Design and Evaluation for *Safe* Improvisation in EMS Technologies

Steven R. Haynes, David R. Mudgett, John M. Carroll
College of Information Sciences & Technology
The Pennsylvania State University
University Park, PA 16803
{shaynes, dmudgett, jcarroll} @ist.psu.edu

ABSTRACT

In this paper we explore the concept of *safe improvisation* and propose principles for design and evaluation of interactive technologies to support improvisational action in safety-critical domains. A particular focus here is on the interactive technologies used in emergency medical services (EMS). In EMS improvisation is necessitated by events, but discouraged within its culture. Designing and evaluating for this conflict is central to development of technologies that are at once institutionally acceptable, usable in the field, and safe to employ.

Author Keywords

Improvisation, evaluation, design, emergency medical services.

ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms

Human Factors.

INTRODUCTION

In this paper we explore how technologies can be designed and then assessed in terms of their ability to support *safe* improvisation. Many safety-critical activities such as piloting an aircraft, driving a car, managing a power plant, administering radiopharmaceuticals, combat operations, and emergency response happen within an organizational and social context that places strict limits on the scope of human behavior. At the same time, the flow of events in particular circumstances can necessitate improvisational action, actions that violate protocols of standard practice but are required to respond effectively to emergent situations. The protocols, operational guidelines, and policies that bound activity in these domains are there for a good reason. They are designed to ensure the safety of both the performer and those directly and indirectly affected by their actions.

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee.
Copyright is held by the author/owner(s).
CHI'13, April 27 – May 2, 2013, Paris, France.
ACM 978-1-XXXX-XXXX-X/XX/XX

We consider improvisation as a sub-type of creativity. Improvisation is creative action situated in an activity being practiced, in real-time, and within a particular and often unique context. Improvisation is emergent, necessitated and shaped by events rather than planned. This differentiates improvisation from creativity in the arts, for example, where creative action is (or can be) both more deliberate and more 'organic'. The relationship between necessity and improvisation is particularly salient in safety-critical domains, where task performers typically intend and prefer to operate within established, regulated boundaries, and where deviation from protocol is a sign that something has somehow gone wrong.

Our focus here is on the role of interactive technologies in situations requiring potentially unsafe improvisations, and in particular how these technologies can be designed and then evaluated in terms of their ability to support, guide, and enhance the quality of improvisation while ensuring the safety of those involved. Our study domain is emergency medical services, in particular the technology used in EMS, and how improvisation is both necessitated and governed by EMS practice. Our analysis is based both on literature and on experience; one author is a volunteer emergency medical technician (EMT) within a regional EMS service. Note that our experience and our analysis focus on EMS practices, technologies, and improvisation in the United States. We acknowledge that this context and EMS practice may differ widely from nation to nation and from culture to culture.

EMERGENCY MEDICAL SERVICES

Emergency medical services (EMS) are the forward-facing extreme of the patient healthcare continuum. Among the most pressing challenges to effective EMS are information gathering, information capture and integration, and information use. Emergency medical services generally perform three types of service: responding to emergencies (in the United States they are typically initiated by a telephone call to 9-1-1); routine and critical-care transports between a patient's residence and a healthcare facility, or between healthcare facilities; and ambulance standbys at both planned (e.g. a state fair) and unplanned (e.g. a

structure fire) events. Here the focus is on 9-1-1 emergencies and the intensive information capture, creation, communication, use, and management activities that attend these events.

Ambulance emergency responses (9-1-1 calls) are generally categorized in one of two ways: *medical*, such as a diabetic emergency or myocardial infarction (heart attack); or *trauma*, such as a broken leg at a sporting event, or multi-system injury at a motor vehicle accident. In either case a very large quantity of information is required to be captured in a relatively small amount of time. This includes dispatch information, the location and nature of the call; patient information both demographics and healthcare-relevant; treatment information, what was done to address the patient's condition; and transport information including emergency status (lights and sirens), transport times, and mileage.

Paramedics and EMTs use a variety of interactive technologies to support emergency response, situational and patient assessment, and patient care. Information gathering practices are however, still largely based on verbal communication with patients themselves, with their family members, and with bystanders who might have witnessed the event. Emergency information capture and integration is still largely done with pen and paper. Because of this, we view EMS as an information-intensive domain that is so-far under-served by available information technologies.

Figure 1 - A Patient Monitor Used in EMS

Interactive technologies in EMS must be small and portable, durable, easy to learn and use, and secure. Information is central to effective response and patient care and is used intensively in communication, navigation, situational awareness, clinical decision making for patient assessment and treatment, and patient care reporting. Many EMS services, especially smaller regional and rural services, are relatively under-funded, making information technology investment a significant challenge.

A 2007 report from the US National Academy of Sciences [1] identified a number of pressing challenges to achieving more effective pre-hospital emergency care. These include especially that EMS is a relatively under-resourced layer in the continuity of care that begins in the field and extends through emergency departments to more specialized care facilities. The report also highlights the importance of information and communications systems integration as a key enabler of more seamless and cost-effective information sharing across different levels and functions in the health care system.

Current and emerging technologies considered especially relevant to EMS include increasingly capable mobile devices, voice control interfaces, location-aware services, and cloud computing. On the horizon are technologies such as mobile ultrasound, and non-invasive blood testing, both of which represent powerful tools for enhanced patient assessment in the field. The potential for integration of these technologies is especially promising. Real-time communication of patient imaging and blood test results between healthcare providers in the field and hospital emergency departments could be a life-saving advantage in many critical care cases.

Still needed though is a reference design model of an integrated EMS architecture focused on delivering critical and time-sensitive information to pre-hospital care providers. Components of the architecture should include a service layer supporting common EMS capabilities, and a presentation layer making use of emerging mobile technologies and alternative interfacing styles. Perhaps most important is to develop ways that the potential for such technologies can be understood and measured in the context of actual EMS operations.

The role of improvisation in EMS is a difficult and conflicted topic. On one hand, performers in the United States are bound by a detailed set of protocols (see for example: [2]) that determine the scope of practice (what they can do) as well as how they are allowed to do it. On the other, the culture of EMS, at least in principle, emphasizes "the thinking EMT" who should be capable of responding effectively to emergent problems arising in the sometimes chaotic and always time-constrained course of an ambulance call. Improvisation in EMS is driven by necessity and sometimes lives depend on effective improvisation. Improvisations, however, can also expose healthcare providers, patients, and others to a wide range of risks.

DESIGN & EVALUATION FOR SAFE IMPROVISATION

In this section we identify a set of nine principles for designing and evaluating interactive technologies in terms of whether and how well they support safe improvisation. We view principles such as these as useful resources for both *formative* evaluation in the design phases and *summative* evaluation once a technology is built and deployed. These principles are derived from both the literature of improvisation and from experience in the field of EMS. The proposed principles are intended to provoke discussion. Ongoing and future work will involve

expanding, refining, and validating this list through studies in the field with a local regional EMS organization.

Nine Principles for Safe Improvisation

Because EMS and other safety-critical domains are often protocol-driven, with established procedures for task conduct [3], interactive tools should explicitly implement **activity themes, genres, rules, standards** into task support. Such task support technology would have the ability to monitor performer actions in terms of its deviation from accepted norms and warn when a deviation might result in an unsafe improvisation.

A common theme in studies of creativity and improvisation is that they are a form of expert performance requiring deep **knowledge of tools, materials, processes** [4]. This knowledge is a function of training and practice, but might also be provided or cued in real-time to a performer of a situated activity. Notification-based 'help' systems such as these are notoriously challenging to implement so that fluid task support is provided without needless interruptions.

Incorporating **risk awareness and risk analysis** into improvisational activity support is essential to ensuring that tools providing such support also ensure the safety of the performer. This might involve, for example, a notification facility that warns a performer engaged in a task where deviations from accepted practice carry known risks.

Some researchers have highlighted the role of **organizational memory** in supporting improvisation [5]. Improvisations in EMS, for example, occur within organizations that possess deep knowledge of local environmental factors and how they both constrain and enable safe improvisations. Such organizational memory might be made available to performers informally, as an online forum, for example, or more formally as part of an organization's explicit standard operating procedures.

A particularly challenging criterion is the ability of interactive systems to promote **divergent thinking** in the course of task performance. Divergent thinking is at the core of improvisation [6]. The challenge to technologies in safety-critical domains is to support divergent thinking while concurrently monitoring the performers drift from established practice and into modes of behavior that might endanger the stakeholders involved in an EMS scenario.

Though we include it here as a proposal, encouraging real and perceived **freedom to act** within safe boundaries may not be within the scope of an interactive technology's design. Freedom to improvise is likely more a function of organizational, institutional, and professional culture, which in EMS must account for the direct risks of improvisation to the patient and to oneself, and indirect risks arising from the regulatory and legal contexts.

An advanced, perhaps idealized future capability for improvisation support technologies is helping to identify or even predict situations where **necessity** will dictate an improvised response. Time is often critical in emergency medicine and real value might be gained from knowing in advance when an established practice is not going to result in a positive outcome.

As mentioned earlier one aspect of improvisation that distinguishes it from other forms of creativity is that composition and performance (to use terms from music) occur simultaneously or near-simultaneously [5]. Supporting simultaneous **composition and action** suggests both an information filtering and system performance criterion. Actors must have the ability to quickly obtain and integrate information related to the current situation then formulate this information as a safe plan of action.

A final proposed criterion for technologies supporting safe improvisation is their ability to support **situational decision-making.** In a sense, of the criteria that have been discussed are in service of operational and clinical decision-making tasks.

A Role for Design Rationale?

One emergent idea from our analysis to-date relates to the potential role of *design rationale* in helping to implement these principles. Design rationale is the reasoning behind a design. This can be and has been thought of in a variety of ways. Design rationale can be a description of the space of issues, possibilities, and decision criteria that framed a design process [7]. It can be a structured account of the *particular* issues, possibilities, and decision criteria that comprised a given design process [8]. Design rationale can be a tradeoff analysis of the features of a design with respect to given criteria [9], or a tradeoff analysis the *usage contexts* for an envisioned design as in scenario-based design [10].

These activities and the products that result provide a rich knowledge base that helps relate the form of a particular design to the reasoning process that led to its realization. Designers of technologies for use in safety-critical domains must be ever-mindful of how their designs ensure safe use of the devices they create. How they evaluate safety within a design space as a whole, and within the context of a particular design decision or design 'move' describes the safe boundary of design use. This knowledge is brought to the surface in the design process, but then once a decision is made it is typically made invisible, despite being inscribed into the technology. Making this knowledge more accessible to users of a technology may help them see how the safety parameter was included in activity support.

In Figure 2 below we show some theorized relationships between these evaluation criteria. We suggest that some of the enablers and determinants of improvisational practice supervene, or are otherwise determined by the existence and scale of other related factors. Again, understanding the nature of both these factors and their relations will be explored in future empirical work.

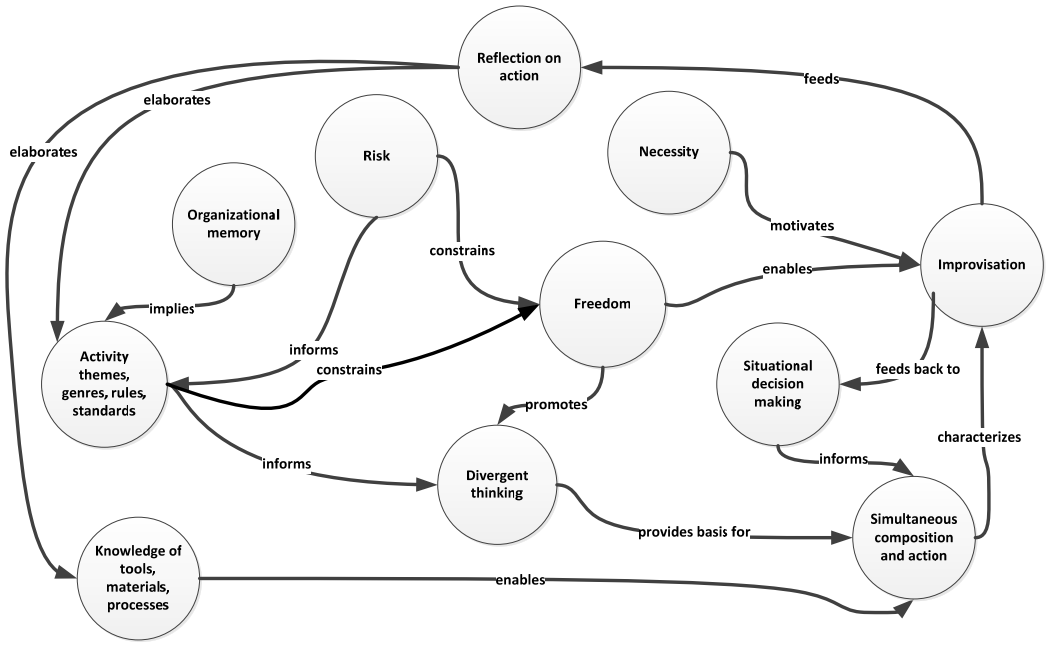

Figure 2 - Evaluation criteria for interactive technology supporting safe improvisation.

MOVING FORWARD

As information systems become increasingly pervasive our approach to design must adapt to include new principles and constraints introduced by new domains. Future generations of technology users will demand that the technologies they use acknowledge and inscribe the cultural norms that govern their work. In domains where risks are significant, failures consequential, and improvisation necessary, information systems should act as a kind of 'third hand' to help guide and govern the boundaries of human action. Technologies in safety-critical domains present special requirements for improvisational use.

We are working to better understand these requirements and how they can be applied when creating new technologies. Much of the work so far has been analytic. Moving forward we are planning a series of empirical studies that we hope will extend the range of our understanding and help ground design prescriptions in the practices for which they are intended. Our current focus is on a qualitative field study examining the role of improvisation in the work of EMTs and paramedics in a regional emergency medical service.

REFERENCES

[1] IOM-US, *Emergency medical services at the crossroads*. Washington, D.C.: National Academies Press, 2007.

[2] PA-DOH, "Pennsylvania Statewide Basic Life Support Protocols," ed. Harrisburg, PA: Pennsylvania Department of Health, 2011.

[3] S. R. Haynes, W. A. Schafer, and J. M. Carroll, "Leveraging and Limiting Practical Drift in Emergency Response Planning," in *40th Annual Hawaii International Conference on System Sciences*, Waikoloa, HI, USA, 2007, pp. 200-208.

[4] D. Schön and J. Bennett, "Reflective Conversation with Materials," in *Bringing Design to Software*, T. Winograd, Ed., ed: Addison-Wesley, 1996, pp. 171 - 189.

[5] C. Moorman and A. S. Miner, "Organizational Improvisation and Organizational Memory," *Academy of Management Review*, vol. 23, pp. 698-723, 1998.

[6] C. Dym, A. Agogino, O. Eris, D. Frey, and L. Leifer, "Engineering Design Thinking, Teaching, and Learning," *Journal of Engineering Education*, vol. 94, pp. 103-114, 2005.

[7] A. MacLean, R. M. Young, V. M. E. Bellotti, and T. Moran, "Questions, Options, and Criteria: Elements of Design Space Analysis," in *Design Rationale: Concepts, Techniques and Use*, T. P. Moran and J. M. Carroll, Eds., ed Mahwah, NJ: Lawrence Erlbaum, 1996, pp. 21-51.

[8] Kunz, W. and H. W. J. Rittel (1970). Issues as elements of information systems (Working Paper 131), Institute for Urban and Regional Development, University of California, Berkeley.

[9] J. Lee and K.-Y. Lai, "What's in Design Rationale?," in *Design Rationale: Concepts, Techniques and Use*, T. P. Moran and J. M. Carroll, Eds., ed Mahwah, NJ: Lawrence Erlbaum, 1996, pp. 21-51.

[10] J. M. Carroll and M. B. Rosson, "Getting around the task-artifact cycle: How to make claims and design by scenario," *ACM Transactions on Information Systems*, vol. 10, pp. 181-212, 1992.