Using a Mobile Multimedia System to Improve Information Exchange in EMS.

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Using a Mobile Multimedia System to Improve Information Exchange in Emergency Medical Services

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ABSTRACT
This research uses multiple research methodologies guided by Information Systems Design Theory (ISDT) to design and evaluate a mobile multimedia information system for Emergency Medical Services (EMS). We examined the impact of multimedia information for EMS information exchange and decision-making. A field study was designed and conducted in the Boise, Idaho region for three months to evaluate the system and validate ISDT design propositions. Findings from qualitative analysis illustrated the value of digital images and audio recordings for improving information exchange and augmenting medical decision-making. This paper describes the problem and justification, presents the system design, the pilot test methodology and findings and overall implications and future research directions.

Keywords (Required)
mHealth, emergency medical services, EMS mobile application, multimedia.

INTRODUCTION
Emergency Medical Services (EMS) provides pre-hospital emergency medical care and/or transportation to definitive patient care (i.e., a hospital). During a medical emergency, communication ensues between pre-hospital responders (paramedics) and emergency department (ED) staff prior to and during patient arriving to the hospital. This information exchange is crucial to the decision making process for healthcare practitioners and for achieving positive health outcomes for patients (Aase, Soyland, and Hansen, 2011). Prior research has identified significant challenges to efficient, accurate, and complete data exchange in the EMS context including: 1) limited time for paramedics to collect data on-scene, 2) a limited number of electronic tools for paramedics to collect value-added contextual data (Schooley, Hilton, Abed, Lee, and Horan, 2011), 3) often fragmented communications or lack of information exchange standards and practices (Aase et al, 2011), 4) significant reliance on the use of synchronous two-way voice radio communication technologies (Chu and Ganz, 2004; Xiao, Gagliano, LaMonte, Hu, Gaasch, Gunawadane, and Mackenzie, 2000), and 5) frequently missed, unreported, or incorrectly reported information to the ED. For example, in regards to the fifth point above, (Vaca, Anderson, Herrera, Patel, Silman, DeGuzman, Lahham, and Kohl, 2009) found that paramedics’ reporting of patient injury indicators for motor vehicle crashes (MVC), such as airbag deployment, steering wheel damage, and windshield impact, was less accurate than other types of incidents. These MVC variables are important indicators for patient injury severity, and can be used to promote more extensive diagnostics and medical evaluations if collected and communicated to the ED.

With the rapid advancement of commercial wireless telecommunications network technologies (e.g. 3G and 4G) and the emergence of high-capability Smartphones and mobile devices, many in industry and research are motivated to explore new approaches to collect and transmit voice and non-voice information (e.g. multimedia and biomedical signal information) between healthcare practitioners. The goal of this paper is to explore the potential impact of multimedia information (digital images, video and audio) delivered via a Smartphone mobile health application from pre-hospital emergency responders to the ED and trauma centers. This paper uses a design science approach to design, implement and evaluate a mobile multimedia EMS mHealth system that allows pre-hospital responders to capture and transmit digital images, video and digital audio about patients and related emergency incident information to the hospital prior to patient arrival. In this paper, we follow the ISDT approach to describe: 1) the system requirements, 2) the system design processes, 3) the field study design, 4) the evaluation framework, and 5) evaluation findings.
MHEALTH OVERVIEW

Mobile health, or mHealth, generally refers to the use of portable devices, mobile computing, and/or medical sensors in the health care context (Istepanian, Jovanov, and Zhang, 2004; Kyriacou, Pattichis, and Pattichis, 2009). Today, an increasing number of mHealth applications are presented in the literature. Some of these applications focus on achieving efficiencies in patient care from a managerial perspective such as for mobile e-prescription (Ikhu-Omoregbe 2008), mobile electronic patient record keeping (Chan 2000), applications that provide a cost-effective solution to improve patient adherence (Bakshi, Narasimhan, Li, Cherinh, Ray, and Macintyre, 2011), or public health surveillance and disease outbreak control (Li and Ray 2010; Li, Moore, Akter, Bleisten, and Ray, 2010). Many other mHealth applications focus on providing medical information connectivity via the use of biosensors and/or multimedia (i.e. digital images or video). For example, (Mougiakakou, Kouris, Iliopoulou, Vazeou, and Koutsouris, 2009) designed a mobile Smartphone monitoring system to help people with diabetes better self-manage their health by periodically collecting and storing blood glucose and feed/drink intake measurements through the use of biosensors. The Smartphone transmits the collected information to a server for analysis and visualization. Similar work in heart disease also exists, including electrocardiogram (ECG) monitoring (Sannino and De Pietro, 2011; Minutolo, Sannino, Esposito, and De Pietro, 2010; Song, 2011; Secerbegovic, Mujcic, Suljanovic, Nurkic, and Tasic, 2011), as well as a range of other consumer-oriented mHealth applications. While a variety of mHealth applications have recently become available to the marketplace for the EMS context, very few have been developed, tested, and reported in the research literature. These are described below.

MHEALTH AND MULTIMEDIA IN EMS

Several research papers in the literature demonstrate the potential role of mHealth applications to effectively communicate information about critical care patients between pre-hospital practitioners and emergency departments. For example, (Chu and Ganz, 2004) used an off-the-shelf mobile hardware platform and utilized commercially available 3G wireless networks to create a mobile teletrauma system that simultaneously transmits patient videos, medical images, and electrocardiogram signals to ED physicians. Their work was limited to the design of the system by stakeholders other than end-user requirements and the system was not field tested by practitioners. Furthermore, the impact of the system on EMS care practices and the perceived value of the system from medical provider perspectives were not investigated. The study discussed herein is aimed at extending mHealth research for EMS in these three regards. In terms of using multimedia for EMS, (Dickinson, O’Connor, and Krett, 1997) examined the impact of instant photography for decision making in motor vehicle crash (MVC) incidents. In their study, paramedics were provided with instant cameras and detailed instructions to 1) take two images for each MVC they responded to, and 2) place the images inside the ambulance for later collection and viewing. The photos were not shared with the ED for patient decision-making purposes. Rather, the pictures were viewed in a controlled environment well after the emergency incident occurred. Using a questionnaire, physician and ED staff were asked to rate the incident severity and to provide a list of planned patient management procedures before and after images were presented. Participants reported frequent changes in physician perceptions of crash severity levels. While this study reported important findings on the impact of MVC images on physician perceptions, the impact of these images for time-critical decision making (e.g. before or at patient arrival to ED) was not studied, nor was the use of a Smartphone for collecting and transmitting such information studied. The study described herein is positioned to address these research gaps and extend the work of these authors.

RESEARCH APPROACH AND METHODOLOGY

This study employed a multi-method research approach. First, prior work by the research team: 1) identified practitioner challenges to exchanging information across pre-hospital and hospital settings, 2) examined existing and alternative methods and tools for addressing data exchange solutions across three case studies(Schooley and Horan, 2007; Schooley, Horan, and Marich, 2009), 3) assessed practitioner requirements for an mHealth solution within the EMS context, and 4) constructed a prototype system in multiple iterations and feedback cycles with practitioners (Schooley et al., 2010; 2011). Through these research phases, both qualitative and quantitative data were collected and analyzed including interviews and observations with over 150 EMS practitioners across 4 states, quantitative performance data analysis on the use of EMS data systems, a California statewide survey (Schooley et al., 2010), and group interviews on EMS performance information. Details on the methodologies, findings, and design artifacts from these prior phases can be found in the references described above. The results of this prior research were utilized to inform and guide a new design iteration together with practitioners from the Boise, Idaho field study location (discussed below).

An information system design theory (ISDT) approach was then employed, based on the findings, to infer how an artifact might function and to identify the underlying theoretical drivers for developing a prototype system (Havner, March, Park, and
Using a Mobile Multimedia System to Improve Information Exchange

Ram, 2004; Walls, Widmeyer, and Sawy, 1992). Table 1 shows the ISDT framework used to formulate findings into design elements for the prototype. The framework specifies a design product and a design process.

<table>
<thead>
<tr>
<th>ISDT component</th>
<th>The proposed mobile multimedia system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design Product</td>
<td></td>
</tr>
<tr>
<td>Meta-requirements</td>
<td>To improve patient information exchange in EMS</td>
</tr>
<tr>
<td></td>
<td>To improve EMS decision making by ED practitioners</td>
</tr>
<tr>
<td>Meta-design</td>
<td>System shall allow paramedics to:</td>
</tr>
<tr>
<td></td>
<td>• Capture multimedia information (digital images, video and audio)</td>
</tr>
<tr>
<td></td>
<td>• Enter basic patient information (age, gender, name).</td>
</tr>
<tr>
<td></td>
<td>• Enter basic incident information (incident type, patient indicators)</td>
</tr>
<tr>
<td></td>
<td>System shall:</td>
</tr>
<tr>
<td></td>
<td>• Send information securely to ED personnel.</td>
</tr>
<tr>
<td></td>
<td>• Notify authorized ED staff when a new incident is received.</td>
</tr>
<tr>
<td></td>
<td>• Display information from mobile application to authorized ED staff.</td>
</tr>
<tr>
<td>Kernel theories</td>
<td>• Media richness theory</td>
</tr>
<tr>
<td></td>
<td>• Media synchronicity theory</td>
</tr>
<tr>
<td>Testable design product hypotheses</td>
<td>• Multimedia (images, audio and video) will be perceived by users to positively augment decision making</td>
</tr>
<tr>
<td>Design process</td>
<td></td>
</tr>
<tr>
<td>Design method</td>
<td>• Requirements elicitation by interviews, questionnaire and focus groups with end-users.</td>
</tr>
<tr>
<td></td>
<td>• Implementation with multiple iterations and in multiple feedback cycles with practitioners.</td>
</tr>
<tr>
<td>Kernel Theories</td>
<td>• Agile software development</td>
</tr>
<tr>
<td></td>
<td>• Wide Audience Requirements Engineering (WARE) method</td>
</tr>
<tr>
<td>Testable design process hypotheses</td>
<td>Paramedics and ED staff will utilize the mobile application and the multimedia data</td>
</tr>
</tbody>
</table>

Table 1: ISDT Framework

As shown above, this analysis was used to establish the meta-requirements, meta-design, kernel theories, and testable design product and process propositions. The meta-requirements in Table 1 illustrate the class of goals to which the theory applies. The meta-design describes the class of artifacts to meet the meta-requirements (Walls et al., 1992).

We applied several kernel theories for governing the product design and process including Media Richness Theory (MRT), (Daft and Lengel, 1986) and media synchronicity theory (MST) (Dennis, Fuller, and Valacich, 2008; Dennis, Valacich, Speier, and Morris, 1998). MRT states that the higher the level of ambiguity and uncertainty in a task, the richer the media needs to be. A second component of MRT is that the main goals of communication are to resolve ambiguity and reduce uncertainty. Thus, as information increases, uncertainty and equivocation (where there are multiple interpretations for available information) decrease. Ensuring that emergency responders and medical practitioners clearly understand a given situation from the media presented to them is key to the ability to provide quality emergency medical decision-making and subsequent services. As such, media richness theory was applied to this study to explore the suitability of multimedia information and the qualities needed in the media used in EMS to make quality medical decisions. Specifically, the appropriateness of the multimedia information, types of media (digital photos, digital voice, and video) sent via Smartphone, and the ability of the media to resolve ambiguity and reduce uncertainty in EMS decision-making were applied in the design and evaluated. Media synchronicity theory (MST) is an approach to media selection and task performance that also informed
this study. This theory focuses on the ability of people to work together at the same time with a common focus (synchronicity) when provided with the appropriate media (Dennis, Fuller, and Valacich, 2008; Dennis, Valacich, Speier, and Morris, 1998). This again is critical to EMS practitioners’ ability to effectively deliver medical care in emergency situations, as multiple agencies and people are often working together (e.g., hospitals, ambulance crews, first responders, medical practitioners). The theory posits that there are five intrinsic capabilities of media: 1) transmission velocity (e.g. how fast the messages or information can reach the destination), 2) parallelism (the number of transmissions that can be sent simultaneously), 3) symbol sets (the different ways the message can be encoded), 4) rehearsability (the ability to fine-tune a message before sending it), and 5) reprocessability (the ability to retrieve/reprocess a message for better understanding). As such, media synchronicity theory was applied to this project to understand the extent to which EMS practitioners can benefit from using the multimedia information and its capabilities. For example, it is important for our system to provide reprocessability so that information can be reprocessed by ED staff for better understanding.

Testable design product and process propositions are illustrated to test whether the meta-design satisfies the meta-requirements. Findings from qualitative and quantitative evaluation are presented in the evaluation section. In this manner, the research team was able to design, analyze, and improve the system in a structured manner that satisfied both design outcomes and the prescriptions and disciplines of this theory-based framework.

**PROTOTYPE DESIGN**

**System requirements**

As noted above, high-level system requirements and features were collected using multiple feedback cycles with EMS practitioners. Findings from prior research were synthesized and generalized into guiding principles, based on specified kernel theories, to meet the design product meta-requirements as follows:

- **The system must allow paramedics to capture multimedia information** through a user friendly interface similar to what can be experienced on the latest hand held device, multi-media, social networking, and location based applications. It must not take long to enter information. Responses from participants included: “I’ll take a picture of an accident with my own personal cell phone and show it when I get there [to the ED].” (Paramedic)

- **The system must transmit information in a timely manner** at or before the patient arrives to the ED. Responses included: “We have to find a way to get it [information] to the ED on time. There has to be some way to resolve this.” (ED Physician)

- **The system must have a visual capability** to display the information that was sent by paramedics to ED personnel. Responses included: “I want to have some way to see a picture and then, you know, let the medics in the field know what I think. Like, move in closer [with the camera] or ask a question [to a patient].” (Trauma Surgeon)

Several other support features were identified to embed within the software application. These included:

- Data must be transmitted in a secure manner between mobile devices and other system components.
- The mobile application must be available to use by paramedics independent of whether a cell tower signal is present or not. Data must be sent at the earliest available time.
- Data must be stored securely, encrypted in the mobile device and then deleted immediately after transmittal.
- The system must allow drill-down on an incident to display multi-media details including a gallery of images, video, and digital audio files pertaining to a specific patient and incident.
- The system must notify the ED when a new incident is received.

Drawing from the requirements above, the system architecture is described below.

**System Architecture**

The artifact was developed utilizing a range of current and emerging concepts and technologies including web services, encryption, and multimedia mobile applications. The system has three primary components: 1) a mobile Smartphone application, 2) middleware component, and 3) an ED web application.
The mobile application was developed for paramedics to use at emergency sites using the Java programming language on the Google Android operating system. The application enables paramedics to collect data for an incident and patient, take a picture of the patient and/or scene, record digital audio notes, and capture video for the incident.

The middleware component facilitates data integration between devices and interfaces. It provides security capabilities such as authorization and authentication when transmitting data to and from devices and interfaces. It also provides administrative features, such as user, device, identification, and notification management. The middleware was implemented using an open-source enterprise application server (i.e., Glassfish).

The ED Application displays the collected incident and patient information. Detailed incident information, including the multimedia files can also be displayed. The system architecture is illustrated in Figure 1 above.

**EVALUATION FRAMEWORK**

**Evaluation design**

To evaluate the artifact and to understand the impact of multimedia in medical decisions, the research team conducted a three month pilot test in the Boise, Idaho region inclusive of the following participating organizations: Ada County Paramedics, Canyon County Paramedics, St. Alphonsus Boise hospital, St. Alphonsus Nampa hospital, St. Alphonsus Eagle hospital, St. Luke’s Boise hospital, St. Luke’s Meridian hospital, and West Valley Medical Center. The pilot started on July 17 and 18 with visits by researchers to each of the Boise hospitals. The pilot ended on October 31, 2011. For the pilot, each medic unit at each ambulance agency was equipped with one Motorola Droid Smartphone activated on the Verizon 3G network. User names and passwords were created and distributed to each paramedic and to emergency department managers/directors to provide access to the web application in each Emergency Department. Training occurred via video conference and in-person at each ambulance agency and hospital. Phone and email support were offered throughout the duration of the pilot. Software bug fixes, general system administration, development of new features, security monitoring, technical assistance and problem solving occurred throughout the pilot by the research team. Paramedics and nurses alike were not required to use the system.
at any time. Rather, they were invited to test it and provide candid feedback to the research team. All users were asked to stop using the system at any time they felt that the system interfered with patient care.

**Pilot Evaluation Data Collection**

At the conclusion of the pilot, field visits were made to each participating organization. Qualitative data was collected through a series of focus groups and semi-structured interviews with practitioners whom used the system at least once during the pilot. Participants (i.e., paramedics, nurses, physicians, administrators, and IT representatives) were asked a series of questions in order to understand their perceptions about the utilization, usability, and impact of multimedia information on EMS communication processes and decision-making. Example questions included:

- How was multimedia information used within your regular work practices?
- How did using the multimedia information affect the decisions you made?
- How did using multimedia information impact routine EMS tasks?
- How do you believe using the Smartphone application impacted your day-to-day work?

A summary of focus group and semi-structured interview sessions is shown in table 2.

<table>
<thead>
<tr>
<th>Methods</th>
<th>Description</th>
<th>Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group Interviews</td>
<td>A total of two group interview sessions with pre-hospital EMS practitioners</td>
<td>22 – Paramedics, 2 Ambulance Agency Directors</td>
</tr>
<tr>
<td>Group Interviews</td>
<td>A total of three group interview sessions with hospital practitioners from all five hospitals</td>
<td>17 Nurses, hospital administrators, and 2 Physicians</td>
</tr>
<tr>
<td>Interview</td>
<td>One interview</td>
<td>IT representative</td>
</tr>
</tbody>
</table>

Table 2: A summary of focus groups and semi-structured interviews sessions

All interviews were recorded, transcribed, and uploaded into a qualitative data analysis tool (Atlas.ti). Data was aggregated, categorized in terms of media type and potential for impact on each of the design propositions stated in the ISDT for this study.

**FINDINGS**

The findings from the qualitative analysis are organized and described below in relation to the testable design propositions listed in table 1.

**Proposition 1: Paramedics and ED staff will utilize the mobile application and the multimedia data**

In terms of system use, paramedics transmitted over 800 records, 400 digital images, and 400 voice recordings during the three-month pilot test as shown in Table 3. Over half of all paramedics used the mobile application at least once, with approximately 25% of paramedics using the system at least 10 times. The consistency and frequency of use provided a solid experience base to increase the validity of research evaluation findings giving that paramedics voluntarily used the system and were not required to do so.

<table>
<thead>
<tr>
<th># of incidents</th>
<th># of attached images</th>
<th># of attached video files</th>
<th># of attached audio files</th>
</tr>
</thead>
<tbody>
<tr>
<td>801</td>
<td>437</td>
<td>25</td>
<td>446</td>
</tr>
</tbody>
</table>

Table 3: Usage Summary

**Proposition 2: Multimedia will be perceived by users to positively augment decision making**

The research team studied three types of multimedia: images, videos, and recorded audio. A description of each multimedia type used, and a summary of its perceived impact on augmenting decision making are discussed below:
Digital Images

Over 400 on-scene digital images were taken by paramedics to communicate various types of patient information. Findings illustrated that digital images were used most often to capture patient information in one of the following three categories:

1. Evaluating Motor Vehicle Crashes (MVC):

Paramedics took the following types of pictures: crash intrusion into the vehicle, damaged windshields, damages as seen from inside of the vehicle, unused seat-belt restraints and motorcycle helmets, the surrounding crash site (e.g., vehicle at a distance, vehicle close up, depth of ditches, and existence and length of skid marks). Several participants discussed how images were utilized throughout the pilot. For example, a charge nurse explained how pictures, taken effectively to portray the severity of an automobile crash, impacted thought processes and potentially led to augmented decision making:

“You’re sending me a picture of a car that’s totally demolished and you say you’re bringing in a patient that [lived.] You kinda stood up and get all the attention.” (Nurse)

2. Estimating the severity of trauma:

Paramedics also took pictures of various trauma injuries including: immobilized patients, severe wounds, and blood pools. These pictures were used to augment decision-making due to their ability to reveal the severity of a trauma situation. For example, one nurse explained:

“Seeing the picture, I’d be able to judge before I get there how severe the trauma is.” (Nurse)

One paramedic claimed that a physician used a picture, as a reference, to resolve the negotiation between paramedics and nurses in deciding the trauma severity level. He explained:

“Get it to the doc, and the doc actually sees it and says, ‘Yes this is significant. I don’t know what you were thinking? Of course it’s a (trauma) level two...’” (Paramedic)

3. Prompting for more extensive diagnostics and medical evaluation:

Many participants saw significant value in the use of effective pictures to raise the level of situational awareness and to better allocate needed resources at the hospital. For example, one charge nurse explained:

“If we saw a picture of a two feet intrusion onto the driver’s side or the front end is completely in like this, then they’re going to get more scans and they’re going to get more – you see everybody, but if you’ve got a background to go by you can say oh my gosh, this person really took it in the door or wherever and we need to be very cautious here.” (Nurse)

Other pictures taken included: Brain attack facial pictures, burns, EKG reports, paper run reports, and medication bottle descriptions. Most participants saw significant value in the use of effective pictures in combination with the mobile application. Most participants agreed that pictures can provide important insight into patient care if taken effectively. Many images did not provide value as per participant responses; and future studies should investigate the types and quantity of images that do provide value. Participants also agreed that using a Smartphone application to capture and send pictures provided a more secure, timely, and permanent way to communicate those pictures than using a standalone digital camera or personal Smartphone owned by a medic. While the overall use of the mobile Smartphone application and web interface in the ED was perceived to provide actionable value as described above, several participants also described perceived value of each of the other media types. Findings in this regard are discussed below.

Video Recording

Only 25 on-scene recorded videos were taken by paramedics to communicate different types of incidents and patient circumstances. According to a hospital IT manager, video can be effectively used to capture patient’s information in stroke situations. She explained:

“The videos…wouldn’t that be cool if we could tape like a stroke, because you could always go back and see where’s that change.” (IT manager)

However, compared to the digital images uses (over 400 images), the number of videos (25 videos) was relatively small. This was likely due to the fact that the time required for encrypting a video file on the mobile device and then sending it through a 3G network was far too extensive. According to one paramedic:

“The thing [recorded video] took 45 minutes and the files still hadn’t sent. I sent an email, or a couple of emails to you about the first couple of times that we used it.” (Paramedic)
As such, researchers found that the size of the video files and the strength of mobile network signals may limit the use of the video recording feature. Some of these challenges may be alleviated with a faster 4G network and/or a modified process for sending the video. Future studies should investigate such enhancements.

**Recorded Audio**

Paramedics recorded a large number of audio files (total of 446 audio files). The information recorded generally included the same (or similar) information typically reported over the radio to the receiving hospital including: patient demographics, patient condition, relevant details about the incident, and interventions and medications provided on-scene. Several paramedic participants explained that the system allowed them to record audio at their own convenience and not have to wait for the ED to respond before talking. One nurse explained:

“Like a radio report sent, they [the hospitals] need this system.”

Similarly, charge nurses explained how they could listen to audio recordings when convenient and allow physicians to listen to the context if they felt the information was important. One charge nurse valued the ability to repeat (reprocess) the audio recording, as many times as needed, especially for unclear and noisy recordings. She explained:

“I struggle a little bit, but I have the ability to replay it or whatever [or something to play it again]. Because a lot of the time the medics have background noise.” (Nurse)

Medic participants also explained how the CrashHelp mobile app design enabled efficient data entry and multi-tasking on scene. For example, one participant explained:

“I take pictures or do the audio while I’m walking to the rig. Maybe it’s a generational thing, but I use it while I’m doing other things so you know it doesn’t really get in the way more than what we already do.”

Most participants related significant perceived value in the use of voice recordings in combination with the mobile system.

**CONCLUSION**

In this paper, we described the design of a mobile health information system including how end-user oriented design can be applied to improve information exchange in EMS. Findings indicated the potential role of multimedia information to positively impact information exchange in the fast-paced, complex, and dynamic emergency medical context. Findings support the ISDT propositions that images and digital audio represent a proper medium to deliver patient information and can positively augment decision-making in EMS. However, the limited use of video recording did not provide sufficient information to support the proposition that video could augment decision-making in EMS.

There are several limitations of this research that would encourage future work in this area. First, the field study was conducted in one U.S. City. Future studies should examine the use of mobile and multimedia in other locations in the U.S. and globally to test the propositions herein. Second, the study participants included only two ED physicians. Physicians are traditionally a difficult participant group to access in health information technology studies. However, these participants represent a critical user group and thus should be included in larger numbers in future studies. Third, due to the exploratory nature of this study, the manner in which the mobile devices were used lacked protocols and processes. For example, users were not instructed as to what kinds of pictures to take, how many to take, in what circumstances to use the devices, and at what angles and light settings to apply. As per some participant responses, the images may provide much greater value if paramedics follow picture taking protocols that are tied to specific types of incidents (i.e., stroke, trauma, burn, motor vehicle crashes, etc.). Future work might consider examining the qualities and features required in an effective image that conveys critical patient information, which could lead to better medical decisions. Finally, this research applied a qualitative evaluation methodology, which fit well with the exploratory focus of the study. However, future studies should examine a much wider audience and utilize a range of other evaluation methods including surveys, experiments, and a larger sample of qualitative participants. Future research can also seek to evaluate the utility of advanced telecommunication networks, such as 4G networks in mHealth applications.

While this study has its limitations and future research directions, it also provides significant contributions to the discipline of health information systems. First, from a methodological perspective, this study demonstrates the use of multiple research methods to iteratively design, develop, prototype and evaluate an mHealth system guided by the ISDT approach. In the process, the study developed and applied a specific ISDT for a new generation of multimedia mHealth systems in EMS. From a practical perspective, this research provides a robust mHealth system for EMS to utilize in the future and demonstrates its potential benefits to EMS practitioners.
In terms of theoretical contributions, participant responses provided evidence to support the notion that digital multimedia information, captured and sent via a Smartphone application, may provide an added level of information richness to help resolve ambiguity and reduce uncertainty in time-critical EMS decision making. As such, this study provides an illustration on how MRT may be applied in mHealth applications. The findings herein also provide evidence that the capabilities of multimedia information (captured and sent via a Smartphone application) enable synchronicity (i.e., Media Synchronicity Theory) between ambulance paramedics and ED nurses. Findings indicate that the use of the application may enable information to be represented in multiple different ways for different users, enable the customization of a message before sending, and enable reprocessability, or the ability to retrieve/reprocess a message for better understanding. As such, this study provides support for the two media theories discussed herein (i.e., MRT, MST), and at the same time validates the rigor in which this study was carried out. That is, the application of these theories to the design of the mHealth system are in turn supported in the evaluation.

REFERENCES


