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Evaluating the potential of new technological tools for safety critical work

Leena Norros [a,*], Marja Liinasuo [a], Rob Hutton [b]

[a] VTT Technical Research Centre of Finland, Vuorimiehentie 3, Espoo, P.O. Box 1000, 02044 VTT, Finland
[b] BAE Systems, Advanced Technology Centre, Sowerby Building, Filton, Bristol BS34 7QW, UK

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ABSTRACT

Defining user requirements of complex human–system interaction technologies and testing the fulfilment of these requirements in the end-product are issues of design practice that are currently not solved in an optimal way. In the current paper several dilemmas of "task-artefact-cycle", "abstraction level of requirements" and the "tendency for conservative decisions" in requirement definition and testing are tackled. A new simulation method is proposed to tackle these design dilemmas in a case study on emergency response (ER) activity. Modelling and simulation are used as means to anticipate future activity, and the concept of "zone of proximal development" serves to illustrate the change in work demands of the ER activity. One of the key issues in ER is to create a realistic and timely understanding of the situation and to identify adequately the needs for action, the Common Operational Picture (COP). In the project, prototypes of new technological tools were designed to facilitate creation of an appropriate COP. First, normal emergency response activity was modelled. Then, the modelled situation and corresponding activity were enacted by competent actors as undisturbed as possible. Parallel to this, a second activity took place. This involved two professional fire fighters acting in the roles of incident commander and supporting officer. They observed the actual demands of the situation and the activities of the first responder actors. They also observed the available information provided by the new technologies. In the present paper the focus is on the presentation of the design and evaluation methodology. The demonstration of the methodology in a complex design task indicates the feasibility of the approach.

1. Introduction

The practical context of the present study was the design of information technology tools for multi-agency emergency response (ER) activities. Many attempts are currently devoted to providing technical innovations to improve efficiency of emergency management and the safety of first responders. Yet, it has been found difficult to bring real added value to the ER work through introduction of new technologies. One reason for this is that the R&D projects typically are technology-driven. In the present study special emphasis was devoted to follow a usage-centred design approach with intensive end-user participation and with professional input from cognitive ergonomics in all phases of the design (Norman, 2005). The study was accomplished as part of an EU-funded project called Common Operational Picture Exploitation (COPE). In this project the aim was to develop Information and Communication Technological tools and new practices to improve ER activity.

2. Background

Even if the value of a usage-driven approach is acknowledged, there are still problems concerning how to achieve the desired outcomes within the process of designing complex technological systems. In this section, the challenges of applying a usage-driven approach are demonstrated by describing three generic dilemmas that are faced when integrating human factors in the design process. Thereafter, a proposal is made for a simulation-based approach which we used in an attempt to tackle the design dilemmas and to enable considerations of human factors issues in design.

2.1. Three design dilemmas and the ways out

The analysis of user demands for the purpose of identifying user requirements in usage-driven design normally draws on relevant current activities. The generic dilemma that the designers and their human factors collaborators then face is that the tools and activities for which the tools are used typically change interdependently. Once the redesigned new tools are implemented the activity has also changed, and the user demands that the tools should support are more or less outdated. This vicious circle was labelled the task-artefact cycle (Carroll et al., 1991). The introduction of rapid

* Corresponding author. Tel.: +358 40 5616774; fax: +358 20 7226027.
E-mail addresses: leena.norros@vtt.fi (L. Norros), marja.liinasuo@vtt.fi (M. Liinasuo), Rob.Hutton@baesystems.com (R. Hutton).

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prototyping (Holtzblatt et al., 2005) to enable frequent feedback from user tests is one attempt to tackle this problem. This approach makes sense particularly within a design mode that has been labelled as "immediate design" by Keinonen (2007). Characteristic to this design mode is sensitivity to the users' current or expressed future needs which are queried by different elicitation methods. Immediate design is context dependent and utilizes layman designers rather extensively. Immediacy in the name of this design mode does not only refer to time and location but also to causal and value-based immediacy. For example, the needs of the users are the immediate reasons for design, not e.g. new activity, new business strategy or technical opportunity.

The "task-artefact cycle" dilemma is also connected to a second dilemma. This deals with the difficulty of finding an appropriate level of abstraction for defining requirements. In the analysis of the user demands it is most natural to focus on the immediately perceivable behaviour of the users. Attending to what the actors are actually doing leads the analyst to describe singular actions or tasks, and their smaller perceivable elemental operations. From the descriptions of tasks and operations, very detailed and long lists of requirements emerge, which also become endless if different contexts of use should be taken into account. As tasks and operations are very intimately connected with the tools used in their accomplishment, task-oriented requirement analysis is prone to fall into the "task-artefact cycle" trap. An alternative, but a much less used possibility of defining user requirements also exists.

The focus of the alternative approach is directed on the more generic functions that need to be accomplished by the actors in order to meet the global aims of the activity, and on constraints that need to be taken into account. The focus is not on the tasks as such but on the ends, means and constraints that should be accounted for when task performance is described. Such a formative orientation in the definition of requirements was proposed by Vicente (1999), inspired by his mentor Jens Rasmussen. The rationale behind this approach is that degrees of freedom are maintained in the design process and that detailed design decisions are not made too early. Control is achieved by keeping the design decisions within the envelope of relevant global constraints and focused towards higher level aims.

A third dilemma faced in the usage-centred design perspective is that because evaluation of the functionality and usability of the technologies for future work is supposed to take place as early as possible, immature solutions will be introduced to users for test. Immature concepts or prototypes may receive negative end-user feedback. The problem here is not the critique itself but rather the fact that promising technologies may be rejected too easily. The design becomes conservative and less innovative than expected. Practical experience of such tendencies have been reported by industrial partners with whom the authors have been collaborating.

The way out from the design dilemmas described above is to develop tools that enable *anticipation of changes* in the activity, and to orient the users and designers to *reflect on the potential* of the technologies for future work. A further starting point should be that the *joint functioning of the human-technology system* should be adopted as the target of design and evaluation see e.g. (Norros and Salo, 2009; Woods and Hollnagel, 2006; Rabardel and Beguin, 2005). These features appear to require another design mode called "remote design" (Keinonen, 2007). Such a design approach aims at structural changes in the products and their usage, i.e. at new concepts of operation, and it focuses on new possibilities for activity. Remote design aims typically at outlining generative solutions, and shapes both expectations and possibilities of the users concerning their activity, as well as creating possibilities and concepts to further design. Scientific work and innovations are needed to accomplish results, the impacts of which become apparent later e.g. when technologies have matured sufficiently to be implemented. The context of implementation of the results of remote design expands beyond the original area of application, and design is motivated by societal and technological policy forces. Attempts to create design approaches that could be characterized as remote design have been proposed by different authors (Woods and Hollnagel, 2006; Salo and Norros, 2008; Elm et al., 2003). Our intention is to define methods and procedures that could strengthen the advantages of the immediate design but which also apply formative tools in order to reach more forward-looking ends.

2.2. A new type of simulation-based design method

One of the key issues in developing new design methods is simulation. Simulation refers here to different ways of modelling the work situation, not to simulation of specific cognitive functions of people. According to a standard definition given in The Universalis Encyclopedia, cited by Beguin and Pastré (2002) "Simulation is experimenting with models". This definition reveals the role of simulation for design by implying that simulation enables developing a model of the targeted situation of use for testing design solutions. On the basis of experience gained by using the solution, new knowledge of the solution is created. It is also maintained that simulation supports learning in two ways, i.e. through the building of a model, and through the use of the model (Morgan and Morrison, 1997). These two roles mentioned by Morgan and Morrison were discussed thoroughly by Beguin and Pastré (2002) who – drawing on the cultural historical theory of activity – elaborated them in a way that has immediate relevance to our purposes.

Begin and Pastrè state first that the model, i.e. a simulation, serves a pragmatic function. Simulation provides possibilities of making explicit the demands of future contexts of use and enables testing the functionality of the solution under different constraints. This most evident role of simulation was exploited in the current study by preparing a conceptual model of a typical usage situation, and by developing a real-life test situation to observe the actual use of the prototype technologies.

By a further epistemic role of simulation, Beguin and Pastré refer to the actual activity that takes place when using the simulation for experimenting with the design solutions. From this perspective the point is that a simulation enables drawing attention to certain targeted features of activity. In our case the target of simulation was to study the macro-cognitive function of creating a shared understanding of the emergency situation and the common ground among the fire fighters (Schraagen et al., 2008) which can be considered a key demand in emergency response activity. In our study this function was called the Common Operational Picture, the formation of which was supposed to be supported by the comprehensive information system under development.

Our problem was that the design was still on the level of a concept, and, yet, in order to test its potential, the test situation needed to be rather complex. Hence there was doubt about the possibility to maintain the targeted ER activity while simultaneously testing the technology. Moreover, it could not be assumed that the actors would have developed sufficient skills to use the technology to be tested, which would be required in order to draw relevant conclusions from the added value of these technologies.

By questioning the sense of testing the design in a real-life emergency response exercise the trainer brought up the third role of simulation that Begin and Pastré call the heuristic role. This role draws attention to the fact that activity during a simulation has specific meaning to professional actors. The possible success or failure has significance for the actors' professional identity, competences, self-esteem and self-confidence, etc. Therefore the exercise and the testing of technology must make sense to the participants