured, respectively.

Around 11:47 PM, three more calls arrive from the apartment complex, each reporting screaming and the sound of gunfire:

> 911, where is your emergency?
>
> *I am in Chandler.*
>
> Where do you live?
>
> *651 E. Commonwealth…*
>
> We have lots of help in the area, what are you hearing or seeing?
>
> *I don't know. I don't know what that is.*
>
> Ok, that is gunshots, ma'am. What apartment are you in?
>
> *Apartment [#].*
>
> Ok, is everyone accounted for in your apartment?
>
> *Yes. I cracked the door a little bit because I heard some screaming and then I heard a gunshot and then I kept the door shut…*

These are promptly dispatched as they are entered into CAD: "We had several people saying it was 651 E. Commonwealth… Unit [#]... Confirms suspect is reported in the southwest corner." However, as the dispatcher reiterates, "No one has a visual [description of the shooter]."

The IC directs the newly arrived UAV unit to launch and surveil the southwest corner of the apartment complex. "Drone is up. I'm over the target location," radios the UAV pilot, "Nothing seen so far." The helicopter also arrives and illuminates the rooftop of the apartment buildings as "He may have an elevated position." These searches fail to locate the suspect: "We are not seeing anything on the roof or the air conditioning," radios the helicopter observer. "I do have the windows on the second level but I'm not seeing any movement or heat signatures there." After ten minutes, the PSAP has now processed 74 calls, of which only 8 callers (11%) have provided any suspect information, and none have led to a confirmed description and location of the suspect.

Lull (11:55 PM-12:20 AM)

For a few seconds around 11:56 PM, call takers are no longer speaking with 911 callers for the first time since the start of the incident (Figure 1). The decrease in 911 call volume corresponds with a pause in gunfire. "There is a lull now," radios an officer north of the apartment complex, "No one has a visual." During this period, the Chandler PSAP receives fewer 911 calls (n=35) than during the preceding 10 minutes. However, while these calls are more informative, 23% (n=8) report locations of possible suspects, they are also less accurate. None of the 911 calls over the next 25 minutes lead to the suspects' identification or capture.

Since arriving on scene, the IC has been triaging ground and aerial search tasks based on the perceived accuracy of 911 callers' reports. Hearing the dispatch for Call 40, "[#] E. Commonwealth residents advising that someone is in their backyard… Someone might be in the shed," the IC sends two ground units to contain the residence and "work on a plan to clear it." With the helicopter now over the apartment complex, the IC also instructs the UAV pilot to move to the residence and support the search of the backyard. However, when the dispatch arrives for Call 59, "We also had a worker at [#] E. Fry and Hidalgo [Roads] hearing noises at his property." The IC declines to send units to the area. "Okay, Hidalgo is a little far away."

Around 11:57 PM, the IC begins receiving dispatches of new suspect locations reported by 911 callers (Table 1). The dispatches describe multiple suspects with different descriptions at imprecise locations. Call 97, for example, suggests the suspect is somewhere inside an 18-building apartment complex on South Elizabeth Way. As searching these locations requires allocating limited on-scene units, the IC continues to triage search tasks based on sparse details such as the time (i.e., latency) and location of the report, or indicators such as the sight of a weapon. However, despite searching multiple locations, responders fail to find the shooter during the lull in gunfire.

Time	Dispatcher	Incident Commander
11:57 PM	We have an RP at [#] E. Erie 64 hearing footsteps on the roof of trailer. (Call 81)	Still a little far away. Our officers are on scene where they are receiving fire.
12:00 AM	Male riding north on Exeter and believes he might be holding a weapon. (Call 92)	What was the time delay on that? That's gonna be outside the perimeter where we are at… I don't think that's gonna be the guy.
12:05 AM	We're receiving a report from [#] North Naco Way, someone pounding on the door there, not expecting someone and can't see who is outside. (Call 95)	2Paul17, your GPS is showing you're on McQueen, can you go over to that Naco address… 3Paul17, can you go over to the Naco address with 2Paul17.
12:08 AM	We have someone calling in now from Building [#], [#] S. Elizabeth Way, saying a man jumped the wall wearing black clothing and glasses. (Call 97)	If we have any non-essential personnel, I need them to move the perimeter to Fry and Kingston. Can we have the air unit check 250 S. Elizabeth Way… It's an entire complex you're lighting up right now."
12:13 AM	Same time as the lady from [#] S. Elizabeth Way, we had another caller saying a Hispanic male, dark blue shirt, tan shorts, black shoes running southbound past [#] S. Hamilton near Unit [#]. (Call 101)	Copy. 3Sam18, you're in that neighborhood, do you have eyes on anything running through [#] S. Hamilton?
12:14 AM	We have a homeowner at [#] S. Robbin stating that a subject ran past their home eastbound on Butler but couldn't provide a description. (Call 104)	Copy. 2Paul5, the suspect running southbound on Robbin toward Butler, he should come towards you if you can keep eyes up Kingston.
12:14 AM	We also had a worker at [#] E. Fry at Old Castle hearing noises at his property about 10 minutes ago. (Call 105)	Copy. [IC does not direct units to search the property].

Table 1. Radio communications from the dispatcher and incident commander (11:55 PM-12:20 AM)

Capture (12:20-12:45 AM)

The Chandler PSAP processes 27 more calls during the final 25 minutes of the incident. Of these calls, 10 (37%) are informative and 5 (19%) report accurate, albeit coarse-grained, locations of the suspect. Continuing to operate as a collaborative team, telecommunicators work together to identify the suspect's location from a second surge of 911 calls that allows the helicopter unit to investigate a location half a kilometer east of the apartment complex. Near 12:30 AM, the helicopter observer spots the suspect in an empty field southwest of the intersection of E.

Commonwealth Avenue and McQueen Road, and guides ground units to the location where they take the suspect into custody.

Around 12:21 PM, a new surge in 911 calls reports more gunfire, this time along the unpaved stretch of E. Commonwealth Avenue that forms an alley behind the row of homes that stretch past the Commonwealth Avenue apartment complex to McQueen Road. Working together, call takers continue to follow the modified call handling script to search for the suspect's location:

> Call taker: 911, where is your emergency?
>
> *Caller: There's gunshots happening right behind my house*
>
> Is it right at this minute or a little while ago?
>
> *Nope, right at this minute.*
>
> What is your address?
>
> *[#] East Boston Street. I have a huge empty field right behind my house.*
>
> [#] East Boston Street and Chandler? And how many did you say you heard?
>
> *I just heard six [gunshots] and there goes two more. There [gunshots in the background] —they keep coming. I hear the helicopter.*
>
> Don't go outside. Did you see anything other than just hearing it?
>
> *I didn't see anything. I mean I'm nine-months pregnant, so I'm hunkered down on the floor.*
>
> Ok, we just want everyone to be safe. We have officers that are still in the area. We are getting more reports of it as well.
>
> *Ok.*
>
> Ok, Thank you. Bye-bye. (Call 112; 12:24 AM)

This call is followed by three more calls also reporting renewed shooting "on Commonwealth in the back alley" (Call 118; 12:25 AM). Although this small surge in 911 calls provides coarse-grained location information, the multiple reports of active gunfire offer the most reliable information since the initial calls reporting the outbreak of shooting at the apartment complex.

As the IC receives these dispatches, units at the intersection of E. Commonwealth Place and McQueen Road also report shots fired near their location. The IC directs the helicopter crew to search this location and the observer spots the suspect "under the power lines just east of McQueen." Providing a series of instructions to nearby ground units, the observer helps them navigate to the location where they identify and take the suspect into custody. The incident has lasted nearly an hour and ends without casualties.

DISCUSSION

This case study describes collaborative information seeking (CIS) among telecommunicators and first responders during a surge of 911 calls received by a PSAP outside of Phoenix, Arizona. In view of the adoption of NG911 technologies that allow PSAPs to gather information from diverse sensor systems (Grace, 2021; Grace & Potts, 2022), the findings suggest that mass emergencies require telecommunicators and first responders to work as collaborative teams to perform broad and deep searches within complex information environments.

The findings of the case study compare with prior studies that find that CIS begins with triggers related to complex, time-critical information needs and the capabilities of teams performing information seeking tasks (Karunakaran et al., 2013; Reddy et al., 2008). Regarding the latter, the case study highlights the inaccessibility of supplemental NG911 sources among telecommunicators limited to answering 911 calls who, as a result, needed to collaborate with on-scene ground and aerial units to investigate tips reported by 911 callers.

However, in addition to these needs and capabilities, the case study identifies triggers of CIS that characterize the complex information environments:

- *Information overload*: Telecommunicators needed to work together to efficiently process the volume, velocity, and variety of incoming 911 calls.
- *Fragmented information*: Telecommunicators and first responders worked together to gather relevant information from numerous sources, including 911 callers and UAV and helicopter cameras.

- *Questionable information*: Telecommunicators needed to work with on-scene units to verify inconsistent and unconfirmed 911 caller reports of suspect locations.
- *Imprecise information*: Telecommunicators needed to work with on-scene units to locate the suspect within course-grained areas reported by 911 callers.

Given the needs and capabilities of responders, these triggers caused a shift from IIS to CIS among telecommunicators and first responders who began performing interdependent broad and deep search tasks.

Unsure of the description or location of the shooter(s), telecommunicators worked together to conduct a broad search for information that would reduce uncertainty in the situation. Whereas telecommunicators typically work as a co-acting group by performing independent search tasks (i.e., call taking), the call surge saw telecommunicators work as a collaborative team to improve the efficiency of the broad search required to identify the 25 (18%) of 136 callers who could help identify and locate the shooter. Telecommunicators collaborated by modifying their call taking scripts based on "where" and "what" information already gathered by other telecommunicators, to focus on "who" questions that could quickly determine whether subsequent callers saw the shooter or only heard the sound of gunfire. From these 25 callers, telecommunicators identified 15 suspect locations that reduced uncertainty by helping the Incident Commander (IC) to refine information needs: a set of locations that needed to be searched to identify the suspect.

To conduct deep searches to investigate these locations, telecommunicators identified and dispatched 15 suspect locations to the IC who, limited by time constraints and available assets, triaged, and assigned eight search tasks to on-scene patrol, UAV, and helicopter units. Seven of the follow-up searches failed to locate the suspect, but one saw the helicopter crew locate the shooter and direct ground units to his precise location. Over the hour-long response, telecommunicators and first responders worked as a collaborative team to conduct deep searches that reduced ambiguity by verifying caller's reports and acquiring precise information needed to apprehend the suspect.

Requirements for CIS and Command and Control

The case study shows that CIS in the Chandler PSAP, like most PSAPs in the United States, was limited to gathering information from 911 callers. At the time of the incident, the PSAP could not seek information from multiple, heterogenous sources now accessible through NG911 technologies. Consequently, the case study suggests requirements for supporting CIS and command and control in PSAPs across the US and Europe that are now incorporating NG911/112 systems within their operations (Lumbreras, 2022).

Support broad and deep searches across multiple, heterogenous sources

The adoption of NG911 technologies allows PSAPs to seek information from multiple, heterogenous sources, including traffic and building cameras, gunshot detectors and other sensors, various databases, and open sources such as social media (Grace, 2021; Grace & Potts, 2021). This case study suggests that conducting broad and deep searches across these sources will also require new coordination mechanisms that support CIS among telecommunicators.

First, the case study suggests opportunities for dynamic call-handling protocols that telecommunicators adapt to address evolving information needs. When one telecommunicator gathers information satisfying a need (i.e., "what"), other telecommunicators can question callers to efficiently address remaining needs (i.e., "who). In addition to changes in organizational procedures that allow for task-self assignment (Zhang & Sarcevic, 2018), decision-support systems such as ProQA—software that guides call takers through questions-and-answer scripts—can support CIS by building dynamic protocols that help telecommunicators focus on time-critical information needs during mass emergencies.

Second, AI applications can support telecommunicators using NG911 tools (e.g., communications specialists) to search multiple sources to address broad, unrefined information needs. For instance, to identify the location of an unknown suspect, telecommunicators might search video data from area cameras for the presence of a "weapon," "shooting," or other semantic queries that can retrieve relevant instances over a specified time interval. Similarly, to identify the location of a specific suspect, telecommunicators might search the same video data for persons matching a description reported by a 911 caller. Future work in this direction, such as conducted in the beAWARE project (Schenk, 2019), can provide PSAPs with capabilities to conduct broad and deep searches for information across multiple NG911 sources during emergencies.

Coordinate and triage search tasks within emergency response systems

The case study also highlights the need to coordinate search tasks among intra- and inter-organizational teams of responders. Again, the adoption of NG911 technologies stands to emphasize this need as it creates opportunities for telecommunicators and first responders to perform interdependent broad and deep search tasks during an emergency response. In particular, the case study suggests that triaging information seeking tasks is critical for the effective coordination of information seeking within and across teams of responders.

First, PSAPs might triage 911 calls by routing calls originating from locations near an incident to the primary PSAP while routing calls from remote locations to PSAPs with lower call volumes. When a mass emergency generates a 911 call surge, the first-come, first-served call routing model results in calls overflowing from one PSAP to another. In these situations, 911 calls might be temporarily triaged by routing calls relevant to the emergency to the responsible PSAP, while routing all other calls to neighboring PSAPs. Relevance might be predicted by call location: the case study shows that callers who reported suspect-related information were geographically proximate to the site of the incident (Figure 2). Temporarily routing 911 calls based on proximity would allow one PSAP to concentrate on the emergency response while neighboring PSAPs process simultaneous, but unrelated, calls for service.

Second, the case study suggests the challenge of coordinating deep search tasks among telecommunicators inside a PSAP and first responders at the scene of an emergency. This coordination may take several forms based on the roles defined for telecommunicators. PSAPs can make communications specialists responsible for using NG911 technologies to gather supplemental information alongside call takers and dispatchers or ask call takers to use these tools when 911 callers fail to provide requested information. In either case, however, triaging time-critical search tasks among telecommunicators will become necessary when a surge of 911 callers report numerous unverified and imprecise events, suspects, or victims.

Lastly, the case study suggests the challenge of coordinating inter-organizational search tasks among telecommunicators and first responders. In the case study, the IC prioritized locations reported by 911 callers for search by ground and aerial units. As NG911 technologies will allow PSAPs to support on-scene responders by monitoring areas using camera systems or searching for personal identifying information using various databases and open sources (Grace & Potts, 2022), an IC will have more capabilities but also greater demands for coordinating search tasks among telecommunicators and on-scene responders.

In this regard, exercises can help train teams of responders to perform and coordinate broad and deep search tasks. These exercises also provide opportunity to deploy and evaluate various material and immaterial coordination mechanisms supporting CIS (Zhang & Sarcevic, 2018), including common operational picture tools such as CAD that can help telecommunicators and ICs triage broad and deep search tasks (Borglund, 2017). Such exercises require careful logistical and operational planning and should leverage frameworks for evaluating performance and reporting recommendations that promote organizational learning (Nordström & Johansson, 2019). However, future work is required to define key performance indicators and other evaluation criteria for assessing the breadth, depth, and completeness of information collaboratively gathered by cross-functional teams of responders working with remote sensor systems such as UAVs.

CONCLUSION

This case study examines CIS during a 911 call surge generated when a man fired an assault rifle at police officers and evaded capture over a one-hour period. Overwhelmed by questionable and imprecise reports from 911 callers, telecommunicators and on-scene responders conducted broad and deep searches to locate the shooter. While broad searches improved the scope of information gathering by identifying multiple, albeit questionable and imprecise, reports of the suspect's location, deep searches improved the quality of information gathering by investigating 911 callers' reports using UAV, helicopter, and patrol units. These findings suggest requirements for supporting CIS in PSAPs that are incorporating NG911 systems within their operations.

ACKNOWLEDGMENTS

This research was supported by the National Science Foundation under grant no. 2129126.

REFERENCES

APCO. (2018). *Public Safety Communications Incident Handling Process [1.113.1-2018]*.

Baker, D. P., Day, R., & Salas, E. (2006). Teamwork as an Essential Component of High-Reliability Organizations. *Health Services Research*, *41*(4p2), 1576–1598. https://doi.org/10.1111/J.1475-6773.2006.00566.X

Borglund, E. A. M. (2017). The Role of Artefacts in Creating a Common Operational Picture During Large Crises. *Proceedings of the 14th ISCRAM Conference*, 191–203.

Buck, B. H., Starkman, S., Eckstein, M., Kidwell, C. S., Haines, J., Huang, R., Colby, D., & Saver, J. L. (2009). Dispatcher recognition of stroke using the national academy medical priority dispatch system. *Stroke*, *40*(6), 2027–2030. https://doi.org/10.1161/STROKEAHA.108.545574

Burke, C. S., Stagl, K. C., Salas, E., Pierce, L., & Kendall, D. (2006). Understanding team adaptation: A conceptual analysis and model. *Journal of Applied Psychology*, *91*(6), 1189–1207. https://doi.org/10.1037/0021-9010.91.6.1189

Curtis, C. (2020, March 24). Zachary Victor Rhodes arrested after shooting at police in Chandler for an hour. *The Arizona Republic*. https://eu.azcentral.com/story/news/local/chandler-breaking/2020/03/24/zachary-victor-rhodes-arrested-after-shooting-police-chandler-hour/2910998001/

Ellis, D., & Haugan, M. (1997). Modelling the information seeking patterns of engineers and research scientists in an industrial environment. *Journal of Documentation*, *53*(4), 384–403. https://doi.org/10.1108/EUM0000000007204/FULL/PDF

Gardner, M., & McEntire, D. A. (2003). The community dispatch center: An assessment of a neglected component of emergency management. *Journal of Emergency Management*, *1*(1), 49. https://doi.org/10.5055/jem.2003.0009

Gillooly, J. W. (2021). "Lights and Sirens": Variation in 911 Call-Taker Risk Appraisal and its Effects on Police Officer Perceptions at the Scene. *Journal of Policy Analysis and Management*. https://doi.org/10.1002/PAM.22369

Gillooly, J. W., Clayman, S., Thacher, D., Friedman, B., Ralph, A., Morenoff, J., Raymond, G., & Whitehead, K. (2020). How 911 callers and call-takers impact police encounters with the public: The case of the Henry Louis Gates Jr. arrest. *Criminology & Public Policy*, *19*(3), 787–804. https://doi.org/10.1111/1745-9133.12508

Grace, R. (2021). Overcoming barriers to social media use through multisensor integration in emergency management systems. *International Journal of Disaster Risk Reduction*, *66*, 102636. https://doi.org/10.1016/J.IJDRR.2021.102636

Grace, R., & Potts, M. (2022). Opportunities for Multisensor Integration in Public-Safety Answering Points. *Proceedings of the 19th ISCRAM Conference*, 895–904.

Grace, R., & Sinor, S. (2021). How to text 911: A content analysis of text-to-911 public education information. *The 39th ACM International Conference on Design of Communication*, 135–141. https://doi.org/10.1145/3472714.3473633

Hackman, J. R., & O'Connor, M. (2004). *What Makes for a Great Analytic Team? Individual vs. Team Approaches to Intelligence Analysis*. Intelligence Science Board, Office of the Director of Central Intelligence.

Hertzum, M., & Simonsen, J. (2019). How is professionals' information seeking shaped by workplace procedures? A study of healthcare clinicians. *Information Processing & Management*, *56*(3), 624–636. https://doi.org/10.1016/J.IPM.2019.01.001

IAED. (2012). *Special procedures briefing (PPDS v4.1a). Protocol 136 Active Assailant (Shooter)*.

Karunakaran, A., Reddy, M. C., & Spence, P. R. (2013). Toward a model of collaborative information behavior in organizations. *Journal of the American Society for Information Science and Technology*, *64*(12), 2437–2451. https://doi.org/10.1002/ASI.22943

Kozlowski, S. W. J., & Bell, B. S. (2013). Work groups and teams in organizations. In N. W. Schmitt, S. Highhouse, & I. B. Weiner (Eds.), *Handbook of psychology: Industrial and organizational psychology* (pp. 412–469). John Wiley & Sons, Inc.

Kropczynski, J., Grace, R., Coche, J., Obeysekare, E., Bénaben, F., Halse, S., Montarnal, A., & Tapia, A. (2018). Identifying Actionable Information on Social Media for Emergency Dispatch. In K. Stock & D. Bunker (Eds.), *Proceedings of ISCRAM Asia Pacific 2018* (pp. 1–11).

Kuhlthau, C. C. (2004). *Seeking meaning: A process approach to library and information services*. Libraries Unlimited.

Lum, C., Koper, C. S., Stoltz, M., Goodier, M., Johnson, W., Prince, H., & Wu, X. (2020). Constrained Gatekeepers of the Criminal Justice Footprint: A Systematic Social Observation Study of 9-1-1 Calltakers and Dispatchers. *Https://Doi.Org/10.1080/07418825.2020.1834604*, *37*(7), 1176–1198. https://doi.org/10.1080/07418825.2020.1834604

Lumbreras, C. (2022). *Next Generation 112*. EENA. https://eena.org/our-work/eena-special-focus/next-generation-112/

Miller, M. L., Merola, M. A., Opanashuk, L., Robins, C. J., Chancellor, A. S., & Craun, S. W. (2020). "911 What's Your Emergency?": Deception in 911 Homicide and Homicide Staged as Suicide Calls: *Https://Doi.Org/10.1177/1088767920948242*, *25*(3), 256–272. https://doi.org/10.1177/1088767920948242

Nordström, J., & Johansson, B. J. (2019). Inter-Organisational Learning – A Review of Knowledge Sharing in Post-Exercise Reports. *Proceedings of the 16th ISCRAM Conference*, 173–185.

Pirolli, P., & Card, S. (2005). The sensemaking process and leverage points for analyst technology as identified through cognitive task analysis. *Proceedings of International Conference on Intelligence Analysis*, 1–6.

Reddy, M. C., Jansen, B. J., & Krishnappa, R. (2008). The role of communication in collaborative information searching. *Proceedings of the American Society for Information Science and Technology*, *45*(1), 1–10. https://doi.org/10.1002/MEET.2008.1450450259

Reddy, M. C., Paul, S. A., Abraham, J., McNeese, M., DeFlitch, C., & Yen, J. (2009). Challenges to effective crisis management: Using information and communication technologies to coordinate emergency medical services and emergency department teams. *International Journal of Medical Informatics*, *78*(4), 259–269. https://doi.org/10.1016/j.ijmedinf.2008.08.003

Rivera, J. D. (2021). Factors Influencing Individual Disaster Preparedness Information Seeking Behavior: Analysis of US Households. *Natural Hazards Review*, *22*(4), 04021042. https://doi.org/10.1061/(ASCE)NH.1527-6996.0000510

Salas, E., & Rosen, M. A. (2008). On Teams, Teamwork, and Team Performance: Discoveries and Developments. *Human Factors*, *50*(3), 540–547. https://doi.org/10.1518/001872008X288457

Salas, E., Shuffler, M. L., Thayer, A. L., Bedwell, W. L., & Lazzara, E. H. (2015). Understanding and Improving Teamwork in Organizations: A Scientifically Based Practical Guide. *Human Resource Management*, *54*(4), 599–622. https://doi.org/10.1002/HRM.21628

Spangler, D., Edmark, L., Winblad, U., Colldén-Benneck, J., Borg, H., & Blomberg, H. (2020). Using trigger tools to identify triage errors by ambulance dispatch nurses in Sweden: an observational study. *BMJ Open*, *10*(3), e035004. https://doi.org/10.1136/BMJOPEN-2019-035004

Wilson, T. D. (2000). Human Information Behavior. *Informing Science*, *3*(2), 49–55. http://informationr.net/tdw/publ/papers/2000HIB.pdf

Yin, R. K. (2013). Validity and generalization in future case study evaluations. *Evaluation*, *19*(3), 321–332. https://doi.org/10.1177/1356389013497081

Zhang, Z., & Sarcevic, A. (2018). Coordination mechanisms for self-organized work in an emergency communication center. *Proceedings of the ACM on Human-Computer Interaction*, *2*(CSCW). https://doi.org/10.1145/3274468