Applying ISO 9241-110 Dialogue Principles to Tablet Applications in Emergency Medical Services

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ABSTRACT

In the safety- and time-critical context of pre-hospital medical care, usability is a major challenge that needs to be addressed, because interaction problems or errors may have serious consequences for patients as well as employees of Emergency Medical Services (EMS). In this regard, a user-centered human-computer interface is a crucial factor for efficient usage as well as user acceptance. Well-established design principles can serve as directives throughout the analysis, design, implementation, and evaluation of applications. For standard PC-based applications the ISO standard 9241-110 serves as a practical guide since many years. However, new types of devices, especially mobile systems impose new challenges and ways of interpreting usability standards and guidelines. In this paper, we apply the ISO-Standard 9241-110 dialogue principles to mobile applications in EMS, considering the challenges of designing a system suitable for supporting users in both regular day-to-day services as well as rare Mass Casualty Incidents (MCIs).

Keywords

Emergency Medical Services, Mass Casualty Incident, Dialogue Principles, Ergonomics, Usability, User Interface Design, Mobile Devices, ISO 9241-110

INTRODUCTION

For at least 25 years, several studies and articles (e.g. Ellinger, Luiz and Obenauer, 1997; Wischhöfer, Hotzel and Wisser, 1987) recommend Emergency Medical Services (EMS) to accomplish documentation and information tasks by mobile computing solutions. *"Enhanced quantity and quality of patient data at hand"* (Leitner, Ahlström and Hitz, 2007) and a pervasive flow of information are two potential advantages of mobile applications. Nevertheless, most EMS still rely on a variety of paper-based media and a paperless workflow reaching from pre-hospital care to final accounting is still the exception rather than the rule. This is expected to change within the next few years.

Sellen and Harper (2002, pp. 52) point out that replacing or supporting paper-based workflows *"is not simply a case of giving workers a computer and links to a network"*. The usability of the application is crucial to both user acceptance and delivering added values and benefits for their users. In this respect, the human-computer interface is of the utmost importance; it can *"either make or break the system"* (Vicente, 1999). While interaction errors in office or entertainment contexts can usually be fixed easily and do not lead to serious consequences, in safety- and time-critical domains they might result in injuries, loss of lives or damages to the environment.

Considering well-established design principles abstracted from individual requirements and contexts might help to avoid major design flaws and can be of great use at any stage of a user-centered development process (Herczeg, 2009). Such guidelines summarize current best practices, can be used as a reference for stakeholders, enable structured analyses and finally serve as criteria for evaluations. One of the most important and recent system of guidelines, rules and best practices is the ISO Standard 9241, with part ISO 9241-110:2006 defining "dialogue principles". They are related to the ergonomic design of the human-computer dialogue and provide *"a framework for applying those principles to the analysis, design and evaluation of interactive systems"* (ISO 9241-110:2006). Compared to the preceding standard ISO 9241-10:1996, it leaves the context of mainly well-defined office-based work systems and intends to give advice for all kinds of interactive computer system, opening up especially to mobile contexts.

BACKGROUND AND RELATED WORK

The need for improving ergonomic design and usability of applications in pre-hospital medical care has been identified repeatedly ever since the first field studies by Ellinger et al. (1997), who compared paper-based and computer-based documentation running parallel in 52 emergency missions and presented mixed results:

1. Working with the mobile computing solutions led to superior data quality.
2. Easing the emergency physicians' interaction was deemed necessary.

While Ellinger et al. (1997) focused solely on regular missions and identified mainly hardware-related problems (e. g. low-contrast screens); the majority of the following projects and publications were geared to Mass Casualty Incidents (MCIs) and addressed design more general (e.g. Chan et al., 2006). Kyng, Nielsen and Kristensen (2006) recommend using the concepts of *"challenges, visions and design principles"* when developing interactive systems for MCI response. While challenges are meant to be *"succinct formulations"* to reflect understanding, visions *"address one or more challenges, and do so in a way that directly points towards a design solution"* and design principles *"address how to design in such a way that one or more challenges are met, but are not visions of a design"*. In particular, the latter ones are *"embrace change"*, *"understandable reliability and trustworthiness"* and *"familiarity"*. White (2007) describes design aspects of a tablet application for the Advanced Health and Disaster Aid Network (AID-N) as follows: *"The GUI also takes into consideration the stress a medic is under, so when they request to make any extreme changes in the GUI, like turning off the alerts for a patient, the GUI should request confirmation. This prevents medics from accidentally disregarding a patient. Lastly, pop-up alerts are difficult to manage when the number of alerts increase."* Humayoun et al. (2009) describe the development of mobile applications for emergency operators and identify the most important design issue as *"grasping the users' mental attention onto the system as little as possible"*. Non-standard evaluation criteria like *"components are intuitive and easy to use"* or *"screen design is attractive"* are used. Nestler (2010) designates non-functional requirements for PDA-based triage support, e.g. low response times to user inputs (< 0.5 seconds) and claims that triaging a patient must not take more than 45 seconds in total. Acoustic feedback should be used to inform users about successfully completed interaction steps.

With respect to these and similar approaches, two conclusions can be drawn:

1. MCIs are rare events in terms of a specific EMS employee. However, routine can only be derived from regular application and is necessary to carry on the workload of a MCI. Therefore, we suggested the Care & Prepare approach. It states – explained briefly - that an application for managing MCIs has to be a "natural" extension of a daily used system. With respect to this claim *"an exclusively pen-enabled interface can be considered as an appropriate single device solution for EMS"* (Mentler et al., 2012).
2. Self-defined principles and evaluation criteria can successfully serve as directives. However, comparing conclusions and results is complicated and their reliability and validity have to be ensured.

Apart from ISO 9241-110:2006, there are other sets of established design rules or principles, e.g. the *"eight golden rules of interface design"* by Shneiderman and Plaisant (1998) or the *"ten usability heuristics"* by Nielsen (1993) which can *"be a starting point for those new to user-centered design"* (Searle, 2010). Nevertheless, considering the dialogue principles of ISO 9241-110 has certain advantages:

1. The provided framework connects them to other parts of ISO Standard 9241 that covers various aspects of ergonomics of human-computer interaction (e.g. presentation of information, user guidance).
2. Validated questionnaires (cf. Figl, 2009) are available in order to assess the conformity of applications.
3. The established principles have been revised by experts from all over the world since the 1980s (starting with the initial German standard DIN 66234-8) and proven to work in many application areas.
4. Various examples and advices accompany the standard and illustrate its practical applications.
5. Contracting parties are used to making ISO standards part of their system development and evaluation contracts as well as requirements documents and feel safe on such a well-established foundation.

APPLYING DIALOGUE PRINCIPLES

ISO 9241-110:2006 defines the following principles *"without reference to situations of use, application, environment or technology"*: suitability for the task, self-descriptiveness, conformity with user expectations, suitability for learning, controllability, error tolerance, suitability for individualization. As one result of a two-year user-centered design process including five workshops with stakeholders and participant observations of two MCI simulations and regular shift duty, we apply these principles to the specific context of EMS as follows.

Suitability for the Task

EMSs are characterized by regular day-to-day services (transport and emergency missions) and infrequent MCIs. In order to be suitable for the specific tasks and with respect to our Care & Prepare approach, an application must offer both a consistent interaction design as well as clearly distinguishable and adjusted modes for these situations. They could be selected either manually or according to keywords from the dispatch center. Because transport missions can turn into emergency ones (e.g. patient collapses) and emergency missions can turn into MCIs (e.g. minor car accident results in a pile-up of cars), all data must be exchangeable between the mentioned modes.

In the event of an MCI, organizational structures and tasks can be complex and diverse. The incident command needs universal and multi-purpose overview information, which can e.g. be visualized on an interactive map if location-based or listed in tabular form. However, the paramedics or physicians in charge gather and require patient-related data. Role selection should be supported to adapt to a set of specific tasks and functions for the selected role. Role-oriented hierarchical task analysis (HTA) will help with task allocation.

Under no circumstances should users have to worry about network configuration, connectivity or other mainly technical issues. These types of technology-oriented tasks (internal tasks) are completely handled by the software itself while the application-oriented tasks (external tasks) stay with the human experts.

Conformity with User Expectations & Suitability for Learning

The principles "conformity with user expectations" and "suitability for learning" are central to the Care & Prepare approach. Because of different documentation and information requirements, input masks and dialogs cannot be the same for managing regular missions and MCIs. Nevertheless, a consistent user interface can support action planning and realization. In terms of Norman's model, it can minimize the gulf of execution while well-known feedback mechanisms, error messages and colors have a favorable effect on the gulf of evaluation (Norman, 1986). The users' mental model[1] of the application system stabilizes and deepens. Safer and more confident usage is possible and can be improved further by allowing common color schemes, e.g. for triage categories, specific terminologies and symbols.

Suitability for Individualization

A mobile application system for EMS should *"avoid too many alternatives and modes"* (Leitner et al., 2007). This contradiction to the claim "suitability for individualization" can be derived from the statement that users are rarely capable of individualizing systems in their interest and to their benefit (Herczeg, 2009). Under extreme conditions users should not be enabled to make modifications, even if undo or reset mechanisms are available. Because of many differences in regulations, backgrounds and notions, it must be possible to localize applications with respect to terms, abbreviations, drugs, transport destinations and vehicles in advance as well as to update this information at any time. This might even be necessary when different EMSs need to co-operate in an MCI. This kind of individualization is restricted to content and keeps the user interface stable.

Self-Descriptiveness

Tablet PCs offer quite limited screen space. Therefore, displaying detailed information and not losing track of present elements are conflicting design goals. Tabs or foldable elements like outlook bars allow direct access to categories without increasing the number of concurrently visible components disproportionately.

Button labels should tell users about corresponding action. Even if they miss headlines or alignments due to the impact of several stressors, self-explanatory identifiers increase the probability of choosing the right option. Generic labels like "Yes", "No" or "OK" may lead to misunderstandings and errors.

Controllability

Especially in situations where users are distracted, assuming that notes, messages or alerts are perceived within a specific time period is error-prone. As they may occur frequently and numerously, sophisticated alarm management is necessary. Alarm lists distinguishing new, acknowledged and cleared alarms have been proven

[1] meaning the emergency physician's or paramedic's set of beliefs and perception how the mobile application system works (cf. Gentner and Stevens, 1983)

to work in other safety-critical domains like power plants. No information should get lost by automation.

Modal dialogs dictate a certain order of activities and could therefore be felt as restricting. However, they follow an easy concept, which can help to prevent mistakes or uncertainty in encumbering situations. Cooper et al. (2007) confirm that in general, modal dialogs are easiest to understand. That is why they should be favored over modeless ones in this particular context, although they usually should be avoided.

Error Tolerance

ISO 9241-110 knows error control, correction and management as means for error tolerance. Especially in time-critical situations, avoiding errors is the preferable option. We propose a button-oriented design (cf. Fig. 1) offering a choice of valid input values, e.g. for triage categories, diagnoses, drug names, doses or feed rates.

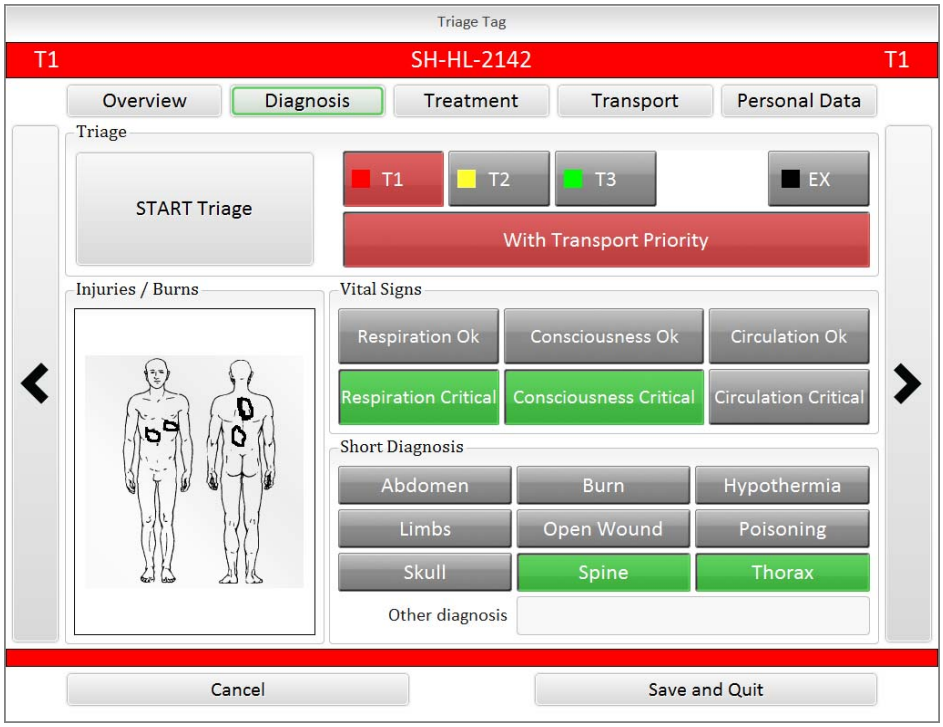

Figure 1: Diagnosis mask of a patient's MCI record

This approach can be further supported by

- providing plausibility checks, e.g. according to value margins or task completion;
- automating calculation, e.g. adding up single values of the Glasgow Coma Scale;
- collecting tracking data by default, e.g. locations or time stamps;
- making functions available in a well-directed way, e.g. by (de)activating buttons at certain stages;
- sorting lists and tables automatically, e.g. according to transport priority or triage categories;
- providing wizards for stepwise and controlled completion of tasks, e.g. triaging patients;
- favoring filtering over searching functions, e.g. according to transport destinations;
- searching phonetically when needed, e.g. same results for “Schmidt”, “Schmitt”, and “Schmied”.

CONCLUSIONS AND FURTHER WORK

ISO 9241-110 dialogue principles should be considered when designing applications for pre-hospital medical care and can serve as directives throughout analysis, design, implementation and test. Our advanced prototype has been developed according to these rules and presented to more than 40 representatives of 8 EMS and emergency departments throughout Germany. It was generally judged to be positive. Formative evaluations, which led to the presented recommendations, were carried out by reoccurring expert reviews and focus groups.

Currently, we prepare MCI trainings and use the ISO 9241-110 principles as criteria for summative evaluation.

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