Visioning Future Emergency Healthcare Collaboration: Perspectives From Large and Small Medical Centers

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New video technologies are emerging to facilitate collaboration in emergency healthcare. One such technology is 3D telepresence technology for medical consultation (3DMC) that may provide richer visual information to support collaboration between medical professionals to, ideally, enhance patient care in real time. Today only an early prototype of 3DMC exists. To better understand 3DMC’s potential for adoption and use in emergency healthcare before large amounts of development resources are invested we conducted a visioning study. That is, we shared our vision of 3DMC with emergency room physicians, nurses, administrators, and information technology (IT) professionals working at large and small medical centers, and asked them to share their perspectives regarding 3DMC’s potential benefits and disadvantages in emergency healthcare and its compatibility and/or lack thereof with their and their organization’s current ways of working. We found that social and technical challenges can be identified regarding new innovations even before working prototypes are available. The compatibility of 3DMC with current ways of working was conceptualized by participants in terms of processes, relationships, and resources. Both common and unique perceptions regarding 3DMC emerged, illustrating the need for 3DMC, and other collaboration technologies, to support interwoven situational awareness across different technological frames.

Introduction

As discussed in Sonnenwald et al. (2008), trauma is a significant health problem (Meyer, 1998; Coates & Goode, 2001). Using video technologies to provide emergency healthcare services may help improve trauma patient outcomes in both urban and rural areas when time is of the essence in providing care. However, before designing and investing in such technologies we should not only evaluate their potential impact on medical care (AHCPR, 1996) but also their propensity for adoption and use within the emergency healthcare context. Results from previous research in innovation adoption and use (e.g., Rogers, 1995; Venkatesh, Morris, Davis, & Davis, 2003) have consistently shown that when innovations are not perceived as providing advantages over current ways of working, being compatible with existing values and structures, or being easy to try out and use people will not use them unless perhaps there is strong social influence to use the innovation. Our previous research evaluated the potential impact of a new video technology, called 3D medical consultation (3DMC) (Welch et al., 2009), or 3D telepresence, on emergency healthcare (Sonnenwald et al., 2008; Söderholm et al., 2008). In this paper we investigate its propensity for adoption and use in large and small medical centers.

A goal for 3DMC is to provide a seamless view of a remote scene, and the ability to interact with people and virtually point to objects at the remote location (Welch et al., 2009). The view of the remote location would, ideally, dynamically change as the viewer walks around, changes position, or moves their head just as if they were present at the remote location. Only an early prototype system demonstrating components of 3DMC exists today (Welch et al., 2009). In trauma and other emergency medical situations 3DMC could enable a physician at a medical center to virtually move around a trauma victim, the paramedic, and the equipment at a remote accident scene. It could also facilitate collaboration among physicians at large and small rural medical centers. The technology would ideally let the physician quickly look at different parts of the patient’s body and to look more closely at an ongoing intricate medical procedure. This could enable more effective interaction than is currently possible via today’s 2D video conferencing technology.

In previous research (Sonnenwald et al., 2008; Söderholm et al., 2008) we simulated an emergency medical situation involving practicing paramedics working alone
and paramedics working remotely via two conditions: with today’s 2D videoconferencing and a 3DMC proxy. We examined task performance, paramedics’ self-efficacy, and information sharing between the attending paramedic and collaborating physician to help predict the utility of 3DMC. Analysis of paramedics’ task performance shows that paramedics working with a physician via a 3D proxy performed the fewest harmful interventions and showed the least variation in task performance time. Paramedics in the 3D proxy condition also reported the highest levels of self-efficacy and found the information provided by the collaborating physician more useful (Söderholm et al., 2008; Sonnenwald et al., 2008).

However, questions remain regarding the adoption and use of 3DMC in emergency healthcare. Do individuals who will use 3DMC to provide healthcare services, make decisions regarding its purchase and adoption, and/or support its operations perceive 3DMC as potentially useful? Do they believe the proposed technology is compatible with their values, goals, and current ways of working? What social influences might shape their perceptions and why? Thus, in this study we examine the vision of 3DMC within the broad context of emergency healthcare from the perspectives of those who will ultimately shape its adoption and use. Our aim is to identify potential benefits and barriers to the adoption and use of 3DMC within the U.S. healthcare system and to increase our understanding of the complexity of technology adoption within emergency healthcare. In this paper we present findings regarding 3DMC in the context of large and small medical centers and discuss implications of these findings. In a subsequent paper we explore the perceptions of 3DMC in the emergency medical services (EMS) context, investigating the perspectives of paramedics and EMS managers on the county and state level.

Theoretical Framework

Innovation Adoption and Use

The theory of innovation diffusion (Rogers, 1995) provides insights to explain and predict innovation adoption and use. An innovation is defined as an idea, practice, or object that is perceived as new by an individual or other unit of adoption (Rogers, 1995). How members of an organization or social system perceive certain characteristics of an innovation influences its adoption. Similarly, the technology acceptance model introduced by Davis (1989) and later expanded to the Unified Theory of Acceptance and Use of Technology (UTAUT) by Venkatesh et al. (2003) help to explain and predict an individual’s acceptance of innovations, specifically in information technology (IT).

Synthesizing over five decades of innovation adoption research, Rogers (1995) identifies five attributes of innovations that are correlated with the adoption of innovations. Numerous researchers have validated these attributes in a variety of domains including medicine (Rogers, 1995; Tornatsky & Fleischer, 1990). The five innovation attributes are: relative advantage, compatibility, complexity, trialability, and observability. Similarly, in the UTAUT model Venkatesh et al. (2003) identify four attributes of information technology that facilitate adoption: performance expectancy, facilitating conditions, effort expectancy, and social influence. When examining the definitions of each attribute in these two sets we found similarities between them. That is, although the names of attributes are different, their meanings significantly overlap or are identical. Synthesizing the two sets yields a set of six attributes: relative advantage, compatibility, complexity, trialability, observability, and social influence.

Relative advantage. Relative advantage is the degree to which a new innovation surpasses current practices. Grudin (1994) has observed that collaboration systems often require additional work without providing obvious benefits. Relative advantage can be operationalized, or measured, in terms of variables such as usefulness in accomplishing work goals, quality of work outcomes, added convenience, and social prestige provided by the innovation. Within UTAUT these aspects are linked to the attribute performance expectancy. This attribute includes to what extent a person believes that using IT will enhance their job performance, how useful the technology is perceived, or a person’s expectations on the outcome of using a technology or system (Venkatesh et al., 2003). When investigating physicians’ IT acceptance Chismar and Wiley-Patton (2003) found that the variable, perceived usefulness, was a strong determinant of intention to use the technology, which in turn has been found to directly influence actual usage (Venkatesh et al., 2003).

3DMC may be perceived as useful or providing relative advantages because today emergency room (ER) medical personnel usually have very limited knowledge about patients brought to the ER by paramedics, and may find it difficult to focus on the paramedic’s report upon arrival because the physician is focusing on the patient (Sarcevic & Burd, 2009; Reddy & Spence, 2006). 3DMC has the potential to offer an advantage to current practice by providing ER personnel with visual information about the patient before the patient is physically admitted and thus facilitating ER personnel’s job in coordination, preparation, and subsequent patient care. However, we do not know whether ER personnel will find 3DMC compatible with their current ways of working.

Compatibility. The degree to which an innovation is perceived to be consistent with adopters’ existing values, past experiences, and needs is referred to as compatibility. It includes individual, group, and organizational goals, needs, culture, and structure and is concerned with the agreement/differences between a group’s traditional work patterns and the work patterns required by the innovation. Specific values, needs, and work practices vary due to individual preferences and particular contexts. Technology should, ideally, be compatible with these fundamental values, needs, and practices. Grudin (1994) and Olson and Teasley (1996) stress the importance of compatibility for collaboration technology. Similarly, the UTAUT uses the attribute facilitating
Trialability refers to the ease of experimenting with an innovation. It includes the level of effort needed and risk involved in observing and participating in small-scale demonstrations of the system, including easily recovering from, or “undoing,” operations using the systems and the costs involved in reversing the decision to adopt. Experimenting with and exploring system features is also a component of usability engineering (Chin, Diel, & Norman, 1988). Furthermore, Chau and Hu (2004) found that trialability can be an important aspect for physicians to accept a technology. They conclude that a required consensus with respect to adopting a technology needs to be reached through peer-to-peer and hands-on experience among physicians and not on managerial or administrative level influence alone. Our study investigates physicians’ and healthcare professionals’ attitudes towards trialability with respect to 3DMC.

Observability. The degree to which the results of an innovation are easily seen and understood is referred to as observability. Grudin (1994) cautions that users need to develop a clear understanding of collaboration technology before they will adopt it. Observability has been operationalized as “results demonstrability,” i.e., the ease of telling others the consequences or results of using a system. In general, observability may also include visibility, i.e., the degree to which the results of an innovation are visible to others. However, when investigating physicians’ compliance with practice guidelines, Berta et al. (2005) did not find any significant influence of observability on physicians’ guideline compliance.

Social influence. Social influence is the degree to which an individual perceives that important people or actors believe they should use the new system. It has been operationalized as: subjective norm, social factors, and image. When studied by Venkatesh et al. (2003), social influence was found to be more important in mandatory use situations than in voluntary settings. Chau and Hu (2004) investigated technology implementation in the context of telemedicine and found that early in the implementation process the role of a “motivated and determined clinical administrator was critical” (p. 90). This influence was especially important when the technology was designed to be used by physicians (Chau & Hu, 2004), as physicians on an individual level might be resistant to adopting new IT (Chismar & Wiley-Patton, 2003). Furthermore, physicians’ decisions to accept IT are not influenced by peer pressure or image, but rather their own assessment of a technology (Chismar & Wiley-Patton, 2003). However, it appears that physicians influence other colleagues’ attitudes towards new IT. Hu, Chau, and Sheng (2002) found organizations where physicians as a group had a positive attitude toward telemedicine IT to be more likely to adopt the technology.

Technological Frames

One of the most frequently reported limitations and criticisms of technology acceptance studies is the tendency to examine only one information system within one group of subjects (Lee, Kozar, & Larsen, 2003). Thus, the attributes discussed above have only partial power to predict innovation adoption because they do not explicitly take into account differences between groups within the same context. It is imperative to build on the theories of innovation diffusion and UTAUT to identify and analyze different perceptions of 3DMC that arise in different technological frames within a context such as a medical center or hospital. A medical center can be viewed as its own social system within which the innovation adoption process takes place. Furthermore, the social system is constituted by subgroups of actors, primarily based on professional roles in work settings. These subgroups are also referred to as relevant social groups, i.e., “individuals whose interactions and experiences with a technology are similar” (Davidson, 2006, p. 25). We have examined technological frames within the medical centers and the emergency medical services (EMS) contexts. This paper presents findings from the medical center context; a subsequent paper will present findings from the EMS context.

Technological frames in the context of medical centers. A context such as a medical center or hospital may be comprised of several technological frames. Technological frames are “the subset of members’ organizational frames that concern the assumptions, expectations and knowledge they use
When considering other types of medical services, e.g., treatment of cancer, the paramedic provides information about when they expect medical centers as different contexts with respect to emergency medical care. In large and small medical centers we decided not to consider large and small centers with limited resources the physician might consult with a specialist or ER physician at a large medical center and further transfer the patient to that facility. Through 3DMC the consulting physician would have visual access to the patient not in their center, potentially leading to faster and more accurate treatment decisions.

In this context we identified three categories of technological frames based on professional roles. The frame categories are based on the role professionals in the context have in relation to 3DMC: using the technology to provide healthcare services, managing people using the technology, and providing technical support for the technology. Within each category there are multiple technological frames that distinguish different perspectives that emerge from specific professional roles within the healthcare system. Potential 3DMC users include ER residents, physicians, and nurses. Managers of potential 3DMC users include ER department and EMS managers. Large medical center IT operations personnel include support managers and other IT professionals (Table 1).

We interviewed multiple representatives from each frame to identify benefits and barriers to the adoption and use of 3DMC within the U.S. emergency healthcare system.

### Research Methods

Our research design is a new approach in studies of technology and users, including social informatics and human–computer interaction studies. We call this approach a visioning study. The concept of visioning falls under the umbrella of futures techniques and futures studies (e.g., Bell, 2003) that has frequently been used in planning, e.g., in city and/or community planning projects. A basic definition of the use of visioning is “creating images of the future to serve as goals or guides for planning decisions” (Shipley, 2002, p. 7). In comparison, we created images of the future to serve as guides for research. We shared a vision of 3DMC with multiple representatives from different technological frames and asked them to discuss their perspectives on that vision. The research approach and results may be generalizable to other studies examining the potential of technology adoption before a large investment has been made designing and implementing a new technology.

### Research Study Setting

We conducted the study during 2 months in the autumn of 2007. The study was conducted within a geographic region located in a southeastern state in the U.S. that has a combination of both suburban and rural population areas.

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**TABLE 1. Technological frames in large and small medical centers.**

<table>
<thead>
<tr>
<th>Categories of technological frames</th>
<th>Potential 3DMC users providing patient care</th>
<th>Managers of potential 3DMC users</th>
<th>IT operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Physicians and 3rd year residents at large medical center ER</td>
<td>5 interviews</td>
<td>4. ER administration, including EMS and ER department managers</td>
<td>5 interviews</td>
</tr>
<tr>
<td>2. Physicians at small medical Center ER</td>
<td>2 interviews</td>
<td></td>
<td></td>
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<tr>
<td>3. ER Nurses</td>
<td>3 interviews</td>
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</tr>
</tbody>
</table>

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1Because this is the only overall difference between emergency services in large and small medical centers we decided not to consider large and small medical centers as different contexts with respect to emergency medical care. When considering other types of medical services, e.g., treatment of cancer, large and small medical centers would be viewed as different contexts.
This region has a large, nationally acclaimed teaching and research hospital, multiple independent public and private EMS organizations, and a rural medical center with a small ER. The region is typical of many areas of the U.S.

Study Participant Selection

As previously mentioned, we interviewed representatives from frames who would most likely see their jobs change with the adoption and use of 3DMC and/or might influence its adoption and use within the medical center context of emergency healthcare. We used purposeful sampling to select all study participants. Initially, our colleagues, experienced ER physicians, and later study participants, helped us identify the representative participants to interview. A total of 17 people were identified and interviewed. Their years of work experience varied from a few months to over 20 years of experience. Gender distribution among participants was 6 women and 11 men.

Data Collection

Interviews with study participants took place at their work location. At the beginning of each interview we discussed the overall purpose of our research and their rights as a study participant. Each participant was given a study consent form to read, discuss, and sign. Next, we showed a 5-minute video that presented a vision for 3DMC. The video explained the goal of 3DMC and gave examples of emergency medical situations where the technology might be used. Furthermore, it showed some of the proposed equipment and system features, including a portable system for paramedics to use in the field and permanent setups for medical centers.

After this introduction we used a semistructured interview protocol, with open-ended questions to allow great flexibility and detail to emerge in participants’ responses. The topics covered by the open-ended questions were guided by the theories of innovation adoption (Rogers, 1995) and UTAUT (Venkatesh et al., 2003) discussed in the Theoretical Framework section. In particular, we asked participants to discuss the potential benefits and disadvantages of 3DMC on emergency health for patients, emergency healthcare professionals, healthcare organizations, and any other relevant parties. We asked whether 3DMC would be compatible with their current way of working, including professional and organizational processes and regulations, and if they see any problems that might arise using 3DMC. We also asked what others in their context might think about using this technology and what might influence the use of technology in their organization.

A total of 17 interviews were conducted. One of these was a group interview including two participants. One participant was interviewed twice, thus a total of 17 people were interviewed. The interviews ranged from 24 to 110 minutes in length, with an average length of 47 minutes. The interviews were digitally recorded and then transcribed. The wide time range is explained by both participants’ individual characteristics and time constraints facing many people working in emergency healthcare. Some participants expressed their opinions in a very concise and precise manner, while others shared their perspectives using more elaborate answers and multiple examples. Furthermore, some participants had a very limited amount of time for the interview due to the nature of their job. For example, we had to reschedule interviews several times when unexpected medical emergencies, such as multivehicle car crashes, occurred. Even given this constraint we were able to discuss all major questions in our interview protocol with all of the participants.

Data Analysis

The interview data were analyzed using the innovation attributes discussed in the Theoretical Framework section. While coding we also sought out new attributes, or codes. For example, we discovered that aspects of trialability and observability merged together conceptually within the frames. For example, clinical trials in which results are clearly observable emerged as an important issue but there is no ‘undoing’ (a component of trialability) in emergency medicine. This differs from other technologies, such as accounting systems where book entries can be deleted and redone. Thus, we combine the attributes of trialability and observability when coding. Operational definitions and examples of the codes are provided in Table 2.

During coding, two researchers analyzed interview data to determine if there was consensus regarding data coding. An agreement of 0.82 using Cohen’s kappa intercoder reliability measure was reached. A kappa value above 0.75 is considered excellent (Robson, 2002).

Limitations

The use of a video to help explain our vision of 3DMC rather than a demonstration of or the opportunity to use 3DMC technology provides both advantages and limitations. It is certainly possible that participants could have envisioned additional benefits and challenges or requested more detailed design features if presented with a 3DMC working prototype or system. Alternatively, “only” showing a video illustrating the vision of 3DMC may have enabled participants to think more creatively when conceptualizing and discussing the technology because they were not bound to or limited by an existing design. A study comparing the use of a prototype with the use of a video would provide additional, concrete insights into this issue.

A second limitation is that an urban geographical region was not included in the study. However, since the vision for 3DMC is to improve medical care across geographic distances, studying an urban context was not a first priority and is left for subsequent studies.

A third limitation is that several stakeholder groups were not included in this analysis or in the study. This concerns in particular health insurance companies, potential patients and their families, and paramedics and EMS organizations.
TABLE 2. Coding examples.

<table>
<thead>
<tr>
<th>Codes</th>
<th>Code definition</th>
<th>Examples from the data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative advantage</td>
<td>Benefits for stakeholders/study participants. Potential for different uses. Usefulness of 3DMC</td>
<td>“This could improve the relationship between physicians in the emergency department and paramedics in the field”</td>
</tr>
<tr>
<td>Compatibility</td>
<td>Disadvantages for stakeholders/study participants. Situations or contexts where 3DMC would not or be useful. Issues that would stop 3DMC from being used.</td>
<td>“If it falls down to the EMS system to pay for the cost of it- [it’s] not gonna’ happen. Some of them are struggling to make ends meet as it is.”</td>
</tr>
<tr>
<td>Complexity</td>
<td>If 3DMC is perceived as cumbersome or complicated to use. Aspects of learning to operate 3DMC.</td>
<td>“So, more equipment with more potential for failure I think would be a problem.”</td>
</tr>
<tr>
<td>Trialability &amp; observability</td>
<td>What would be required for technology to be accepted in relation to outcome or evidence of effectiveness?</td>
<td>“You have to show quantitatively, not just for administrators, but to staff how is it affecting their work... For nurses, if you can show that it positively is good for the patient, they’re gonna’ do it. They’re gonna’ push their fellow nurses to do it.”</td>
</tr>
<tr>
<td>Social Influence</td>
<td>What would other people in the organization think about using 3DMC? Would 3DMC be a status symbol for the organization?</td>
<td>“I think a lot of places would be interested in something like that. Some places just buy the newest thing because they want to be noted for being advanced. And that’s how they market themselves.”</td>
</tr>
</tbody>
</table>

as well as potential patients and their families. Health insurance companies and healthcare agencies, such as Medicare, in the U.S. could play an important role in the adoption of 3DMC, as they may or may not be willing to reimburse patients for the cost of 3DMC services. We contacted several health insurance companies and all declined to participate in an interview.

Interviewing potential patients could be beneficial because 3DMC will involve the transmission of sensitive personal visual information in situations where it might not be possible to obtain patient consent. Patients and their families may have strong perspectives regarding both immediate and long-term access to this visual information, and these concerns might be possible to address in the sociotechnical design of 3DMC. Because the group of potential patients and their families is rather large, spanning all ages and socioeconomic groups, we leave this to a future study.

Paramedics, EMS administrators, trainers, and regulators were interviewed, and results from those interviews along with a description of the EMS context will be reported in a subsequent paper, augmenting the results reported here. Including a description and perceptions from the EMS context in this paper would potentially give a more complete illustration of the perceptions of 3DMC. However, due to space limitations this is not possible in this paper, while keeping the richness of the study participant stories intact.

Results

As discussed previously, we identified five technological frames within the medical center context (Table 1) that take account of professional roles that have a high degree of influence on the adoption and use of innovations, such as 3DMC, in the emergency healthcare system. We analyzed how the relative advantages, compatibility, complexity, trialability, observability, and social influence attributes of 3DMC were perceived in each frame. Examining these attributes within each frame illuminates the multiple perspectives possible. We found unique and overlapping perspectives across frames.

Technological Frame 1: Physicians at Large Medical Center ERs

The ER in the large medical center included in our study has 25 beds and is staffed by physicians, residents, and nurses specializing in emergency medicine. It has its own administration, academic curricula, and research programs. It has strong liaisons with the local county EMS agency; one of the medical center’s ER physicians is their medical director and is responsible for EMS training and policies. The local paramedics who bring patients to the ER usually know the physicians and nurses there, and vice versa. However, as the medical center is a large (level 1) trauma center with several specialized care facilities, many patients from other counties are also brought to the ER either by ambulance or helicopter. Subsequently, the physicians and nurses interact with a large number of paramedics whom they have not met previously.

Relative advantage. Physicians explained that the geographic area served by the ER is relatively small in size and it does not take a lot of time to transport a patient from most areas in the county to the ER. Thus, physicians opined that 3DMC would be most advantageous when used between their medical center and smaller, rural medical centers or hospitals. For example, physicians are frequently contacted by other physicians at small medical centers asking about transferring their patient to the large medical center. 3DMC could provide new advantages in these situations both in determining whether a patient should be transferred to the larger medical center and to help in providing immediate care at the smaller center. As two physicians explained:

I take between one and ten calls in an eight hour period... from other physicians trying to transfer patients. And to be...
able to utilize that technology to see that patient and talk about that patient [and to determine] what we can offer that patient would be useful.

You can see what’s going on with the patient . . . the trauma team here . . . can help [immediately]: ‘hey you know what, . . . can you put a chest tube here, do that there.’ And then the patient’s packaged and brought here, so you’ve already started to be involved in their care.

Compatibility. Physicians questioned whether 3DMC would be compatible with some aspects of patient care, current ways of working, and the current legal liability system. However, possible solutions to these issues were also mentioned. With respect to patient care, physicians worried that 3DMC might introduce delays in providing critical patient care.

There have been patients that I have taken care of who . . . were literally five minutes away, but . . . [paramedics] spent twenty minutes . . . in the field doing things that they didn’t need to do, and it had severe consequences for the patient. . . . That delay cost the patient’s life. . . . And so I’d be concerned that there’d be too much reliance on this type of technology, and I’d be worried that that could delay patient care.

A possible solution could be to explicitly specify in paramedic protocols (operating instructions) when the technology could be used.

Maybe use it in certain protocols, but not use it at [paramedics’] . . . discretion

With respect to their current ways of working, some physicians explained that they prefer working hands-on with patients:

There is very little I’m going to do in terms of treating a patient [via 3DMC]—I want them here. . . . I want them in front of me.

Other physicians expressed concern that the technology would encourage “unnecessary” calls from paramedics and increase the need to do multitasking at work, resulting in an increased workload. As one physician said:

It would be a change in how we view things, and how the work process is. I usually have enough going on in front of me that I don’t need to have more input from the outside.

Possible solutions to these issues could be a hand-held viewing device, as it would not require time or take too much attention away from other patients, and a physician dedicated to 3DMC.

If I could do it on a . . . [hand-held viewing device] then I could see it working well. If I have to go to a screen, and sit—I do not see that ever working, in my current [way of] working.

[As done today for] telemedicine . . . you have a separate person responsible for that. Not that you’re on shift and then responsible for . . . [3DMC] as well, because it’s hard to [do] . . . when you’ve got patients in front of you.

Several issues related to legal responsibility, liability, and authority with respect to patient care were also mentioned. Because 3DMC uses digital network technology, sessions can be easily recorded, archived, and incorporated into a patient’s electronic record. This raises concerns regarding the potential for malpractice lawsuits. As one physician commented:

We all know that things don’t always go perfectly in an operating room. But not every detail of the procedure . . . [or] every suture that’s made is recorded. There’d be much more potential for litigation. That would somehow have to be protected.

Complexity. None of the physicians mentioned that the 3DMC should be easy to use for them personally. Rather, they reported that this was important for the paramedics to facilitate timely patient care. As one physician remarked:

Concerns I would have would be delaying transport of the patient, for the purposes of either setting up equipment, or making sure it works, or tinkering with it in some way.

Trialability and observability. Several physicians discussed the importance of seeing evidence from field tests and real-life trials as prerequisites before being willing to use 3DMC and for medical center administration to buy into it. In particular, data regarding cost effectiveness and improved patient outcomes would be needed.

Social influence. One physician thought the 3DMC could be a status symbol for the medical center:

If a hospital prides itself on technology and savvyness, I think it [3DMC] could be a good thing.

However, as mentioned by another participant, this might not be reason enough for the medical center to invest in it:

Part of it is a status symbol. For many hospitals it boils down to money. Is the cost of the system going to be recuperated somehow, somewhere, besides just as a status symbol?

In summary, ER physicians at the large medical center saw relative advantages to 3DMC in terms of large–small medical center interactions and patient care. They also questioned its compatibility with some aspects of patient care, their preferred ways of working, and the medical legal system. However, potential solutions to these issues were also reported. Field tests and real-life trials would be needed to convince physicians that the expense and changes to their current ways of working that may be imposed by 3DMC would be worthwhile.

Technological Frame 2: Physicians at Small Medical Center ERs

The small medical center that participated in our study is located in a rural area and has 25 beds in total. Its ER has eight beds and at any one point in time is staffed by one physician working together with a number of nurses. The physicians rotate in the center as independent contractors
from the large medical center where they specialize in family medicine. Paramedics who bring patients to the center work for a private state-wide EMS company. There does not appear to be any close working relationships between the physicians and paramedics (often they do not know each other), and the physicians are not necessarily familiar with the paramedics’ practice guidelines and policies.

Relative advantage. These physicians thought that 3DMC might provide advantages allowing the physician to see and interact directly with a patient at an accident scene and that this would trigger different ways of thinking and asking questions about, or directly to, the patient compared to when a paramedic mediates the contact via radio. However, they found it hard to come up with specific use situations in the field where 3DMC might be beneficial for physician–paramedic consultation:

[Paramedics] move certain patients directly to the [nearest large] trauma center. . . . That’s one of the downsides of being only 45 minutes from the Mecca [the nearest large medical center]. That is, you may not actually see some of the patients upon whom these kinds of technologies would be really helpful.

3DMC was also seen as facilitating additional in-depth contact with other physicians, which might be beneficial for procedures they do not perform frequently. This is especially useful because physicians who staff the ER at the small center are often inexperienced when it comes to emergency care:

Over the years a high proportion of them have been folks pretty much fresh out of residency. . . . [They] wind up doing a lot of things for the first time [here].

Furthermore, the technology could be beneficial in providing expert care for patients in their area who do not want or feel comfortable going to the large medical center. One physician shared the following story:

The patient said, ‘No, if you can’t fix it . . . duct-tape it together, I’m going home.’ I mean it was a, a kind of a rural, I ain’t goin’ to [a bigger city] thing.

Compatibility. There are professional hierarchical and legal issues to consider when physicians at a small medical center ER and a large medical center collaborate regarding patient care. This is not unique to 3DMC but if 3DMC increases such collaboration it may also increase the need to formally address these issues. Participants suggested that mutual agreements or contracts should be created to define in what situations collaboration should (and should not) occur in order to reduce questions regarding egos and legal responsibilities. One physician who had previous experiences collaborating with other physicians using telemedicine technology surmised:

Many of the issues are not about hardware or software—they’re about people.

When you have distributed centers . . . there is often a gradient of expertise. In the medical transfer world, you’re always talking about transferring to higher levels of care, and so . . . you’re always making work for someone else. And so they are entitled to feel irritation with you, and impatient if you request more . . . intellectual bandwidth than you’re entitled to.

Another physician reported:

You will run into doctors’ egos. . . . I think some physicians . . . would love it . . . if it were actually mandated—that sort of takes away the ‘I’m just asking you for help.’ . . . [There] needs to be something contractually agreed upon by the institutions, and accepted by the physicians participating. And, obviously then, liability insurance needs to cover it.

Furthermore, there needs to be a way to bill for the collaborations. If large medical centers have many small centers calling in, increasing the demand for their physicians’ time, the large medical center may need to hire more physicians. As one physician pointed out:

It would be a mixed blessing for the [large medical center] physicians—on one hand it would let them get their skills out into the field and possibly make a difference, on the other it would suck much more time and resources from them.

3DMC between the small medical center and paramedics in the field could be based on protocols. That is, using 3DMC could be required for specific circumstances just as today when protocols dictate specific permission must be obtained for certain procedures. Physicians explained:

EMS personnel have a certain level of training, and it’s fairly clear what they should be capable of doing. It could be fairly easy to delineate these are the things that they are capable of doing, and anything beyond that . . . needs to be referred back to a host facility, for consultation

[The paramedics] are more bound by protocol. . . . Even if they don’t like what I say . . . they are obliged in some way to follow that. . . . If somebody says, ‘you in the field will submit every patient you get that meets these criteria to . . . [3DMC]’ then it goes that way. There aren’t exceptions.

The risks related to using 3DMC would be higher for physicians and small centers than for paramedics. Because small medical centers are often minimally staffed, it might be problematic if the only ER physician at the small center is collaborating with a medic in the field when the ER is full of waiting patients. 3DMC would also introduce additional legal issues for the small center.

You bring in a technology that gives you the capability of offering a higher level of care—you incur a burden because if you fail to engage that higher level of care, and something goes wrong . . . for whatever reason—you’re incurring liability.

And they [paramedics] are covered—if things go wrong, it’s not their problem.

In sum, 3DMC has the potential to magnify medical hierarchical, billing, and legal issues that arise from collaboration among medical personnel with different levels of training and working in different types of organizations. These problems
may not be insurmountable but should be addressed before 3DMC is deployed.

Complexity. The physicians at the small medical center ER mentioned the need for IT support and additional resources for operating the 3DMC technology. For example a physician with previous experience in telemedicine trials said:

I would find it very difficult to use a telemedicine solution, if you gave us the same old system that we had in the ER that I work in today. . . . I’d have to have somebody else with me to make it worthwhile.

Furthermore, if the system is too complex it would be incompatible with the overall work goal:

Our commitment is to what’s best for this patient. And if it doesn’t seem like fifteen minutes of extra fiddling with knobs and dials is going to be in the best interest of the patient—or the other patients I’ve got to take care of—then, then we’ll not use it.

Another physician believed that unless the technology is really easy for paramedics to use it would not be useful to them.

Trialability and observability. One physician mentioned the need for evidence of effectiveness in patient outcomes, in particular with respect to evidence of cost-effectiveness and that trials are required to explore certain kinds of interventions and measures showing in what ways it is effective to use this technology or not.

Social influence. 3DMC could act as a quality assurance symbol for smaller medical centers. As a physician explained:

It’s probably reassuring to patients to know that it’s not an isolated small hospital but you can get good consultative information. And it’s probably a benefit to the hospital to say that we have this kind of . . . connection with other hospitals; I imagine it would help with the image of the hospital . . . making it appear more modern, and up-to-date, and with it, so to speak. . . . A problem, with some of the small local hospitals is that [it’s often perceived] they’re just like little way-stations, and they get the worst doctors, and they have the worst equipment, and it’s all old, and if you really want good care, you go to the University Center. So it’ll probably help with the image of some places.

Technological Frame 3: ER Nurses

Working as a nurse in the ER entails immediate hands-on patient care and resource coordination. For example, the nurses triage patients, answer and administer calls from paramedics and physicians at other medical centers, and based on this information prepare beds, identify and procure expertise, expert teams, and equipment needed upon patients’ arrival. This work is similar at both the large and small medical centers in our study.

Relative advantage. All nurses interviewed opined that 3DMC would lead to better patient care. A primary benefit mentioned was receiving more accurate and/or richer information in advance of a patient’s arrival that would be afforded by the technology. This information would help when determining triage criteria and subsequent actions. Furthermore, it could increase the accuracy of those decisions because they would have more reliable information regarding the severity of injuries and/or symptoms. This could further save time because nurses would be better prepared for patients’ arrival:

You only have the picture of what the paramedic is telling you over the radio. EMS can call in and say, ‘We’re inbound, patient MVC, who appears to be stable right now’ [Our response is:] ‘Oh, okay, we’ll make it a yellow.’ Well, when they get here, bam, . . . [the patient is] ten times sicker than what they thought. So then you’re kind of behind the eight-ball. If we had this technology, we could see for ourselves what the patient looked like, what the situation was, and then we could be better prepared when the patient got here.

Compatibility. When discussing 3DMC’s compatibility the nurses focused on physicians’ use of the technology. They thought that it will be a major challenge for the physicians to have time to respond to 3DMC calls. The nurses also pointed to the potential problem of getting a physician to come to a 3DMC unit to take the call. Today, the nurses have problems getting physicians to come to the phone to take incoming phone calls from EMS or physicians at other medical centers. Furthermore, physicians are always responsible for the patient when the patient arrives at the facility; there might not be sufficient incentives for physicians to put in extra time to take a call from a paramedic.
Relative advantage. Overall, the ER administrators were most optimistic about 3DMC compared to all other categories of study participants. They saw multiple potential benefits with respect to the technology. For example, they felt 3DMC might increase productivity by providing better specialized care to rural areas and thus reducing healthcare costs:

Until you can teleport the surgeon into the remote area this is . . . the next best thing.

This point was confirmed by the clinical director at the small medical center ER:

We could actually potentially keep patients here because we could deliver some of those cares, some of those specialty things that we’re not able to do [now] because we don’t have the more qualified people.

Along the same lines, administrators suggested that 3DMC could turn paramedics into physician extenders. Paramedics would be able to make better patient care decisions and increase their skills and experience by learning from the physician during 3DMC sessions. The better field of view available in real time and in the digital records could provide more information about patients to help in subsequent diagnoses and also minimize the need for medical centers to repeat tests when patients are being transported from one facility to another. Additional potential benefits might come from digitally recorded sessions and using the recordings for multiple purposes such as patient history, legal protection, and education or training. In sum, administrators saw many benefits and felt that additional healthcare and cost benefits would emerge as 3DMC became integrated into healthcare practices.

When you factor in . . . things . . . like decreased ICU calls, decreased medical legal risk, you can actually go above that million dollars [investment] pretty fast. . . . Once you really start working the numbers, then you can start realizing the impact. And then I think the other thing you see in a technology like this is [that] your costs are justified for the five hundred patients a year, but then you find another five hundred patients a year that you could really use it upon, and then that’s when you really start seeing the economic value to it.

Compatibility. Similar to the physicians at the small medical center ER, administrators also raised liability concerns related to consulting with physicians at other facilities:

Now we are consulting on a more personal level. Once we consult with this [3DMC] . . . do they [physicians at another facility] share any of the liability of our patients? You’ll find more resistance from that group that’s being consulted, more so than the group that’s doing the consulting.

One of the administrators at the large medical center ER expressed similar opinions as the physicians at the medical center. The physicians’ current way of working would need to change, e.g., limitations on the number of calls or more physicians on staff would need to be established:

I think the way we operate now, it [the technology] wouldn’t [fit in]. We’d have to change the way we operate. . . . They [the physicians] are already working hard . . . like ‘right now I’m doing all these things, I got patients right here in front of me . . . and, now I got to answer to some guy who want me to look at his patient, or a paramedic. . . .’ So if we set up limitations on that and provide enough manpower, I think, it probably would be . . . accepted.

Several of the administrators identified cost and return on investment as major barriers to adopting 3DMC, especially in relation to current billing infrastructure:

So, in order to bill for this, you’re gonna’ have to have that video so you’re gonna’ have a permanent record of whatever it is that transpired and . . . [you can review] that for billing. [and you need to decide] who gets billed. Is it the patient, is it EMS that gets billed, is it the facility?

I think there’d be a mix of feelings from ‘this is cool.’ ‘Nah that’s really not practical.’ . . . I think most people would come to the same conclusions — we would use this for one percent of our patient population. And then it’s just like, why would I do a million dollar investment for, what, it’s gonna’ be less than five hundred patients a year.

To be widely accepted and used throughout the healthcare system 3DMC should be as inexpensive as possible so that many large and small medical centers, clinics, and EMS agencies can afford it. As with other social networking technologies, more advantages accrue when the technology is widely used. However, as pointed out by several of the administrators, there might be more gain and other ways for medical centers to get revenue than through reimbursement alone.

Complexity. Administrators expressed that the usefulness of 3DMC would depend on the amount of equipment that needs to be set up, how comfortable people are with it, and how fail-safe it is. Furthermore, all 3DMC equipment should be easy to use and operate, and easy to train people to use.

Trialability and observability. Administrators reported that observability of 3DMC’s value must come in different forms or with a combination of several important outcomes such as improved patient outcomes, decreased risks, decreased morbidity and mortality, cost-effectiveness, and additional revenues for the medical center. As one person pointed out:

Is just the economic cost benefit from the cost of the equipment, versus the benefit that you gain from decreasing your risk management profile. . . . You know, would it convert patients that are currently now dying to being alive? What’s the social economic impact on that?

Social influence. Administrators commented that different actors, including physicians, potential patients, and their families and politicians, would formally and informally influence the decision to use 3DMC. Administrators explained:

Administrators would be the decision makers, but something like this would need a physician champion in order to succeed. . . . [Administrators] have one eye on, or one ear, to what the physicians are saying. . . . The nurses and the paramedics are more end-users, so [for them] it’s less about
be directed immediately to experts, perhaps even bypassing coordination of patients and resources because patients could decrease the time needed for patient triage and help facilitate through re-use of recorded sessions and real-time learning; Relative advantage. The IT personnel saw multiple benefits: data and network security, the U.S. Health Insurance Portability and Accountability Act (HIPAA), patient privacy; and training for the medical center’s personnel and medical department that is responsible for IT infrastructure, support, and encrypted? will have access to them? How will the sessions be indexed where will the original files be stored before editing and who would generate additional work for them. They would need to develop new policies and solutions for protecting patient privacy and patient data. The collaborative sessions would need the same protection as medical records, yet when would the patient legally be considered the medical center’s patient? Whose data would we need to protect and archive, and for how long? Furthermore, because 3DMC will produce visual patient data, new procedures for encrypting and archiving such visual data would be needed. Will editing or anonymization of faces be required in order to store the collaborative sessions? If so, who will decide what to cut or anonymize, and where will the original files be stored before editing and who will have access to them? How will the sessions be indexed and encrypted? But I don’t know how you would index it, and integrate it, and deal with issues of patient images. . . I mean, you have to think about these kind of things. How do you protect this information. And if a patient is recognizable, it is a patient identification issue, how you handle that. Complexity. Complexity for the IT personnel focuses on providing technical support to distributed locations and organizations. If this is not built into the system it can be very challenging to provide ad hoc. Furthermore, who would pay for the technical support if the equipment is owned by multiple organizations? Participants explained: If half the system belongs to volunteer rescue squads around . . . the county and half of the equipment is in the hospital, how do you support that equipment if there’s a problem? . . . In which end is the problem? Now, I’m not even getting to who pays for it. The support piece . . . that’s gonna’ be what would hit IT [hard]. Trialability and observability. The IT personnel opined that for 3DMC to be adopted and used its benefits would need to be made visible not only to administrators but also healthcare professionals. As one person explained: You have to show quantitatively, not just for administrators, but to staff how is it affecting their work. . . . For nurses, if you can show that it positively is good for the patient, they’re gonna’ do it. They’re gonna’ push their fellow nurses to do it. Social influence. Participants opined that the technology could work as a status symbol for the medical center’s trauma care, by gaining credibility through technology innovation.
TABLE 3. Summary of relative advantages perceived by each frame.

<table>
<thead>
<tr>
<th>Relative advantage attributes</th>
<th>Physicians at large medical center ER</th>
<th>Physicians at small medical center ER</th>
<th>ER Nurses</th>
<th>ER administration</th>
<th>Medical Center and ER IT support</th>
</tr>
</thead>
<tbody>
<tr>
<td>Better patient care/outcomes</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Enhanced patient record provided</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase productivity &amp; efficiency</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Improve medical teaching &amp; training</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Decrease health care costs; save money</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Improved coordination &amp; save time</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Address lack of experience &amp; training outside large hospital settings;</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Enhance paramedic profession</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Improve collaboration between large &amp; small medical centers</td>
<td></td>
<td></td>
<td>X</td>
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<tr>
<td>Better for patients who don’t want to go to large hospital</td>
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<td></td>
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<tr>
<td>Reduce need to repeat tests</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Better subsequent diagnoses</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Keep more patients at small medical centers</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Better support for billing</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inspire new approaches to care</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Improve triage decisions</td>
<td>X</td>
<td>X</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

rather than academically, as is frequently done today. However, this needs to be related to evidence of better patient care:

If it’s proven that . . . the numbers improve because of this technology and its use, then yes [it would increase our technical creditability]. But if you’re really not seeing that gain, then it’s hard to say, ‘Oh, look what we have.’

Discussion

In this section we discuss implications for the future of 3DMC and collaboration technology in general from the perspective of each attribute, that is, synthesizing what we learned about each attribute across all five frames.

Relative Advantage (Table 3)

Potential relative advantages of 3DMC were identified for a wide variety of actors in emergency healthcare. Advantages were identified for patients, physicians, nurses, paramedics, large medical centers, small medical centers, EMS, and society in general. Many advantages were mentioned by more than one frame, e.g., better patient outcomes were mentioned by study participants in every frame. In addition, study participants in all but one frame mentioned at least one advantage not mentioned by participants in any other frame. For example, physicians at the small medical center mentioned that 3DMC could improve medical care for patients who do not wish to go to large medical centers, whereas no participants in other frames mentioned this potential advantage.

These results imply that study participants shared a common understanding of 3DMC, while at the same time had a unique understanding of 3DMC for their context. This is a positive outcome for 3DMC, our research approach, and theory development. Perceptions of relative advantages from 3DMC across emergency healthcare actors and organizations provide strong support for adoption of 3DMC in the future. Common and unique perceptions across actors and organizations show that our research approach of using a video and open-ended interview questions can enable study participants to understand a future technology and relate it to their context. The result also extends the theoretical concept of interwoven situational awareness (Sonnenwald & Pierce, 2000). The concept, interwoven situational awareness, posits that to collaborate effectively actors need not have identical understanding of the situation but rather have common and unique understandings that enable them to apply their own expertise while working together. Our study participants were from different frames and all collaborate across frames in different configurations to provide emergency healthcare services. The fact that they identified common and unique advantages illustrates an interwoven situational awareness. This result is repeated for all innovation attributes, i.e., unique and common perceptions of attributes emerged for each attribute. We recommend that designers and developers of collaboration technology that goes beyond providing basic features should strive to understand the interwoven situational awareness.

Compatibility (Table 4)

Compatibility issues were mentioned by study participants in all frames. No participant thought that 3DMC would be a perfect fit with the way they work today or that 3DMC would mean less work for them. More compatibility issues were unique to frames than were in common across frames.
TABLE 4. Summary of compatibility issues perceived by each frame.

<table>
<thead>
<tr>
<th>Compatibility attributes</th>
<th>Physicians at large medical center ER</th>
<th>Physicians at small medical center ER</th>
<th>ER Nurses</th>
<th>ER administration</th>
<th>Medical center and ER IT support</th>
</tr>
</thead>
<tbody>
<tr>
<td>Processes</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Difficulty to get physician to equipment/hand-held device needed</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reduction in physicians’ hands-on with patient</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Possible delays in patient care</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relationships</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Requirement of new EMS protocols &amp; agreements between large &amp; small medical centers</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Legal liability issues for physicians &amp; hospitals</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost allocation &amp; billing structure</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Magnification of medical hierarchy among health care professionals</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resources</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monopolization of sole physician at smaller medical center</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low cost for wide adoption</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase in physician work load/calls at larger medical center</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Additional nursing, physician, IT staff needed</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Security encryption &amp; archival of visual patient data</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

(seven were unique, five were in common). This may make designing and implementing 3DMC more challenging because unique sociotechnical features may be required for different frames. For example, our data analysis indicates that it may be necessary to design and finance new sociotechnical structures such that today’s sole physician at a small medical center has sufficient time to support 3DMC and attend to patients coming into the medical center. Whatever solution to this challenge is developed it will apply only to one frame, small medical centers.

In sum, three types of compatibility issues emerged from our data: issues with respect to current processes, relationships, and resources. All three types of issues require both social and technical solutions. Process issues include difficulties in getting physicians to 3DMC equipment (today nurses have problems getting physicians to come to the phone), and lack of compatibility with today’s EMS protocols. Handheld portable 3DMC devices may address the former issue but for the latter new socially constructed solutions such as new EMS protocols developed with representatives from ER physicians, ER nurses, ER administrators, and paramedics will also be needed.

Relationships among medical professionals, large and small medical centers, and the U.S. legal system, physicians, medical centers, and IT will need clarification and perhaps modification for 3DMC to be adopted. 3DMC will introduce new collaborative relationships between physicians at large medical centers and at small medical centers, between physicians and paramedics, and between ER nurses and paramedics. While these collaborations will provide advantages for patients and all involved, informal and formal agreements regarding these new ways of working together will be needed to facilitate effective collaboration. For example, new agreements between large medical centers and small medical centers regarding the type and number of collaborations and accompanying billing practices will be needed. 3DMC will also introduce new questions regarding legal responsibilities. When a physician guides a paramedic through a procedure, who is legally responsible for the procedure’s outcomes? Today in the U.S. paramedics have legally binding constraints regarding types of procedures they cannot perform without approval from a physician, and thus they have limited legal liability when they perform procedures. When using 3DMC will the remote physician be held legally responsible when advising a paramedic even though a lot that will be done (or not done) is not under the physician’s control? If limits to patients’ ability to sue medical professions that have been much discussed in the U.S. are implemented, some of these issues may become less important but nonetheless such issues should be addressed before 3DMC was widely deployed.

Increased staffing, financial, and technical resources will be needed throughout the medical care system to enable 3DMC. Because 3DMC will provide higher levels of medical expertise to patients in the field and/or small medical centers more expert physicians and nurses may initially be needed to provide those higher levels of care. However, providing earlier expert- and better-coordinated care may subsequently decrease the need for subsequent medical procedures, lowering task load on physicians and nurses and medical costs and discomfort for patients. Furthermore, paramedics’ skill levels may increase through collaboration with physicians and nurses. Thus, it may be possible that over time the need for additional medical expertise to support 3DMC will be offset by decreased costs in the longer-term care of trauma patients. This should be monitored in trials of 3DMC.
TABLE 5. Summary of complexity attributes perceived by each frame.

<table>
<thead>
<tr>
<th>Compatibility attributes</th>
<th>Physicians at large medical center ER</th>
<th>Physicians at small medical center ER</th>
<th>ER Nurses</th>
<th>ER administration</th>
<th>Medical center and ER IT support</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conveniently located at hospitals</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimal equipment needed in the field</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Under local control</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Easy to learn</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quick set-up &amp; operating time; not delay transport of patient</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24/7 reliability</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Need IT support &amp; operation resources</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Need to provide &amp; finance IT support to multiple locations</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

TABLE 6. Summary of trialability and observability attributes perceived by each frame.

<table>
<thead>
<tr>
<th>Trialability and observability attributes</th>
<th>Physicians at large medical center ER</th>
<th>Physicians at small medical center ER</th>
<th>ER Nurses</th>
<th>ER administration</th>
<th>Medical center and ER IT support</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Clinical) Trials to show cost-effectiveness &amp; improved patient outcomes</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Physicians might resist it most (have most at risk)</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potential users &amp; stakeholders need to observe value via multiple quantitative measures</td>
<td></td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paramedics &amp; nurses need to observe explicit advantages when they use it</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
</tbody>
</table>

Financial and technical resources will be needed to cover the cost of installing and operating the technology needed for 3DMC, and adding security encryption and archival processes to protect patients’ privacy with respect to this new type of visual medical data. As with other network-based technologies, 3DMC will only be as good as the network infrastructure. Network reliability, speed of connections, and number of nodes or sites connected will influence the success of 3DMC. Goetz and Mayer-Patel (2004) and others are conducting research in telecommunications networks to support 3DMC and similar applications. How will new network technologies be financed to support 3DMC? In many regions financial and political arguments and partnerships are needed to install new network technologies and associated equipment broadly. The importance of this issue should not be underestimated. Study participants reported that in some areas of the region where they work cell phone coverage is not available today.

Complexity (Table 5)

Typical complexity issues such as ease in learning were mentioned by participants from different frames. Participants were also more specific regarding complexity and ease of use in their context. They indicated that 3DMC should be designed and developed with features to help install, operate, and troubleshoot problems with 3DMC equipment across geographic locations. These features will be needed right from the start and should be well integrated with other system features. In the past such features were often added on to systems after problems emerged.

Quick set-up time, instantaneous connections and transmissions, robustness, and 24/7 reliability were also mentioned. In addition, 3DMC reliability was well integrated with other equipment paramedics must carry in the field. Today paramedics typically carry several packs of supplies and equipment when going from their truck or ambulance to where a patient is located. When returning to their truck or ambulance they are often also carrying a patient in addition to carrying their equipment. Can 3DMC equipment be sufficiently small in size and/or well integrated with other equipment such that no additional carrying burden is placed on the paramedics? Similarly, 3DMC equipment should ideally be ubiquitous in medical centers such that physicians will have immediate physical access to 3DMC equipment without having to ‘go to’ a dedicated room or area housing the equipment. This might be achievable through mobile viewing devices or viewing devices well integrated into ERs. However, as stated in previous research (Chismar & Wiley-Patton, 2003), low complexity can never compensate for low relative advantage. That is, unless stakeholders see the usefulness or advantages of a technology, it does not matter whether the technology is easy to use or not, it will not be adopted anyway.

Trialability and Observability (Table 6)

Although complexity is introduced when implementing 3DMC for emergency healthcare, there are unique advantages that 3DMC may provide to emergency healthcare. Field trials are needed to determine if the advantages outweigh...
the complexities. Multiple quantitative measures, such as improved patient outcomes, decreased risks, decreased morbidity and mortality, cost-effectiveness, and additional revenues could be used in field trials to convince administrators, policy makers, and healthcare professionals that 3DMC provides value. Participants reported that physicians would want to see results from scientific clinical trials, whereas nurses and paramedics would want to see results from real-world, hands-on field trails. These differences may reflect the different educational backgrounds and differences in everyday work tasks of healthcare professionals.

Social Influence (Table 7)

In this study social influence emerged as a bidirectional force. In previous studies (e.g., Venkatesh et al., 2003) social influence was defined as influence that impacts a person's propensity to adopt and use an innovation. This emerged in our data, e.g., it was reported that a physician who championed 3DMC would greatly influence other's use of it, and government officials might influence organizations' decisions regarding adoption of 3DMC. However, our data also showed that 3DMC could act to influence others. For example, it could help attract the "right kind" of (paying) patient to a medical center. It could increase an organization's technical credibility and profile in medical and local communities. It might act as a quality assurance mechanism for small medical centers.

Conclusion

Our results illustrate that both social and technical challenges can be identified with respect to new innovations even before working prototypes are available. We propose that a video providing a basic vision of a proposed technology effectively elicits these challenges across different frames, and may perhaps reduce the need to develop multiple, successive prototypes and versions of systems. We, the researchers, only provide a basic vision of the new technology and potential adopters critique that vision. We listen and learn from those who have expertise and awareness of situations within that context.

In addition to providing insights to computer scientists early in the research and development cycle, visioning studies could be used by funding agencies and corporations to help them make decisions regarding strategic technology investments. We use the term "strategic" because obviously our approach has costs associated with it, and developing a prototype of an innovation that has minimal complexity might cost the same as, or less than, a visioning study. Also, if a new innovation will only be introducing incremental changes, then standard design methods such as observations of existing work practices may be sufficient. Our approach seems most applicable for innovations that will require large amounts of resources to develop and may introduce radically new ways of working.

Our results also contribute to innovation and adoption research in healthcare. For the medical center or hospital context we found that the innovation attribute compatibility was conceptualized in terms of processes, relationships, and resources. Trialability and observability were not separate concepts for participants, and social influence was perceived as being a bidirectional force.

We recommend that designers and developers of collaboration technologies strive to understand the interwoven situational awareness that exists across the multiple frames in which a new technology will be situated. Orlikowski and Gash (1994) propose that successful technology implementation depends on alignment and congruence between different frames. However, we propose that when technology, such as 3DMC, is to be used to facilitate collaboration among actors in different frames, each of whom has different ways of working and interacting with the technology, we should strive to understand and design to support these differences rather than to align them. This is especially important for technologies that strive to support collaborative work in time-critical emergency situations where there are few, or no, opportunities for humans to compensate for a technology's shortcomings. Early identification of and designing for common and unique social and technical concerns emerging from different frames may lead to systems that require fewer modifications when implemented in order to be adopted.
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References


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