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Research Article

RFID based patient registration in mass casualty incidents

Abstract

In MCIs (mass casualty incidents) the EMC (emergency medical chief) has to gain an overview on all patients at the scene. When using paper based patient tags the patient-related information remains at the patients themselves and the information relay is complex. We propose a mobile, RFID based solution, which makes the local patient-related information available to all relief workers at the scene. As a consequence all processes in an MCI are more transparent and the resulting medication and transport of the injured is more efficient. The introduction of RFID enhanced patient tags leads to various usability challenges which are discussed in this paper. Furthermore, three different implementations show, how these challenges can be solved in the future. These solutions have been evaluated in a disaster control exercise in order to get an impression of the practical suitability of the proposed solutions. The future introduction of RFID tags in rescue and emergency services can be based on this work.

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1 Introduction

In MCIs (mass casualty incidents) the emergency medical chief (EMC) cannot triage all patients contemporarily due to the great number of injured. Consequently the first relief units at the scene instantly start with triage in order to identify the severely injured patients as quickly as possible [1]. Nevertheless the EMC has to gain an overview on all patients at the scene. In MCIs not all patients can be medicated at once. The optimal resource allocation, however, can only be guaranteed when information on all patients is available to the EMC promptly. Therefore, the patient-related information is important for the overall incident response.
This paper focuses on the design, implementation and evaluation of user-interfaces for the mobile registration of patients in MCIs. In this paper different mobile, RFID based and electronic approaches are compared to paper based approaches for registering patients during triage and treatment. In collaboration with TUM (Technische Universität München) Feuerwehr a disaster control exercise was organized in order to evaluate the performance of these different approaches.

1.1 Usability in MCIs

Mobile user-interfaces, which can be intuitively used by the relief units, differ significantly from standard mobile user-interfaces. In MCIs relief units focus on triage and medication of severely injured patients. Documenting the patients' condition and the treatment plays a secondary role. In stable environments – such as hospitals – documentation is performed by nurses who on the one hand assist the doctors and on the other hand document the treatment. However, in order to use the available resources at the best, in MCIs the documentation process has to be integrated in the treatment process. In unstable and time-critical situations, which occur in lower frequency, intuitive and usable mobile user-interfaces are essential for the success of the whole rescue operation. The requirements on these kinds of mobile user-interfaces are high and the introduction of novel user-interfaces is a challenge.
Geographical information, static information and patient related information are of upmost importance in MCIs. Concepts for presenting geographical information on mobile userinterfaces have already been presented elsewhere [2]. Static information, however, has not to be entered during the MCI itself. This paper focuses on mobile user-interfaces for entering patient related information. An approach for supporting triage by electronic means has been already published [3]. The advantages of combining RFID technologies and paper based approaches for documenting patient-related information have been presented in Nestler et al. [4]. Details on the implementation of the overall system which is used for the evaluation of the mobile user-interfaces can be found in the thesis from Endres [5].

1.2 Motivation

The quick relay of all patient-related information is of crucial importance in MCIs. Mobile devices offer various functionalities for the quick and wireless relay of information to surrounding devices. Spreading paper based information in an MCI, however, is more difficult, more laborious and slower. Therefore, the usage of mobile devices is reasonable with regard to the transmission of patient-related information. Inappropriate mobile user-interfaces frequently hinder the relief workers from using mobile devices in MCIs. The mobile user-interface is crucial for the successful introduction of new solutions in the emergency domain. The best mobile user-interface has to be identified by implementing different promising approaches and evaluating them in a disaster control exercise.

First of all the requirements on mobile user-interfaces are identified. On the basis of these requirements prototypic implementations are developed and different alternatives are evaluated.

2 Related work

First of all the term *mobile* has to be defined. An MCI is a scenario in which the term *mobility* can be described very concrete. According to Rügge et al. [6] three different types of mobility exist: (1) interaction on the move, (2) interaction at changing places and (3) focus in the reality. This definition shows, that medical emergencies in general are a challenging environment for mobile solutions. The interaction on the move (1) is especially important in situations in which the relief workers have to move permanently. In regular emergencies relief workers change their place (2) only once – in order to reach the patient. All other interactions can be performed during standstill (≠ 1). In MCIs, however, the relief workers change their position permanently (= 2) and interaction on the move is essential for finding the next patient (= 1). Consequently the requirements regarding mobility are significantly higher in MCIs as opposed to hospital care or standard emergencies. The mobility is not limited to the relief workers, patients are mobile to some extent as well.

2.1 Triage

In MCIs mobile user-interfaces can support the registration of new patients during the triage. Killeen et al. [7] proposed a mobile user-interface to gather triage information. This basic entry mask is always shown when a new patient is registered. The triage category is deduced from the entered information. Furthermore, the performed treatment and the applied medication including dose, way of application, unit and time can be documented. The user-interface supports the direct documentation of the performed treatment and increases the flexibility and mobility of the relief workers, due to the fact that they can seamlessly switch between various patients. Furthermore, the two aspects context and focus are combined in this user-interface. Whereas the context usually depends on place and time, in MCIs the context is additionally influenced by unanticipated events. By combining different information sources and by reacting on these changes of the environment, the overall system becomes even more flexible [8].

2.2 Monitoring

The *SMART* system from Sorelle et al. [9] is an example for a simple, mobile system for patient monitoring. The system is attached to the patient and supervises the condition and position of the specific patient. Although the *SMART* system bases on mobile devices, no user-interface is provided. The developers assume, that most of the patients are not able to interact with the mobile device – even if the user-interface is rather simple and intuitive. Considerations on the general need for mobile user-interfaces in the health care domain are presented by Grisedale et al. [10]. This work focuses on the challenges, which occur when mobile user-interfaces are presented to less experienced users. As soon as the users become aware of the importance of their information, the acceptance of novel user-interfaces increases. By incorporating the immediate feedback in mobile-user interfaces, mobile-user interfaces could even be accepted by seriously injured patients. Literature search revealed three different basic approaches for monitoring patients: (1) indirect monitoring (patients are monitored by relief workers), (2) automatic monitoring (patients are monitored by a combination of mobile devices and sensors) and (3) interactive monitoring (patients are monitored by giving feedback).

2.3 Mobility

Some years ago various researchers started to develop novel mobile user-interfaces, due to the fact that former technical limitations regarding communication, portability and mobility could be solved [11], [12]. Chen et al. [13] present an overview on different mobile userinterfaces. Furthermore, they developed mobile user-interfaces which adapt automatically to extreme situations. The concept from Baus et al. [14] illustrates how this adaption could look like in practice. At the example of internet applications [15] show how mobile userinterfaces can adapt to small displays, limited input modalities and slow communication channels. Concepts for context awareness which are not limited to location awareness are presented by Schmidt et al. [16], [17]. Furthermore, different researchers focus on the question how mobile user-interfaces could be utilized in hospital environments. A combination of public displays and mobile, personal devices in hospital settings is proposed by Favela et al. [18]. The mobile presentation of patient-related information, general medical knowledge and hospital related information is discussed by Ammenwerth et al. [19]. Ancona et al. [20] give an overview on the different concepts for presenting information in hospitals – some of these concepts include the interaction with mobile user-interfaces. Hospital information systems and possible interfaces to mobile applications are also presented in publications [21], [22], [23]. Technologies such as GPS and GSM are the basis for mobile user-interfaces, as argued by Fischer et al. [24]. According to Grasso [25] mobility mainly leads to new challenges regarding fast, reliable and secure communication. Only few researchers, such as Killeen et al. [7], are aware of the fact that mobility primarily leads to usability challenges.

2.4 RFID

In the last years various concepts for extending patient tags with RFID-chips have been presented. These concepts base on RFID-chips, which can be read and written with the mobile devices of the relief workers. Inoue et al. [26] developed a mobile system for the MCI triage on the basis of RFID enhanced patient tags. Their approach, however, bases on the assumption that communication between the mobile devices is permanently possible. A similar approach for patient registration with RFID in combination with a wireless network was developed by Chao et al. [27]. In contrast to these two solutions Massey et al. [28] presented a peripheral system for MCI triage. Their network, *AID-N*, is composed of embedded systems, which are extended with different sensors. These modules facilitate the storage of triage results and the monitoring of vital signs – further information on the medication, however, cannot be stored on these embedded systems. Gao et al. [29] use 2D barcodes for the unique assignment of paper based tags and electronic data sets. The *ITT* is an intelligent patient tag with microprocessor, memory and communication module [30]. When using *ITT*, patients can be visually and acoustically labeled for treatment or transport. However, the field of application for RFID patient tags is not limited to MCIs; other projects focus on introducing RFID in the health care domain in general [31], [32], [33]. RFID based approaches require additional hardware, such as mobile devices [27], [34], [30]. In general RFID identification is considered to be error-prone [29] and difficult [28].

3 Requirements

The aim is to improve the documentation of patient-related information by using an appropriate mobile user-interface. The practitioners for TUM Feuerwehr expect that the improvement of the documentation process results in a better assignment of relief workers and emergency doctors. The mobile user-interface has to be integrated in the triage, treatment and transport process. Consequently the current processes are analyzed within the scope of this requirements analysis before requirements at mobile user-interfaces are determined.

3.1 Current process

In an MCI every patient gets a paper based patient tag, on which particulars as well as information on triage and treatment is documented. During triage relief workers hang the tag around the patient's neck. At the earliest at the second contact – during treatment – a short diagnose and vital signs are documented on the tag. Typically the patient's particulars are registered at the treatment places. Finally details on the transport are written on the tag before the patient is transported to hospital. Due to the fact that the colored bar at the bottom of the tag is visible to the relief workers even from greater distances, a quick perception of the patient's category is facilitated. Patients with life-threatening injuries are labeled with *red* tags, patients with severe injuries are labeled with *yellow* tags and patients with minor injuries are labeled with *green* tags. Dead persons are labeled with *black* tags. Moreover all patient tags contain an unique identifier and various input fields for surname, name, date of birth, gender, time, date and team as well as input sections for information on transport and treatment.
Paper based patient tags which are hung around the patient's neck have the advantage, that all relief units who medicate a certain patient have unrestricted access to all patient-related information. By fixing the patient tag, the risk of accidental loss or permutation can be reduced. The major problem is, that paper based patient tags are not directly visible to the incident commanders. When documentation is limited to patient tags, no central patient-related information is available. In order to access information on a specific patient, the concrete patient has to be found. Because the risk of overlooking patients is too high, relief workers additionally document all triaged patients on a spread sheet. This spread sheet contains the patient's unique identifier as well as his category. After triage is completed this spread sheet is handed to the incident commanders. This redundant documentation of the patients is error-prone for three reasons: (1) relief workers might forget to hang the tag around the patient's neck, (2) relief workers might forget to document the patient on the spread sheet and (3) the patient tag might be inconsistent to the entry on the spread sheet. The proposed concept has to be robust against these three different types of errors.

3.2 Mobile user-interface

The requirements have been determined in cooperation with TUM Feuerwehr, especially with Thomas Schmidt – the deputy fire chief. During the conversations with TUM Feuerwehr it became clear, that the introduction of new technologies and mobile user-interfaces may not complicate the existing processes. First of all, however, we had to describe the characteristics of the RFID technology to TUM Feuerwehr. Most of the relief workers have never come in touch with RFID technology before.
The major requirements on mobile user-interfaces for interacting with RFID chips are: (1) intuitiveness of the registration process, (2) field of application not limited to MCIs and (3) high learning rate. Especially the first requirement is a challenge because the question how the registration of RFID chips can be realized in an intuitive way is not solved, yet. In other words: Is it possible to interact with RFID enhanced patient tags, even though it is not clear to the user, that he interacts with RFID enhanced patient tags? The second requirement can be achieved as soon as advantages of using RFID enhanced patient tags can be shown. For instance in the everyday rescue services the paper based and electronic information could be coupled via RFID chips as well. The learning rate as

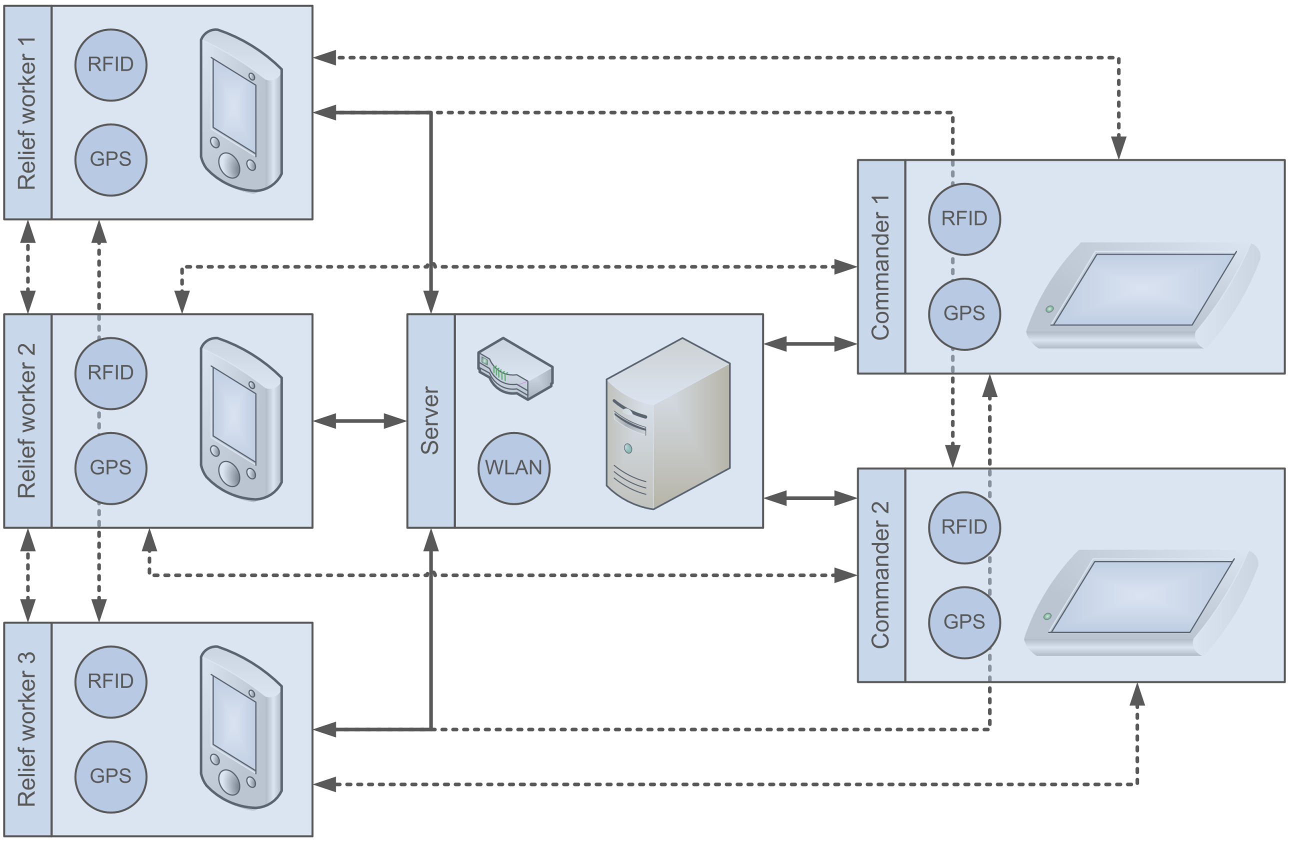


Figure 1: System architecture

well as the intuitiveness of the interaction model, however, can only be proven within a disaster control exercise. From evaluations in the past, especially regarding the electronic support of *mSTaRT* triage, we know, that the complete digitalization of the triage process on the one hand increases the traceability and on the other hand slows down the overall triage process [4]. The reason can be found in the good learnability of *mSTaRT* and in the fact that most relief workers don't strictly adhere to the *mSTaRT* process. The requirement on the mobile user-interface is, to facilitate the electronic documentation of the triage result. During the conversations with TUM Feuerwehr it became clear, that the triage result is more important for the subsequent treatment than the triage path. The result is the most important information, which is gathered during triage. In case of inconsistencies between the patient's condition and the triage result in most cases the relief workers or the EMC perform a re-triage.

An additional requirement on mobile user-interfaces for the interaction with RFID-chips is the transparency in the process of information relay. The most important results have to be electronically available to the incident commanders. Furthermore, relief workers have to have access to patient-related information even if wireless communication is not possible. This requirement leads to the need for a peripheral storage of the most important information. In discussions with TUM Feuerwehr it turned out, that an electronic approach could be successful if and only if the electronic approach is equal to the paper based one or leads to an additional benefit for the incident commanders. Therefore, every relief worker has to be able to access all electronic patient-related information when he medicates or transport the patient.

4 Concept and implementation

For the evaluation of mobile user-interfaces different alternatives have to be implemented. The implementation of the overall system is described in the theses [35] and [5] in detail. Therefore, in this paper only the basic concepts of the different implementations are described. Besides the different mobile user-interfaces a central server and communication layer is required as shown in Figure 1. The interfaces to this communication layer were designed in a way that they can be used with mobile hand-held devices as well as with mobile Tablet PCs. The *Zypad WL 1110* was used as hardware platform for the implementation of the mobile user-interfaces. The ruggedized devices are shown in Figure 2. These devices are equipped with an integrated RFID-reader. The mobile user-interfaces have been implemented with the .Net Compact-Framework 3.5 in C#. This framework guarantees a high portability of the user-interfaces to a wide variety of hand-held devices.

Our first implementation which was evaluated in a disaster control exercise concentrates on the triage process and the storage of the triage result on the RFID enhanced patient tag.

The implementation of the mobile user-interface was driven by the aim to keep down the distraction. In sum-

Figure 2: Implementation on the Zypad WL 1110
(a) Implementation on the Zypad; (b) Scanning an RFID enhanced patient tag with the Zypad

mary three different dialogs for the documentation of the triage process have been implemented. These three alternatives differ in the interaction concept.

The central element of $RFID_{double}$ – the first alternative – is the dual scanning of the RFID-chip. In order to start the triage process the RFID enhanced patient tag has to be scanned with the mobile device. In the mobile user-interface all on the RFID-chip available information can be accessed. The dialog facilitates the selection of the triage category, whereas the pre-defined triage category is already pre-selected. This pre-definition of the RFID-chip is similar to the pre-definition of the paper based colored bar. In the case that the pre-defined triage category conforms to the actual triage category the information is confirmed by a second scan of the RFID-chip. The triage dialog is automatically stored and closed by the second scan. In the rare case that the triage category has to be changed, the user can set the right category by interaction with the touch-screen of the mobile handheld device. Consequently the triage with $RFID_{double}$ consists of four steps: (1) hold the patient tag in front of the mobile device, (2) check the triage category on the display of the mobile device, (3) change category if necessary and (4) hold the patient tag in front of the mobile device a second time.

The second alternative, $RFID_{single}$, bases on non-recurring scanning of the RFID-chip. The triage dialog is shown as soon as the patient tag is hold in front of the device. Furthermore, the triage category – similar to $RFID_{double}$ – is pre-selected. The triage dialog, however, is closed by clicking the button "report" instead of scanning the RFID-chip a second time. When the pre-defined triage category is not changed (changing the pre-defined category is only necessary if no tags with the required category are available) the triage is finished and the information on the tag is consistent to the information on the mobile device. When the user changed the triage category, however, the RFID-chip has to be scanned a second time in order to adapt the information on the chip. Consequently the triage with $RFID_{single}$ consists of five steps: (1) hold the patient tag in front of the mobile device, (2) check the triage category on the display of the mobile device, (3) change category if necessary, (4) report the triage result and (5) hold the patient tag in front of the mobile device if the triage category was changed in step 3. The $RFID_{single}$ is a simplification of $RFID_{double}$, because in most cases the second scanning is left out. The $RFID_{single}$, however, is less consistent, because in some cases (if the category is changed) a second scanning of the patient tag is required.

The alternative *Number* does without an RFID-chip – the assignment of paper-based and electronic information is done by manually entering an unique identifier. The mobile userinterface includes a numeric keypad, which is used for entering the identifier. After the identifier has been entered, the triage dialog is shown. Due to the fact that the category cannot pre-selected in this alternative, the category is selected by interacting with the touch-screen and confirming the category via the "report"-button. The disadvantage of *Number* is, that the triage result cannot made available at the patient in an electronic way. The major advantage is, that neither an RFID enhanced patient tag nor a device with RFID capabilities is needed. The triage with *Number* consists of four steps: (1) open the triage dialog, (2) enter the unique identifier, (3) select the triage category and (4) report the triage result. The first two steps are not automatically performed by reading the RFID-chip, consequently they are more error-prone as opposed to the RFID approaches.

Besides the dialog for entering the triage result, additional dialogs for entering information on particulars, treatment and transport have been implemented. During the medication a short diagnosis, measurements and medication are documented. The particulars consist of name, surname, date of birth and gender. Before the patient is transported, mode of transportation, destination and priority are entered. For a sound documentation the paper based patient tag has to be displayed on the mobile user-interface. In Nestler et al. [4] concepts for presenting the complete patient tag on small-screen devices have been discussed. Due to the conversations with TUM Feuerwehr, the dialogs were ordered in main dialogs and subdialogs. The classification bases on the different processes in MCIs: (1) Triage (triage category), (2) registration (name, surname, date of birth and gender), (3) diagnosis (short diagnosis and injuries), (4) condition (consciousness, breathing, circulation), (5) therapy (measurements, medication) and (6) transport (mode of transportation, destination and priority).

5 Evaluation

The evaluation of the implementations is of crucial importance to determine the practical suitability and efficiency of the different mobile user-interfaces. The evaluation was performed in close cooperation with TUM Feuerwehr, which was supported by prospective paramedics from Walner-Schule in Munich. The evaluation focused on the question how an RFID enhanced patient tag can be integrated in the triage process at the best. In summary nearly 40 persons very involved in the evaluation: 10 mimes, 16 subjects, 4 supervisors, 2 technical coordinators, 2 evaluation coordinators and 2 photographers.

The scenario for the evaluation was the following: On a highway a serious road accident has occurred, in which several cars are involved. Four cars are seriously damaged and in each of these cars are three injured passengers. The cars are spread over a distance of about 50 meters. The accident lead to different injuries: head injuries, fractures, abdominal traumas and fatal injuries. Two dead passengers are represented by training mannequins, all other injured are played by mimes. The 16 relief workers formed 8 triage teams; each of these teams had the task to triage all 12 patients. In summary each of these teams performed four runs – one run with $RFID_{double}$, one run with $RFID_{single}$, one run with *Number* and one run with *Paper* (without a mobile user-interface). Each of the teams performed 48 (12 patients * 4 runs) triage processes. Each of the patients was triaged 32 (8 teams * 4 runs) times. In summary 8 (teams) * 48 (triage processes per team) = 12 (patients) * 36 (triage processes per patient) = 384 triage processes have been performed.

In cooperation with TUM Feuerwehr we designed a training concept which allowed the simulation of 32 MCI situations within 180 minutes.

During the preparation phase a flexible card concept was explained to the mimes. An injury type was assigned to each mime and he got a card on which the appropriate behavior was described. For each injury type one red, one green and one yellow card existed. By this concept a direct conclusion from the injury to the category without performing a proper triage (triage primarily focuses on the influence of injuries on the vital signs and not on the injuries themselves) was avoided. After each run the mimes changed their cards with other mimes with the same injury type. Furthermore, all cards had an unique identifier, with which the correctness of the triage could be checked.

The four supervisors escorted the triage teams and documented their triage processes – including the mimes' identifiers. Moreover the elapsed time was protocoled. In order to reduce the total time of the evaluation four teams were evaluated simultaneously. Each of the four teams started at one of the four cars and rotated synchronously from car to car – similar to a circuit training. Consequently the supervisors were also responsible for covering the tracks – especially for removing the patient tags. Subsequent to the run the four teams had to fill out several questionnaires and the other four teams performed the evaluation.

5.1 Questionnaires

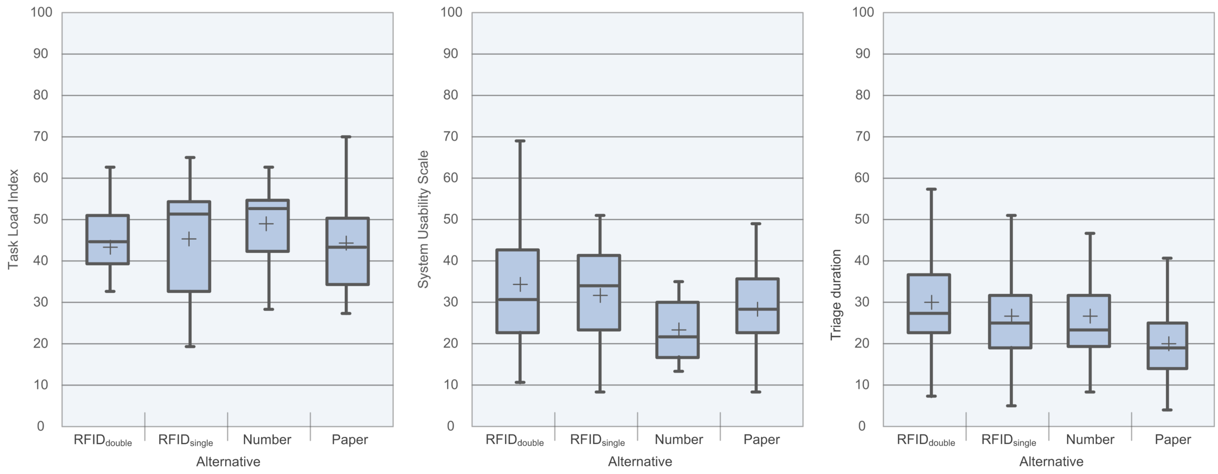
Standardized questionnaires were used to measure the subjective impression of the relief workers in connection with the mobile user-interfaces. The relief workers judged the mobile user-interfaces with regard to the aspects usability, attractiveness and workload. We used the questionnaires *SUS*, *AttraktDiff* and *NASA-TLX*. These questionnaires enrich the quantitative triage times which were measured by the supervisors.

SUS is a standardized questionnaire to identify the usability of user-interfaces. *SUS* was developed by Brooke [36] and consists of 10 questions. The subject can agree and disagree with 10 statements on a 5-point Likert scale. The analysis of the *SUS* leads to a value between 0 and 100, whereas a value of 0 is the equivalent of very bad usability and 100 is the equivalent of very good usability.

The *AttrakDiff* is used for measuring the attractiveness of a user-interface. This questionnaire rates the attractiveness according to the aspects pragmatic quality (PQ), hedonic quality (HQ) and attractiveness (ATT). PQ describes, if the user-interface is effective and efficient in solving the challenges. User-interfaces with a high HQ are self-oriented, the liaisons with the users are stronger and the emotions which are caused by the interface are more intensive. ATT describes the overall attraction of the interface on the user [37]. The results of *AttrakDiff* can be presented as a matrix.

NASA-TLX is used to measure the workload. The *NASA-TLX* consists of six continuous subscales which measure the different aspects of the workload [38]. These different categories are: (1) mental demand, (2) physical demand, (3) temporal demand, (4) own performance, (5) effort and (6) frustration level. The analysis of the *NASA-TLX* leads to value between 0 and 100, whereas a value of 0 represents a very low workload and 100 represents a very high workload.

All results from the questionnaires as well as the quantitative data were analyzed with an ANOVA (ANalysis Of VAriance). With an ANOVA significant differences between the various alternatives with regard to the different aspects (usability, attractiveness, workload, time need) can be identified. The single-factor ANOVA bases on three assumptions: (1) Gaussian distribution of the values, (2) homogeneous error variances between the groups and (3) independence of the values. The null hypothesis is, that no significant differences exist between the groups. If the null hypothesis has to be neglected and the error probability lies below 5%, significant differences exist. In cases when the null hypothesis cannot be negclected, no clear statement can be drawn on the basis of the measured data.



(a) Analysis of NASA-TLX (b) Analysis of SUS (c) Analysis of triage duration

Figure 3: Evaluation results

5.2 Results

In Figure 3(a) the results of *NASA-TLX* are displayed as boxplots. The alternative $RFID_{double}$ has a workload of 42.8 (± 17.2), the alternative $RFID_{single}$ has a workload of 45.9 (± 14.9), the alternative *Number* has a workload of 49.2 (± 10.1) and the alternative *Paper* has a workload of 44.4 (± 13.3). Regarding the workload no significant differences could be shown. The trend, however, is, that the workload slightly increases when a mobile user-interface is used as opposed to the alternative *Paper*. In Figure 3(b) the results of *SUS* are shown as boxplots. The alternative $RFID_{double}$ has an usability of 31.6 (± 20.0), the alternative $RFID_{single}$ an usability of 28.4 (± 15.8), the alternative *Number* an usability of 19.4 (± 9.1) and the alternative *Paper* an usability of 25.0 (± 13.1). The ANOVA shows, that none of these differences is significant. Nevertheless the results are revealing, especially the low usability of *Paper* is remarkable. Because of this result we assume, that the subjects rated the usability of the triage process itself and not the usability of the documentation method. The result that *Paper* is more difficult to use than a mobile user-interface with RFID-reader, cannot be interpreted in a different way. Triage itself turned out to be complex, difficult, inconsistent, not easy learnable and cannot performed without help – we could not prove that this is not the case when a mobile user-interface is used. We got the impression, however, that subjects are of the opinion that a mobile user-interface somehow simplifies the complexity of triage. We had various discussions with TUM Feuerwehr about these results – before rashly conclusions are drawn, these results should be verified in a larger evaluation. The attractiveness of the different alternatives discussed in detail in Endres [5]. An ANOVA analysis did not reveal significant differences between the various alternatives. All alternatives, however, have a rather high PQ as opposed to the HQ. The ATT does not tend to “unnecessary”, that is a positive result for this first implementation.

The quantitative results are shown in Figure 3(c). When using the alternative $RFID_{double}$ a triage process lasted 29.4 (± 11.4) seconds, when using the alternative $RFID_{single}$ a triage process lasted 25.9 (± 10.6) seconds, when using the alternative *Number* a triage process lasted 26.1 (± 14.9) seconds and when using the alternative *Paper* a triage process lasted 19.0 (± 8.2) seconds. The ANOVA revealed that the alternative *Paper* is significantly faster than all other alternatives. Moreover the alternative $RFID_{double}$ is significantly slower than all other alternatives. According to these quantitative results, the alternative *Paper* seems to be the most effective alternative. Due to the fact that only the patient tag is filled out with the alternative *Paper* and no spread sheet is generated, this alternative is less efficient than the mobile user-interfaces. Extending each triage process by 7 seconds ($RFID_{single}$ or *Number*) leads to an electronic availability of the triage result. When looking on the quantitative results a second time, it becomes clear that the positive aspect is the low additional time for the electronic storage of the triage results. The negative aspect, however, is that $RFID_{double}$ is slower although it is more consistent as compared to $RFID_{single}$.

6 Conclusion

The supervisors could give us additionally feedback, why the many advantages of RFID based triage did not have that massive effects on the results. These impressions could be verified by additional conversations with the relief workers. The implementation was not complete and the integration of the reader was not ideal. During the evaluation sometimes the RFID-reader did not work properly at all. Due to the fact that the relief workers did not have a clear understanding of the RFID technology they used it in a wrong way. When explaining the RFID technology to them, we used the description “scanning RFID tags”. This description lead to the impression that the tags have to be moved in front of the reader – similar to scanner cash registers. For scanning a RFID-chip properly, however, it is important that this tag is not moved in front of the reader. Holding the chip in front of the reader is preferred to making fast "scan" movements. This evaluation showed that the introduction of RFID technology in MCIs leads to more challenges as we expected at the beginning of our research. Successful user-interfaces have to undergo an iterative design process in order to lead to ideal results. In future evaluations we will provide better explanations of the RFID technology to the relief workers. We are confident that the better briefing of the relief workers will result in significantly better evaluation results.

Notes

Competing interests

The authors declare that they have no competing interests.

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