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ABSTRACT

The implementation of healthcare information technology largely exhibits a 'lack of fit' with medical practice workflow, especially when data collection devices interfere with care during emergencies. Employing the design science paradigm and interpretive theory building, we examine the credibility, utility, and sharing of near-auto generated, near-real-time content regarding motor vehicle accidents. We began constructing a mobile security information model and building a mobile prototype to study the dynamics of contents sharing in the pre-hospital and hospital settings. From our focus group interviews, we learned that the most valuable feature of the prototype was the ability to capture and transmit data, audio, photo, and video contents prior to the arrival of the patient to the hospital: contents that inform clinical decisions regarding diagnostic preparedness, triaging, and therapeutic activities. We theorize that a credible content incentivizes sharing attitude and instrumental use which influence sharing behavior. We plan further observations to refine the proposition.

Keywords

Emergency medical service, credibility, sharing behavior, utility, near-real-time, mobile security information, instrumental use, pre-hospital data

INTRODUCTION

Studies have shown that timely emergency response and rapid treatment depend strongly on availability of information, which is why near-real time sharing of incident content among emergency medical responders and providers is critical to health outcome (Trunkey, 1983; Peters and Hall, 1999). In this study, we examine the credibility and utility of near-real-time content of motor vehicle accidents by instantiating a prototype of a mobile security information model. The prototype is an application that allows a near-automatic data, image, photo, and video capture, and near-real-time transmission of the content during an emergency medical service (EMS) activity.

The task domain of EMS is characterized by time urgency, accurate decision making and communication, and threats of injury or death to self and others (Murphy, Beaton, Pike, and Johnson, 1999). Thus, we review existing literature in three

domains: public health emergencies, social psychology, and information system security to gain relevant definitions, concepts, theories, and IT artifacts that have been published pertaining to these tasks. Following, we discuss our methodology being informed by design science guidelines.

The remaining sections discuss evaluation by user acceptance and focus group interview coding. We then theorize the sharing behavior in emergencies and discuss our findings. The limitations of the study are discussed. We conclude with the discussion of our contributions in forms of model, instantiation, and theory as IT artifacts, and instrumental use implications for first responders and healthcare providers.

LITERATURE REVIEW

Based on public health emergencies, social psychology, and information systems security domains, a set of literature was selected as part of the heuristic search to identify gaps or bias in existing knowledge constructs and build on what has been answered.

Public Health Emergencies

In 2008, there were 37,261 fatalities, out of which 90% occurred as a result of motor vehicle crashes. In NHTSA's 2006 survey, there were 42,642 fatalities in the United States, out of which 38,588 cases were automobile crashes. Automobile crashes result in over 40,000 deaths per year in the United States. The total economic cost of crashes is estimated to be 2% of the gross domestic product or approximately $290 billion. Medical and emergency services costs are roughly 15% of this total (NHTSA, 2007, 2008). Timely emergency medical response to vehicle crashes can significantly reduce the cost incurred and more importantly the likelihood of death and disability consequences (Grossman, 1997; Trunkey, 1983). But timely emergency response is highly dependent on accessibility and availability of credible and useful health information; and IT has an important role in improving the credibility and utility of health information and reducing the response time (Peters and Hall, 1999).

The digitization and exchange of the health information, an electronic health record (EHR) and personal health record (PHR) through the implementation of healthcare information technology (HIT), and emergency medical service information systems (EMS IS) promise to improve quality of care and asset efficiency, reduce medical errors, drive cost savings, and foster universal health coverage (Shapiro, et al., 2007). However, HIT has history of a high miss rate due to several factors (Economist, 2009) and skeptics express HIT's general 'lack of fit' with medical practice.

Among the factors inhibiting adoption of HIT is the credibility of shared data. A report by DesRoches, et al. (2008) p.56 states that "about 40% of respondents with and without an electronic-records system also reported that protecting physicians from personal liability for record tampering by external parties could be a major facilitator of adoption". This evidence implies a critical need to explore factors that affect the credibility of clinical content and sharing attitude change among in-patient and ambulatory healthcare delivery organizations, and external parties including EMS agencies.

Social Psychology

Information from a credible source is highly likely to be processed by the receiver (Hovland and Weiss, 1951). The information will generate less internal counter-debate, thereby triggering attitude change and bringing about sharing behavior change (Janis and Smith, 1964).

Researchers agree that credibility is a perceived quality, i.e. credibility does not reside in a piece of information, a person, or a product (Self, 1996). A phenomenon is perceived to be credible if it can be perceived as having expertise and being trustworthy. Trustworthiness, the other dimension is described in terms of being truthful and unbiased. A photo or video of a crash incident taken by an emergency medical technician paramedic (EMTP) on the street using a mobile phone for example shows the reality, the truth, and is unbiased. Incident content is factual and generates less internal debates when passed on to be processed (Hovland and Weiss, 1951).

The expertise dimension is described by terms such as knowledgeable, experience, and competent (Fogg, Lee, and Marshall, 2002). The content source expertise dimension of a mobile device might be viewed as its quality characteristics (DeLone and McLean, 2003), which in pre-hospital and hospital setting, speaks to training and motivation encounters. The effect of the disparities in training and motivation of stakeholders across the pre-hospital and hospital continuum needs to be addressed.

When a medical emergency occurs such as an automobile crash, multiple personnel from different organizations are involved including: PSAP – 911 dispatchers, first responders, fire stations, public safety police, EMT paramedics, triage nurses, ED physicians, trauma surgeons, hospital and IT administrators, and patients. These personnel and their organizations need to

collaborate as a team in an effective manner in order to reduce the total time it takes to respond and treat the injured. They also need to share patient care record (PCR) in a secured and efficient manner.

Intended users of pre-hospital clinical contents are varied and the intended use of the pre-hospital contents might serve different purposes. Patton (2008) identifies different types of uses: instrumental use, conceptual use, symbolic use, persuasive use, process use, unintended use, nonuse, and misuse. We will look at instrumental use as it related to sharing behavior. Instrumental use, a type of use defined as findings that directly inform a decision or contribute to solving a problem; the findings are linked to subsequent actions which in a sense become an instrument of action.

The potential multiple uses of pre-hospital clinical contents and differences in training encounter are sources of possible tensions and distrust between and among different users, which affect attitude of users. The diversity of users also brings motivation differences in terms of job satisfaction leading to different levels of involvement (Park and Mittal, 1985). Involvement, tensions, training, and motivations: all these factors needed to be examined in order to understand the dynamics that evolve sharing behavior. At the time of this writing, little is known about these dynamics of behavior change towards pre-hospital contents.

Information System Security

Technological advances in Beyond-3G (B3G) systems, a derivative convergence of mobile and wireless communication systems, and IP technologies offer a multitude of services including network access, communication services, personal digital assistance, and more over a wide range of platforms. These platforms allow the deployment of more and more privacy critical applications over mobile platforms.

Cell phones in particular are widely distributed and have a high user acceptance rate which has motivated the development of mobile health (m-health) (Chatterjee and Price, 2009; Tulu, Chatterjee, and Laxminarayan, 2005). The quality of healthcare and patient safety can be immensely improved through the use of mobile technologies in voice communication, messaging, medication alerts, tracking, remote access, data capture and more (Horan and Schooley, 2005). These technologies include: GSM, SMS, WAP, UMTS, 3G, Bluetooth, GPS, XML, WML, and Wi-Fi.

Schooley, Horan, Marich, Hilton, and Noamani (2009) present a clinician focused, Integrated Crash Trauma Information Network (ICTIN) encompassing public health players, information systems, and data sharing devices including mobile phones. We focus on the handoff phase of the workflow between the pre-hospital and hospital part of the network and develop a secure network information service model: Mobile Security Information (MSI) model.

Mobile healthcare applications will benefit from a reliable storage, single sign-on, and secure transmission required to guarantee confidentiality, integrity and service availability (Sax, Kohane, and Mandl, 2005). Meeting these requirements needs a balanced tradeoff between performance and security. Security services through cryptosystems require intensive algorithms which is a challenge in mobile computing due to limited computing power, limited bandwidth, and specific software platform constraints.

One of the means of implementing secure transmission and at the same time allowing ease of use is to deploy single sign-on and global sign-out (SSO/GSO) architecture. The SSO/GSO refers to the ability of a user to once log in to or out of multiple applications that would traditionally require their own separate logins and logouts (Steel, Nagappan, and Lai, 2006). Though most organizations still maintain silo authentication security infrastructure while few are deploying single domain SSO, an inter-domain SSO/GSO architecture will enable an EMTPs' camera-equipped mobile phone to authenticate with the EMS servers and base receiving hospital systems within their jurisdiction.

METHODOLOGY

Having discussed the apparent issues in the literature and the rationale for this study, we employ the design science research (DSR) paradigm (Hevner, March, Park, and Ram, 2004) to address the issue of technology fit by designing and instantiating an artifact, and interpretative method to assess the value of the artifact and its impact on behavior change.

The fundamental principle of DSR is that knowledge and understanding of a design problem and its solution are acquired in the building and application of an artifact (Samuel-Ojo, et al., 2010). The term artifact is used to describe something that is artificial, or constructed by humans, as opposed to something that occurs naturally (Simon, 1981). Such artifacts must improve upon existing solutions to a problem or perhaps provide a first solution to an important problem. IT artifacts, which are the end-goal of any design science research project in our community, are broadly classified into (Walls, et al., 1992; March and Smith, 1995; Hevner and Chatterjee, 2009):

- Constructs (vocabulary and symbols),

- Models (abstractions and representations),
- Methods (algorithms and practices),
- Instantiations (implemented and prototype systems), and
- Better design theories.

DSR guides researchers to engage three cycles: relevance, build, and rigor (Iivari, 2007; Hevner and Chatterjee, 2009). The relevance cycle speaks to the need for a purposeful IT artifact. IT artifacts must be socially situated (i.e. useful to addressing problems and opportunities of or capable of process change required by the stakeholders, within the artifact's nomological net) (Benbasat and Zmud, 2003). The design cycle speaks to the design as a product and process. This cycle entails the construction and evaluation of the product, the artifact. During construction, design alternatives are generated and evaluated until a satisfactory design is obtained in an iterative manner, while drawing from the requirement, theory, and method inputs of the relevance and rigor cycles. The evaluation process assesses the functionality, performance, or utility of the artifact. The third cycle, the rigor cycle allows systematic critique and building of the knowledge base encompassing theories, methods, algorithms, and, meta-artifacts including design products and processes.

In our study, we facilitated a first round of focus group interviews of participants comprising of stakeholders both at the local and national to gain information on the potential needs of and barriers to data capture and sharing, and learn the critical need for multimodal mobile data feeds. Two critical needs discussed by the participants include clinical usability and data communication and standards.

Clinical usability

This need addresses improvements in software including enhanced interfaces that enable automated data capture that 'fit' with the emergency care processes as opposed to manual data entry.

Data communications and standards

Participants emphasize the need to adopt standards that allow for secure and enhanced levels of information integration across organizational boundaries.

Based on these key needs, we designed a mobile security information (MSI) model. The model enables us to construct a prototype that capture contents and provide secure signature service.

The prototype, a pre-hospital content capture and transmission mobile application enables us to observe the kind of structures, schedules, security data profile, and instrumental use that will facilitate rapid response of the first responders and the base physicians. We assess the value of the output of the prototype in another second round of focus group meeting (Russ-Eft and Preskill, 2009).

Next, the following sections discuss the model, UML activity diagram, and feedback focus group interview in details.

Mobile Security Information (MSI) Model

The MSI model is a three layered model consisting of authentication as the top layer, message pairing as the middle layer, and transport as the bottom layers (Figure 1). To instantiate this model, we combined tested and proven technology components (Arthur, 2009). We chose federated single sign-on and global sign-out (SSO/GSO) at the authentication layer of the model due to the unique nature of the cooperative relationship between an ED and EMS agency. We implement the middle and bottom layers to provide content and signature secure service.

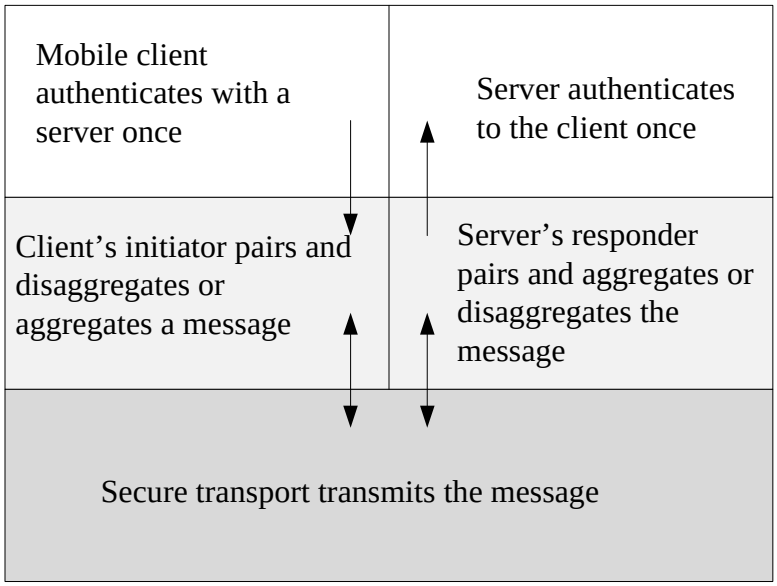

Figure 1. Mobile security implementation (MSI) model

Pre-hospital content capture and transmission mobile application

During an emergency, the image senders (the camera equipped mobile phone clients) initiate an identification dialog with the hospital service provider which in turn redirects it to a nearby domain identity provider. The identity provider associates the user attribute values to its identity. The client accesses the image service provider. The image service provider obtains the client identity information including authentication and role attribute values from the identity provider. After validating authentication, the service provider opens a session with the remote client and enforces access control restrictions based on the user's identity and attribute. The client then uploads the image as a secure channel service to two inter-domain servers after a single authentication. See the activity diagram shown in Figure 2.

The mobile client interface use case provides a content ensemble service which was developed in the Python programming language for use on a Nokia N97 global positioning system (GPS) enabled cell phone. Figure 3 illustrates the archive server interface.

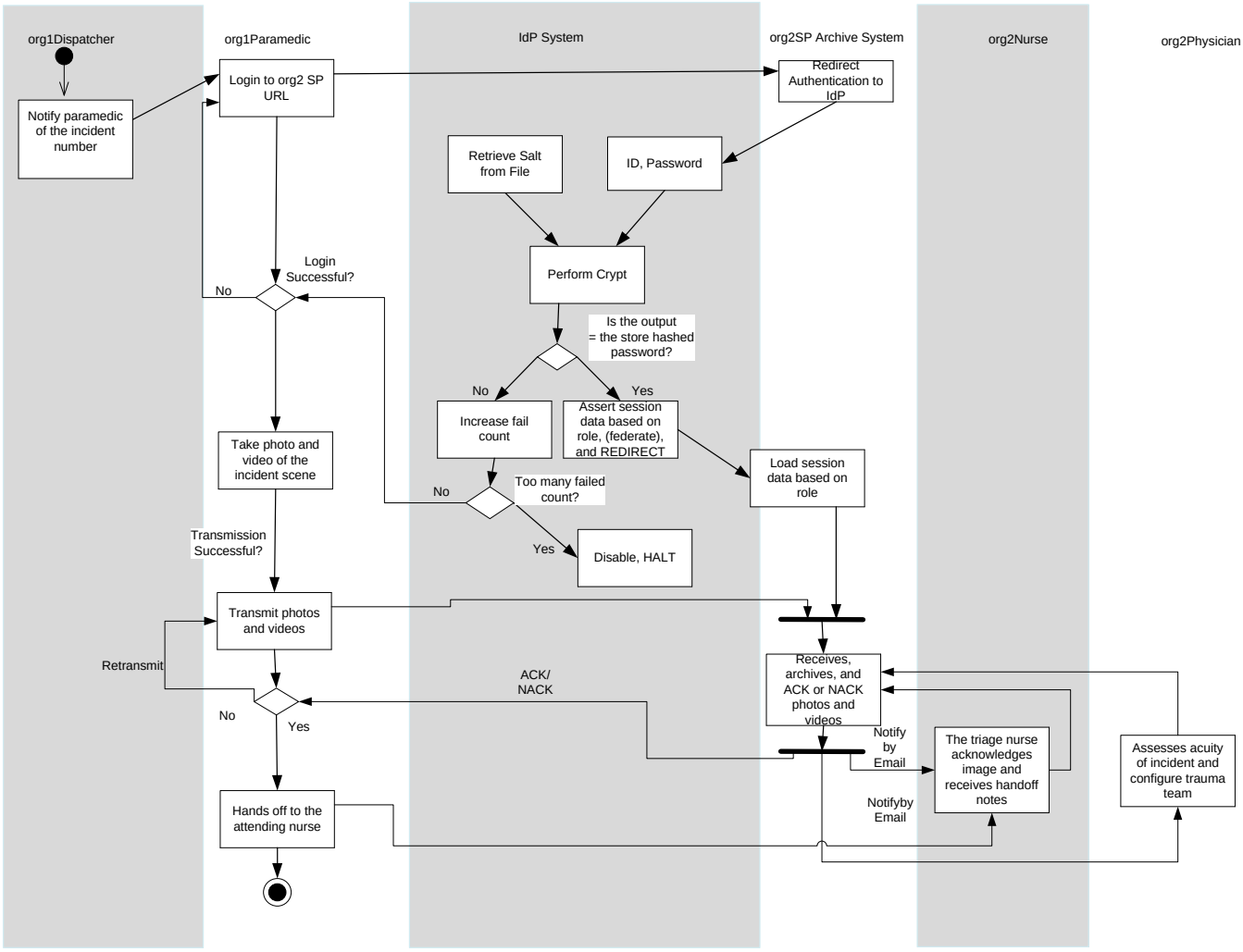

Figure 2. Activity diagram shown in the flow of dialog among the mobile client, identity provider and service provider

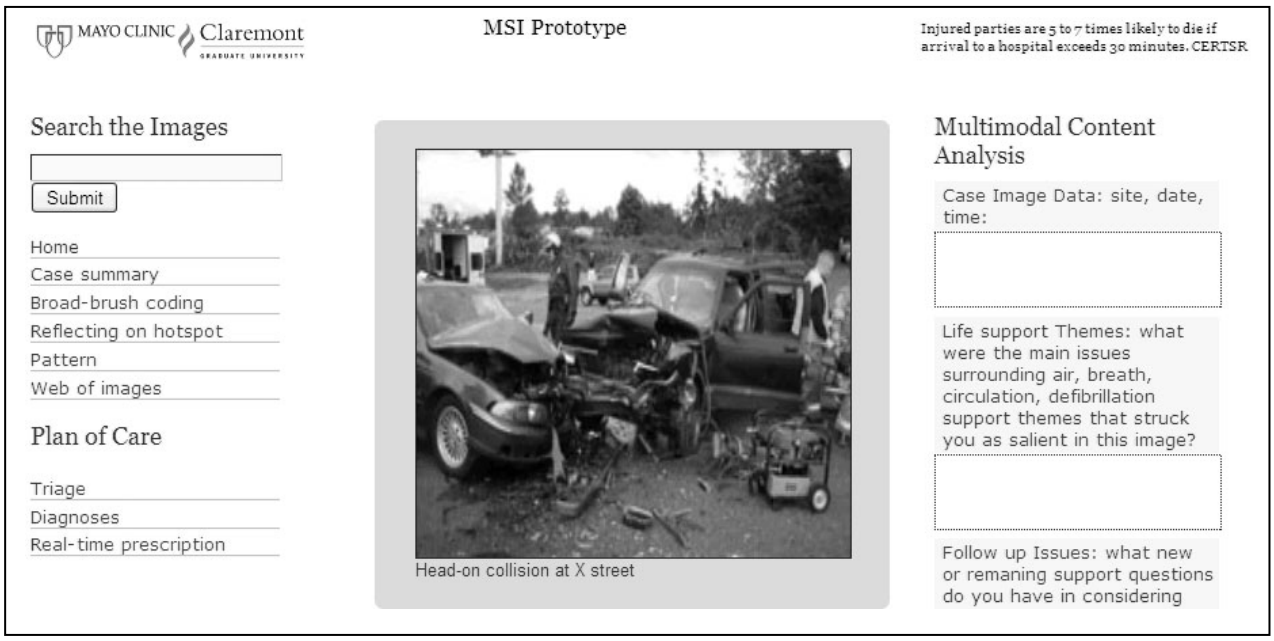

Figure 3. Archive server interface

RESULTS

We went back to the participants in Mayo Clinic to receive their response regarding the prototype. The feedback reports were analyzed using QSR NVIVO content analysis software. We performed open-code, axial-code, and selective-code (Charmaz, 2006; Strauss and Corbin, 1990). The emerging concepts include: factual content trustworthiness, content source expertise, content sharing attitude, response and treatment shaping, trauma configuring, response and treatment quality, sharing behavior of emergency content. Connecting these concepts as constructs, we derived the network diagram of sharing behavior in pre-hospital and hospital emergency settings (Figure 4).

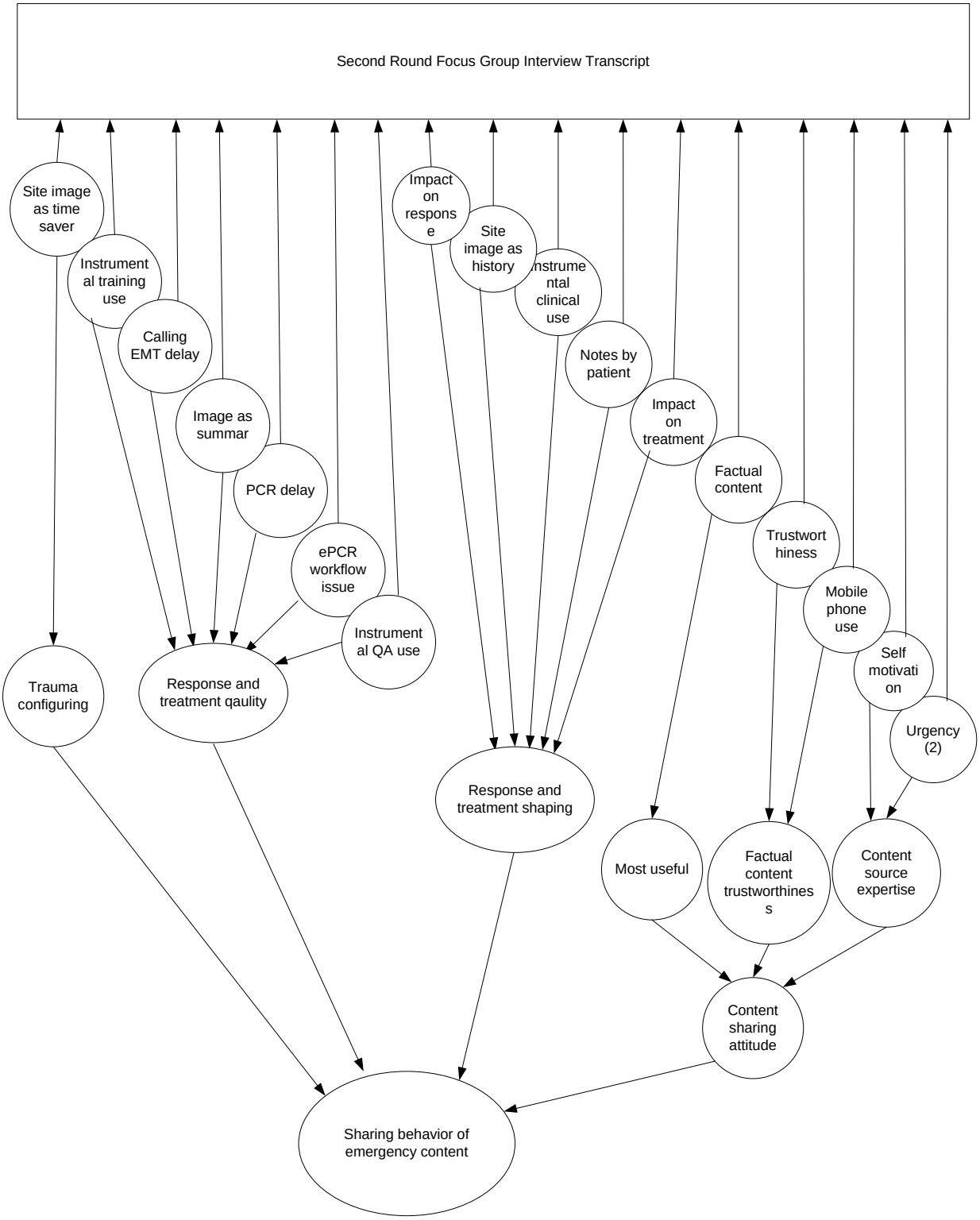

Figure 4. Network diagram of category codes

DISCUSSION

In the previous section, we have discussed the methodological procedures including the focus group need assessment, model and prototype development. We have also obtained a set of qualitative dataset which we have coded and categorized. In this section we will discuss our findings.

An EMTP equipped with a mobile phone running the MSI prototype application featuring high performing camera and view finder, points and snap the image or video of scene. Capturing the audio, photo, or video of the scene and entering a minimal set of data like name, age, and sex provides a timely "quick (verbal) snapshot" or content that is transmitted to the receiving hospital as alluded to by a participant.

"I usually give a quick [verbal] snapshot to whoever meets me there [at the ED]. The PCR just isn't done in time" (EMT)

The timely incident content will produce near real-time factual content that is perceived to be trustworthy as a representation of the reality on-scene. It is even perceived to be more trustworthy when a signature of the EMTP who captures and authors the content, can be accounted for or traced.

A factual trustworthy content, together with a content source expertise that is perceived to exercise high assertions will induce better sharing attitude, for it will be accepted and processed with little or no counter-argument by the receiving hospital (Hovland and Weiss, 1951). The expertise of the source of the content which is described by the EMTPs' credentials bears on the validity of their assertion. The expertise is perceived to be high when certification is current and motivation is high, as in when an EMTP uses own "phone to take pictures and show someone at the ED" (EMT). EMTPs are perceived as highly motivated for they are sometimes publicly reported as heroes.

A better content sharing attitude brings about novel instrumental uses: high response and treatment shaping, most useful trauma configuring, and huge response and treatment quality. The content highly shapes the process and practice of response and treatment both at the responder and receiving hospital sides. Physicians "need the information at patient's side" (Physician).

"A picture is worth a thousand words" (ED Physician)

"We need something we can read, hear, look at. Calling the EMT after they've left seems to be too common a practice" (EMS System Medical Director)

The content is most useful in determining whether a trauma team (which is expensive to assemble) will be needed and if needed, the rapid configuration of the trauma team reduces response time and drive cost savings.

"I think the basic information, the context of what happened on scene helps out the most" (Director, Trauma).

"Assembling a trauma team is really expensive and can take a lot time. If a simple thing like having a picture could help us know whether we need to assemble our [trauma] team or not, that would really benefit the hospital, the team, and I think it would help the patient" (Trauma Director).

The content has a huge positive impact on response and treatment quality, in that it allows the physician to listen to the factual conversation that took place during the incident. The archive incident logs contain the audio, photo and video factual account of the incident.

"If we can get our units back on the street faster and not waiting around at the ED, that would be a huge positive for us" (EMS administrator)

"I think having pictures and the audio could be useful for training, for our case reviews, for preparing and presenting the case at our MAC [Medical Advisory Committtee] meetings" (EMS Clinical Coordinator)

The paramedics will not be waiting around to hand off note to receiving nurses or physician. This early releases of paramedic resources, cuts off 30 min of waiting time, and keeps the 'paramedic off the street' which might drive cost savings of eliminating a 'whole paramedic crew from the street for a whole day per week'.

The EMS generated pre-hospital multimedia is novel and instrumentally useful to the ED clinicians (Patton, 2008) as callback to EMTPs will cease to be a common procedure. The hospital organizations are going to share appropriate information with the EMS organization in return (because they received something is instrumentally useful). Thus we theorize that *a credible content incentivizes sharing attitude and instrumental use which influence sharing behavior*.

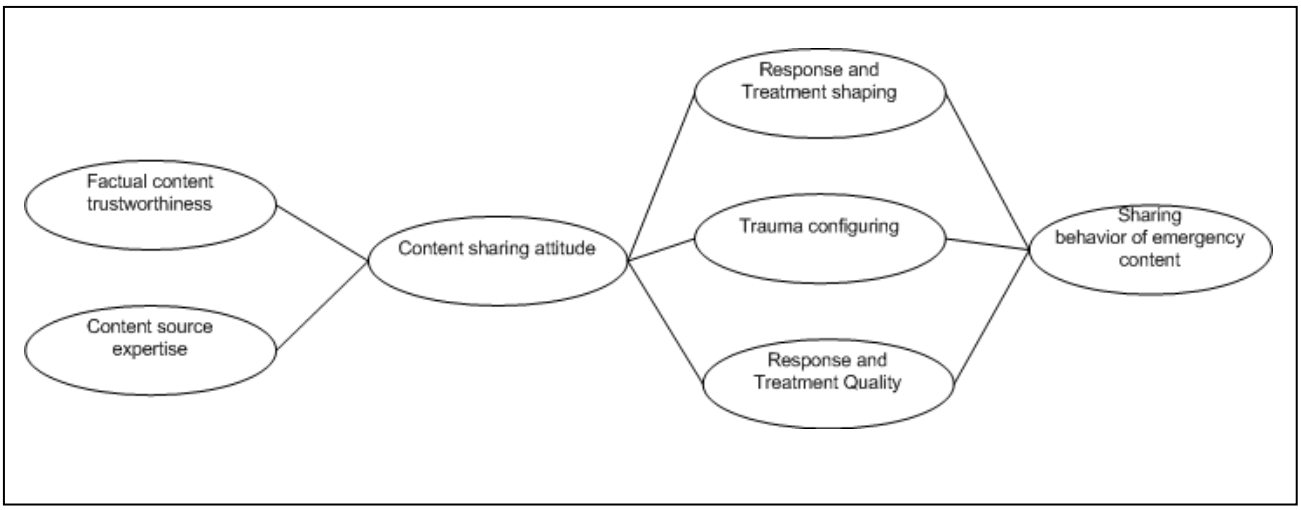

Figure 5. Sharing behavior theory in pre-hospital and hospital settings

In other words, a credible multimedia content characterized by factual trustworthiness, together with a content source expertise is perceived to be valuable. This sense of value encourages sharing attitude in that it is less prone to counter-argument (Hovland and Weiss, 1951). A positive sharing attitude brings about novel instrumental uses: response and treatment shaping, trauma configuring, and response and treatment quality - all promoting sharing behavior of emergency content. See figure 5. We return favor when we receive one. Reciprocity holds that people owe one another duties because of their prior actions (Gouldner 1960, p.171). When two parties interact in a manner that one perceives being instrumentally helped by the other, it is expected that the other party will reciprocate in congruence with Gouldner's rule of reciprocal.

LIMITATION OF STUDY

Sharing behavior in pre-hospital and hospital settings may help explains the effect of credibility of content. We plan to conduct a series of confirmatory focus groups to confirm the utility of the artifacts and further refine the sharing behavior regarding emergency content. At the time of writing, this study did not operationalize the constructs of sharing behavior in pre-hospital and hospital setting.

CONCLUSION

We have constructed and instantiated a mobile security information model. This model can be used by health information researchers to study design considerations of location-based mobility devices and applications, design and evaluate current implementation of mobility device and application, thereby advancing knowledge in ubiquitous and pervasive computing in healthcare.

While implementing the prototype, we theorize that credibility of the content of an emergency incident inspires content sharing attitude, and instrumental uses which in turn influence sharing behavior of the content. Capturing the audio, photo, or video of the scene and entering a minimal set of data such as name, age, and sex provides a timely "quick snapshot" or content of the emergency incident. The incident content is perceived to be trustworthy as a factual representation of the on-scene reality. A factual trustworthy content, together with a source that is perceived to exercise high expertise in its assertions, will induce better content sharing attitude. The expertise is perceived to be high when certification is current and motivation is high. Better content sharing attitude brings about novel instrumental uses: response and treatment shaping, trauma configuring, and response and treatment quality. These uses inspire better sharing behavior of pre-hospital contents.

The prototype artifact minimizes intrusion in the process of emergency response and treatment. Paramedics might employ it to include their reports to go with the patient on or before handoff time point. The EMS administrators might use it for training, case reviews, and quality improvement. Physicians may find it most useful when employed in triage cases, device plans of care, or configure trauma teams.

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