Towards a Design Space and Guidelines for E-Triage System Design

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Abstract
Triage, the categorisation of disaster victims by priority of injuries, is currently performed manually. Triagers must quickly assess a victim in less than 45 seconds and move on to the next. Information in near-realtime is desirable, but reporting the state of the process and localizing the victims for following paramedics takes too long. Research in practical emergency response and literature reveals that, although technically feasible electronic triage systems have been proposed, none of them is truly accepted by end users or applied in the field. This work analyzes approaches from literature as well as extensive fieldwork from a four-year research process in the scope of emergency management. The result is a first set of dimensions for a design space for e-triage systems that allows the categorization, comparison, assessment of approaches against the dimensions, as well as ground for new design ideas.

Author Keywords
Electronic Triage; Fit Dimensions; Design Dimensions; Design Space; User Acceptance; Disaster Management

ACM Classification Keywords
H.5.1 [Multimedia Information Systems]: Evaluation/methodology; H.5.3 [Group and Organization Interfaces]: Computer-supported cooperative work; K.4 [Computers And Society]: Human Safety

Topic	Papers
Hospital triage	39
Partial solutions	35
E-triage systems	24
Unrelated / Example	6
Technology analysis	5
IT impact analysis	2
Total	**111**

Table 1: Count of triage-related papers by type of contribution. In total 569 papers contained the word "triage", but only these 111 refer to disaster triage. The rest are about "bug triage" in software engineering.

Introduction to Disaster Triage

A disaster, by the WHO definition, is an incident that overwhelms a community's ability and resources to respond. "Disaster triage" is the categorisation of disaster victims according to severity of injuries, so that scarce medical resources can be used in the way that saves the most lives.

At an abstract level and disconnected from other response-related activities, triage consists of four steps:

1. Estimating the victim's injuries and measuring her vital values
2. With the above input, mentally running a triage algorithm to determine the victim's priority.
3. Marking the victim visibly with a marker that represents the priority and can be recognized from afar.
4. Triggering further handling of the victim.

The triage algorithm's output is only a suggestion; the actual priority depends also on other information known to or assumed by the triager.

The priority marker is called a "triage tag"; it most often is a piece of colored paper [4]. The presence of the tag a) shows the victim has been triaged (no need for other triagers to come), and b) shows the victim's priority so that highest priority victims can be transported and treated first.

For estimating, triaging, and marking a victim the triager is allowed 15-45 seconds. Triggering the further handling of the victim usually means reporting the victim by radio. To save time, reporting is only done after several or all victims have been triaged. Only after triage is complete can transport and treatment be planned and started. Delays of 20-40 minutes before treatment are common [11, 26]. Lost, damaged, or stolen tags, illegible handwriting, duplicate and manual work, frequent miscommunication, lack of vital value monitoring for victims, and the need for recurrent, expensive training are only a few of the problems with paper-based triage.

Challenges With the State of the Art

Among 111 triage-related papers in the ACM, IEEE, and ISCRAM publications databases as of 26 December 2016, twenty-four papers present 17 different electronic triage (e-triage) systems for disaster triage (see Table 1). None of these systems is in use by first responders, who instead prefer paper-based triage workflows and paper-based tools from the 1960's [4]. No research could be found on why responders do not adopt e-triage systems, nor could we find any work on guidelines, best practices, or patterns for designing e-triage systems for *acceptance*. The suitability of certain IT technologies for triage is analyzed in 5 papers, but they focus on one technology, in isolation, and do not take into account all the facets and users of triage systems. Only two papers (one by this author) consider the impact and consequences of introducing IT into the triage process.

Several models explain the adoption and success of IT systems as a function of how well the systems "fit" to user characteristics, tasks, and other factors: [29, 8, 7, 28, 10, 9, 16, 2]. These models posit that an individual's attitude to IT influences their propensity (intention) to use IT, which in turn influences their decision whether to use IT [29]. While the validity of these models is not in doubt, they have limited usefulness as a guide to e-triage system design:

- The models are generic, not tuned to healthcare systems, and certainly not to triage.
- The models were based on business and MIS software. Their generalizability to e-triage is neither given, nor has it been proven.
- The models relate system acceptance to user perceptions and the fit between user, task, and tech-

nology. Yet neither user perceptions nor fit can be judged *a priori*, before the system is constructed and used (or rejected) in the real world.

DERMIS [27] aims to generate a MIS for emergency response, but some of its design premises are valid for any emergency-related system, including e-triage. Its drawback is that it generates a *Management* Information System for emergency response, not a system to support triage.

The AID-N project [14] also tackled human-computer interaction in e-triage and provided some design principles. The project was focused on medics and re-triage only, paying less attention to the rest of the response chain and to the other user groups that triage impacts. The limited focus carries through to the proposed design principles, some of which call for WIMP GUIs on PDAs without offering proof of their optimality. Indeed, DERMIS deems PDAs to be suboptimal for disaster response.

Undesirable changes that IT introduces in emergency response and triage were presented in [19, 12]; a complete analysis and model of acceptance for e-triage systems is presented in this author's doctoral thesis [13]. The current paper presents a first step that a) identifies the dimensions that influence responders' acceptance of e-triage systems, and b) offers guidelines on how to design well-accepted e-triage systems.

Methodology

The research for this work was carried out over four years as part of the BRIDGE project (see Note 2). It involved firefighters, paramedics, doctors, police, disaster relief workers, logistics support managers, incident commanders, and hospital doctors from the following countries: Norway, UK, Netherlands, Ireland, Switzerland, Austria, and Germany.

An e-triage system was developed and used to gain insights through the methods listed below.

The user-centered approach (see Note 1) recommended by [23] was used initially, but was not deemed sufficient. There are few "end users" of the triage system, but, since triage is at the very beginning of the emergency response chain, it impacts the work of most other responders, even if they are not end users. Designing for the "end user", as per UCD, does not afford the appropriate focus to these other participants and stakeholders. We therefore switched to a participant-centered approach [22] and involved all responders named above. An End User Advisory Board guided us, helped us generate ideas, and participated in the design of system prototypes. To extract lessons about the acceptance of e-triage systems, we approached the gathered knowledge from a grounded theory perspective [15]. By categorizing and coding the findings from our user research, a preliminary design space and a set of six e-triage acceptance dimensions were determined, which influence the chances of an e-triage system being accepted. The user needs and requirements on which these dimensions are based have all been derived from user statements and expert reviews of existing systems.

The research in this paper is based on more than 300 hours of observations, contextual enquiries, interviews, focus groups, sandbox and blue sky sessions with experts and practitioners, prototype workstation sessions, scenario walkthroughs, expert workshops and reviews, and more than 30 hours of user testing in three large-scale, realistic exercises with 20-400 participants.

Designing E-Triage Systems for Acceptance

Certain particulars of triage impact both the e-triage acceptance dimensions and the process of designing e-triage

Note 1
User Centered Design is an approach that puts the end user in focus throughout the design process: analyzing the user's context, finding user needs and requirements, prototyping and testing the system with real users in real settings. For more information, please see ISO 9241-210 [17] and Don Norman's "User Centered Design" [21].

Note 2
The BRIDGE project was an EU FP7 Program, Grant No. 261817, which focused on developing technical and organizational solutions that significantly improve crisis and emergency management in the EU Member States. More information can be found at http://www.bridgeproject.eu/en

systems. We discuss these particulars first, followed by the acceptance dimensions and related design guidelines.

Role and Process Characteristics in Triage
When designing for emergency response, the same user may hold different roles and use the system in completely different contexts. The roles do not overlap in time, i.e. one user holds one single role at any moment. The role also is the best predictor of the needs and the context that each particular user faces at a given moment in time. Because of this, it makes sense to design for roles, not for user groups.

The chain of activities in emergency response amplifies the effect of the e-triage system on the "downstream" roles and tasks. It is also impossible to predict who will undertake what role in a crisis situation [27]. Designing systems for a "restricted" or "primary" user group is, therefore, a false economy. The roles that e-triage systems impact are of two kinds and include, at the very least:

- "Person" roles: triagers, victims, firefighters, police and/or army, paramedics, treatment area medics, incident commanders, and hospital doctors.
- "Organization" roles: Hospital administrations, Response organizations, and Logistics organizations.

Note 3
In the chaos and destruction of the disaster, the triage system will eventually break down, be overloaded, its provision will be delayed, or it will otherwise fail. Responders are trained to improvise in such cases, and a triage system that embraces improvisation will have that much more chance of being accepted among the "trusted tools".

The difference between marking and monitoring is a key point in designing e-triage systems [19]. Triage is a marking process: victims are marked with a priority. Monitoring of the victims is needed by some roles and tasks downstream, but is not part of triage. Introducing monitoring tasks into a marking context is tricky and may be counterproductive, for reasons explained in [19].

Dimension 1: Completeness and Appropriateness for Triage
A complete and appropriate system for triage a) allows triagers to perform their tasks b) supports all other roles and tasks that are impacted by triage c) presents correct and reliable results, and d) requires minimal effort and discomfort for the participant. Designing for this dimension means:

G1.1 Allowing responders to input as much or as little data as they have about the victim, at any point during the triaging and handling of that victim. The system should neither require particular data items, nor require a particular input order. Due to the ad-hoc nature of the response, it should also be able to deal with unforeseen or unstructured data.

G1.2 Allowing triagers to use any triage algorithm they want. This does not mean a system should implement all known triage algorithms, but that the system should allow triagers to take the triage decision and input any priority they deem appropriate, except when the stakeholders explicitly request automated triage *and* the triager role will be undertaken by unskilled or untrained people [5].

G1.3 Requiring little additional work compared to the paper-based triage.

G1.4 Designing a system that allows and embraces improvisation and "mixing and matching" of tools and markers (see Note 3).

G1.5 Designing not only graceful degradation but also *useful* degradation to a well-known, minimum-functioning state that allows triage to continue uninterrupted or allows responders to improvise with the remains of the system.

G1.6 Avoiding information flood by carefully designing the system's output.

G1.7 Designing for the physical environment and physical restrictions of the responders. Carefully considering what kinds of devices and interfaces are most ap-

Note 4
In the words of a triager, "When dozens of people are screaming for help all around you, even tearing strips off of a tag might be too much for you to do reliably, let alone fill out a complicated form." [4]

Note 5
A logistics manager reported: "[Companies] come and offer us computer-based emergency management systems. We ask, “How do we power the system in the disaster field, where the power lines have been destroyed?” They promise to give us a generator. Then we ask “Where do we find the petrol for the generator, since no oil truck can drive over the piles of rubble on the road?” Then they go away." [26]

propriate for each role and each task. PDAs and AR glasses may be sub-optimal [27, 3].

G1.8 Carefully designing interactions and interfaces for extreme stress (see Note 4).

Dimension 2: Impact on Workflows
Response workflows and processes are the only behavior patterns that have proven useful time and again. Response organizations are wary of changing them, both because of the need to retrain large numbers of people, and because possible side effects may show up too late. Designing for this dimension implies:

G2.1 Understanding that the responsibilities of each role are very clearly divided for a reason. Instead of moving a task to another role, e-triage system designers should look for opportunistic or implicit ways of achieving the same goal.

G2.2 Understanding marking and monitoring as different aspects, mixing them very carefully and only when the affected responders accept this change.

G2.3 Extensively using implicit and opportunistic approaches, especially for networking and data acquisition. The timeline, geographical organization, and movement patterns during disaster response are particularly favorable for this approach [13, 20].

G2.4 Minimizing or avoiding the need to attend to the system. "Attending to the system" ranges from setting up IT and network infrastructures, to the smallest interactions, such as inputting passwords or pulling a PDA out of its protective cover.

Dimension 3: Consideration for Organizational Needs
Commissioning, provisioning, maintenance, logistics, training, and integration issues associated with an e-triage system affect response agencies at the organizational level and will directly affect their decision to use the system.

G3.1 The system should have few or no special requirements related to storing, transporting, setting up, powering, networking, and maintaining the system. Logistics, especially power and communication infrastructure, are a common hindrance (see Note 5).

G3.2 The system should not require setup steps immediately before the response begins.

G3.3 The system should be usable both in disasters and in daily emergencies. This keeps training costs down, since triagers may use the system in their daily job.

G3.4 The system should require little or no training.

G3.5 The system should use open emergency communication protocols that are supported by other emergency response tools.

G3.6 The system should be deployable in pieces, i.e. not all parts of the system need to be purchased before the organization can see an improvement. This helps with gradually building trust in the system.

G3.7 The system, or at least its "consumable artifacts" (triage tags, etc.) should be very cheap.

Dimension 4: Appropriateness of Interaction
Triage systems present both human-machine interactions, and human-human interactions mediated by a machine. Both of these interaction types must be optimally supported by e-triage systems.

G4.1 At the very least, the system should be free of usability problems according to the ISO9241 standard.

G4.2 The system should not force responders to interact with it instead of with another human. This is particularly important for triage and medic roles, where interaction with the victim represents both actual care (vic-

Note 6
Fog of War is the uncertainty of information, which accompanies a disaster. The term was coined by Carl von Clausewitz.

tim's state is observed), and perceived care (victim feels taken care of). Loss of eye contact also makes it impossible to observe, comfort, or reassure victims.

G4.3 Implicit interactions are preferred over explicit interactions. Attention is a precious resource in the disaster field.

Dimension 5: Consideration for Responders' Attitude to IT
[1] reports that handling of electronic devices is the biggest stressor in disaster response. Various other sources report or imply that responders' attitude towards IT is one of distrust [23, 24, 18]. E-triage systems need to overcome this distrust.

G5.1 The system should be extremely reliable. The most degraded state of the system must be at least as useful as paper tags.

G5.2 Logging capabilities should be designed very carefully. They are useful for training and reconstruction, but they may also be abused to prosecute responders for not "abiding to the letter of the law" [25, 19].

G5.3 The system should strike a balance between "seamless work" and "seamful design" [6], whereby responders can mix and match, reuse, or replace parts of the system with confidence. This requirement stems from the trust responders put in their tools: it is based on understanding the tool, its failure modes, and how the failed tool can be repaired or reused.

Dimension 6: Sound Design Methodology
The following activities have particular importance:

G6.1 Defining a risk model before designing the e-triage system. The disaster triage context is hostile in all meanings of the word. A risk model is indispensable for clearly stating the expected risks and for triggering designers to consider mitigation and avoidance.

G6.2 Testing the system in realistic conditions, with real responders, *and* realistic-looking victims. Physical and mental stress, information overload, and the "fog of war" (see Note 6) affect humans in ways that cannot be experienced in tabletop or lab tests.

G6.3 Explicitly designing for all stakeholders and participants of a triage system. In particular organizational participants need to be taken into account, as their needs are most often neglected in the e-triage systems proposed so far [13].

Conclusion and Future Work

Based on an exhaustive search of the ACM, IEEE, and ISCRAM libraries, this work a) argued the need for an analysis of why proposed e-triage systems have so far not taken hold in disaster response and b) presented and analyzed six triage acceptance dimensions that impact how responders perceive and accept e-triage systems. As the first analysis in this field, this work is far from complete. Future work will include assigning weights to the acceptance dimensions, verifying whether and how they overlap, and finally presenting the model as a design space where existing and future e-triage systems may be analyzed, compared, and improved. Once the design space is defined, the compatibility of concrete technologies with the acceptance dimensions will be considered and ways to balance design tensions will be identified.

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