The Design and Evaluation of an Emergency Call Taking Interface for Next Generation 9-1-1

Punyashlok Dash, Carman Neustaedter, and Carolyn Yip
School of Interactive Arts and Technology
Simon Fraser University
Surrey, BC, Canada
{pdash, carman, carolyn_yip}@sfu.ca

ABSTRACT
Emergency services in North America will soon be shifting towards supporting new forms of media including texting, video calling, and photo sharing capabilities. We conducted an exploratory study to understand how to design emergency call taking software to support such media with an emphasis on video calling and picture sharing. This involved the creation of paper prototype and digital versions of software, along with studies with call takers at both design phases. Our results show that call takers need ways to easily view, interact with, and share media with dispatchers in a lightweight manner. They also need to suggest camera work to call takers but may require guides on how and what media is best for the specific emergency situation. Options for receiving media from callers and the ability to quickly glance at instruction lists were thought to be valuable and time saving. History systems that show past events and media are valuable yet need to balance concerns over traumatic visuals.

Author Keywords
Emergency calling; call taker; video call; video conferencing.

CSS Concepts
• Human-centered computing → Empirical studies in HCI

INTRODUCTION
In North America, people experiencing an emergency situation call the number 9-1-1 and are connected with an emergency call center. They share information about their situation with a call taker and a dispatcher relays the information to a first responder (e.g., fire, police, ambulance). First responders attend to the scene. In the next few years, emergency calling services in Canada will move towards Next Generation 9-1-1 (NG911) and include support for text messaging, video calling and the sharing of photos or videos between callers and 9-1-1 call centers [8,9,31]. In turn, this will involve new ways of sharing information between 9-1-1 call takers, first responders and dispatchers.

Studies have looked at 9-1-1 video calling between callers and call-centers to understand the potential benefits and pitfalls of the technology [29,38]. Yet there is a gap when it comes to understanding how user interfaces should be designed for 9-1-1 takers and dispatchers such that they can properly view and act on information sent to them by 9-1-1 callers. We also do not know how software user interfaces should be designed for 9-1-1 call takers to direct the flow of a media-rich call and guide callers in capturing valuable video footage of a situation; this is called *camera work*.

In this paper, we focus on addressing this gap by exploring the design and evaluation of 9-1-1 call taking software. Our efforts are directed at how to design software that allows call takers to deal with small-scale emergencies like burglaries, house fires, car accidents, and medical emergencies. This contrasts emergency response in crisis situations (e.g., earthquake response, flooding) that are typically less frequent and often require large units of first responders over a prolonged period of time [29]. Our emphasis is on the future exchange of video call information and photos as they can offer rich visual information about a situation [29,38].

First, we created low fidelity paper prototypes of a 9-1-1 call talking system that supports media-based calling including video conferencing capabilities, picture sharing, and text messaging. Next, we worked with a local 9-1-1 call center to conduct a study with 9-1-1 call takers where they tried out the system for a range of small-scale emergency situations using mock calls and gave feedback on the design and its associated workflow. Following this, we performed changes to the user interface and created a medium-fidelity digital version of the prototype. We then, again, had 9-1-1 call takers work through a series of mock calls with the interface and provide feedback. The goal of both studies was to understand how 9-1-1 call takers interact with prototype software that allows them to receive video calls, images, and text messages as data, and how we should design such systems to best meet the workflow and information acquisition needs of call takers. We also wanted to understand how systems should be designed so that call takers and dispatchers could then share information they received from callers with first responders using the system.

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Our results show that call taking interfaces for NG911 need to allow call takers to easily move between accessing audio, video, and photos from calls. Call takers find value in interface components that let them suggest camera work to callers, but they require aids to know what suggestions should be made. Interactions with media in NG911 systems can be more time intensive than existing interfaces and so minimal interactions are needed to view and interact with media and share it with dispatchers. Call takers also find value in seeing past calls with their associated media, but interfaces need to balance information presentation with concerns around seeing media with traumatic visuals.

RELATED WORK

Emergency Call Centers

During an emergency when people call 9-1-1, a call taker asks them a series of questions [14,25,26] and records this information in a Computer-Aided Dispatch (CAD) system [29,42]. This information is then dispatched to a first responder [29]. The call taker relies on the information provided by the caller. Sometimes the information is not accurate, or it can be difficult to acquire [13,43]. 9-1-1 call takers face the challenge of acquiring information from callers who are panicked and sometimes people who have language barriers [2,14]. Call takers ask specific questions in a specific order to take control and structure calls as clearly as possible [29,38]. A study of 9-1-1 call takers showed how video calls would benefit call takers in assessing a situation [29]. We also know that during crisis management, first responders find strong benefits in seeing live video [24].

Some researchers have looked at the ways on-line photo sharing on social media can help in disaster management by first responders [44]. Similarly, text message archives and dedicated crisis-oriented Twitter accounts [36] have been found to provide timely updates on scenarios over time. During the response to an emergency, short videos from incident commanders have been found to provide important contextual information for other crewmembers [4]. While this research is valuable, the focus of our work is not on large-scale crisis management. Instead, we focus on small-scale emergency scenarios. We explore how media like photos and videos shot on an ordinary citizen's smartphone can be leveraged by 9-1-1 call takers.

Researchers have looked at ways of improving work practices in environments like ambulances [12]. They have also built technical solutions that help support better communication between fire-fighters while working [5]. Some have looked at providing a software-based solution for the collection and management of media data curated by third party volunteers [6]. Our work is similar in that we explore how everyday people can share videos of a scene with a 9-1-1 call taker. For improving efficiency in watching a large number of videos, various software solutions can be implemented that change playback speed based on the content of videos [16,22]. Our work builds on this literature.

Video Calling and Streaming

More generally, video calls using mobile devices between family and friends have been found to require careful camera work to sufficiently show the remote viewer a scene [19,28,32,33]. By camera work, we refer to changes in camera orientation to find appropriate camera angles and zoom levels to show an ideal view of the scene [17,20,34]. This is required for remote viewers like call takers. This act has been found to be difficult for people to do because sometimes it requires holding cameras at awkward angles [17,19,34]. To overcome these challenges, design work has focused on combining or providing multiple camera views [10,11,30,35] and exploring ways to ensure live video can be useful in emergency response work [6].

Next Generation Emergency Systems

Many researchers have envisioned a full-featured next-generation emergency system in the past that moves beyond just audio-based calling. However, most research work focuses on the technicality of implementing such a system or testing basic functionality [27,45], as opposed to our focus on user interface design. For example, research has explored the feasibility of implementing IP-based network hubs, so that they can be used for enabling audio and video calls to call takers [27]. Others have tried utilizing better location-based services to track callers' mobile phone positions and develop better tracing software for call takers [45]. Some researchers have looked at implementing ubiquitous systems like large displays to efficiently plan and create evacuation strategies in the case of fires [18]. Others have sought to implement better visual analytics tools for emergency call centers by understanding existing work practices and implementing user centered design approaches [15]. These works mostly discuss the software infrastructure that is needed to carry out a transition from existing 9-1-1 systems to futuristic ones. Some look at implementing specific functionalities that make operations better. However, most research work has not focused on understanding the requirements to build new call-taking interfaces that would enable call takers to leverage rich media during 9-1-1 calls. This is our focus where we explore call needs and workflows for video calling, photo sharing, and text messaging.

PAPER PROTOTYPE DESIGN

We began our explorations by brainstorming and iteratively creating paper prototypes of possible call taking interfaces for 9-1-1 call centers. The primary objective was to understand how to design a 9-1-1 call taking software interface such that call takers could leverage media-based calls that allowed them to conduct an audio or video-based call with callers, receive photos or video clips, and exchange text messages. Our ideas were based on an analysis of the related literature [29,38] along with our own past observations within 9-1-1 call centres and interviews with first responders, dispatchers, and call takers. Through our prototyping efforts, we explored different ways of laying out video call components, as well as ways to present photos shared by callers, and methods to then send this information

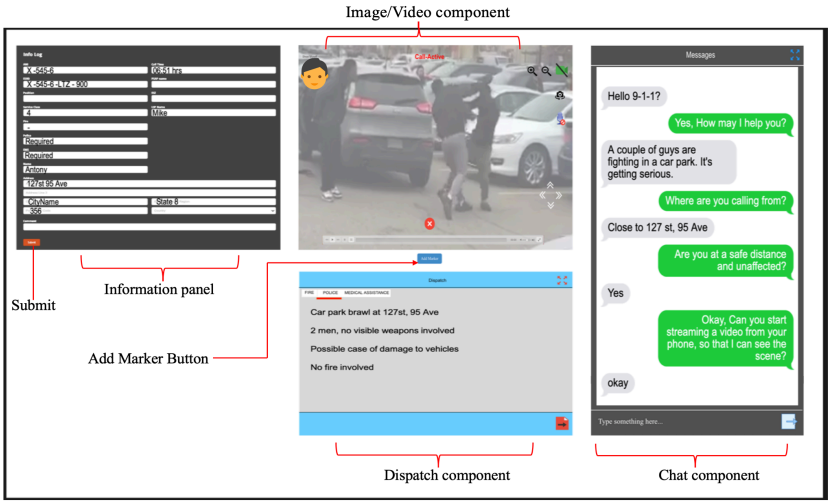

Figure 1. Paper Prototype Media Screen.

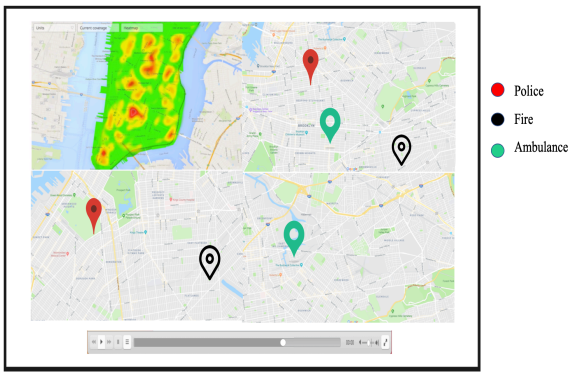

Figure 2. Map Screen.

on to dispatchers and, subsequently, first responders. We chose to create paper prototypes so that we could engage with 9-1-1 call takers in an early state of design and solicit their feedback.

Our design work led us to converge on the paper prototype shown in Figures 1 and 2. The prototype included interface components that can be printed on paper and used as components for Wizard of Oz interactions. Most call takers have been shown to use multiple monitors in call taking centers [29] and so we emulated this with our prototype. We printed interface components on two A3 sheets of paper and placed them on 27-inch monitors to emulate typical screen sizes. One of the paper sheets showed the proposed new call taking interface which we call the *Media Screen* (Figure 1). The other sheet emulated a mapping system that builds on their existing mapping software, described more shortly. We call this the *Map Screen* (Figure 2). Most 9-1-1 CAD systems use fairly generic white/grey screens and interface components. We purposefully chose a slightly more colorful design in hopes of shifting the thinking of call takers to be more future looking. The colors we chose were not necessarily meant to suggest an ideal color scheme.

The Media Screen included the essential CAD system components used by present day 9-1-1 call centers to enter and store data. This included name, address, age, cause of distress, phone number, approximate co-ordinates, service emergency category, etc. (Figure 1, left). Users use a keyboard and mouse to interact. In addition to this information, we included components to support futuristic call taking scenarios. We discuss these features next.

1. Video and Picture Viewing: The middle column of the Media Screen shows an audio/video component on the top of the screen (Figure 1, middle). When a call comes in to 9-1-1, the call taker clicks a 'phone' icon to answer it (not shown in Figure 1 since a call is already in progress). All calls begin as an audio-only call by default based on study results from prior research [38]. This reflects concerns that callers may not be comfortable immediately showing video and call takers want to assess the situation first before seeing video [29]. The call taker can push the green camera button in the top right corner of the component to ask the caller to switch to video mode. The caller receives a request and can choose to turn on video from their phone, if it is a mobile phone with camera support. Once a call taker decides to communicate through video and the caller engages the video mode, the UI looks like the one shown in Figure 1. The call taker can choose to not show their face and keep their camera off by clicking on the face icon present at the top-left of the video call component; again, this reflects prior research [29,38]. In Figure 1, the call taker has decided not to show his/her face to the caller and a face icon is shown in the top left of the Image/Video window. The call taker can switch off the caller's video feed by clicking on the cancel camera icon in the top right corner of the window. The system then switches to audio-only for communication. These features were suggested as a part of prior work since call takers may not want to always show their face to callers because of concerns about staying anonymous [29]. Call takers are also sometimes cautious about seeing gory video footage and were found to want to be in control of when video from the caller is shown [29].

Prior work has shown the need for call takers to direct the camera work of the caller [29]. We support this with magnifying glass icons in the top right corner of the Image/Video window that allow the call taker to send a suggestion to the caller to zoom in on their video feed. Arrow icons in the bottom right corner of the Image/Video window allow the call taker to suggest that the caller move their camera up, down, left, or right. For example, a mouse-click on the left arrow sends visual feedback to the caller's mobile phone. This visual feedback is overlaid on the caller's screen with an arrow suggesting that they move their phone camera in the direction indicated. A shift key + left arrow click creates visual feedback on the caller's phone to tilt their phone to the left. The amount of distance to be tilted or translated can be explained using verbal instructions from the call taker. The add marker button (Figure 1, middle) can be

pushed when the call taker wants to create timestamps in the video to mark important events. If timestamps are created, a photo gallery is shown under the video. If a caller sends in photos from the scene, these appear in the same gallery.

2. Information Sharing with First Responders: The Dispatch component located at the bottom of the audio/video window (Figure 1, bottom middle) is used to send useful information to the appropriate first responder, e.g., police, ambulance, or fire department. This component is very similar to what already exists in 9-1-1 CAD software. After entering data into boxes on the left of the screen, the call taker can select the appropriate data and copy and paste it into the dispatch window. Photos or timestamped videoclips are saved into a database for an ongoing case and are automatically available in the dispatch window. The call taker can choose to remove any photos they feel are not necessary for the case. The call taker can type in the dispatch window and add any information that they feel may be required by the first responders; this is presently standard practice. When the call taker clicks the red send icon (bottom right corner of Dispatch component), all the photos and textual comments are sent to the first responders.

3. Instant Messaging: The right most column shown in Figure 1 supports the ability for call takers to exchange text messages with 9-1-1 callers. There are situations where texting may be preferable, especially if a person is trying to connect with 9-1-1 in a covert manner. A call taker sees incoming messages assigned to them inside the messaging window and is then able to talk to the caller through text messages. This interface is similar to commercially available instant messaging system like Facebook Messenger or iMessage. All information is saved to a database automatically. Any information that the call taker finds important can be copied and pasted into the Dispatch component for review by first responders.

4. History and Mapping: While our primary design focus was on the main call taking window, we also explored the presentation of call history information as part of a map interface. This was secondary throughout our work however. Figure 2 shows the Map Screen. There are two main components, a map and slider. The map supports zoom features, which can be done using a mouse scroll-wheel or through keyboard interaction. The slider is interactive and can be moved left or right (e.g., "scrubbed") like timelines in most media players. The timeline goes from oldest to newest. Based on the scrub position, the map updates to show 9-1-1 call events that have occurred within a 24-hour time window of the selected time in the timeline. Events appear as pins located across the map based on their respective addresses. The call taker can click on a marker to open callup information.

STUDY 1 – PAPER PROTOTYPE SESSIONS

Next, we worked with a 9-1-1 call taking center in a major metropolitan city within Canada to explore our paper prototype design. This call center handled more than 8000 calls a day for the metropolitan area and various other regions within the province. Here we focused on understanding how our prototype could be used by 9-1-1 call takers to carry out their tasks; how call takers could use video/photo data; and, how they could help callers to capture media by guiding them to perform appropriate camera work. Across all of these topics, we were interested in learning how our user interface could be redesigned to improve workflows and what design elements were important to include and how. The study was approved by our research ethics board.

Participants

We conducted our study with 5 male and 4 female call takers from the call center. Participants' ages ranged from the early 20s to late 30s. Three of the nine participants had been recently recruited and had job experience of less than a year. The remaining participants had more than five years of experience each. Each participant, on average, dealt with around 120 calls in an eight-hour work shift. Of these 120 calls, roughly 30% translated to a ticket raise. A ticket raise is a proper emergency that needs to be stored in a call taker's CAD system and has to be attended to by emergency responders like police, medical staff or fire-fighters. All participants had some experience in making video calls in their personal lives using software like Skype.

Method

We started off by asking the participants basic background questions like age, experience as a 9-1-1 operator, number of calls they received in a day and the categories these calls fell into. Next, we had our participants go through six mock scenarios where they interacted with the paper prototype for each scenario. The scenarios were designed to test out a range of NG911 capabilities and cover a relatively broad set of circumstances. These scenarios were based on situations presented in the user-guide manual used by call-takers during a call. The guide presents the series of questions that call takers ask for different types of calls and covers a wide range of police, fire and medical emergencies. For each scenario, participants used the prototype and its new features in some way or another. First, we had the call takers read through a printed script for each scenario. This script described the conversation between the caller and a call taker. Next, participants would enact the scenario using the paper prototype where a researcher would manually change pieces of paper to update the screens, depending on what the participant did (e.g., touch for mouse clicks).

Scenario 1 – Break and Enter: A person sees an attempt at a break-in in a house across the street. The person engages in a 9-1-1 audio call and is asked to capture and share photos of the scene by the call taker.

Scenario 2 - Parking Lot Brawl: A person sees two people quarrel in a car parking lot and witnesses it escalate to a physical altercation. The person notifies 9-1-1 over text and is asked by the call taker to stream a video of the ongoing altercation. The call taker saves the video and bookmarks certain moments for future referencing.

Scenario 3 – Medical Assistance at Home: A person calls 9-1-1 about an unconscious grandparent. The person is asked by the call taker to check if the victim is still breathing and, upon negative affirmation, is asked to perform cardiopulmonary resuscitation (CPR). The call taker sends a short video clip of CPR to guide the caller. Medical assistance is then sent out.

Scenario 4 – Roadside Accident: A driver is in a car accident while taking a turn. He calls 9-1-1 for assistance. The operator asks him to check the health condition of his passenger and decides whether immediate assistance is required, like CPR. A backup ambulance is sent. In the meantime, the caller is asked to send photos of the situation and later is asked to stream a video. The call taker saves the photos and marks important scenes from the video.

Scenario 5 - Roadside Accident with Map: A caller calls in to report a car accident that she had witnessed a few blocks before. The caller is asked for a description of the vehicles. The operator uses the map's time slider to check if this is a redundant case. The operator finds out that it's a closed case and has already been dealt with. The caller is notified.

Scenario 6 – Fire: A caller calls in to report a fire that seemed to emit from a transmission line. The caller is asked to immediately stream a video so that the size of the fire can be gauged. Some camera work like zooming and titling is suggested by the 9-1-1 operator. Dispatch is sent to fire units and the call is ended.

We probed our participants about our prototype's design in relation to each scenario along with the scenario's workflow. We asked questions like, 'Do you think a video or photo sent as media in the scenario will be useful? Why/Why not?'; 'What are the things you want to see in the streamed video?'; 'How will this type of media affect your work?'; 'What features in the prototype do you think will be helpful for you? Why?'. 'What other functionalities do you want added?' We also asked participants for layout suggestions of the components, if they had any. Each session lasted about 50-60 minutes. Sessions were done individually in a separate room away from the call taking floor and in private so that each participant could openly express their opinion.

Data Collection and Analysis

We audio recorded all sessions and kept handwritten notes. We transcribed the audio recordings and conducted open and axial coding on our notes and the transcriptions. Open codes revealed issues with texting, work-flow impact, camera-control, likes and dislikes in viewing videos, and broad UI suggestions. Axial codes grouped open codes into categories such as information gain and video data. The aforementioned coding was done by a single researcher initially, and then reviewed with a second researcher. Categories were updated based on these conversations and the review. Lastly, we performed a selective coding pass which focused on drawing core themes out from our axial groups. This involved two researchers exploring and talking about the themes. We report our high-level themes in the results sections next. We show quotes from call taker participants with C#.

PAPER PROTOTYPE STUDY RESULTS

Video and Picture Viewing

Participants firmly believed that having visuals in the form of videos or images would improve the comprehensibility of an emergency situation with the hope of improved call taking efficiency, similar to prior work [29]. Yet it was clear from participants when working through the scenarios that video needed to be easily turned on or off because it was not always useful and depended on the situation. Thus, participants valued the controls we put in the interface to perform this function. They also really liked being able to select portions of the video clips and share them with dispatchers.

We introduced participants to the idea of being able to guide the remote caller to capture good media of the emergency situation. This involved conducting the appropriate camera work, including holding the phone properly so that videos and photos were captured at valuable angles. We also wanted to ensure that, apart from getting the basic angles correct, the call taker could ask the caller to move their phone or themselves in any direction. Our prototype allowed this information to be relayed to the caller's screen as a visual overlay, like augmented reality, where call takers could input what to show on callers' phones. Participants really valued this idea. They felt that in places which were crowded and had a lot of external noise, such a visual overlay would be useful. Participants felt that such a feature would be beneficial for older adults who may have limited experience using a mobile phone camera and for those who do not speak English. For example, they could look at on-screen visuals as opposed to trying to understand verbal instructions.

Yet, despite such a feature, it became clear that participants did not always know how to direct the camera work. That is, they didn't always know what to ask the caller to do with their camera and what would produce the best video or pictures for them to see. Our interface lacked features that might help them out with suggestions based on different types of emergencies. This is somewhat akin to the manual that call takers have which lists what questions to ask and in what order for a certain emergency. No such suggestions or manual were available for camera work. Participants were also concerned that, even if there was guidance or they knew what to tell the caller to do with their phone, the caller might not be able to do so because of the stress of the situation.

Interactions

The existing CAD system used at the 9-1-1 centre by our participants did not allow details from the various input textboxes to be easily added into the dispatch window, e.g., dragged and dropped or copy and pasted. Participants told us that most of the information had to be re-typed and they had to decide what was important for the first responders to know about. They felt this created a considerable amount of cognitive load. With our paper prototype, we allowed participants to copy text from any window and paste it in the

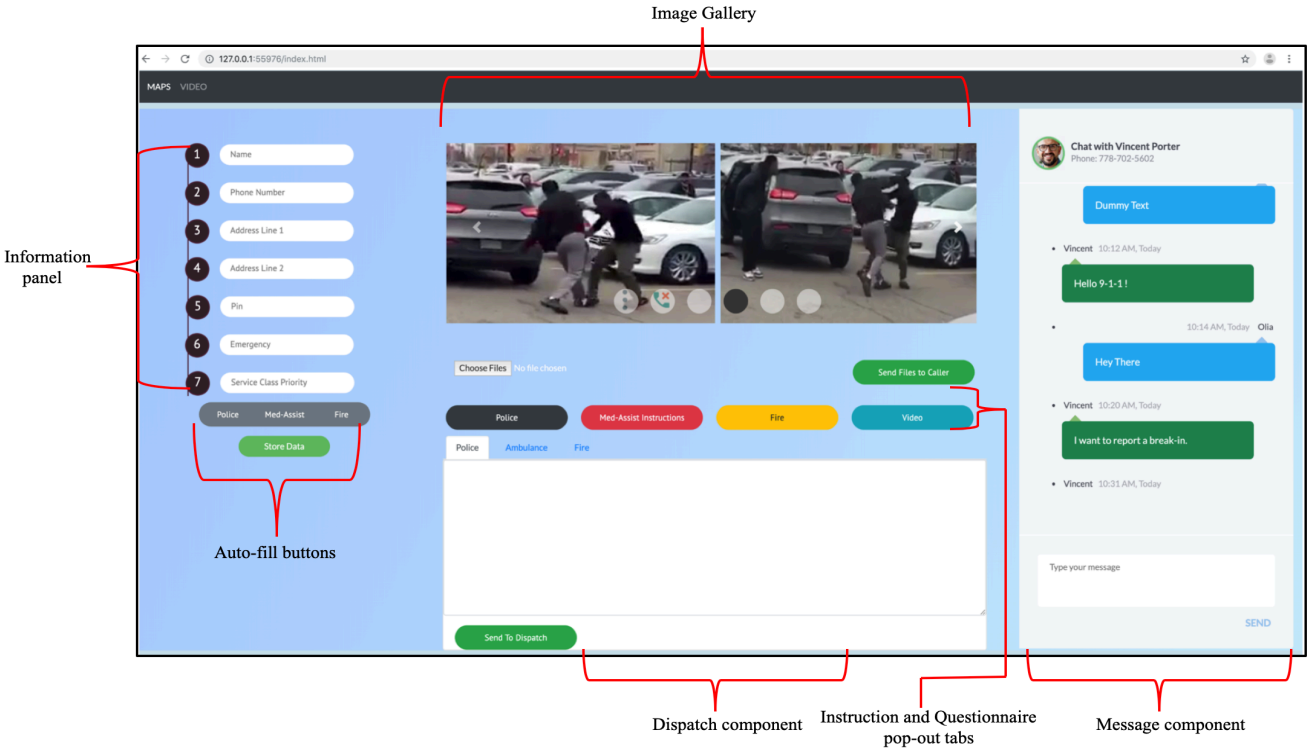

Figure 3. Digital Prototype Media Screen.

Figure 4. Video stream (top) and selected clips (bottom).

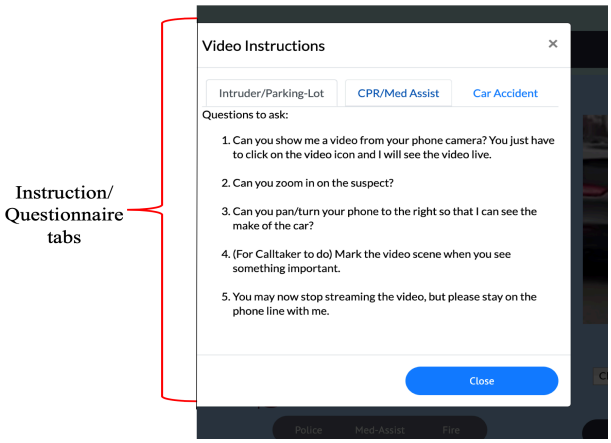

Figure 5. Video Instructions window.

dispatch window. Our system also allowed participants to select photos or video clips and add them to the dispatch window. Participants felt that this would help save time and better communicate the situation to dispatchers and first responders. They also thought easily adding video clips or images to the dispatch window would reduce back and forth conversations with dispatchers and first responders who may ask for clarifications on the points entered.

"So the dispatcher has the full context. Because sometimes with call takers and dispatchers what the call taker conveys to the dispatcher doesn't make sense because to us it makes sense in our heads, but when we type it it's nonsense. So if the dispatcher sees what we're seeing like a photo or video, then they can connect the dots a bit better."- C2

Most participants felt that new designs would lead to an increase in interaction time as the system was based on an information rich model where additional input devices like a mouse or other controllers would be heavily needed to interact with media, e.g., clicking on photos, scrubbing through video. It was clear from our scenarios that interactions would generally take a long time with the interface. Participants were mixed in whether they wanted to use touch/mouse interactions over keyboard interactions for working with media and what would be most efficient.

Instant Messaging

Texting between call takers and callers was mostly seen to be efficient in cases where the texter had to be surreptitious, like in the case of an abusive relationship. Based on the knowledge they had gained from a trial implementation of texting services at another 9-1-1 facility, participants felt that texting came with many problems. They said that people often used it to abuse 9-1-1 operators or send inappropriate content. Moreover, people with emergencies often texted abruptly and didn't respond fast enough which left 9-1-1 operators anticipating the worst, when in most cases the reality was not necessarily as serious. For these reasons, participants were cautious about the benefits of text messaging and preferred communication over audio or video, unless the caller was forced to communicate via text. In terms of our user interface, participants liked the basic layout and the fact that they could easily transfer text from the messaging window to the dispatch window.

"Text messaging wise, having the option to directly link it into the file would be helpful because right now we have to retype everything that comes." - C4

History and Mapping

Currently the existing CAD system only allowed 'open' cases to be seen. Participants liked the fact that they could go back in time with our paper prototype and check for incidents that were closed using the Map Screen. Participants talked about wanting to see additional details about each scene in the map view without having to open each individual case. Currently our design just showed balloons for each incident. Participants felt that seeing media from the cases directly on the map could make it easy to spot repeat calls. Yet they were cautious that showing video or images of an emergency directly on the map could easily present traumatic situations that they may not want to necessarily see when searching.

Some participants were concerned that when they adjusted the slider in the timeline, they may miss out on knowing what was inside or outside the selected time range. Participants also wanted additional filters, such as incident type and date.

"It's very interesting. This would be pretty beneficial to have the slider bar and be able to go back on the timeline. Yeah. It maybe would also be nice to have an option where you can type in exactly how many minutes you want to go or filter files through different category types." - C9

Call Taking Instructions

As mentioned, call centers usually have a manual which is color-coded, bookmarked, and provides extensive coverage of a wide variety of emergency scenarios and steps to take with each. With time, a call taker usually gains enough experience to memorize most scenarios such that they do not have to refer to the manual. A large number of participants suggested including an optional window that the call taker could refer to in order to see what questions they should ask for different scenarios, cross-referenced by category.

DIGITAL PROTOTYPE

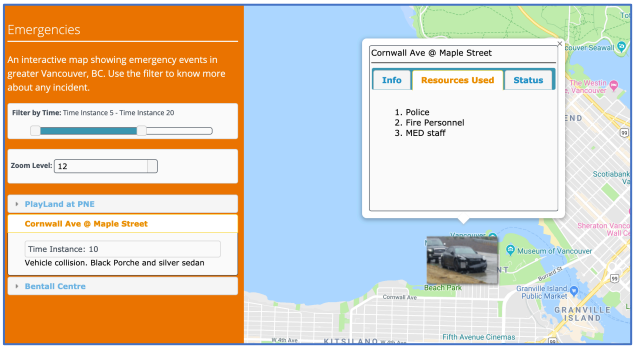

Figure 6. Digital Prototype Map Screen

Based on our study findings, we iterated our design and created a medium-fidelity prototype to test out our design ideas as an interactive user interface. We used HTML, CSS and JavaScript to create a front-end web application that showcased our design ideas. The prototype was created as a responsive web design that could scale to any layout. The system was of a medium fidelity in the sense that it did not integrate with the 9-1-1 call taking network and infrastructure. This was purposeful because we were focused on understanding user interface and not infrastructure needs. We did not create a user interface for the caller side as we were focused on the call taker's view/interactions. Our goal for the digital prototype was to probe call takers on some of our refined design ideas and gain feedback on the user interface when they could actually interact with it.

We kept the same main features in our interface. Figure 3 shows the digital prototype's Media Screen, which contains the same basic components as the paper prototype. Currently the figure shows images shared by a 9-1-1 caller as part of an Image Gallery. If the "Video" button is pushed, this view changes to show live video, shown in Figure 4. We made a custom video player that streams live video and provides the call taker with the ability to take snapshots of the video-stream. These snapshots are time stamped. Figure 4 shows two such snapshots taken at different timepoints. Based on the findings from our first study, we made the following main changes to the design:

1. Instructions: Like the paper prototype, the call taker could suggest directions for moving or zooming the phone and these would appear on the caller's phone as visual overlays. We also added an 'instructions' window (Figure 5). Clicking the "Police", "Med-Assist Instructions" or "Fire" button in the middle of the screen will open the instructions window, which lists a series of questions to ask callers for specific types of emergencies. To better support camera work, we added a "Video Instructions" tab. Clicking it shows steps to suggest to the caller to best capture video of a scene for a specific type of emergency.

2. Fast Interactions: To improve interaction speeds, we added keyboard shortcuts. For example, users can press 'tab' on their keyboard to easily move between data entry fields, or press 'spacebar' to pause the video feed, 'M' to save a

snapshot from a live video feed, etc. When a live video feed is open, call takers can press arrow keys on the keyboard to suggest directions for the caller to move their camera as a part of camera work. These appear as visual overlays on the caller's phone. Ctrl/Cmd + arrows can be pressed to suggest tilting the camera. Alternatively, users click areas of the video with their mouse to trigger visual overlays of arrows on the caller's phone.

3. Media and Filters for the Map: Figure 6 shows the Map Screen that ideally is opened on a separate computer display. We enhanced the features in the map interface by letting call takers filter cases shown on the map based on the type of emergency (fire, police, ambulance) and select date ranges. While participants in our first study were cautious about seeing visuals from each emergency on the map, we added this functionality to further probe call takers about the idea.

STUDY 2 - DIGITAL PROTOTYPE SESSIONS

We conducted our second study at the same call-centre. We focused on understanding how our digital prototype would be used by 9-1-1 call takers to carry out emergency calls. This included further exploring the design features and the changes we had made since our first prototype study. We also wanted to understand if call takers had different views of the user interface now that they could actually interact with it.

Participants

We interviewed eight call takers: three males and five females. Only one participant overlapped with the previous study. Participants' ages ranged from the early 20s to early 30s. Two of eight participants had job experience of less than a year. The remaining participants had more than five years of experience. Each participant, on average dealt, with around 140 calls during their eight-hour work shifts. Of these 140 calls, roughly 40% translated to a ticket raise.

Methods

We asked our participants background questions regarding their age and work experience as a call taker. Then we had participants work through the same mock scenarios that we had used in our first study. Participants were now shown the digital version of the system and asked to interact with the medium-fidelity prototype. For the scenarios, we showed them videos of each incident using example video clips that we had gathered from YouTube. These videos were played within our digital prototype and participants had to perform tasks based on the scenes they saw. After going through the scenarios, we interviewed them to find out their reactions to the prototype and interactions. We probed them with questions like: 'How do instruction menus help you in guiding camera work of a caller?', 'How helpful do you find the mechanism for suggesting better camerawork?', 'What do you think about the photo sharing with callers and how will it impact your work?' We also asked for suggested improvements to the user interface. Each session lasted about 40-45 minutes.

Data Collection and Analysis

We audio recorded the study sessions and, again, kept handwritten notes. We transcribed the audio for analysis purposes and then conducted open and axial coding. Open codes revealed issues around camera control, saving snapshots, uploading files, and slider control. Axial codes grouped open codes into categories such as workflow impact and media interaction. We then performed a selective coding pass that created high level themes, which we report in our result sections next. Like the first study, the analysis was initially done by one researcher and then reviewed and adjusted based on conversations with a second researcher. In the results, quotes are, again, listed with C#.

DIGITAL PROTOTYPE STUDY RESULTS

Video and Picture Viewing

Again, participants believed that videos, both live and recorded, were important as they could reveal more about an emergency than was possible with a verbal description. Participants highly valued that they could turn video on/off if they chose not to see the video being played live. Most participants felt that, beyond a certain point, visual information could be unnecessary and they would choose to ignore it to lessen traumatic experiences or cognitive overload. The visual arrow markings that would suggest camera work directions were seen as an important add-on. Participants valued the keyboard shortcuts to make it easier to interact with media and suggest camera work for the caller.

Like Study 1, participants liked being able to send photos to dispatchers. They also liked the added ability to capture and share snapshots of live videos as a form of personally curated content for dispatchers. Participants felt that this additional feature would reduce their reliance on photos sent in by callers alone. Participants thought that callers may simply not notice important information and these features would help the call taker add to the available information.

"You may be able to get those specific snapshots of what's going on and then later help the police with our investigation or court and stuff like that. So I think the ability to be able to take an actual picture of somebody's face or tattoo would be incredibly useful from a video." - C15.

Participants felt that snapshots could potentially save a lot of time for police officers and dispatchers in gaining information like suspect descriptions or licence plates.

History and Mapping

When it came to the Map screen, some participants liked the idea of being able to visually search faster with thumbnails of events shown on the screen, while some, again, expressed concerns over the possibility of gory images being shown. Some raised concerns that thumbnails could clutter the map if they had to see too many clustered together. A potential solution was given by a participant who wanted icons at a zoomed out level, but images at a deeper zoom level. A deeper zoom level would reduce the chance of overlap.

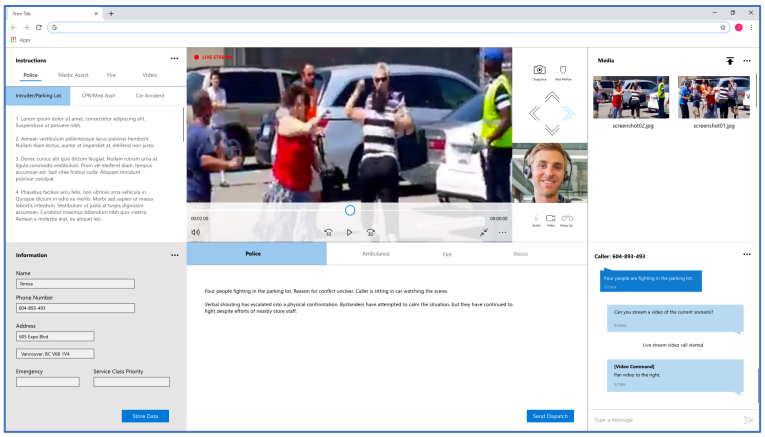

Figure 7. Updated UI of Digital Media Screen

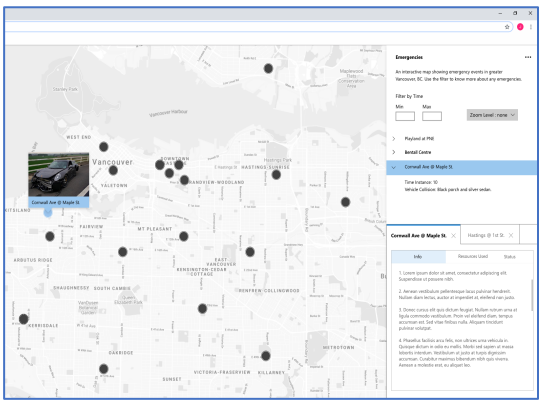

Figure 8. Updated Digital Map screen

Participants also wanted additional filters which could more deeply sort cases based on additional incident types like motor vehicle accidents, burglaries, etc. Thus, the categorization of police, fire, or ambulance that we provided was still not fine-grained enough.

Call Taking and Camera Work Instructions

We had participants use the instructions window (Figure 5) in our mock tasks. Most participants found the 'Video Instructions' on how to suggest appropriate camera work to be useful when dealing with camera work. They felt such a list would be helpful for both experienced and new employees in dealing with future 9-1-1 technologies. Participants explained that the instruction set for videography should be customized for different scenarios as the camera work required for a 'break and enter' would be different than that involved for a car accident, for example.

Layout

We probed participants about their preferred layout for the system. Two key areas of improvements emerged. First, participants did not think that the messaging window and media gallery did not need to be shown all of the time. They suggested allowing them to hide behind one another. The idea was to be able to flip between the gallery or the messaging window, as needed. Participants wanted to optimize screen space and enlarge the dispatch section since it received a lot of their attention. The second suggestion was to add a fourth tab to the dispatch window. This tab would be called the media tab and was meant for dispatchers exclusively. When call takers attached photos and video clips from their system for dispatchers, they wanted the dispatchers to be able to directly access photos or video clips from the media tab. This was to ensure that any video links or image thumbnails would not get lost in the massive amounts of text that were usually sent to dispatch. It was believed that having a dedicated media tab for dispatchers would make searching content easier.

FINAL UI DESIGN

Based on the findings from our second study, we refined the design further (Figures 7 and 8). This involved building on participants suggestions and adjusting the layout to utilize the available screen space better and improve the flow of interactions (Figure 7). We enlarged the dispatch window and added a media tab for dispatchers (Figure 7, bottom middle) to reflect participant comments. We also made it so the media gallery and messaging windows were stacked on top of each other (Figure 7, right) but could be collapsed to only show one. This would allow the visible item to display in the full height of the window. Events on the map (Figure 8) can be clicked on to reveal media and show details of the call. More filters were added for various types of emergencies.

DISCUSSION AND CONCLUSIONS

Our study points to a range of design possibilities and highlights some challenges that designers should keep in mind when building NG911 call taking systems. To be clear, we are not proposing that we have produced a best-case user interface for call taking. Instead, we have used our design explorations to draw out an understanding of what is important to consider when designing call taking interfaces.

Video and Picture Viewing

Our study reveals design opportunities for providing mechanisms to support instruction-giving from call takers to callers about how to use their phones to get the best possible footage; this extends prior work [29,38]. In our specific case this involved call takers interacting with the interface to provide visual markers on caller's phones. Our solution was liked by participants, yet it was also clear that interactions had to be very easy to perform. This included, for example, the addition of keyboard shortcuts. Other solutions are likely possible as well as long as they are able to allow call takers to direct camera work in simple ways without increasing cognitive load. Our study was exploratory in nature, thus, we did not actually test for cognitive load. This is an area for future study where one could assess the cognitive load of various interaction styles.

An important design opportunity lies in the way call takers can provide their own experienced and nuanced opinion on a case by being able to share their own version of images with dispatchers and first responders. In our case, call takers found the ability to take snapshots of a livestream/recorded

video crucial to future 9-1-1 call-taking operations. We learned that call takers do not want to solely rely on a caller's photos as callers may not share the best information.

It is also important for call takers to be able to control when callers are able to share photos and video [29]. Call takers need the ability to decide if they want to see a livestream or receive photos to ensure they are not unnecessarily overwhelmed or traumatized [29]. We supported this through buttons that would turn on/off such features and ask callers to begin/stop sharing such media, while not permitting media to simply 'pop-up' on-screen during a call. Again, there are likely other ways of supporting this need as well; the importance is that call takers remain in control of media sharing. Our study found ways of achieving this result.

Sharing with Dispatchers and First Response

Our work reveals design opportunities for improving the way files are shared between call takers, dispatchers and first responders in NG911 systems. In our study, we found that of vital importance was the ability to easily move content between different parts of the call taking interface, e.g., copying text, video, and photo data to the dispatch window. This was not previously found in the related literature. We supported this through 'copy and paste' keyboard shortcuts and drag and drop interactions. Other solutions may include buttons that could be pushed next to content where it is then automatically copy and pasted into a dispatch window. It was also very important for textual information to be visually separated from media that was shared in a dispatch window, e.g., additional tabs. Call takers share a lot of text information with first responders and searching for links/thumbnails of videos and photos can become quite cumbersome if they are shown together in a single view.

Call-Taking Instructions

Our study highlighted a key design opportunity in helping call takers in understanding how to best use NG911 technologies. Our proposed solution used instruction windows that listed steps for how call takers could direct camera work. This was valued by participants and is potentially a good first step. Prior work described that it was important for call takers to control 9-1-1 calls but did not illustrate how to do this with media in CAD systems [29]. Moving forward, it would be pertinent to explore additional instruction sets that can support a range of emergency situations. Of course, there is a chance that not all emergency situations will easily fit a particular pattern and it could be challenging to use a set of generic instructions. Alternative solutions may involve additional computational processing that looks for elements within a photo or video and suggests context-specific instructions on-the-fly. For example, if a caller calls in about an injured person, systems could detect if a person is in the camera view or not and make camera work suggestions to the caller. Similarly, systems could check for large amounts of sky or ground in a camera feed, which may not be useful and make suggestions for camera adjustments to the call taker. A decision could then be made to ask the caller to perform certain types of camera work.

History and Mapping

We learned that improved mapping features were valuable, but more secondary in importance when compared to methods to handle live calls. This is because the review of historical cases was a less frequent need. Most participants liked our proposed map interactions, yet we learned that additional information filters would be useful. Further design explorations could, for example, focus directly on mapping systems and such filters. There are also many opportunities to explore the visualization challenges that come with showing media from calls on maps. This includes more standard visualization issues and ideas that have been addressed by many researchers including visual clutter, detail-in-context views, zoom, etc. Specifically related to NG911, it is important to consider ways to reduce call takers in having to view traumatic media from past calls. Prior work found this for live 9-1-1 calls [29], not historical data.

Limitations and Future Work

Our study focused on a relatively small sample of call takers within each of our studies, however, as a whole, we worked with what we feel was a suitable number of call takers at the 9-1-1 call center. Our call taker interviews were also in-depth and time-intensive, and we found that data saturation occurred prior to the completion of all 17 participants. Our study was conducted specifically in Canada, though at a general level, our findings likely apply to 9-1-1 call-taking services in most Western countries where procedures are relatively similar. Nonetheless, future work should explore call taking and associated user interfaces in other regions of the world.

We specifically chose to present early designs to participants in order to gain feedback for improving our design ideas. This means that we do not know what reactions call takers might have if working with a fully-fledged NG911 interface similar to what we created. Our future work will involve exploring how a high-fidelity prototype would be used by call takers based on the design lessons from our current work. This will be complemented with further design work and field testing of technologies. Our work is also limited in that we did not create and test a user interface for 9-1-1 callers. This was purposeful so we could deeply explore the call taker user interface first. Future work should involve designing and testing a 9-1-1 caller app that allows people to call 9-1-1 and share texts, images and stream video. This work may provide additional design suggestions for call taking user interface as well.

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