The Impact of Usability in Emergency Telemedical Services

Shirley Beul[1]*, Sarah Mennicken*[2]*, Martina Ziefle*[2]*, Eva-Maria Jakobs*[1]*,*
Daniel Wielpütz[3]*, Max Skorning*[3]*, Rolf Rossaint*[3]
[1]Textlinguistics and Technical Communication,
[2]Communication Science, Human Technology Centre,
[3]Clinic for Anesthesiology
RWTH Aachen University, Germany

ABSTRACT

The aim of this study is to identify key usability requirements in telemedical services; in particular, services specialized on emergencies. To generate an optimal user-centered workflow, the communicative and organizational structure of an exemplary system was analyzed. We focused on the impact of new technologies, which are introduced to the medical workflow. The graying of societies implicates two major consequences in this context: An increasing number of older people needing medical care and a shortage of medical staff in the next generation reveal a threatening supply gap concerning the security of people's health. To bridge this gap, it is necessary to develop alternative systems, which can guarantee an area-wide supply of emergency medical services, especially in rural regions with an insufficient infrastructure. Results show a high potential of telemedical emergency care, though the benefit critically depends on the given system's usability and the appropriateness of the workflow. On this basis, we introduce first guidelines, in both, communicative and ergonomic criteria, which should be carefully followed by medical practitioners, and designers, likewise.

Keywords: telemedical service, teledoctor, emergency, usability, workflow analysis

INTRODUCTION

When people call an ambulance in case of emergency, they depend on the medical aid provided by emergency medical services (EMS). Due to the demographic change in western countries, the area-wide supply of EMS cannot be maintained in the future in its current form and quality. Because of the graying of societies, the population of experts in the medical sector, especially in EMS, declines while the number of older people relying on medical support increases. In rural areas of Germany, the shortage of emergency physicians has already been noticeable.

Looking behind the scenes of today's EMS in Germany, several shortcomings are revealed. Up to now, these systems lack of a systematic and standardized quality control, for both, communicative and or organizational structures: No nationwide standard or rather standardized quality control is implemented in EMS, so far. This is especially harmful as a rescue process entails a highly complex time-critical organizational workflow, with many actors on-site and remotely (hospital, police, fire brigades) as well as a high probability of pitfalls within this process. As a consequence of the complex circumstances a rescue mission is executed in, the documentation of the process often is insufficient in order to guide the rescue team in chaotic and time-critical situations. Also, the legibility of hard copy materials suffers from illegible handwritings of doctors, and the general problem of noting data while riding fast in an ambulance over bumpy streets.

One possible solution to bridge this upcoming supply gap and to overcome these present shortcomings is the implementation of telemedical services in the rescue chain, allowing the emergency doctor (referred to as ED) or paramedics on-site to access telemedical support if necessary. To derive full advantage of the telemedical services, requirements of its users (i.e. paramedics, the ED on-site (if present) as well as of the medical staff in the central unit remotely) have to be studied. How should an emergency telemedical service (ETS) be designed to be efficient, usable, and, most importantly, perceived as a surplus regarding time-critical information supply? How can ICT be smoothly integrated in the workflow without burdening, but supporting the medical personnel?

The majority of studies concerning ICT usage in EMS context so far concentrated on the usage of technology as such. Few studies focused on organizational issues and the communicative needs within different emergency teams [Reddy 2009]. Yet, the focus of studies dealing with emergency cases is mainly patient-centered [Trout 2000], while the perspective of emergency doctors has been widely neglected, even though he/she is the main actor taking the full responsibility for the treatment, organization of the whole operation, and the team coordination [Chisholm 2000]. In German EMS, the ED is the most important person as he is legally responsible for the patient's safety and the medical treatment of the first aid.

THE USAGE OF ICT IN EMS

One of the key factors for effective emergency management is designing and implementing ICT within the EMS workflow. ICT has the potential to effectively support the coordination and cooperation between staff involved in the EMS workflow. To date, there is an upcoming number of studies reporting on the usage of ICT in the emergency-rescue-chain. In the United States, telemedical consultations between physicians in the hospitals and paramedics on-site are widely used and mostly accomplished via radio. By the use of ICT, the quality of primary care and intra-hospital procedures could be optimized respecting a faster and a more focused transfer of information [Wuerz et al. 1995, Adams et al. 2006, van Halteren et al. 2006]. As a reaction to recent crises, as 9/11, or hurricane Katrina in the United States, medical informatics researchers started to develop ICT as corrective measures to be used in disaster situations [Walderhaug et al. 2008, McCurdy et al. 2005]. Another innovate approach [Na et al. 2010] aims at the broad implementation of a telematic system in EMS, a so-called "teledoctor". We will describe this concept in more detail in the following chapter. Across studies, a major claim is a high quality of ICT data reliability, security and safety, when designing innovative interactive systems for emergency response in a major incident [Kyng et al. 2006, Li et al. 2006].

Nowadays, it is widely accepted that ICT plays an increasingly important role in EMS and the workflow in hospital emergency departments. Though, to date, only few studies concentrate on communicative and as organizational issues as well as the coordination and cooperation of the different persons involved in the rescue chain. In a very recent study [Reddy et al. 2009], the coordination between a hospital emergency department and EMS team in the United States was examined, uncovering the enormous importance of social and communication aspects in the EMS workflow. Sociotechnical aspects [Berg, 1999] in the EMS-context are especially multifaceted and highly complex, accompanied by a high time pressure and responsibility. [Reddy et al. 2009] claim that the ICT usage within the EMS process must be based on a thorough understanding of the workflow and should face the potential areas of breakdown in the coordination between emergency personnel. In addition, the interaction of communication and interaction of humans with technology is an extremely important success factor to be considered in technology-supported EMS settings [Aarts et al. 1998, Manoj & Hubenko 2007, Wears & Perry 2002]. Among other factors, the technical competence of EMS staff, but also their acceptance barriers towards technology usage should be carefully studied prior to implementing technology in such a sensitive area [Arning & Ziefle 2009a+b, Ziefle 2002].

THE TELEDOCTOR CONCEPT

In the following, we explain the course of events in an emergency situation, actors, and the involved technology (Figure 1) in the telemedical process.

Firstly, a person calls 911 [112 in Germany] to inform the staff of the primary control unit about the emergency and to request the aid of a rescue team. The control unit transmits some incident describing keywords to the rescue team sent on-site. Usually, one emergency vehicle with two paramedics is sent out, but depending on the severity of the case, an additional car with an ED is dispatched as well. In this telemedical concept we evaluate the utility of additional medical staff: an experienced emergency medical physician in a competence center, the so-called teledoctor. Assisted by advanced mobile data transmission, all vital parameters of a patient, as well as video and pictures of the scene, are transferred in real time to the competence center. The teledoctor and one paramedic on-site can communicate verbally via headsets. The other staff on-site is equipped with headsets, too in order to track the communication.

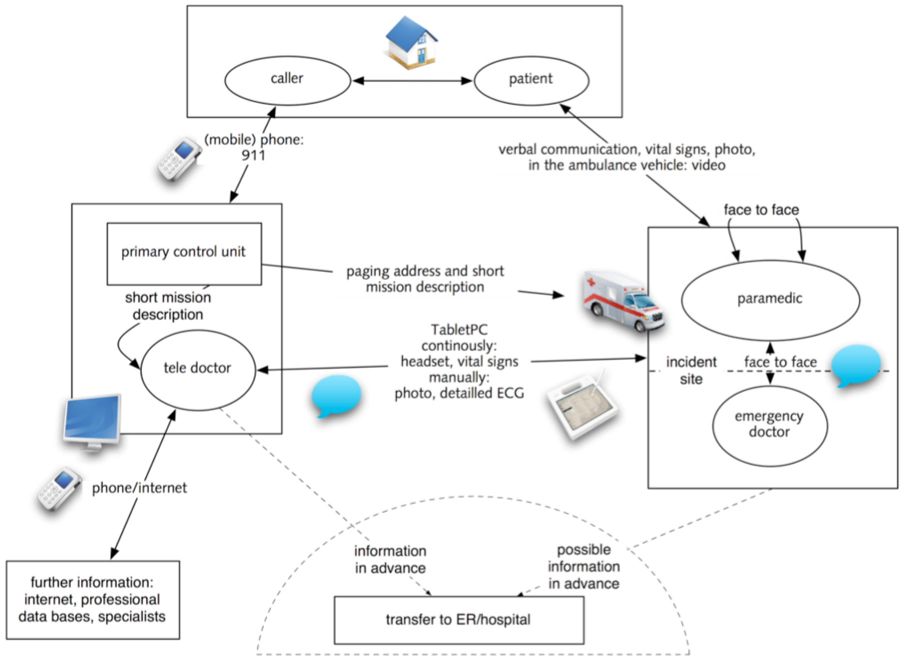

FIGURE 1: Subject of this analysis: the teledoctor concept

Besides verbal communication, the personnel on-site and the teledoctor can exchange information via a software installed on a tablet PC (see Figure 2). The teledoctor has the same software at his disposal and can enter the information with a multi-display workspace setup (see Figure 3).

FIGURE 2: ED using the tablet PC

FIGURE 3: Teledoctor in the multi-display workspace setup of the competence center

The software allows entering information as of a common emergency log. Besides this software, the teledoctor has access to information online as databases, e.g.

with detailed information on pharmaceuticals. Via a protected connection he/she can track the local position of the emergency vehicle on an online maps application and look inside the car by using a controllable camera. With this information, EDs can help the staff on-site with organizational support e.g. to contact a hospital, transfer data about the incident to the doctor in charge, consult with other institutions (e.g., family members, cardiologists, poisoning centers) or assist the completion of the emergency log. The EMS personnel on-site can mainly focus on the patient's care and does not have to handle the various demands of an emergency situation.

ANALYSIS AND EVALUATION OF AN EMERGENCY TELEMEDICAL SERVICE

In the following we describe the methods we used for the analysis and evaluation and the results we derived from them.

METHODS

To evaluate the teledoctor concept a triangulation of methods was undertaken: semi-structured interviews, a participatory observation, and an ergonomic evaluation of the most important mobile technical device in the teledoctor concept, the tablet PC.

For the *semi-structured interviews*, an interview guide was designed. Medical professionals (n=11, $ED_{1\ldots11}$) volunteered as participants. These doctors (anesthesiologists) were on duty on several departments of hospitals (e.g. operating room, intensive care unit etc.) Apart from this, all queried physicians are taking shifts in EMS. Partially, they were experienced in using telemedical support (n=5). The interviews were recorded, transcribed and qualitatively analyzed regarding content.

Also, a *participatory observation* of real emergency cases was run: Two observers took part in eight rescue missions to identify problematic issues within the workflow. Observers were taking shifts alternately in the ambulance and the teledoctor office. Remarkable actions were recorded, as well as problems and individual coping strategies (measures taken by the actor to handle and solve the problem).

In order to evaluate *usability and ergonomic issues* of the tablet PC, we created a hardware dummy with the same measurements and shape as the as the original tablet PC, but made of wood with an adjustable weight. Each participant had to perform different writing tasks on a dummy with a predefined weight. The dummy was given to the people without explaining its handling to observe their intuitive way of grabbing and holding it. This is visualized in Figure 4.

30 participants (18-60 years, 50% of each gender (male: M=34 years, SD=14; female: M=39 years, SD=13) took part in our setting, which were allocated to three groups: Group 1 dealt with the dummy prepared with the original weight of the tablet PC (3.31 lbs/ 1500 g). A 2.43lbs/ 1100 g dummy was handed out to the second group and 1.54 lbs/ 700 g to group 3.

FIGURE 4: Snapshots of participants when handling the dummy and making notes

In the participatory observation on the emergency vehicle, we were able to watch the original tablet PC in use. Since it was never used no longer than five minutes without interruption when standing, we conducted our study not to last any longer than that. To create a realistic task we read out a story to users, while they answered some questions about it by marking the correct answer on a paper questionnaire placed on the dummy. After answering story related questions, users evaluated the appropriateness of the dummy's weight (using another questionnaire).

RESULTS

Integrating ICT in the traditional workflow changes the process of a rescue mission. In particular, technical devices and its usage become an additional issue the medical staff has to deal with. The system presents strengths and weaknesses, which will be discussed. We will provide guidelines to overcome the mentioned risks as well.

Communication, Information and Organization Flow

Due to the integrated ICT, the communication between the medical personnel changes. The actors on-site communicate with the physically absent teledoctor. Neither eye contact nor physical actions (e.g. gestures) can be used to attract the attention of the people on the other location or to react on a natural turn-taking within the conversation. In this case, actors have to ensure with verbal comments that the interlocutor is listening, and to bide the correct moment to speak. „You must develop an own communication culture [within the system]. […] You have to learn to let people finish speaking, and to announce before asking a question as each question may interrupt actions on-site and deflect [actors'] attention" (ED_{10}). To overcome these problems, communicative guidelines should be defined regarding the identification of communicative paths, and the successful turn-taking between teledoctor and speaker on-site. In addition, the teledoctor must turn off her/his microphone when not needed in order to avoid the transmission of unnecessary noise or comments, which distract the rescue team on-site.

Furthermore, the communication on-site is reduced within the rescue team as well as between the medical staff and the patient because of the communicative integration of the teledoctor. The paramedics and the ED on-site are concerned with new tasks: They have to communicate with the teledoctor respectively among the team and interact with ICT (e.g. tablet pc) or medical devices (e.g. ECG etc.) simultaneously, which takes attention and cognitive resources. On the other site, the teledoctor's job demands high multitasking abilities, too. Thus, the amount of information and the workload is to be reduced to the most necessary extent. For this purpose, informational requirements of the medical personnel have to be identified. Mainly, by investigating informational needs of querying EDs (and paramedics) and the actual usage of the system (e.g. input modes) should detect the most suitable way of information representation and the appropriate amount of information.

Additional factors, which determine the success of this ETS, are a consequent report of feedback and a clear division of labor. By analyzing the communication between the teledoctor and the speaker on-site, it becomes obvious that redundant conversations were conducted and one party has to inquire the other about the progress of current actions. Both must give feedback about her/his actions frequently to share the workload efficiently. Therefore, feedback rules are needed and an EMS–related feedback etiquette. Moreover, tasks within the rescue operation have to be divided clearly across the team. The teledoctor should execute actions appropriate to his workspace. To support the rescue team on-site, s/he should be responsible for the enrolment at the hospital, the writing of the emergency log, and the mining of patient data, for instance, retrieving data regarding the patient's anamnesis (physician's letters, medical history) from hospital's or surgery's databases. For this reason, it has to be ensured that the teledoctor can access important patient data.

However, completing these tasks depends on the quality of the information flow: "As the teledoctor, I often take care of the enrolment at the hospital and the transfer of the patient data to the doctor in charge there to support the ED on-site. Thus, I am not having all [required] informations and I can never answer questions [of the emergency room receptionist] regarding the patient. Then, I have to interrupt the talk. In this case, I do not know if data gets lost or is transmitted incorrectly, […] although it [my support] reduces the workload of the emergency physician on-site" (ED_{11}). As a consequence, necessary information must been transmitted (or requested) before beginning to process the task.

Apparently, the patient is not exclusively in the focus of attention in the emergency operation any more. In the interviews, EDs with experience of being telemedically-supported remark an alleged attention shift from the emergency situation and the patient to the advice or discussion with the teledoctor. Also, sometimes the patient is confused by the voice connection between the "invisible" teledoctor and the ED on-site (ED_8). For this, guidelines have to be established in order to control the communication between the teledoctor and the rescue team.

Usage of ICT within the Workflow

The implemented ICT should meet four general requirements concerning appropriateness, robustness, durability, and weight. The technical equipment should fit into the workflow according to the varying circumstances on the incident site.

First, the set of devices must be reduced to a minimum extent at least. If possible, multifunctional devices should be used. Second, regarding the results of our participatory observation, used hardware must be rugged and robust because it is placed everywhere possible on-site. Third, the battery of devices must last for a few hours. Presently, it often has to charge in the ambulance vehicle for which it has to be mounted and cannot be used meanwhile. Recharge and mounting units should be designed in a way that the device can be used while charging. Fourth, it must be lightweight because it is an add-on to the current medical equipment. In our ergonomic evaluation of this device, the majority of participants assessed the original weight (3.31 lbs/ 1500 g) as too heavy (Figure 5). Due to our results, we highly recommend the usage of a handheld device in ETS with a weight between 1.54 lbs/ 700 g and 2.43 lbs/ 1100g.

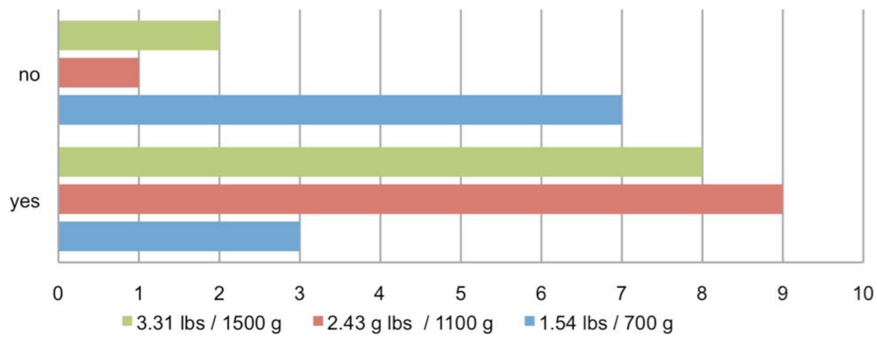

FIGURE 5: Should the tablet PC be more lightweight? For each weight class n = 10.

Concerning the tablet PC in particular: Software should deliver a real time feedback about the teledoctor's notes to the ED on-site to avoid taking the same notes two times. Thus, the teledoctor can write the log of the rescue mission by listening the conversation between ED on-site and the patient, which the ED on-site can see. Therefore, a feature of the system should be a collaborative, real time text editing for both users by employing high-quality audio equipment.

The design of the graphical user interface (GUI) is even more important than adding or improving functions of devices. The common principles of ergonomic design should be followed carefully as the quality of the GUI often determines the user's performance and her/his degree of satisfaction while using the device.

Finally, reliability of the technical equipment in general, and of data transfer in particular is another key requirement, which should be taken for granted in high-quality ETS. The system has to report feedback immediately to the teledoctor and the ED on-site because an emergency case people's health is in high-risk and time sensitive situation.

CONCLUSION

The evaluation and analysis of the teledoctor concept as a telemedical support for emergency situations basically showed positive results. All interviewed emergency doctors agreed that the teledoctor is a powerful concept, which may compensate for the lack of emergency physicians on-site, supports less experienced colleagues (with a possibly) different specialization, and allows to context-adaptively advise paramedics as well as to authorize medical treatment. Also, respondents agreed on the increasing efficiency of the emergency process: with the help of a teledoctor, the diagnosis on-site can be accomplished by virtue of a more detailed and targeted medical information, which basically expedites the logistics and the organization of the rescue operation. Basically, any technical support in the high-demanding and time-critical rescue-chain is a relief to the emergency staff involved in the process.

However, the interviewed emergency doctors also reported shortcomings and barriers towards the usage of a teledoctor. One concern is the low trust in the reliability of the technology involved. The second one was the alleged attention shift from the emergency situation and the patient as such to the advice or discussion with the teledoctor. With respect to optimization of the emergency situation, the teledoctor concept seems to be a promising way of meeting the upcoming challenges in emergency medicine. Future studies will have to examine if the concerns raised by the EDs will vanish with increasing experience in both roles: as ED on-site or as supervising teledoctor in the primary control unit remotely.

REFERENCES

Aarts, J., Peel, V. and Wright, G. (1998), "Organizational Issues in health informatics: a model approach." *International Journal of Medical Informatics*, 52(1-3), 235–242.

Adams, G.L., Campbell, P.T., Adams, J.M. et al. (2006), "Effectiveness of prehospital wireless transmission to a cardiologist via handheld device for patients with acute myocardial infarction." *American Journal of Cardiology*, 98, 1160–1164.

Arning, K., and Ziefle, M. (2009a), "Different perspectives on technology acceptance." In A. Holzinger et al. (eds.). *HCI for eInclusion.* Berlin: Springer, 20–41.

Arning, K., and Ziefle, M. (2009b), "Cognitive and personal predictors for PDA navigation performance." *Behaviour and Information Technology*, 28(3), 251–263.

Berg, M. (1999) Patient care information systems and healthcare work: A socio-technical approach. *International Journal of Medical Informatics*, 52(2), 87-101.

Chisholm, C.D., Collisson, E.K., Nelson, D.R., and Cordell, W.H. (2000), "Emergency Department Interruptions: Are Emergency Physicians "Interrupt-driven" and "Multi-tasking"?" *Academic Emergency Medicine*, 7(11(, 1239–1243.

van Halteren, A., Bults, R., Wac, K., Dokovsky, N., Koprinkov, G., et al. (2004), "Wireless body area networks for healthcare: the MobiHealth project." *Studies of Health Technolology Informatics*, 108, 181–193.

Kyng, M., Nielsen, E., and Kristensen, M. (2006). Challenges in designing interactive systems for emergency response. *6th Conference on Designing Interactive Systems*, 301–310.

Li, J., Wilson, L., Stapleton, S., and Cregan, P. (2006), “Design of an advanced telemedicine system for emergency care.” *18th Australia conference on Computer-Human Interaction: Design: Activities, Artefacts and Environments*, 416.

Manoj, B.S., and Hubenko, A. (2007), “Communication challenges in emergency response.” *Communication of the ACM*, 50(3), 51–53.

McCurdy, N.J., Griswold, W.G., and Lenert, L.A. (2005), “RealityFlythrough: enhancing situational awareness for medical response to disasters using ubiquitois video.” *American Medical Informatics Association*, 510-514.

Na, I.-S., Skorning, M., May, A., Schneiders, M.-T., Protogerakis, M., Beckers, S., Fischermann, H., Brodziak, T. and Rossaint, R. (2010), “Med-on-@ix: Real-time Teleconsultation in Emergency Medical Services – Promising or Unnecessary?” In: Ziefle, M., and Röcker, C. (eds.). *Human-Centered Design of eHealth Technologies.* Hershey, P.A., IGI Global.

Reddy, M., Paul, S., Abraham, J., McNeese, M., DeFlitch, C., and Yen, J. (2009), “Challenges to effective crisis management: Using information and communication technologies to coordinate emergency medical services and emergency department teams.” *International Journal of Medical Informatics*, 78 (4), 259–269.

Trout, A., Magnusson, A., and Hedges, J. (2000), “Patient Satisfaction Investigations and the Emergency Department: What Does the Literature Say?” *Academic Emergency Medicine*, 7 (6), 695-709).

Walderhaug, S., Meland, P., Mikalsen, M., Sagern, T., and Brevik, J. (2008), “Evacuation support system for improved medical documentation and information flow in the field.” *International J of Medical Informatics*, 77 (2), 137-151.

Wears, R., and Perry, S. (2002), “Human factors and ergonomics in the emergency department.” *Annals of Emergency Medicine*, 40 (2), 206-212.

Wuerz, R.C., Swope, G.E., Holliman C.J., and Vazquez-de Miguel, G. (1995), “Online medical direction: a prospective study.” *Prehospital Disaster Medicine*, 10, 174-177.

Ziefle, M. (2002), “The influence of user expertise and phone complexity on performance, ease of use and learnability of different mobile phones.” *Behaviour and Information Technology*, 21(5), 303-311.

ACKNOWLEDGEMENTS

We owe gratitude to the emergency doctors, who volunteered to take part in this study. Thanks also to the EMS staff of the professional fire brigade Aachen, Germany, which allowed us to gain insights into a thrilling professional area. Also, we thank Oliver Sack, Simon Himmel, Stefan Ladwig, and Teresa Schmidt for their research support, as well as Jochen Dahlhausen for helping creating the dummy. This work was funded by the Excellence initiative of German State and Federal government.