International Journal of Information Systems for Crisis Response and Management (IJISCRAM)

Special Issue on Human Computer Interaction in Critical Systems II: Authorities and Industry

IJISCRAM, Volume 7, Issue 3

Christian Reuter (Eds.)

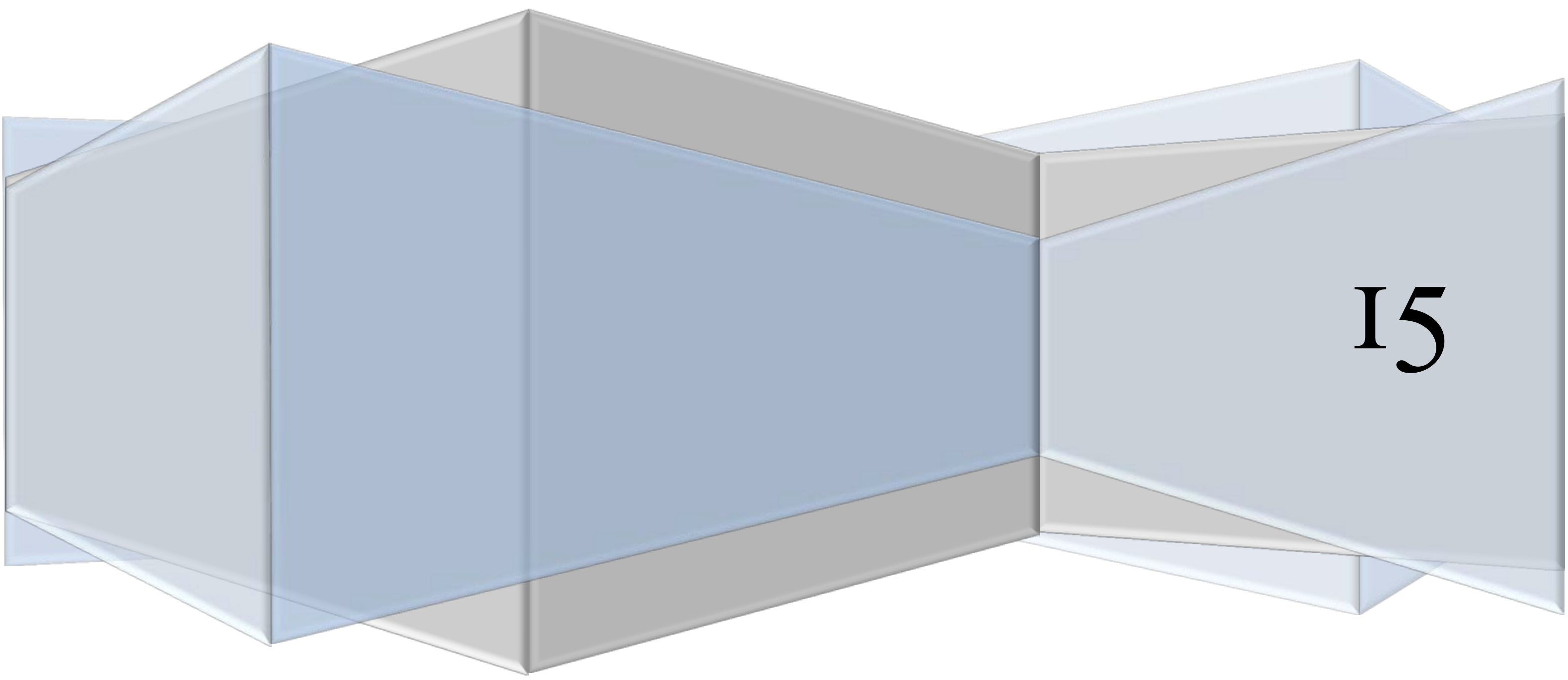

TABLE OF CONTENTS

GUEST EDITORIAL PREFACE

Special Issue on Human Computer Interaction in Critical Systems II:

Authorities and Industry

Christian Reuter, University of Siegen, Germany

ABSTRACT

Human computer interaction in security and time-critical systems is an interdisciplinary challenge at the seams of human factors, engineering, information systems and computer science. Application fields include control systems, critical infrastructures, vehicle and traffic management, production technology, business continuity management, medical technology, crisis management and civil protection. Nowadays in many areas mobile and ubiquitous computing as well as social media and collaborative technologies also plays an important role. The specific challenges require the discussion and development of new methods and approaches in order to design information systems. These are going to be addressed in this special issue with a particular focus on technologies for critical practices for authorities and industry.

1 EDITORIAL

Authorities as well as industry are confronted with many critical practices, they have to deal with. This special issue tries to address these. It is based on the 2015 workshop on "Human Computer Interaction and Social Computing in Critical Systems" (Reuter et al., 2015), however also other articles have been considered for submission. Fortunately we received a large number of submissions which have been reviewed by at least two independent experts as well as by the guest editor. After up to two rounds of major and minor revisions the following five articles will be presented in this issue:

Henrik Berndt, Tilo Mentler and Michael Herczeg (Institute for Multimedia and Interactive Systems, University of Luebeck) address in their article "*Optical Head-Mounted Displays in Mass Casualty Incidents*" the research questions, whether optical head-mounted displays could support members of emergency medical services and civil protection units in challenging medical crises and how human-computer interaction has to be designed with respect to the time- and safety-critical context of use. The human-centered design and evaluation of applications for determining the priority of patients' treatments (triage) and for identifying hazardous materials with the aid of Google Glass are described. Results indicate that optical head-mounted displays are a promising technological approach but designing safe and efficient human-computer interaction for wearable systems augmenting reality remains a major challenge.

Johannes Sautter (Fraunhofer IAO), Denis Havlik (Austrian Institute of Technology AIT), Lars Böspflug (Fraunhofer IAO), Matthias Max (German Red Cross), Kalev Rannat (Tallinn Technical University), Marc Erlich (Artelia Group) and Wolf Engelbach (Fraunhofer IAO) describe in their paper "*Simulation and Analysis of Mass Casualty Mission Tactics*" an interaction concept allowing a simulation-based analysis of mass casualty mission tactics to leading personnel of emergency medical services. Addressing the needs of the medical civil protection domain, beside the interaction concept they describe large-scale emergency scenarios, the context of use and a performed Think-Aloud evaluation.

Kristian Rother, Inga Karl and Simon Nestler (Hochschule Hamm-Lippstadt) outline in their article "*Towards Virtual Reality Crisis Simulation as a Tool for Usability Testing of Crisis Related Interactive Systems*" the general motivation for the development of a virtual reality crisis simulation (VRCS) prototype for usability testing. The VRCS serves as a means to solve the identified problem of taking the crisis context into account in a less resource intensive way than relying solely on real crisis simulations. The paper defines objectives for a solution of this identified problem and identifies the sub-problem that injecting an interactive system that will be tested (testee) into the VRCS could influence the realism of the VRCS. To answer the research question "Does the injection of a testee into a VRCS influence the realism of that VRCS?" equivalence tests with regards to the realism of the VRCS are conducted. The tests show that the VRCS with and without the testee are equivalent with regards to *scene realism*, *audience behavior*, *sound realism* and *realism of the VR-application.* The article concludes with an outlook of future research directions.

Thomas Ludwig, Christoph Kotthaus and Volkmar Pipek (University of Siegen) present in their article "*Should I try turning it off and on again? Outlining HCI Challenges for Cyber-Physical Production Systems*" the adaption of the concept of sociable technologies, as hardware-centered appropriation infrastructures, to cyber-physical production systems (CPPS). CPPS are complex and automated manufacturing systems that usually pose enormous challenges to the machine operator. With regard to understanding CPPS' "behavior" and technical controllability, sociable technologies can help machine operators to appropriate their machines. Within this article, the authors outline and discuss several design implications from a HCI perspective.

Christian Reuter (University of Siegen) focuses in his article "*Towards Efficient Security - Business Continuity Management in Small and Medium Enterprises*" on the use of Business Continuity Management (BCM) in Small and Medium Enterprises (SME). According to the ISO 22301 (2014) BCM is defined as a holistic management process which identifies potential threats to an organization and the impacts those threats might have on business operations. The paper presents a literature research on the use of BCM in SME and discusses research findings concerning this matter. Based on this a matrix for possible impacts vs. quality of the crisis management for different actors is derived. The article concludes with the presentation of lightweight und easy to handle BCM security solutions in form of Smart Services, as a possible solution for the increasingly IT relaying industry 4.0.

The human computer interaction in critical systems will continue to play a major role. With this special issue we want to contribute to help shape this development in a meaningful way.

Christian Reuter

Guest Editors

IJISCRAM

ACKNOLWEGEMENTS

We like to thank the German Informatics Society as well as our reviewers.

REFERENCES

Reuter, C., Mentler, T., Geisler, S., Herczeg, M., Ludwig, T., Pipek, V., … Sautter, J. (2015). Editorial: Mensch-Computer-Interaktion und Social Computing in sicherheitskritischen Systemen. In A. Schmidt, A. Weisbecke, & M. Burmester (Eds.), *Mensch & Computer 2015: Workshopband*. Oldenbourg Verlag.

CV

Dr. Christian Reuter studied Information Systems at the University of Siegen, Germany and the École Supérieure de Commerce de Dijon, France (Dipl.-Wirt.Inf.; M.Sc.) and received a PhD for his work on (inter-)organizational collaboration technology design for crisis management (Dr. rer. pol.) with summa cum laude. He has worked as a web developer, consultant and researcher and has published more than 60 scientific articles. He is voluntary founding spokesman of the section "human computer interaction in security relevant systems" of the German Informatics Society.

Optical Head-Mounted Displays in Mass Casualty Incidents

Keeping an eye on patients and hazardous materials

Henrik Berndt, Institute for Multimedia and Interactive Systems, University of Luebeck, Luebeck, Germany
Tilo Mentler, Institute for Multimedia and Interactive Systems, University of Luebeck, Luebeck, Germany
Michael Herczeg, Institute for Multimedia and Interactive Systems, University of Luebeck, Luebeck, Germany

ABSTRACT

Optical head-mounted displays (OHMDs) could support members of emergency medical services in responding to and managing mass casualty incidents. In this contribution, we describe the human-centered design of two applications for supporting the triage process as well as the identification of hazardous materials. They were evaluated with members of emergency medical services and civil protection units. In this regard, challenges and approaches to human-computer interaction with OHMDs in crisis response and management are discussed. The conclusion is drawn that often mentioned advantages of OHMDs like hands-free interaction alone will not lead to usable solutions for safety-critical domains. Interaction design needs to be carefully considered right down to the last detail.

KEYWORDS

Google Glass, Human-Computer Interaction, Optical Head-Mounted Displays, Mass Casualty Incident, Safety-Critical Human-Computer Systems, Triage

1 INTRODUCTION

A mass casualty incident (MCI) "*generates more patients at one time than locally available resources can manage using routine procedures. It requires exceptional emergency arrangements and additional or extraordinary assistance*" (World Health Organization, 2007,

p. 9). Such medical crises are challenging situations for members of emergency medical services (EMS) and civil protection units. Their rare occurrence can lead to a lack of training (Born et al., 2007). Within a study of Ellebrecht (2013), only 56% of 2052 participating emergency physicians and paramedics had experienced a MCI in their professional life so far. Missing routine and adverse working environments (e.g. weather conditions, high noise level, unpleasant smells, confined spaces, large number of casualties) could yield additional stress (Waterstraat, 2006). These factors might compromise individual performances as well as teamwork with respect to cooperation and coordination.

Currently, paper-based tools and several means of communication (e.g. radios, mobile phones, and messengers) are used for managing MCIs and satisfying information needs (Kindsmüller, Mentler, Herczeg & Rumland, 2011). Mentler and Herczeg (2014, p. 1) state that *"interactive cognitive artifacts might improve the situations compared to using established paper-based artifacts by exchanging and visualizing data in real-time"*. Several research projects, e.g. WIISARD, AID-N, e-Triage, have already made use of off-the-shelf and custom-made mobile devices ranging from personal digital assistants (PDAs) to rugged tablets (Adler et al., 2011; Coskun et al., 2010; Killeen et al., 2007).

In this study, we deviate from the aforementioned approaches by focusing on optical head-mounted displays (OHMDs). By hands-free usage, they might allow emergency physicians and paramedics to interact without interrupting treatments or other mission-related tasks. In MCIs, choices and measures of EMS members are a matter of life or death. Therefore, interactive systems supporting their actions must be classified as safety-critical and usability is a crucial factor with respect to human-computer interaction. Problems or delays in performing certain tasks have to be avoided.

The research questions are addressed, whether OHMDs could support members of EMS and civil protection units in challenging medical crises and how human-computer interaction has to be designed with respect to the time- and safety-critical context of use. After describing background and related work, the human-centered design and evaluation of applications for determining the priority of patients' treatments (triage) and for identifying hazardous materials will be explained in detail.

2 BACKGROUND AND RELATED WORK

In the following sections, background information and related studies according to the triage process (section 2.1) and the identification of hazardous materials (section 2.2) are described.

2.1 THE TRIAGE PROCESS

In order to save as many lives as possible, urgency and effort of each casualty's treatment needs to be determined before advanced measures will be applied to single patients. This process is named *triage*. It results in a classification of casualties specifying an order for treatment and transport. Especially, casualties in need of immediate treatment have to be identified. While the triage process might be repeated or continued at different stages, the first round forms the basis for the patient outcome. It is often performed by the first arriving EMS unit (Schniedermeier & Peters, 2009, p. 103). In Germany, first triage is often named pre-triage because paramedics might be involved. Later triages should be performed by emergency physicians only. Any triage step has to be performed fast and should contain only a few immediate life support actions, e.g. controlling continuous bleedings or positioning airway.

Assigning casualties to wrong categories (named under- respectively over-triage) would make it impossible to reach the goal of best possible patient outcome and would lead to increased mortality (Frykberg, 2002). For getting reliable results, EMS members can be guided by triage algorithms. Several of them have been developed since the 1980s (Jenkins et al., 2008). One of the most common algorithms is the *Simple Triage And Rapid Treatment (START)*. The current version of this algorithm is described by Benson, Koenig & Schultz (1996). It consists of four questions and two instructions in a hierarchical structure. Questions focus on vital signs of the casualty, e.g. the radial pulse or the breathing rate. Instructions contain life–sustaining measures, e.g. controlling a bleeding. The user of the algorithm has to give a positive or a negative answer to each question and gets one of the categories “Immediate”, “Delayed” or “Unsalvageable” as a result. Many other algorithms are modified versions of START. Currently, they are available on paper-based forms (Kanz et al., 2006). Several research projects have already dealt with OHMDs in triage and MCIs in general. Five of them are summarized subsequently (Carenzo et al., 2014; Cicero et al. 2015; Fernández et al., 2014; O'Donnell, 2015; Deutscher Berufsverband Rettungsdienst e.V., 2015).

Carenzo et al. (2014) have published a report about the use of Google Glass in disaster medicine. They state that *“despite some limitations (battery life and privacy concerns), Glass is a promising technology both for telemedicine applications and augmented-reality disaster response support”* (p. 1). It is assumed that such devices would allow for better decision-making and cooperation in medical crises. Google Glass was tested in a crisis simulation in Italy with 100 mock casualties and about 300 health professionals. According to this field study, the prototype for the triage process seems to be promising. Furthermore, telemedicine, operational management and training are mentioned as application fields. In terms of human-computer interaction, the authors propose that the user could interact with the system using voice recognition in order to answer the questions with a positive or a negative answer (L. Carenzo, personal communication, March 4, 2015).

Cicero et al. (2015) have conducted a feasibility study for using Google Glass in telemedicine. They compared the work of two triage teams consisting of two persons. One of them was equipped with a Google Glass application that offered the possibility to consult a physician and disaster expert. The study was conducted during a disaster exercise at which about 20 patients had to be triaged by both teams. The team with the Google Glass consulted the physician disaster expert in two cases. Cicero (2015) et al. state “*there was no increase in triage accuracy […] and [that] telemedicine required more time than conventional triage*” (p. 1). However, the authors describe some limitations of the study and technical problems with the Google Glass. Therefore the results cannot be generalized to other *“more mature”* technologies (Cicero et al., 2015).

The design process for a triage system has been examined by del Rocío Fuentes Fernández, Bernabe and Rodríguez (2014). Their conceptual solution includes modules for the triage process, for communication via messages and for a location service. The module for the triage process consists of an algorithm for classifying the casualties. This algorithm is displayed in form of six symbols, each of them representing a decision of the emergency personnel. The authors have visualized the system in form of mockups on a computer. These mockups show a possible view of the user augmented with the information of the Google Glass display. The system has been evaluated with six members of the Mexican Red Cross. In the evaluation the participants saw the mockups of the application and were asked what they would have done in different predefined situations. Participants used a variety of different commands. A study is proposed which should examine different aspects of the voice recognition including defining a set of commands (del Rocío Fuentes Fernández, Bernabe & Rodríguez, 2014).

O'Donnell, Szotek, Arkins & Priest (2015) have published a poster about a triage experiment with nursing students. They have measured triage accuracy and time in an experiment with four casualties. The authors see a "*trend towards improvement in START triage with Google Glass*" and determine "*a significant learning curve*" concerning the technology. However, they state that an improved implementation would require less technical issues and that there larger studies on the "*role of wearable technology in MCI scenarios*" are necessary (O'Donnell et al., 2015).

In Germany, the AUDIME-project has recently been started. It might focus on the use of OHMDs in MCIs, as a current survey indicates. Participants were asked about suitability of different interaction methods (e.g. voice and gesture recognition) and mobile devices (e.g. smartwatches) in medical crises. OHMDs were named as potential candidates (Deutscher Berufsverband Rettungsdienst e.V., 2015).

2.2 IDENTIFYING HAZARDOUS MATERIALS

In general, members of EMS are not specialized in identifying hazardous materials (Flake & Lutomsky, 2003). Nevertheless, in MCIs as well as in regular missions they can be confronted with them at any time. Accidents involving trucks transporting hazardous goods or containers with unknown contents are just one possible scenario. Flake and Lutomsky (2003) state that missions involving hazardous materials are a major challenge for members of EMS.

United Nations (UN) (2001a) has numbered hazardous materials and divided them into nine classes indicating potential risks. Furthermore, warning signs were specified and realized by national and international agreements, e.g. the European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR). Being applied in nearly 50 states, ADR regulates, that transports of hazardous materials must be labeled with an orange-colored plate containing the UN number of the hazardous material and the number of its class (United Nations Economic Commission for Europe, 2014).

In order to get advices about estimating dangers or responding to dispatch center, EMS members have to rely on books or applications for mobile applications (Flake & Lutomsky, 2003; ThatsMyStapler Inc., 2015). Usually they have to know either the name of the hazardous material or the UN number. If meaning of signs is completely unknown, browsing tables or databases is required.

3 HUMAN-CENTERED DESIGN PROCESS

In the following sections, analysis (section 3.1), concept (3.2) and realization of two applications for supporting the triage process (section 3.3) and identification of hazardous materials (section 3.4) are described. Application scenario and evaluation will be explained in the subsequent sections 4 and 5.

3.1 ANALYSIS

In order to identify practice-oriented use cases, semi-structured interviews were conducted with five professional members of German EMS and five voluntary members of civil protection units. Their age ranges from 24 to 66 years. Seven of the interviewees had training in leadership; all stated that they have knowledge about the procedures in MCIs. Participants were introduced to OHMDs and asked to share their ideas about wearable devices augmenting reality in medical crises without judging feasibility. Based on the interviewees' opinion, the course of conversation varied strongly. A set of pre-defined questions helped to ensure that different application fields were addressed in each interview. In addition, they were seen as a basis for discussion when there were no more ideas from the interview partners. While single suggestions were devoted to realizing sophisticated communication systems with the aid of OHMDs, supporting the triage process and the identification of hazardous materials could be seen as two most promising use cases. Regarding the triage process, nearly all of the interview partners mentioned that algorithms are useful and more and more applied. Moreover, some interview partners stated that triage would be a stressful situation due to its rarity and that algorithms could help in such situations. Currently, algorithms are available in paper-based form. Nearly all interviewees meant that a hands-free usage of an algorithm using an OHMD could yield benefits since members of EMS could use their hands and would have the information in their field of view. They probably could *"focus on the patient differently"*, as one interview partner said. Most participants suspected voice recognition to be the best interaction style. In terms of the identification of hazardous materials, being *"comprehensible from the perspective of EMS members"* was a major request. The interview partners mentioned that the application should include at least some information about the material itself, the risks and the resulting hazard zone. As a starting point for the identification process the interviewees mentioned warning signs on heavy goods vehicles.

For the development process we had to choose between devices of different manufacturers for realization. Since the system is supposed to augment the reality with additional information, all displays designed for complete immersion in virtual environments were excluded from our list of choices. Nevertheless there were different possibilities, for example devices developed by Vuzix, Google or Epson. Finally Google Glass has been chosen for developing the applications. Google Glass is an Android-based augmented reality (AR) device with an integrated camera and support for voice recognition. It also contains a touchpad for interaction on the right spectacle frame. The screen information of the Google Glass is displayed in the upper range of the field of view of the right eye so that it should not hinder the user in his or her work, the display is transparent. These advantages over devices with other screen positioning or non-transparent displays and the fact that Google Glass has been used in the related work described in the previous section led to this decision. Furthermore, Google Glass has been widely used in scientific projects as a search request in the ACM Digital Library indicates (409 results for "Google Glass", 65 for "vuzix", 32 for "moverio", the name of the devices by Epson on August, 7th 2015).

3.2 CONCEPTS FOR INTERFACE AND INTERACTION DESIGN

Google recommends some design principles and patterns for Google Glass, that should be applied *"when appropriate"* in order *"to give users a consistent user experience"* (Google Inc., 2015) These principles and patterns deviate from those of other mobile systems. When starting the glass, a home screen appears. It displays the current time in the middle and the affordance "ok glass" below. The home screen is part of a set of information screens, which can be reached by scrolling on the touchpad in left or right direction. From the home screen it is possible to start applications using two different interaction principles. The availability of a menu for voice interaction is automatically signaled by the text "ok glass" while for touchscreen interaction no such indicator exists. If the user says "ok glass", a list of application names appears and the user can choose the desired application by calling their name. The other interaction method makes use of the touchpad. When clicking on the touchpad from the home screen, a screen with the name of one of the applications appears. By scrolling via the touchpad, the user can switch between application names and by clicking he or she can start the application for the displayed name.

Being part of a safety-critical human-computer system, the avoidance of errors is of particular importance. This matter can at least be divided into measures against human errors, technical errors, errors in organizational structures and errors that occur in human-computer interaction (Herczeg, 2000; Herczeg, 2014, pp. 36-42). Furthermore, the processes in MCIs are time sensitive. Nestler (2014) argues that actors in a crisis would have no additional time to work around usability problems. He concludes that even minor flaws in the user interface might result in a total breakdown of the human-computer interaction. Usability is therefore a crucial factor. It was decided, that both applications, the one for the triage process and the one for identifying hazardous materials, shall have a consistent user interface. Therefore a general user interface using a large main field in the middle of the screen and single-lined header and footer fields has been designed. The fields are visually separated from each other by lines. In the header field general information like the name and the state of the application or the displayed screen is shown. This deviation from the design principles enables the user to know the system state even after interruptions. The application can be stopped from every screen by using the stop command in the menu for voice or touchpad interaction.

Applications running on Google Glass can be controlled by voice recognition or by using the touchpad. Voice recognition enables users to use their hands for other tasks or to assist their team members manually. It complies with the preference of the interviewees. While voice recognition has the additional benefit that users must not touch anything with potentially dirty hands or gloves, it might fail in noisy environments. For such a case, the members of EMS may choose the touchscreen interaction instead. It can be seen as a fallback option that offers the same functionality as the voice recognition. Deviating from the design principles we have experimented with direct voice recognition in the screens of the application. Therefore, every voice command was displayed and marked with quotation marks and a speech bubble. This was necessary in order to make sure that the user knows the possibilities and utilizes the same command set. However, this method had some problems like no direct feedback to the user of the system. Moreover, such a representation of the voice commands takes much screen space. Consequently, we have discarded that option for the benefit of the voice menu from the design principles that can be invoked by the command “ok glass”. When an entry of the voice menu is selected, it is highlighted, so that the user has a feedback before the application executes the actions combined with the selected command. This is not sufficient in terms of an appropriate human-computer interaction as it is only recognizable for a few moments and as it is not visible in the next screen. So we decided, that the system should give a permanent feedback, which voice command was selected most recently in order to give the user the chance to check the input and whether the voice command was detected correctly. Accompanied with this solution it was decided that there must be an undo function so that the user can correct failures or incorrect inputs. This was of particular importance since we noticed the voice recognition of the Google Glass to work unreliable.

We especially needed words for the confirmation and negation of questions. We have experimented with different word pairs and took those that worked best. Still some recognition failures can occur from time to time, but the voice recognition has been tested to be sufficient for a prototypical system and for further evaluation. Finally, the word pair “Positive” and “Negative” was chosen because of good results in recognition, even in combination with the word “Undo”. Although Google Glass does not support German voice recognition officially, there should have been a German version of the application in addition to English because the evaluation with German members of emergency rescue services should take place in their regular language. In German we have chosen the word pair “Korrekt”

(“Correct”) and “Nein” (“No”) because it worked best of all alternatives (e.g. “Richtig” (“Right”) and “Falsch” (“Wrong”)).

3.3 APPLICATION FOR THE TRIAGE PROCESS

Regarding findings from related studies and the interviews, we designed an application for supporting the triage process with hands-free interaction as requested by the interviewees. The triage process can be subdivided into a few ordered tasks: Each casualty should get an identification number, the injuries must be classified, and the casualties must be labeled with the classification for later treatment. In between lifesaving treatment might be necessary. Since this order seems to be the logical chronological order, the application should consider it to avoid errors. It is assumed that registration cards are used for the assignment of casualties to an identification number and for labeling the casualty with the classification result of the triage. These cards consist at least of a field for the classification of the casualty and the identification number which must be unique. For using computer systems in the triage, the number should be machine-readable. This has been ensured by taking QR codes, since these can be printed on the cards by the manufacturers in future without additional costs or alternatively be fixed on them with adhesive stickers. After starting the application on the Google Glass, the application displays the view of the camera with an instruction text for the user to look at the QR code of a registration card. When a QR code is recognized, the application starts with the algorithm as requested by the user. This is signaled to the user by playing a sound. For the algorithm the application shows a question or an instruction per screen (Figure 1). This kind of representation enables us to show each question or instruction in a large font using one or two lines. The user can answer questions or continue after executing instructions by opening the voice menu with the command “ok glass” followed by one of the shown voice commands.

Figure 1: The application shows instructions and questions. To interact with it, the user must open the voice menu using the command “ok glass”.

At the end of the algorithm when a classification finally is reached, it is shown to the user together with the instruction to attach the registration card to the casualty (Figure 2). When seeing the classification screen the user is able to restart the triage for a new patient or to stop the application in the voice menu. In contrast to the paper version the application does not show the whole algorithm at once so that the user will not get an overview. On the other hand the user is guided through the algorithm, so that he or she cannot forget where to continue when being interrupted and so that he or she cannot skip important steps. In the header field, the name of the application, the currently shown step of the triage process or the algorithm and the identification number of the casualty and the registration card are shown. In the footer field a time stamp for the beginning of triaging the current casualty is displayed.

Figure 2: When reaching the end of the algorithm, the application shows the category in which the casualty is classified. Using the voice menu, the user can restart the triage process for a new patient, undo the last step or stop the application.

The displayed information and input of the user have no direct effect on the environment or the casualty. Thus, errors and failures are not harmful if they are recognized and corrected by the user quickly. Therefore, it is not necessary and because of the efficiency not useful to implement confirmation functions for each answer on a question. The application has an undo function and shows the previous question or instruction with the chosen voice command in each screen in order to let the user recognize errors. Nevertheless, especially technical errors and partly errors in human-computer interaction can be critical for the casualties because of the loss of time and probably reduce the acceptance by the users. Errors in human-computer interaction and human mistakes shall be recognized in the evaluation. Technical errors should be avoided, but there are some known issues with the Google Glass. The overheating of the device leads to problems with the recognition of QR codes and voice. Furthermore, voice recognition does not function sufficient in general. Even if these problems could be addressed with a future version of an OHMD, there remains the problem that voice recognition could fail in noisy environments. Therefore, a redundant interaction style supporting the touchpad of the Google Glass has been built in.

3.4 APPLICATION FOR IDENTIFYING HAZARDOUS MATERIALS

The idea behind this application is to enable the members of EMS to identify hazardous materials and to get some important information about their properties and risks. It shall not replace experts or give detailed information. Instead, the application may help when experts are not available yet or if a possible danger is recognized suddenly. In order to substantiate the advantage, four signs for classes of hazardous materials (classes 3, 4.1, 4.2 and 4.3) and an orange-colored plate with the UN number for petrol have been presented to 14 members of EMS. While all of them recognized them as signs for hazardous materials, only one participant identified all of the signs for the classes almost correctly. Two participants knew the UN number for petrol of the orange-colored plate; some wrongly suspected that it would be diesel fuel. All participants mentioned that it would be helpful, if a system would support the identification of hazardous materials. This statement confirms the conclusion drawn from the interviews to realize an application for this purpose.

After being started, the application for identifying hazardous materials shows the camera screen together with the instruction that the user must look at a warning sign. The screen has a similar structure to the screen for reading a QR code in the application for the triage process. The application constantly searches for warning signs in the view of the camera. If a sign has been detected, the application informs the user by playing a sound and switches to the next display. In that display, it shows an image of the detected warning sign and asks the user if it matches with the viewed one. If this is the case, the application displays information about the material including risks and a recommended behavior for the emergency personnel (Figure 3). If the correct warning sign cannot be identified, the detection will be restarted.

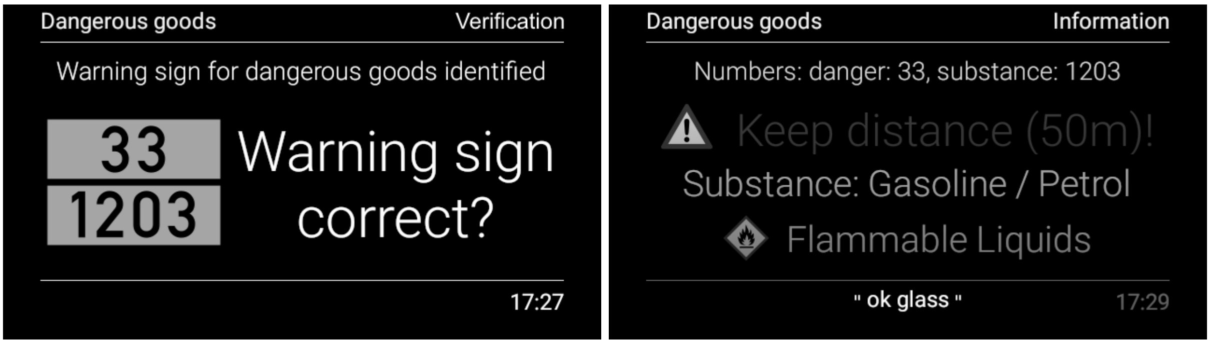

Figure 3: The application questions the user if the warning sign has been identified correctly. If this is the case, it shows information about the danger and the substance.

Incorrect information about the material or the risks could be harmful for the users of the application and other persons in the area. Assumed that the data set is correct, a main cause of error could be an incorrect detection of the warning sign. It must be observed, that these car or building mounted signs may be dirty or broken and that possibly the font types differ. Therefore, the confirmation of the detection as described above seems to be a useful method to avoid such errors. In addition, it may support the belief of the user in the correctness of the displayed information.

4 APPLICATION SCENARIO

When a MCI occurs, several ambulances and other vehicles of EMS are sent to the incident location as soon as the dispatch center assumes or knows that there are many casualties. The first unit responding from the incident site reports a situation description and confirms or denies the occurrence of a MCI. In some cases the dispatch center has no knowledge about a MCI until the first unit responds.

However, there will always be one or more ambulances that reach the incident location faster than others. We assume that the first triage shall be performed by the first or at least some of the first arriving personnel of EMS. Furthermore, let us suppose that all ambulances have been equipped with OHMDs and the triage application and that the users have been trained with the application.

When arriving at the incident location, one of the team members of one of the first ambulances puts on the OHMD and starts the application for the triage using the voice command “ok glass” followed by the command “start triage”. Then he or she takes the bag with the registration cards or registration tags while another team member takes the bag with medical equipment. After exploring the situation and reporting back to the dispatch center these two team members start the triage. Near the first casualty, the first team member looks at the first registration card so that the camera of the OHMD can read an imprinted code and receive the number of the registration card. The second team member starts providing immediate lifesaving activity if necessary. After getting the identification number, the OHMD shows the next questions of the algorithm and the team member who wears the device answers them using the voice recognition. While not interacting with the device, he or she communicates with the other team member about the questions and instructions of the application. Thus, the user of the OHMD has both hands free; he or she can use them to check vital signs or to help the other team member, e.g. when controlling a heavy bleeding by applying a pressure dressing (Figure 4).

Figure 4: Triage of a casualty with a heavy bleeding. The user of the OHMD (Google Glass) helps applying a pressure dressing.

At the end of the algorithm, the application shows the classification for the injured person. The first team member of the ambulance marks the registration card or registration tag and attaches it to the casualty. While both team members go to the next casualty, the user of the OHMD interacts via voice recognition with the device in order to restart the triage process for the new casualty.

Before reaching the last casualty one of the team members recognizes a container with a mark for hazardous materials. While having the registration cards in the hands, the user of the OHMD stops the application for the triage and starts the application for identifying hazardous materials using the voice recognition. Then he or she looks at the warning sign that is recognized by the application as a mark for solids that are flammable and dangerous when wet. There is neither water nor fire. Thus the team decides being able to rescue the casualty near the container and moves it to a safe place since the weather forecast predicts a front carrying rain. After reporting the situation back the team continues with the triage for this casualty.

5 EVALUATION

The applications for supporting the triage process and identifying hazardous materials were evaluated with 14 participants in the age range from 20 to 66. Nine of them were German EMS professionals, the other five were volunteers of a civil protection unit. Seven members of the group of professionals and three members of the group of volunteers had previous experiences with real MCIs. Nearly all professionals had a two- or three-year professional education, only one of them was less qualified with 520 hours of education and more than 200 hours practice. The volunteers have passed courses of at least about 60 hours. In the following sections, methods and results of the evaluation are described.

5.1 METHODS

Nestler (2014) describes some possible types of usability tests for crisis management. We have decided to simulate the application scenarios separated from the crisis. With this method we have ensured same conditions and can observe the process directly. Using casualty performers in a real or exercise scenario would have been more complex and could bring unintentional side effects, for example if the injuries would have not been recognized properly. Since we wanted to evaluate the usage of a proper algorithm and not the algorithm itself in this evaluation, wrong classifications would have brought no new knowledge. However, in further evaluations with new objectives the involvement of casualty performers might be helpful. They should address if using the system changes procedures and processes in MCIs. For the evaluation of the application for the triage process each participant was given four case examples of casualties that must have been triaged. The identification of hazardous materials was simulated with paper prints of different warning signs.

While the participants performed the tasks, we observed them and took notes about problems regarding the user interface. These were classified into problems with the interaction or the comprehension of the application and technical difficulties, e.g. incorrectly recognized voice. Problems of the last mentioned category have been filtered out in the evaluation. This seemed to be useful since technical problems could be seen as a result of the prototypical stage of the application and should be fixed by using future versions of OHMDs. In addition to the observation, every participant was interviewed, leading to the results presented hereinafter. One of the participants could not use Google Glass because of seeing the displayed information distorted. Therefore, 13 EMS members could be considered.

5.2 RESULTS FOR THE TRIAGE PROCESS

We noticed that at the beginning some of the evaluation participants have had some problems in understanding the interaction form of voice recognition. Nevertheless, after a short initial period, eleven of them understood the interaction concepts and seemed to work well with the application. For two participants we noticed uncertainty even in the last case example, for one of them this uncertainty can be stated as very problematical. In contrast to this, all 13 participants said, that the application could be learned rapidly. Other questions concerning the usability have been, whether there were redundant inputs, whether the displayed texts were too short or too long, whether the user knew what to do at all time and whether the interaction was designed useful. All these were answered positive. The participants also said that errors could be resolved in a reasonable way. Nevertheless, there were a few negative remarks on error recognition.

Eight of the evaluation participants said that the application could be useful and helpful in MCIs if the technical problems would have been solved, one of them meant it would be a *"great relief"* for members of EMS. All five of the participants that work voluntary in the EMS or civil protection units belonged to this group. Four other participants meant that the application could be partially useful. Some of them mentioned new members of EMS with rare experience in such situations. Such a statement of a participant with experiences in MCIs was: *"More likely, it will help paramedics who have not been involved in a MCI yet"*. All participants believed that the system could help to perform all important steps and thereby prevent under-triage. On the other hand, only three participants meant that the system could prevent members of EMS from doing too much treatment because of having more experience with individual care. One of them said: *"The application guides to the essential measures"*. Another five of them believed that displaying additional messages or a countdown could help with this problem; the others did not see an advantage in the system for preventing it or did not think that this could happen in a MCI. Another result of the evaluation is that nearly all participants agreed that it would be useful to gather information during the triage like the decisions of the user and the categories of the casualties in order to transfer it directly to operational lead. It could be used for improved situation awareness. Further studies could deal with the question, if information gathered by OHMDs could also help to check procedures in MCIs or evaluate exercises and if this would be accepted by the users.

5.3 RESULTS FOR THE IDENTIFICATION OF HAZARDOUS MATERIALS

All of the evaluation participants agreed to the statement, that the application would be helpful for identifying hazardous materials, several of them noted explicitly that it could not only be useful in MCIs but also in routine situations. 11 participants rated the application with "good" or "very good", the other two were "satisfied". Further possible answers were "bad" and "very bad". Nobody proposed improvements for the recognition process, the user interface or the interaction forms. Nevertheless, we noticed that two of the users wanted to start the recognition of the warning sign with an explicit interaction when it happened not immediately. The interaction patterns only work if the detection happens without a larger delay. Some of the users had suggestions for additional information, for example how to treat contaminated casualties or what type of fire extinguisher could be used for the hazardous material.

6 LIMITATIONS

In the following sections, the applicability of this study (section 6.1) and technical limitations according to the Google Glass (section 6.2) will be explained.

6.1 APPLICABILITY OF THIS STUDY

This study is mainly devoted to the German EMS system. Nevertheless, main results are transferable to EMS in other countries for the following reasons.

Triage refers to the problem of dealing with too many casualties for routine procedures and is part of medical crisis management and response in many countries. The implemented modified START algorithm can be seen as an example and easily be replaced by other triage algorithms depending on vital functions checks. By considering only first triage, the application can be used independently from certain characteristics of German EMS, particularly the presence of emergency physicians in pre-hospital medical care.

Identifying hazardous materials is a major challenge for EMS members in any country. The mentioned classes of hazardous materials and most of the warning signs are standardized and have international validity. Therefore, only language-specific changes would be necessary.

6.2 TECHNICAL CONSTRAINTS

The current version of the Google Glass (Explorer Edition) has some technical constraints that would not be acceptable for usage in real MCIs. Limited battery-life, e.g. below an hour for very energy-intensive applications (LiKamWa, Wang, Carroll, Lin & Zhong, 2014), and overheating are well-known problems. On the one hand, the latter results in reduced performance. On the other hand, it causes inconveniences for the users wearing the device.

Furthermore, there are issues with reliability and performance of voice recognition both in German and in English – not just in noisy environments. For example, a fixed threshold value is used. This can lead to recognition errors if the threshold is reached before the pronunciation of a word has been completed or if two words have a similar pronunciation.

7 CONCLUSION

Optical head-mounted displays (OHMDs) could support the members of emergency medical services in managing medical crises. During the overall development process, involved experts showed great interest in wearable devices augmenting reality. Within a human-centered design process two prototypical Google Glass applications for supporting algorithm-based triage and identifying hazardous materials were realized. They were evaluated by EMS members with respect to human-computer interaction and usability. Apart from one person who saw the displayed information distorted, all participants were able to use both applications without considerable difficulties and judged them to be usable and helpful with respect to the aforementioned technical constraints. In general, these results can be applied to other OHMDs and other EMS systems. Identifying hazardous materials may even be necessary in daily routine. Therefore, OHMDs can be in harmony with the principle “Care & Prepare” (Kindsmüller et al., 2011) which states that interactive systems for managing MCIs should be a “natural” extension of systems used in regular transport and emergency missions.

Nevertheless, hardware and software have to meet the requirements emerging from the safety- and time-critical context of use. Hands-free interaction is a promising approach but usable solutions cannot be derived directly from this superficial argument. While it could mean that solving mission-related (internal) tasks gets easier because users can use their hands more freely, efficiency and safety of human-computer interaction has to be ensured as well. Problems or delays in this area could influence overall performance. Both, reliable speech recognition, especially in noisy environments, and interface design for small display sizes are still major challenges. Realizing redundant but comparable interaction styles, e.g. supporting a built-in touchpad and voice recognition, is recommended. Evaluations during larger crisis response exercises as further studies with improved OHMDs in the fields of crisis management and response seem to be necessary.

REFERENCES

Adler, C., Krüsmann, M., Greiner-Mai, T., Donner, A., Mulero Chaves, J., & Via Estrem, À. (2011). IT-Supported Management of Mass Casualty Incidents: The e-Triage Project. In Proceedings of the 8th International ISCRAM Conference. Lisbon.

Benson, M., Koenig, K. L., & Schultz, C. H. (1996). Disaster Triage: START, then SAVE - A New Method of Dynamic Triage for Victims of a Catastrophic Earthquake. In Prehospital and Disaster Medicine, Vol. 11, No. 2. Solana Beach: Jems Pub. Co.

Born, C. T., Briggs, S. M., Ciraulo, D. L., Frykberg, E. R., Hammond, J. S., Hirshberg, A., et al. (2007). Disasters and mass casualties: I. General principles of response and management. In Journal of the AmericaCn Academy of Orthopaedic Surgeons. Vol. 15 No. 7. pages 388-96.

Carenzo, L., Barra, F. L., Ingrassia, P. L., Colombo, D., Costa, A., & Della Corte, F. (2014). Disaster medicine through Google Glass. In Wolters Kluwer Health, European Journal of Emergency Medicine (Published Ahead-of-Print). London: Wolters Kluwer Health, Inc.

Cicero, M. X., Walsh, B., Solad, Y., Whitfill, T., Paesano, G., Kim, K., et al. (2015). Do You See What I See? Insights from Using Google Glass for Disaster Telemedicine Triage in Prehospital and Disaster Medicine, Volume 30, (S. 4-8). Cambridge: Cambridge University Press.

Coskun, T., Nestler, S., Artinger, E., Benzina, A., & Klinker, G. (2010). Is it possible to interact with a handheld device while holding it in both hands? In Workshop zur IT-Unterstützung von Rettungskräften - Informatik.

del Rocío Fuentes Fernández, M., Bernabe, C. I., & Rodríguez, R. R. (2014). Red Cross Triage App Design for Augmented Reality Glasses. In Proceedings of the 5th Mexican Conference on Human-Computer Interaction (MexIHC '14). ACM, New York, NY, USA, , Pages 11 , 4 pages. New York: ACM.

Deutscher Berufsverband Rettungsdienst e.V. (2015). 10.03.2015: Umfrage zum Einsatz von Datenbrillen bei Großschadenslagen und Massenanfall von Verletzten. Retrieved from http://www.dbrd.de/index.php/aktuelles/238-10-03-2015-umfrage-zum-einsatz-von-datenbrillen-bei-grossschadenslagen-und-massenanfall-von-v.

Ellebrecht, N. (2013). Die Realität der Sichtung. Ergebnisse einer Befragung zur Sichtungsausbildung und MANV-Erfahrung von Notärzten und Rettungsassistenten. In: Notfall + Rettungsmedizin. Ausgabe 16 (S. 369-376).

Frykberg, E. R. (2002). Medical management of disasters and mass casualties from terrorist bombings: how can we cope?. In The Journal of Trauma. Injury, Infection, and Critical Care. Volume 53 No 2. pages 201-212.

Google Inc. (2015). Design for Glass. Retrieved from https://developers.google.com/glass/design/ on 07.08.215.

Herczeg, M. (2000). Sicherheitskritische Mensch-Maschine-Systeme. FOCUS MUL, 17(1), 6-12.

Herczeg, M. (2014). Prozessführungssysteme. München: De Gruyter Oldenbourg Verlag.

Jenkins, J. L., McCarthy, M. L., Sauer, L. M., Green, G. B., Stuart, S., Thomas, T. L., et al. (2008). Mass-casualty triage: time for an evidence-based approach.. In Prehosp Disaster Med.;23(1):3-8.

Kanz, K., Hornburger, P., Kay, M., Mutschler, W., & Schäuble, W. (2006). mSTaRT-Algorithmus für Sichtung, Behandlung und Transport bei einem Massenanfall von Verletzten. In: Notfall + Rettungsmedizin. Ausgabe 9 (Seiten 264–270). Berlin: Springer.

Killeen, J. P., Chan, T. C., Buono, C. J., Griswold, W. G., & Lenert, L. A. (2006).). A wireless first responder handheld device for rapid triage, patient assessment and documentation during mass casualty incidents. AMIA Annu Symp Proc, 429–433.

Kindsmüller, M. C., Mentler, T., Herczeg, M., & Rumland, T. (2011). Care & Prepare - Usability Engineering for Mass Casualty Incidents. In A. Blandford (Eds.) EICS4Med 2011. Proceedings of the 1st International Workshop on Engineering Interactive Interactive Systems for Medicine and Health Care (p. 30-35). ACM: Pisa.

LiKamWa, R., Wang, Z., Carroll, A., Lin, F. X., & Zhong, L. (2014). Draining our glass: an energy and heat characterization of Google Glass. In: Proceedings of 5th Asia-Pacific Workshop on Systems, Article 10. New York: ACM.

Lutomsky, B., & Flake, F. (2003). Leitfaden Rettungsdienst. 3. Auflage. München: Elsevier.

Mentler, T., & Herczeg, M. (2014). Interactive Cognitive Artifacts for Enhancing Situation Awareness of Incident Commanders in Mass Casualty Incidents. In In Proceedings of the 2014 European Conference on Cognitive Ergonomics (ECCE '14), Article 24. New York: ACM.

Nestler, S. (2014). Evaluation der Mensch-Computer-Interaktion in Krisenszenarien. In J. Ziegler (Hrsg.). i-com. Zeitschrift für interaktive und kooperative Medien. 13. Jahrgang, Heft 1 (S. 53-62). Oldenbourg Wissenschaftsverlag GmbH: München.

O'Donnell, D., Szotek, P., Arkins, T., & Priest, C. (2015). The Use of a Google Glass Appliation Improves Acuracy in START Triage Among Undergraduate Nursing Students. Retrieved from http://emergency.medicine.iu.edu/files/7114/2254/7754/ODonnell_GoogleGlass.pdf.

RWTH Aachen. (2014). Audiovisuelle Medizinische Informationstechnik bei komplexen Einsatzlagen (Audime). Zugriff am 03.03.2015 unter http://www.bmbf.de/pubRD/Projektumriss_Audime.pdf.

Schniedermeier, U., & Peters, J. (2009). Massenanfall von Verletzten. In C. Redelsteiner & S. Oppermann (Hrsg.). Handbuch Notfall- und Rettungssanitäter: Patientenbetreuung nach Leitsymptomen (S. 96-109). Köln: Deutscher Ärzte-Verlag GmbH.

ThatsMyStapler Inc. (2015). HazMat Reference and Emergency Response Guide. Version 6. Retrieved from https://itunes.apple.com/us/app/hazmat-reference-emergency/id385775821 on 31.08.2015.

United Nations. (2001a). Recommendations on the transport of dangerous goods. Model Regulations. Seventeenth revised edition. New York and Geneva: United Nations.

United Nations Economic Commission for Europe. (2014). European Agreement concerning the International Carriage of Dangerous Goods by Road. Applicable as from 1 January 2015. New York and Geneva: United Nations.

Waterstraat, F. (2006). Der Mensch in der Katastrophe: Ausgewählte Aspekte der Psychosozialen Unterstützung (PSU). In Bundesministerium des Innern (Hrsg.), Katastrophenmedizin (S. 35-50). Berlin: Bundesministerium des Innern.

White, D. M. (2007). Advanced Health and Disaster Aid Network. Final Report. Zugriff am 11.09.2015. Verfügbar unter http://www.jhuapl.edu/AID-N/Pub/AID-N_Final_Report_v_0_7__091807.pdf.

World Health Organization. (2007). Mass Casualty Management Systems. Strategies and guidelines for building health sector capacity. Zugriff am 11.09.2015. Verfügbar unter http://www.who.int/hac/techguidance/MCM_guidelines_inside_final.pdf. Geneva: WHO Document Production Services.

Henrik Berndt is a research assistant at the Institute for Multimedia and Interactive Systems (IMIS) of the University of Luebeck. He holds a B.Sc. and M.Sc. in Informatics, specializing in Digital Media, and is currently working on his dissertation. His main current research interests include human-computer interaction in safety-critical contexts and interaction design for mobile devices. He is one of the leaders and instructors of a German civil protection unit in a North German district.

Tilo Mentler is a research assistant at the Institute for Multimedia and Interactive Systems (IMIS) of the University of Luebeck. He holds a diploma in Informatics, specializing in Digital Media. Recently, he finished his dissertation about the usability of mobile interactive systems in regular and extraordinary missions of Emergency Medical Services. His main current research interests include human-computer interaction in safety-critical contexts (e.g. medicine), usability engineering and interaction design of mobile devices. He is a founding member and vice-chairman of the sub-group "Human-Computer Interaction in Safety-Critical Systems" within the special interest group "Human-Computer Interaction" of the German Informatics Society (GI).

Michael Herczeg is professor of practical computer science and director of the Institute for Multimedia and Interactive Systems (IMIS) of the University of Luebeck. His main areas of interest are human-computer interaction, software ergonomics, interaction design, multimedia and interactive systems, computer-aided teaching and learning as well as safety-critical human-machine systems. He is a founder and chair of the German ACM SIGCHI and Human-Computer-Interaction section of the German Informatics Society (GI). He is a member of ACM, IEEE, AACE, AAAI and GI and served as a reviewer, chair and keynote speaker for more than 70 conferences and workshops. He has been author and editor of more than 170 publications and is a series editor for books in interactive media. He works as a consultant for industry and government in the area of human-computer-interaction, human factors, software-ergonomics, usability engineering, eLearning and safety-critical human-machine systems.

Simulation and Analysis of Mass Casualty Mission Tactics

Context of Use, Interaction Concept, Agent-based Model and Evaluation

Johannes Sautter, Fraunhofer IAO, Germany
Denis Havlik, Austrian Institute of Technology AIT, Austria
Lars Böspflug, Fraunhofer IAO, Germany
Matthias Max, German Red Cross – Headquarters, Germany
Kalev Rannat, Tallinn Technical University, Estonia
Marc Erlich, Artelia Group, France
Wolf Engelbach, Fraunhofer IAO, Germany

ABSTRACT

Mass casualty incidents (MCIs) cannot be managed with existing resources from operational area. The key to MCI management therefore is the efficient use of the few own resources as well as resources from neighboring administrative units by local medical mission commanders. This paper suggests a computer-based modeling and simulation system with a user- and context-adequate interface for testing local MCI mission tactics with realistic spatial and temporal availabilities of rescue units and hospitals in the vicinity of an accident site. From an organizational point of view, the tool could contribute to a holistic quality management approach for improving MCI management by facilitating site-specific resource deployment, mission structure, and patient evacuation planning. This paper describes the interaction concept of a resource planning application and envisions its usage in training courses, in breaks of leading personnel and for elaborating local preparedness plans.

Keywords: Mass Casualty Incident, Modelling, Simulation, Interaction Concept, Think Aloud

1 INTRODUCTION

Full-time and volunteer staff is operating in relief organizations such as German Red Cross in order to ensure Germany’s medical civil protection on duty for federal, state and local authorities. In addition to regular emergency medical services (EMS) facing small daily-happening incidents, they provide medical civil protection facing larger crisis scenarios. A mass casualty incident (MCI) is defined as: “an emergency with a larger number of injured, diseased or affected people that cannot be managed with existing resources from the operational area” (BBK, 2013). In disaster medicine, special mission tactics apply such as a triage workflow assigning triage categories (T1–T3) to each patient. Since such missions occur quite seldom, both regular emergency medical service staff and voluntary personnel lack of routine in accomplishing such situations. This can result in sub-optimal handling of MCIs. Practitioners and experts therefore desire improved resource planning across county boundaries as well as improved training for decision makers (DRK, 2012).

For strengthening MCI mission accomplishment, mission workflows could be enhanced by new interactive systems as e.g. tablets for assessing triage categories. However, with new technology also new uncertainties for responders appear (Ellebrecht & Kaufmann, 2015). Instead of the response phase, the preparedness phase of MCIs could be enhanced by the use of interactive modeling and simulation systems and applications that allow testing of mission tactics while taking into account local constraints on medical rescue resources and hospitals. The main requirements for such tools are: (1) less effort compared to e.g. organization of field trainings; (2) trustworthy analytical predictions which can be validated against base data; and (3) intuitive user guidance to assure user acceptance (Sautter et al., 2015).

Such simulation tools should be used regularly by leading personnel in civil protection to discuss and elaborate different tactical options under local boundary conditions such as available resources and hospital capacities (Sautter et al., 2014a). Users have to be able to both express their simulation needs and process the resulting data in a way that is as compatible with their current workflows, procedures and organization as possible.

Nowadays, most simulation tools are operated by simulation experts, e.g. in the domain of logistics. A simulation based analysis has been done for the capacity of the planned new underground railway station “Stuttgart 21” (SMA und Partner AG, 2011), which raised an enormous public dialogue (stuttgarter-zeitung.de, 2015). Hence trust in model and modeler is crucial and users need to be aware of uncertainties they deal with. Unfortunately, the civil protection is a particularly critical usage context for interactive information systems (Nestler, 2014). Therefore designing systems that accept parameter inputs and show the results in an adequate manner for non-expert users in the field of modelling is challenging for designers of interaction concepts (Sautter et al., 2012).

This paper presents the findings of a Human-Computer Interaction (HCI) study that was performed in the scope of the CRISMA research project. The technical goal of the study was to design and prototypically develop a resource management planning support tool for medical civil protection professionals in Germany. This is a special case of a more generic quest for „analytical simulation software that can be safely used by users with low affinity for information systems and next to no understanding for capabilities and limitations of the simulation models”. From a medical civil protection point of view, the main research question was: “how to mitigate uncertainty in MCI missions by local-specific preparedness regarding mission tactics and resource planning?”

The work has been structured as follows: first, we built an understanding for the German medical civil protection organizations and their decision-support needs. This was mainly achieved through a combination of literature review, interviews with key personnel of the German Red Cross, and participation in field trainings. The main results of this work, which are in particular local-specific scenarios, relevant indicators, and a description of the context of use, are summarized in the sections 3, 4 and 5 respectively.

In parallel to this work, we have gradually designed and evaluated the human-machine interaction concept (section 6), the underlying resource models (section 7) and the prototype application. All the work reported in sections 3-7 progressed in parallel and in close cooperation between a core group of users and the developers[1]. Additional feedback and assessment of the results by users has been gathered through evaluation studies with leading personnel (section 8). The paper ends with the discussion of achievements and open issues (section 9) and conclusions (section 10).

2 RELATED WORK

A simulation model is a computer-based representation of system or a process (Carson, 2005). Simulation means to control and monitor the output of a model with appropriate parameters (Dugdale et al., 2014). The simulation platform Netlogo, for example, implements a generic interaction concept of simulation for analysis purposes. Parameter input is the first step in user interaction. Once the model execution has started, the graphical model representation and the resulting indicators change (Tisue & Wilensky, 2004). The application described in this paper uses the same high level interaction concept.

The approach followed by Saoud et al. (2006) assesses large-scale emergency rescue plans for mass casualty incidents by an agent-based model. On a detailed level the treatment and transportation of patients is modeled and various experiments are carried out. For parameter validation, expert ratings for durations are utilized. In comparison to the application described in this paper, the application does not use field exercise data for validation and does not foresee a user interface for different parameter configurations allowing to asses resource request times and tactical options. Other examples of analytical model approaches addressing logistics and health modelling can be found in (Pel et. Al., 2012 & Brailsford et al., 2009).

Another example that is not a dedicated analytical simulation but closer to the application domain described in this paper is the MobiKat decision-support-system for strategic planning and operative field use. MobiKat allows calculating the times of ambulance arrivals on an incident site and the durations needed for patient transportation to hospitals, taking into account local-specific constraints (Danowski, 2010). Unlike MobiKat, the application described in this paper complementary focusses on both on-site processes and logistics calculations for vehicle arrival and patient transportation times.

This paper is anchored in the CRISMA research project and shares most of the design methodology, architecture and software building blocks with other CRISMA application prototypes (Havlik et al., 2015a). Of particular relevance for this paper is the overarching CRISMA concept for using quantitative indicators as a way to interpret simulation results for model states, complex data series, and even for comparing different simulation runs (Dihé et al., 2013). The most similar other application prototype aims at improving resource management preparedness in an interactive training application: here incident commanders can take different decisions during a virtual incident and compare the results (Havlik et al., 2015b). Both the agent-based modeling platform and the resource models that are introduced in section 7 of this paper are shared with this and some other CRISMA applications.

3 MEDICAL CIVIL PROTECTION

In Germany, civil protection in peace-time is part of the civil protection mandate which addresses protection of the population and their substantial living conditions. The main responsibility for civil protection is with the German federal states (“Länder”) and

[1] Agile development methodology

municipalities (BBK, 2013). Public civil protection organizations include police units and local fire brigades. Private organizations working in regular EMS and voluntary-based medical civil protection are German Red Cross (DRK), Arbeiter-Samariter-Bund (ASB), Johanniter-Unfall-Hilfe (JUH), Malteser Hilfsdienst (MHD) and Deutsche Lebensrettungsgesellschaft (DLRG). Some resources for disaster protection are additionally provided by the federal government, in particular the German federal agency for technical relief (THW) and the so-called “Medical Task Forces” (MTF) supporting mission accomplishment for mass casualty incidents (BBK, 2007). Medical civil protection is a subset of civil protection facing medical preparedness and mission accomplishment. The management of mass casualty incidents and large scale emergencies[2] are two of the major challenges for the medical civil protection[3].

In the following section 3.1, types of resources and main tactical options are described, which can be varied by leading personnel during MCI missions. In section 3.2, planning and training for MCIs as practiced by German Red Cross today are described. Finally, section 3.3 summarizes domain needs.

3.1 RESOURCES AND MISSION TACTICS

Following the initial alert for a mass casualty event, the command and control center will typically assign a small number of resources to a task of assessing the real extent of the incident. The responders who arrive first on site will do an analysis of the situation and raise a second resource request. In Germany, mass casualty missions are controlled by two roles operating on site: the chief emergency physician (CEP) and the medical incident commander (MIC) (Sautter et al., 2014a & Dirks, 2006). As soon as the victims can be safely accessed, the pre-triage workflow done by the MIC and the paramedic teams and the subsequent triage workflow done by emergency physicians assign triage classifications (T1, T2 and T3) to patients, e.g. using the mSTaRT algorithm (Sefrin, 2012).

The most severely injured patients (T1, red) are treated first on site and then immediately transported to a hospital, while the seriously (T2, yellow) and slightly injured patients (T3, green) are transported out of the danger zone and treated there as soon as sufficient responder units are available (Sefrin, 2012). In subsequent sections the following resource and vehicle types are relevant:

- LF: Fire brigade vehicle (*Löschgruppenfahrzeug*, e.g. used for on-site medical care)
- RTW : Intensive care ambulance (*Rettungstransportwagen,* evacuation of T1 patients)
- KTW: Basic care ambulance (*Krankentransportwagen*[4,] evacuation of T2 patients)
- NEF : Emergency physician vehicle (*Notarzteinsatzfahrzeug*, carries emergency physicians and CEP)
- MTW: Team transport vehicle (*Mannschaftstransportwagen*, evacuation of T3 patients and uninjured persons)

---

[2] Events with a larger amount of injured or affected persons and substantial material damage that are situated below the threshold of a disaster (BBK, 2013).

[3] Other major challenges include CBRN incidents and humanitarian aid in case of refugee movements.

[4] DIN EN 1789: Emergency Ambulance

- GWSan: Medical gear truck (*Gerätewagen Sanitätsdienst*, carries treatment area equipment to incident scene)
- KOM: Bus (*Kraftomnibus*, evacuation of uninjured persons and T3 patients)

Crucial for a successful mission accomplishment is an early start of the spatial planning phase defining locations of so-called tactical areas (Max & Sautter, 2013). As depicted in Figure 1 the following tactical areas are relevant (SKK, 2010):

- GZ: Danger Zone (*Gefahrenzone*)
- PA: Advanced Medical Post (*Patientenablage*)
- BHP: Treatment Area (*Behandlungsplatz*)
- BR: Staging Area (*Bereitstellungsraum*)
- RMHP: Loading Area (*Rettungsmittelhalteplatz*)
- HL: Helicopter Landing Area (*Hubschrauberlandeplatz*)
- SP: Collecting Point (*Sammelplatz*)
- BS: Care Section (*Betreuungsstelle*)

If patients are safely accessible within or near the danger zone, the pre-triage and triage workflows may happen there as well (see arrows in Figure 1). Otherwise technical rescue resources (mostly fire brigade) carry them to the advanced medical post or to the collecting point if not injured. Depending on the CEP's decisions, evacuation (via loading area to hospital) or transportation to treatment area follows. Another challenge that is crucial for mission success is the assignment of patients to hospitals. This task is performed by the CEP and the MIC. The patient distribution is supported by the command center and based on previously defined patient-hospital distribution plans (Sefrin, 2013).

Per definition mass casualty incidents are characterized by resource shortage. The mentioned workflows for mission accomplishment aim to overcome this resource shortage efficiently and return to an individual medical treatment as soon as possible. Therefore the following decisions need to be taken by the first arriving responder as well as by the MIC and CEP:

- Do we need an Advanced Medical Post?

  (if not: e.g. carry patients directly from crashed bus to ambulance)
- Do we need a Treatment Area?

  (if not: enough hospitals nearby – or quick treatment in patient depot sufficient)
- Do we need a Staging Area for queuing vehicles?

  (if not: vehicles directly arrive at Loading Area, which requires enough space there)
- Do we evacuate many patients quickly or treat them on-site first?

  (early evacuation is sufficient if many hospitals are nearby)

Finally, for evaluating mass casualty missions the independence of the evaluation concept from specific mission tactics and local mission concepts is crucial. The achieved well-being and care of patients are ultimate mission goals and therefore preferred evaluation criteria (Brauner & Stiehl, 2014).

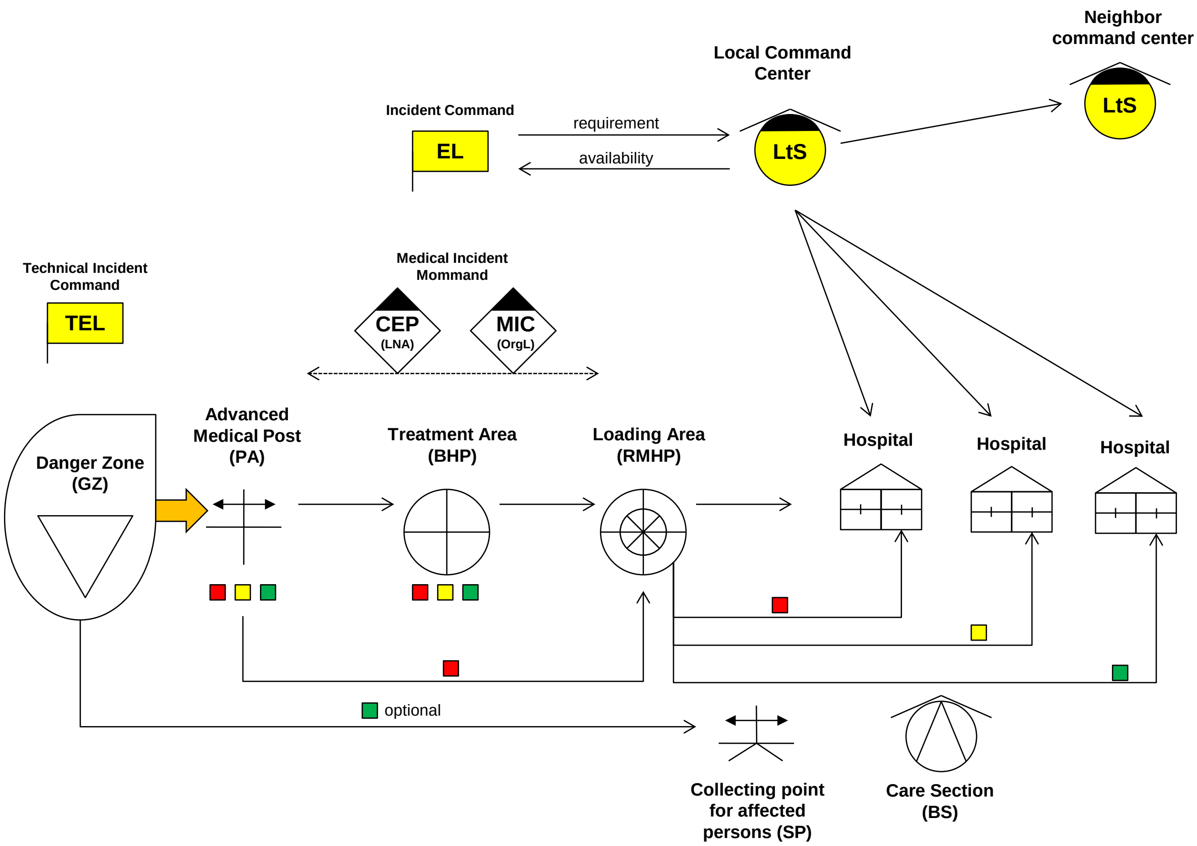

Figure 1. Tactical areas for mass casualty missions (adapted from Donner & Adler, 2013).

3.2 PLANNING AND TRAINING FOR MASS CASUALTY INCIDENTS

The German Federal Office of Civil Protection and Disaster Assistance (BBK) offers a concept for inter-regional assistance in case of MCIs (BBK, 2006) to responsible states and counties. For large-scale emergencies and disasters four service levels are defined. Service level 2 is defined to cover 50 to 500 affected persons using operational EMS, quick response task forces (SEGs), and small disaster protection units (KatS units) (see also section 5.2).

Local mission concepts define resource structures and request chains, e.g. civil protection authorities on county level define the order of alarm and action (OAA[5]). This is a list assigning several types and numbers of vehicles to a particular operational keyword (e.g. MANV50[6]). Some of the states, like Bavaria, also require the existence of emergency plans for all hospitals. Nevertheless such plans are missing for many hospitals (Sefrin, 2013). Further regional plans for the distribution of patients – so called “Wave plans” – exist that help avoiding an excessive use of a single hospital by foreseeing timely “waves” of arriving patients (Sefrin, 2013).

Training activities include courses for medical incident commanders (MICs), chief emergency physicians (CEPs) and others as well as command-level and field exercises to obtain practical experience (Schneider et al., 2015).

[5] German: Alarm- und Ausrückeordnung (AAO)
[6] MCI with up to 50 Injured

3.3 DOMAIN NEEDS

From a strategic point of view, Germany is insufficiently prepared for MCIs[7] (BBK 2010). Beside resource planning across existing administrative boundaries, German practitioners desire an efficient use of existing resources, flexible mission concepts, and means for exercise analysis for deriving educational needs and adjusted tactical concepts. Core questions are “who will really be available in case of emergency?”, and “how many resources do we really need?” (DRK, 2012).

4 MCI SCENARIOS AND INDICATORS

The following section describes MCI scenarios elaborated together with experts of medical civil protection that were used for the design and implementation of the model, and the usability testing of the interaction concept. The subsequent section aggregates quantitative scenario parameters, user parameters, and indicators.

4.1 MASS CASUALTY INCIDENT SCENARIOS

Two exemplary mass casualty incident scenarios are described: Scenario A is a relatively modest accident that can nevertheless overwhelm the first responders in a rural area. Scenario B addresses a realistic large-scale emergency or disaster scenario, illustratively located in a large city with a broader range of available resources.

SCENARIO A: BUS ACCIDENT WITH 25 INJURED IN BAVARIA

The bus left the road with a speed of 70 km/h, tilted to the right and crashed a tree. The incident occurred on a country road in the middle of a mountain scenery. The bus is strongly deformed in the front area and wedged between trees. All the injured people are located in the bus. The temperature is at six degrees Celsius, light rain and calm (Max & Sautter, 2013).

SCENARIO B: TRAIN CRASH WITH 213 INJURED IN BERLIN

A railway derailment happened at a speed of 70 km/h at the railway stop Friedenau. The locomotive crashed into a bridge abutment. The second and third wagon was at right angle to the direction of travel and strongly deformed, located just before a bridge. 213 persons in the train are injured. The temperature is at six degrees Celsius, light rain and calm.

4.2 INDICATORS OF A MASS CASUALTY MISSION

In two workshops (two and eight EMS leading persons) and brainstorming sessions with intended users of the MCI simulation tool, the following key factors for MCI situations were identified, prioritized, and assigned to the “situation”, “tactics”, and “accomplishment” categories:

Situation (model/event parameters)

- Number of patients
- Weather conditions

---

[7] In the meantime some progress has been made (i.a. MTFs), however effects still lack evaluation.

- Number of patients able to walk

Tactics (model/decision parameters)

- Number of involved medical responders
- Number of used tactical areas
- Time until second resource request

Accomplishment (result indicators)

- Time until pre-triage is done
- Time until first red patient is treated
- Time until last red patient is treated
- Time until red patients are taken away from the incident scene
- Time until last red patient arrives at the hospital
- Ratio of responder per patient
- Time until loading area is set
- Time until staging area is set
- Time until treatment area is built
- Time until last patient arrives at the hospital

From a civil protection point of view, measuring these time durations referring to the actual event time is an easy means for evaluating patient outcome in comparison to applied mission tactics. Even tough for evaluating real missions and exercises a pure timely evaluation of the patient outcome goes too short (Brauner & Stiehl 2014 & Schneider et al., 2015); it is regarded as sufficient for evaluating simulated missions as herein uncertainties, in particular of health status development, are inherent.

5 CONTEXT OF USE

The CEP, the MIC (see section 2.1), and other team leading personnel within emergency medical services organizations were identified as potential users of the application. Their potential benefits are:

1. **Training courses:** executive education and sensitization in classroom
2. **Individual preparedness:** gamified preparation in free time at home/rescue station
3. **Resource planning:** new order of alarm and action (OAA) and mission concepts
4. **Local-specific mission tactics:** tactical recommendations for local CEPs and MICs
5. **Field exercises:** preparation and debriefing of field and command level exercises

The tool allows the users to try out the different mission tactics, run them as simulations, and identify the best tactics for local MCI-operations. As soon as the tool has been deployed, for all these areas of operation an immediate usage in the domain is possible, except for the fourth area of “local-specific mission-tactics”. For being not forgotten, mission tactics that were elaborated using the tool and possibly also tested in field exercises need to be described and notated somewhere (see also sections 5.2 and 9).

Simulation results can not only be integrated into planning of real operations, but also in the organization of exercises. Vice versa, the findings from field exercises can be included in resource planning (see Figure 2).

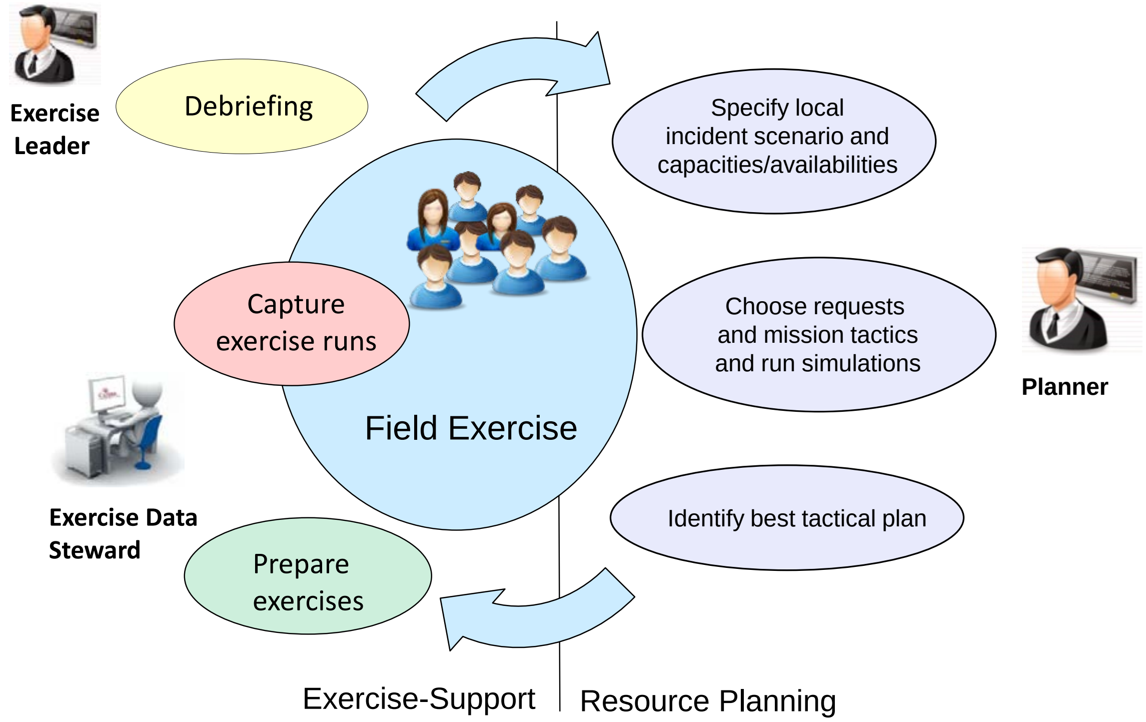

Figure 2: Usage of the simulation tool for preparation and debriefing of MCI field exercises

When taking the exercise scenario as a reference scenario in the simulation tool, a user can identify the influence of certain tactical decisions on the outcome of the overall performance. If used in combination with an application for exercise-support, a holistic quality management for exercise evaluation data and simulated mission tactics could be established (Sautter et al., 2014b & Bracker et al. 2014).

5.1 USERS AND ENVIRONMENT

Leading persons stated that they are willing to use such a MCI simulation tool regularly. A context analysis revealed medical incident commanders (MICs), chief emergency physicians (CEPs) and further executive personnel in emergency medical services of fire brigades as potential users of the analytical simulation tool.

At the beginning of the human-centered design process, we conducted two observations of field and command level exercises and three interviews. Later we did five user-guided-walkthrough sessions (similar method as Think Aloud – just using early mockups and wireframes) and interlinked interviews with one key user. In two workshops, with each about five EMS leading personnel, we identified the following usage environments for the tool: (1) a classroom, for demonstration and educational purposes; (2) a couch at home or a break room in the rescue station, for micro-learning and individual contemplation; and (3) a traditional office desk, for the development of tactical plans. Furthermore, the potential users desired to use the tool in the command vehicle during exercises or real operations.

In all these environments, it is possible to use a keyboard and a mouse for user inputs. However, the users have also expressed interest for a touchscreen-enabled user interface for portable use in a command vehicle or in their free time.

5.2 TASKS FOR ANALYSING MISSION TACTICS

The concept for the MCI simulation application was tested at the Berlin Red Cross. According to local preparedness plans, fast operation and disaster protection units (SEG and KatS units) are requested in situations with 100 patients or more. Smaller scenarios are mainly handled by the fire brigade with their medical rescue resources. The user may now ask: is a smaller MCI with around 25 casualties also handled more efficient with the use of these resources?

Referring to the list above, resource planning is the most relevant usage scenario for the Red Cross. The mission concept variants most interesting to evaluate are:

- Early request of SEG and KatS units
- Late request of SEG and KatS units

To understand how the user can interact with the tool, two possible scopes are explained by sample tasks.

TASK 1: EARLY VERSUS LATE SEG AND KATS UNITS

For evaluating the two mentioned mission concept variants, the mission tactics remain unchanged and the user can test how different request times of SEG and KatS units (see section 2) affect mission accomplishment for a given scenario. The user can choose e.g. an early alert of the mission keyword “MCI25”, which will result in the following request timings:

- Minute 1: one LF and two RTW should be requested
- Minute 4: operation OAA-keyword „MCI25“ should be requested

Alternatively, the user can also choose a late alert “MCI25 FW”, which results in different request timings:

- Minute 1: one LF and two RTW should be requested
- Minute 15: operation OAA-keyword „MCI25” should be requested

A possible outcome of using the application and evaluating the results is implementing an earlier request in a new mission concept for mass casualty missions by the local civil protection authority.

TASK 2: WITH OR WITHOUT TREATMENT AREA

The second example refers to the area “local-specific mission tactic”. In this context for comparing several mission tactics the request timings remain unchanged. In the first step the user sets up several tactical areas for mission accomplishment including a treatment area and assigns vehicles to them. In the second step he or she proceeds equally without using a treatment area. This allows the user to identify the best decisions regarding tactics for a given scenario, location and requests sequence. A potential outcome is either just a training effect and a thumb rule in mind or for instance a regional-dependent checklist (compare section 9).

6 INTERACTION CONCEPT

The resource planning simulation tool was developed iteratively in three steps (Sautter et al., 2014a & Sautter et al., 2015). It offers a capability for experimentation with different mission tactics in mass casualty missions to leading personnel of EMS units. This chapter describes predefined roles and their tasks in the resource planning simulation tool.

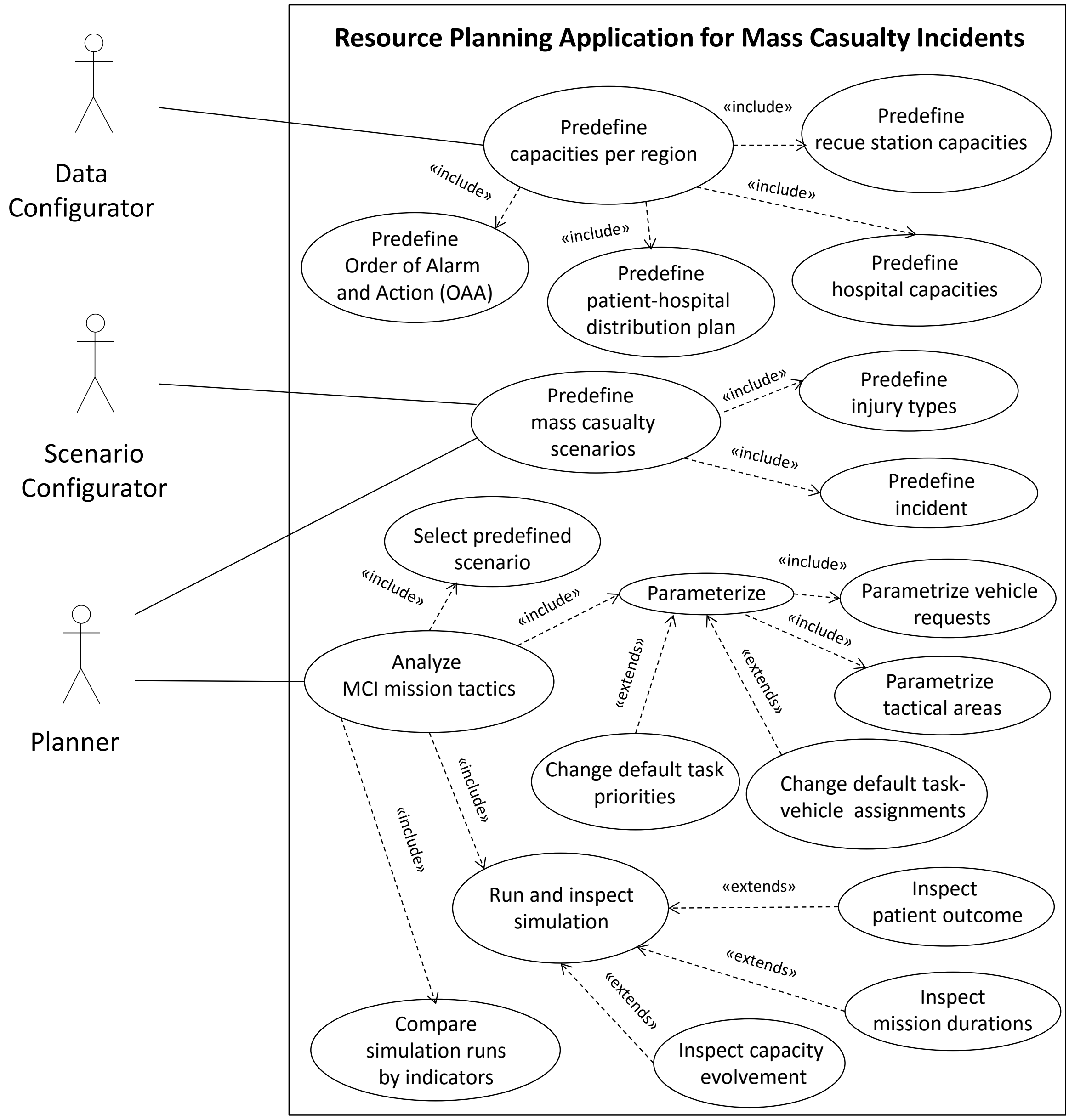

Figure 3: UML Use Case charts showing roles and tasks of the simulation tool

As depicted in Figure 3, first the data configurator needs to predefine locally relevant baseline information on capacities. This contains predefining the local Order of Alarm and Action (OAA), patient-hospital distribution plans and rescue infrastructure and capacities. Optionally, this role could be fulfilled by an intelligent technical interface to systems providing this data as e.g. deployment control computers in the local command and control center.

The scenario configurator role can either be fulfilled by the same person as the planner role, or by somebody else defining locally relevant scenarios. The scenario is modelled including all details on the incident like type of incident (bus accident or incident during a concert etc.), involved houses, vehicles and buildings. Main part is the geo-spatial distribution of patients and their injuries (injury patterns and degree of injury).

If the system is running with predefined medical capacities, the planner is able to use the simulation tool for analyzing possible mission tactics; this role can be fulfilled by crisis managers on various levels. In a first step, the user selects one of the predefined scenarios. Second, the user defines resource requests of rescue vehicles for certain points in time after the incident. A third step allows specifying tactical areas that structure the mission, but also bind resources. The following sections describe user interfaces for the planner. They allow a parameterization of mission tactics, to run a simulation, an inspection of a single mission, and a comparison of results with previously done simulations.

6.1 SELECT PREDEFINED SCENARIO

First, the planning user has to choose an incident scenario (see selection field in Figure 4). The application is loading an initial incident situation (e.g. train crash with 213 injured) including the local Order of Alarm and Action (OAA) and the structure of local emergency medical services. Second, the user can enter the name of a new mission tactic simulation session and add a description on intended mission tactics (see tab General in Figure 4).

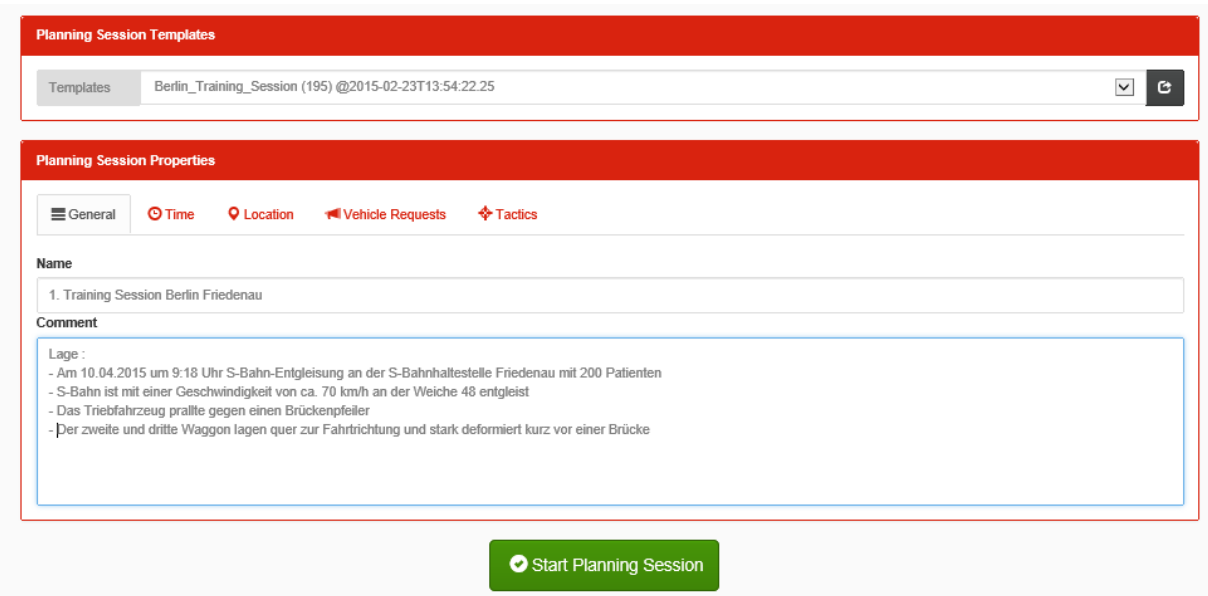

Figure 4: Selection of predefined scenario and description of intended tactic

Optionally the development of the operational picture can be described using keywords. After the user clicks on the tab “Time”, the applications switches to the second screen. Herein the simulation time can be changed, by which the model behavior may vary regarding time of day, e.g. due to traffic conditions and resource availabilities.

6.2 PARAMETERIZE TACTICAL AREAS

A user is capable of positioning the mission area types Danger Zone (GZ), Advanced Medical Post (PA), Treatment Area (BHP), Staging Area (BR), Loading Area (RMHP), Helicopter Landing Area (HL) (see section 2.1). He or she can select an area and position it on the map within a polygon predefined in the scenario (see Figure 5). More specifically, for each area he or she positions the cursor on the map and selects e.g. „Danger Zone“. Then he or she creates the area by clicking „Create Area“.

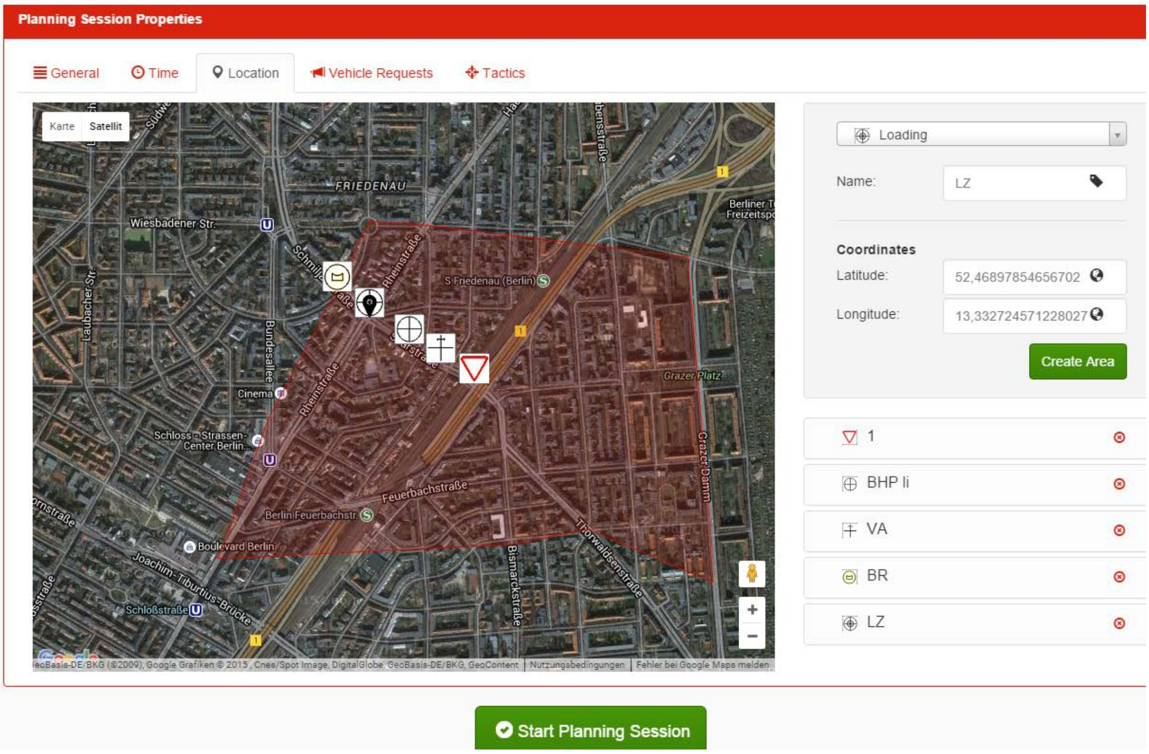

Figure 5: Parameterization of tactical areas

According to defined areas, the simulation tool assigns particular resources to these areas during the virtual mission accomplishment. E.g. the danger zone binds personnel for situational analysis. The advanced medical post binds personnel for leading the area as well as for treating patients. The loading and staging area only binds personnel for leading. The treatment area needs particular time, personnel and equipment for setup and patient treatment.

6.3 PARAMETERIZE VEHICLE REQUESTS

Within the tab “vehicle requests” a predefined table suggests a series of resource requests for particular times based on the development of an operational picture and the mission keywords of the local Order of Alarm and Action (OAA). Further resources are requested at later points in time, depending on the operational picture of the situation that exists for the mission commander. A user is capable of changing times as well as number of vehicles to be requested at these respective times referring to the actual incident time (see Figure 6).

As a next step the user has two options: either he or she starts a simulation run by clicking on the “Start Planning Session” button (user interactions continue in section 6.6), or he or she proceeds in a more detailed parameterization of desired mission tactics by switching to the “Tactics” tab before (see next section).

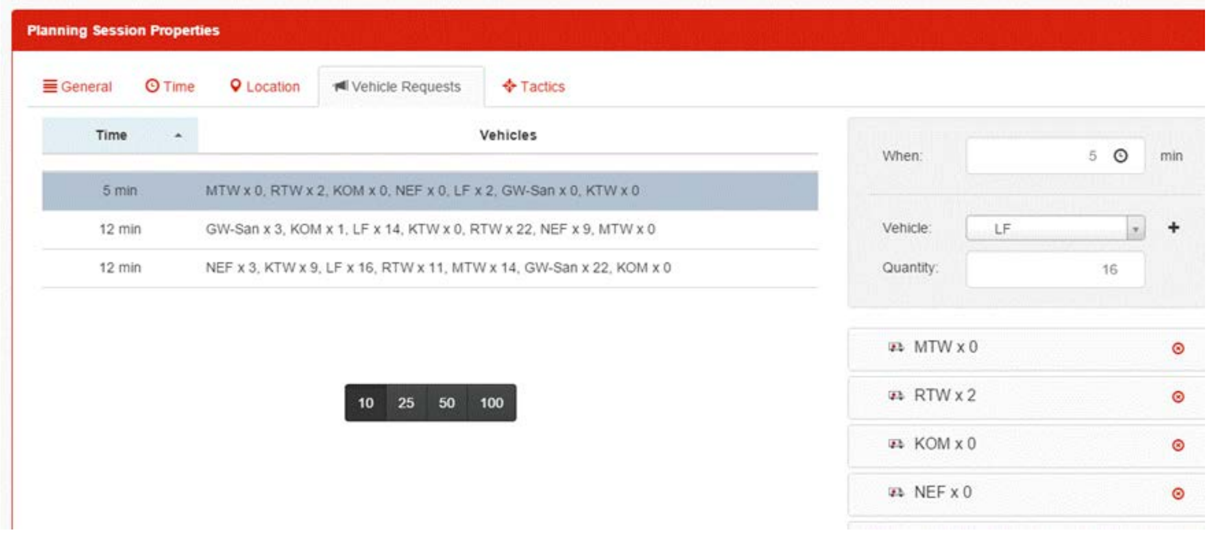

Figure 6: Resource requests for an early request of SEG and KatS resources

6.4 CHANGE DEFAULT TASK-VEHICLE ASSIGNMENTS

The "Tactics" tab shows an initial tactical tasks configuration on the basis of previously defined tactical areas (see Figure 7).

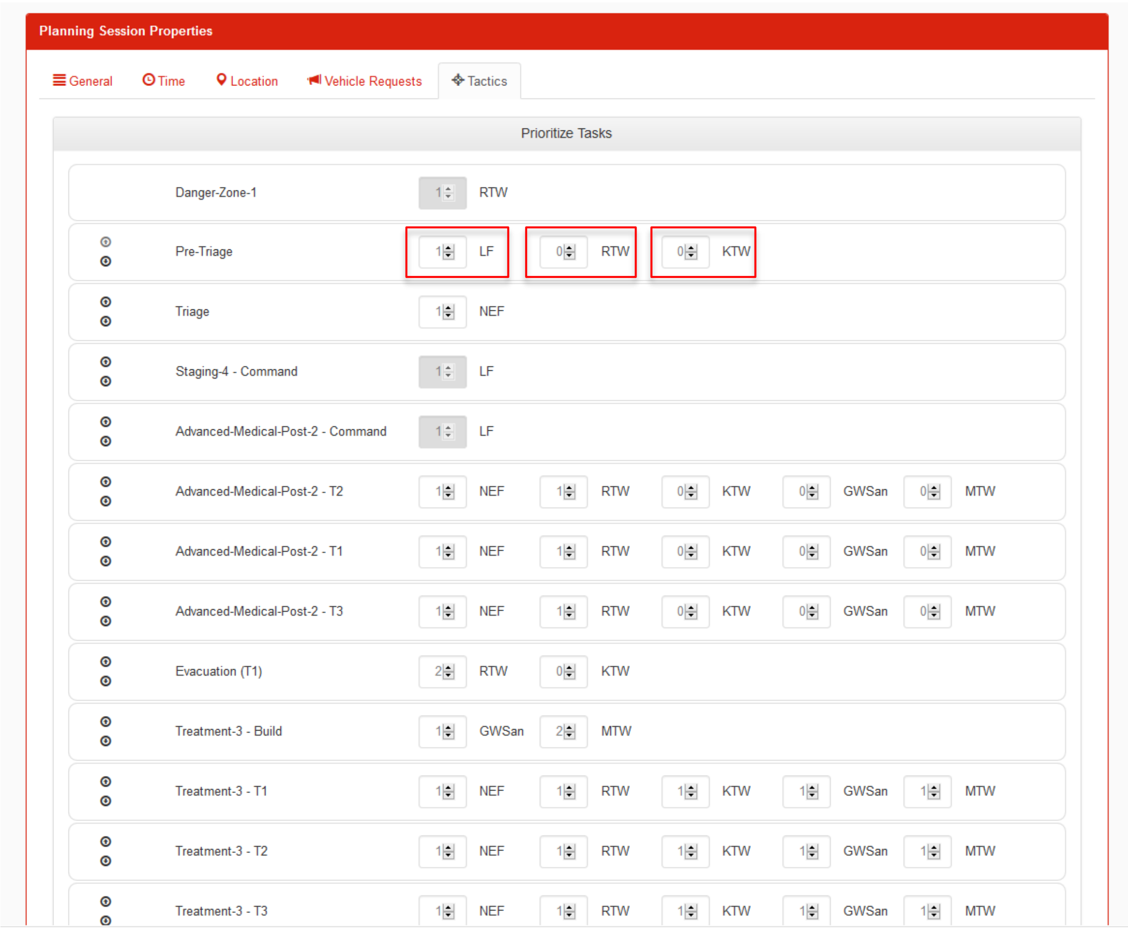

Figure 7: Task resource assignments

The screen first foresees a situation analysis (represented by tactical area "Danger Zone"), followed by the tasks "Pre-Triage" and "Triage". Further on, the task of leading a "Staging Area" occurs, and the four tasks of an "Advanced Medical Post" (PA) are listed (Leading, T1, T2, T3), followed by the tasks for the evacuation of patients of each category.

Reasonable default assignments of vehicles to tactical mission tasks occur in the overview as e.g. for the resources assigned to the task "Pre-Triage" (see red rectangles in Figure 7). For each task reasonable resource types are preset. This pre-configuration (number of vehicles) as well as the vehicle types assigned to each task differ locally and must be adapted according to local MCI mission planning when deploying the simulation tool for a local municipality or county. On this baseline, the user is now capable of changing the number of vehicles for each type. For the user it is important that he or she only can assign those resources he or she ordered previously on the resource request tab.

6.5 CHANGE DEFAULT MISSION TASK PRIORITIES

Also in the "Tactics" tab the user is capable of changing priorities of each tactical task. E.g. a user could alter the priority of the task "Evacuation (T1)" from priority 9 to priority 3 as the evacuation of T1 patients may be of higher priority than the carriage and supply of patients in the Advanced Medical Post (see red rectangles in Figure 8).

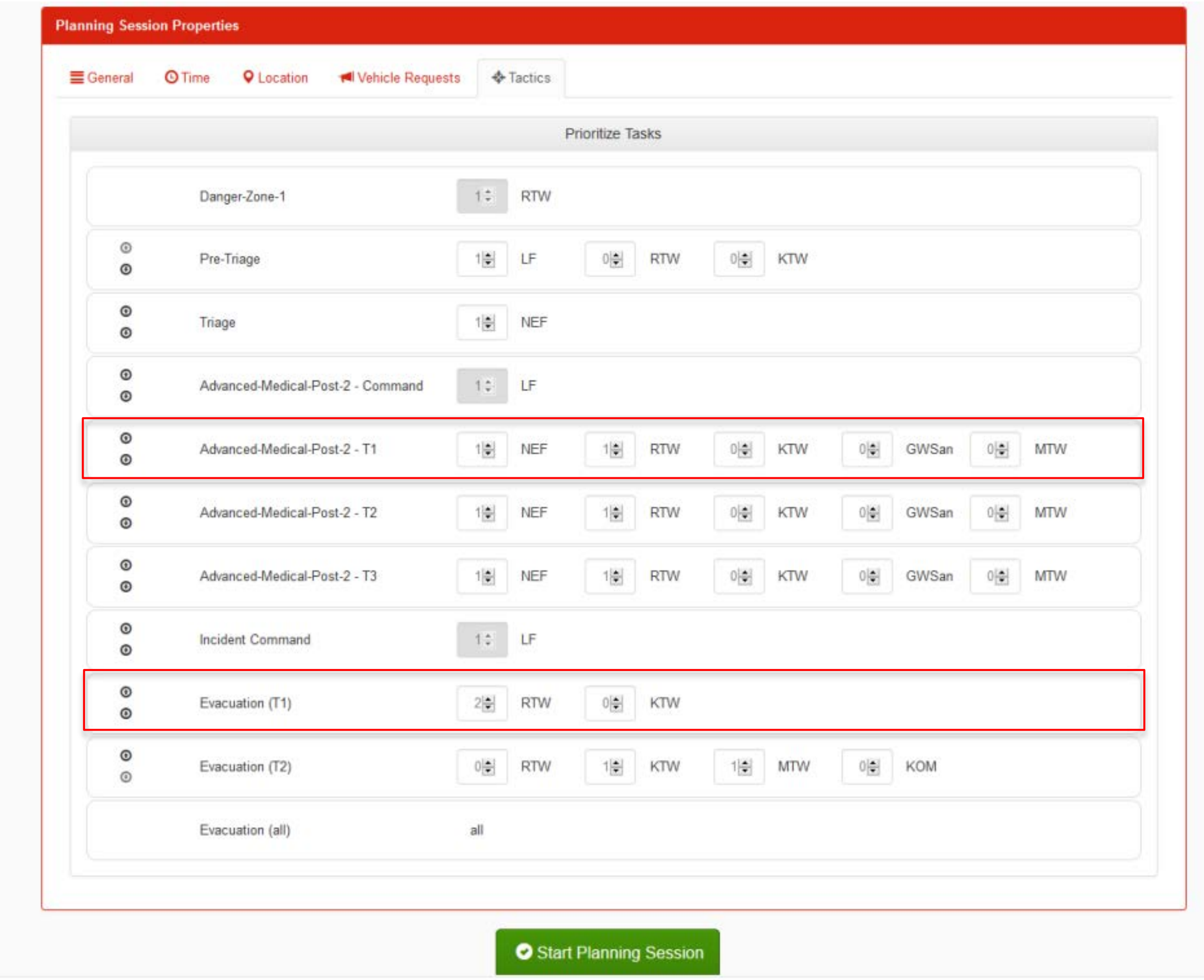

Figure 8: Adjust mission task priorities

Thus the user is able to prioritize tactical tasks depending on his view of the situation regarding local or site-specific constraints on distance to hospitals and resource arrivals on site within the first hour.

6.6 RUN AND INSPECT SIMULATION

After the user has at least defined the tactical areas and adjusted the resource requests, he or she can start the simulation by clicking "Run Simulation". The application switches to the Simulation Results View (see Figure 9).

Figure 9: Simulation Result View for the mission tactic "Early SEG/KatS Request"

The Simulation Results View consists of a list of previously done simulations on the left, where now the current one is highlighted. Time durations for each mission phase are depicted in the Phases widget at the top of the screen. The values of the simulation indicators are shown on the right. E.g. for the previously selected train crash in Berlin (see section 4.1) and the mission tactic "Early SEG/KatS request", pre-triage had the duration of 5 minutes and was finished 42 minutes after the incident time. At the bottom of the screen, the times patients of each triage category remained in a particular state are visualized. E.g. the last red patient received basic care measures ~50 minutes after the incident time, and the last red patient who arrived at the hospital was there 95 minutes after the incident time (see widget below in Figure 9, for details see next section).

Findings of such a comparison of MCI mission tactics can be used to practice mass casualty scenarios within field or command exercises. Furthermore, they may be crucial for a correction of the operational tactics based on simulated exercise results.

6.7 PATIENT OUTCOME

When evaluating MCI missions as mentioned above, the patient's health, their situation, and the time until they perceive individual medical care are crucial. Evaluation of a mission tactic's suitability thus needs to be based on the patients' outcome. As it is difficult to carry out a valid forecast on the health of virtual patients, a preliminary stage was chosen which can be interpreted by medical MCI mission experts. The widget depicted in Figure 10**Fehler! Verweisquelle konnte nicht gefunden werden.** illustrates the times patients of a particular triage category remained in a certain state of medical care during the mission.

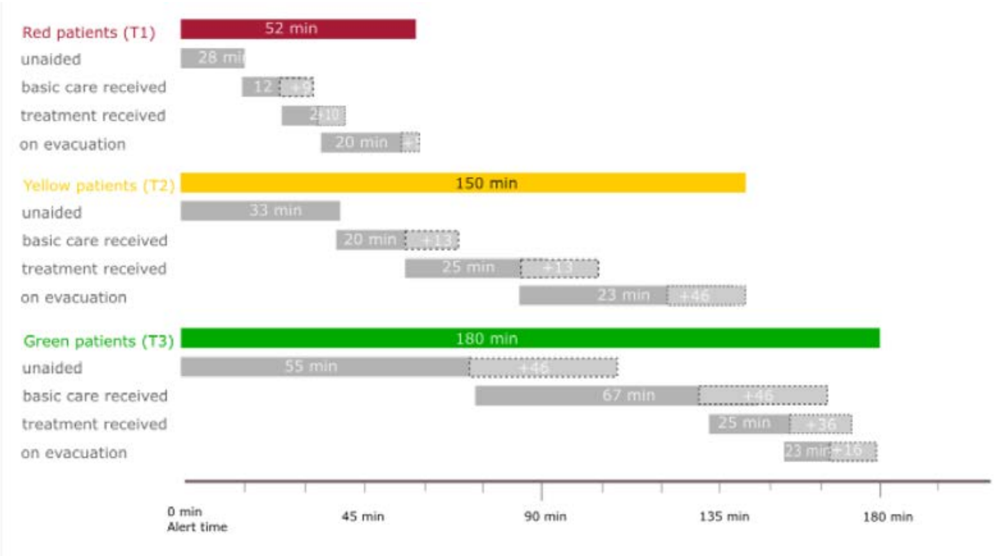

Figure 10: Patient State Widget illustrating the patient outcome

The first state is "unaided" followed by the state "basic care received" which results for patients who have been pre-triaged. Subsequently, as soon as a treatment by an emergency physician was done, the state "treatment received" is entered before the patient is evacuated to a hospital and finally arrives there. The dashed bordered light grey bars indicate the first and the last patient of the patient category group leaving the particular state. The red, yellow and green bars in Figure 10 aggregate the time period from the occurrence of the event until the arrival of the patients at the hospital.

The chart showed in Figure 10 stems from a simulation run analyzing the mission tactic of evacuating red patients immediately after pre-triage and triage instead of first building and treating patients in the Advanced Medical Post.

6.8 MISSION DURATIONS

An additional important aspect to get an overview of the mission accomplishment is to evaluate the times required for the various stages of the mission accomplishment. The bar chart depicted in Figure 9 e.g. illustrates the parallel tasks spatial planning (decisions on where to establish tactical areas), pre-triage, triage, and treatment. Further, the start of the evacuation phase is evident from the chart which allows experts to get an impression on the effectiveness of mission accomplishment. This is especially important when relating values of time indicators and patient outcome to activities happening on the field at the same time.

6.9 COMPARE SIMUALTION RUNS

After testing the different mission tactics, the indicator table (see Figure 11) allows a comparison of the mission tactics by relating the indicators to each other or using a multi-step multi criteria analysis (Havlik et al., 2015a).

Indicator table

Change Mode

Indicators	Pretriage - Treatment + Evacuation T1 - Setup BHP	Pretriage - Treatment - Evacuation	Pretriage - Setup BHP - Treatment
Mission accomplishment			
Time until last patient arrives at hospital	180 min	114 min	126 min
Time until last red patient arrives at hospital	52 min	47 min	75 min
Ratio of responder per patient	3	3	3
Time until red patients are away from incident scene	40 min	37 min	68 min
Time until last red patient is either treated or evacuated	35 min	32 min	63 min
Time until loading area set	42 min	26 min	42 min
Time until Pretriage is done	16 min	16 min	16 min

Figure 11: Indicator table allowing a comparison of several mission tactics for one scenario

7 AGENT-BASED MODELLING

As an essential part of the model development, a calibration and validation of model results has to be carried out, considering the analysis questions (Railsback & Grimm, 2012). User acceptance for analysis simulation tools requires trust in both the model and the underlying base data. For the implementation of a model representing MCI missions, data from field exercises were used (Bracker et al., 2014 & Sautter et al., 2014b). Additionally, data from former operational missions are potentially usable. For routing calculations Google-Maps API[8] (google.com, 2015) was used, even though blue light routing may be a bit quicker than Google-calculated routes.

For studying non-deterministic processes it is practical to compile a model simulating the main actors, their most characteristic behavioral patterns and to look “how the process evolves in time”. What we get for the analysis is a result of collective actions and interactions of the actors and the environment in the area of interest. For this reason the Agent-Based Modelling (ABM) paradigm was chosen. Our prototype thus relies on interacting agents who represent the various objects of interest (OOIs) including the patients, the medical first responders, the firemen, and the hospitals. The incident commander was replicated by a second layer above the agent model layer, translating the parameters from the user’s tactics into resource requests and instructions to the agents based on a reference decision model (Rosqvist et al., 2015). Thus the main technical challenges were the synchronization issues between the model replicating the mission commander (“commands-generating model”) and the real-time resource model.

A modelling and simulation platform designed for research and educational purposes has been used in CRISMA (Meriste et al., 2005). For this MCI simulation application a specific agent-model has been developed. It is designed for real-time simulations with a constant time-step. In this application, the time-steps have been set at three minutes. For simulation results this led to bigger timely variations as the second layer replicating the incident commander only could react within these time-steps.

[8] Application Programming Interface

8 EVALUATION

The described interaction concept was preceded by an iterative development process using different evaluation methods. Based on the findings gained from the evaluation of the first two iterations (Sautter et al., 2014a & Sautter et al. 2015), in the third and final iteration the parameters tactical tasks and vehicle requests have been added and the indicators have been extended.

The parameterization part of the interaction concept for the planner role described in this paper has been evaluated in a usability study following the Think-Aloud Method (Nielsen, 2012). A general finding is that overall workflow is sound, but the details of the application interface need to be improved.

Participants have found it particularly difficult to define the tactical areas within the “Location” tab (see Figure 12). Both test users required approximately nine minutes for this task and complained about lack of drag & drop functionality. Another important shortcoming was discovered in the “Tactics” tab: the participants did not recognize the relation between the tasks in the “Tactics” tab and the previously defined tactical areas in “Location” tab due to inconsistent arrangement of the symbols/functions. Regarding the evaluation of the overall application a key finding was that users did not appreciate the lack of feedback during relatively long parametrization process. A full list of findings is presented in Table 1.

User	**Tab on UI**	**Incident**	**User Comments**	**Time Length (min)**
1	Location	The input of the coordinates by clicking the left mouse button is not intuitive. Participant tries to put the objects on the map by using drag & drop routinely. Further, the Participant tries to move the "Coordinate Marker" using drag & drop.	Participant acts disoriented: "I click it and drag it over. This is what I always do" "Usually I can move it." Confronted with the fact that he has to create a new scenario he responds discouraged: "This is a no go. It takes too long!"	09:00 min
1	Vehicle Requests	Participant tries to delete the listed vehicles by clicking on the red cross. The "+" button has not been noticed.	Participant notices different functions of the same buttons: "This was a delete function in the previous tab."	04:20 min
1	Tactics	Participant doesn't recognize his earlier inputs (tab “Vehicle Requests”) and cancels task.	Participant tries to get an overview and subsequently acts confused: "I have two souths here and up front just one…that doesn't match." He suggests a selection menu in which the previously selected vehicles can be assigned to the different tasks.	04:35 min

User	Tab on UI	Incident	User Comments	Time Length (min)
2	Location	The input of the coordinates button is not intuitive. Participant tries to move objects using drag & drop.	Participant notes that the cross to delete things could be bigger. The tactical signs are perceived as positive.	09:19 min
2	Vehicle Requests	Addition of vehicles causes problems.	”Where do I add an emergency vehicle?”	05:25 min
2	Tactics	Task is not immediately recognized.	“A dropdown menu would be great to select the tactics for the different vehicles.”	11:00 min

Table 1. Excerpt of think aloud study results for Task 1: Early vs. late SEG and KatS units

9 DISCUSSION

The application described in this paper is a simulation-based resource management planning tool prototype that covers the whole rescue chain from occurrence of the event and resource request to the last arrival of a patient at an evacuation target (e.g. the hospitals). Critical points in the timeline are marked by indicators and visualized using bar charts.

The tool can help the civil protection authorities to identify possibilities for improving the OAA, the local mission concepts, or the patient-hospital distribution plans. However, it is unclear how regional- and district-specific findings on location-specific mission tactics can be reflected and represented in the organization of civil protection. One possible answer is “in the minds of leading personnel”. This answer may be adequate as long as the knowledge is refreshed often enough (e.g. by training). Other options, such as small cards or checklists for leading personnel, remain to be explored by further research.

During the elaboration, the validity of the model and the user’s trust in the model’s base data occurred as key challenges for user interface designers, developers and modelers. This issue was partly addressed by using the data from field exercises for model calibration (Bracker et al., 2014 & Sautter et al., 2014b).

The reduction of the problem’s complexity from “real world” over “agent model” to “indicators” is both necessary and dangerous. The possibilities of easy mental detections and comparisons come with the danger of misinterpreting the results. In a worst case scenario, the user’s belief in accuracy of the application’s predictions and appropriateness of the model and the indicators can lead to an over- or underestimation of real coherencies and negatively affect derived preparedness plans or mission tactics. As part of the analysis, decision makers therefore have to consider the limitations of the models with respect to the scale in time and space, the details of the models, and the quality of data.

In the context of the CRISMA project, the same models were used for an interactive training application (Havlik et al., 2015b) and for this application. Even though mass casualty missions in the real world are non-deterministic processes, from a technical point of view, usage of ABMS for this application is not necessary. Other simulation techniques could instead serve as basis for this application. Nevertheless, the aspect of uncertainty of this deterministic predictions needs to be taken into account for both designing the user interface and the usage of the tool.

The results of the various evaluation studies reveal big shortcomings in the design of parametrization widgets as e.g. the 9 minutes needed for the definition of tactical areas. To achieve an efficient interaction flow in subsequent design iteration, a quantitative usability goal for this task could be set at one minute.

User experience can be significantly improved by immediate feedback to changes in parameters. Although such a highly interactive interaction concept had been considered, it was impossible to realize it when using non-deterministic models that were at our disposal (Sautter et al., 2014a & Sautter et al., 2015). From the user point of view, the ideal solution to this issue will be to implement simulation models that can calculate the results with virtually no delays (e.g. deterministic models instead of agents). In this case, the model parameters and the results have to be shown simultaneously at the same screen.

10 CONCLUSION AND OUTLOOK

The key to suitable MCI mission accomplishment is an efficient use of few immediately available resources by medical mission commanders. This paper describes flexible mission tactics, cross-cutting resource planning and targeted training as key challenges in medical civil protection. For arising questions like “whether to use a treatment area for a particular number of patients or not”, a computer-based analysis simulation system is proposed for testing local MCI mission tactics under local circumstances. Leading personnel in a classroom, rescue station, home or desktop environment reveal as an envisioned context of use for such an application. Due to altruistic motivation of users, a high usage-frequency could be identified for increasing their individual preparedness. The interaction concept consists of various screens allowing a parameterization of vehicle requests, tactical areas and detailed mission tactic adjustments resulting from previously done tactical area placement. Findings from a structured indicator-based analysis of targeted MCI scenarios could e.g. result in an adaption of local preparedness plans.

In a performed Think-Aloud study a need for quicker user feedback regarding simulation results became evident and an integration of well-known "gaming features" could help making the application more understandable and increase user experience. In addition the application could more support users in exploring its features.

An extra feature desired by potential users is a hospital distribution planning as a supplementary option of parametrization. This has not been realized in the interaction concept, but is hard-wired in the model. When doing so, presetting the local patient-distribution rules is important. Also not supported by the application is the intentional parameterization of poor mission decisions. For instance it is not possible to perform serial task accomplishment or to not foresee an early triage. However, for the purpose of demonstrating good mission tactics in educational classroom trainings, this was desired by potential users.

Identifying capacity gaps is another potential use case for the tool. The application is adjustable in this direction, even if for this feature regular medical emergencies needed to be integrated.

ACKNOWLEDGEMENTS

The work underlying this paper has been produced in the context of the CRISMA project, which has received funding under the European Community's Seventh Framework Programme (FP7 grant agreement no. 284552). CRISMA aimed at modelling and simulation of crisis management for improved action and preparedness. Seventeen partners formed the CRISMA consortium (www.crismaproject.eu) led by VTT, the Technical Research Center of Finland.

A special thanks to the patient leading personnel at Berlin and Bavarian Red Cross, partly spending many of their free time. A grateful thanks to Friederike Schneider, formerly at DRK headquarters, who had essentially contributed to the presented work as a project manager. Another special thanks to Daniel Orlowski, formerly at Fraunhofer IAO, for performing the Think Aloud study and cross-reading the findings. We kindly acknowledge the underlying work done by a range of CRISMA project partners: Maria Egly, Peter Kutschera and Manuel Warum from AIT, who worked on integrating and developing user interfaces and indicators; Holger Bracker, Martin Sommer and Frank Jonat from AIRBUS, who developed the model replicating the mission commander and model testing; Martin Scholl from Cismet, who was developing the parameterization widgets; Oren Deri, NICE, for the base technology "OOI repository" and the exchange about similar modelling activities for mass casualty incident trainings in Israel; Kuldar Taveter, Merik Meriste, Jüri Helekivi and Tonis Kelder from TTU for underlying requirements engineering using goal modelling as well as resource management modelling activities; Sandra Frings, Sven Wirth and Manuel Habermann from Fraunhofer IAO for many useful supporting activities.

This paper is an enhanced and improved version of a paper (Sautter at al., 2015) presented at the Workshop "Mensch-Computer-Interaktion und Social Computing in sicherheitskritischen Systemen (KritischeMCI)" on the Conference "Mensch und Computer 2015" in Stuttgart, Germany (Reuter et al., 2015).

REFERENCES

Brailsford, S. C., Harper, P. R., Patel, B., and Pitt, M. (2009). *An analysis of the academic literature on simulation and modelling in health care.* J Simulation 3 (3): 130–40. doi:10.1057/jos.2009.10.

Bracker, Holger; Schneider, Bernhard; Rinner, Christian; Schneider, Friederike; Sautter, Johannes; Scholl, Martin; Egly, Maria (2014). *An innovative approach for tool-based field Exercise-support to gain improved preparedness in emergency response*, http://www.crismaproject.eu/docs/FuSec2014_v13.pdf , In: Thoma, K. (Ed.); Häring, I. (Ed.); Leismann, T. (Ed.) ; 9th Future Security 2014. Security Research Conference: September 16th–18th, 2014, Berlin; Proceedings, Fraunhofer Verlag, Stuttgart, 2014.

Brauner, F., M. Stiehl, A. Lechleuthner und O. A. Mudimu. (2014). *Evaluation von Übungen des Massenanfalls von Verletzten (MANV).* Notfall Rettungsmed 17 (2): 147–52. doi:10.1007/s10049-013-1722-x.

Bundesamt für Bevölkerungsschutz und Katastrophenhilfe. (2006). *Konzept zur überörtlichen Hilfe bei MANV.*

Bundesamt für Bevölkerungsschutz und Katastrophenhilfe (BBK) (2010). *Neue Strategien zum Schutz der Bevölkerung 4*, Bonn , 2010.

Bundesamt für Bevölkerungsschutz und Katastrophenhilfe. Hg. (2013a). BBK-Glossar: *Ausgewählte zentrale Begriffe des Bevölkerungsschutzes.* Bonn.

Bundesamt für Bevölkerungsschutz und Katastrophenhilfe (2013b). Katastrophenmedizin. *Leitfaden für die ärztliche Versorgung im Katastrophenfall*, 2013. 6. Aufl., unveränd. Nachdruck. Bonn: Bundesamt für Bevölkerungsschutz und Katastrophenhilfe.

Bundesamt für Bevölkerungsschutz und Katastrophenhilfe. (2007). *Allgemeine Grundlagen: Ausstattungskonzept.* Bonn.

Carlson et al. (Hg.) (2005): *Discrete-event system simulation.* 4th ed. Upper Saddle River, NJ: Pearson Prentice Hall.

Danowski, K., (2010). *Wissenschaftliche Optimierungsmethoden für die strategische Planung und die operative Einsatzführung in der Gefahrenabwehr – Implementierung und praktische Anwendung.* GI Jahrestagung (2), 137-142.

Dihé, P., Denzer, R., Polese, M., Heikkilä, A., Havlik, D., Sautter, J., et al. (2013). *An architecture for integrated crisis management simulation.* 20th International Congress on Modelling and Simulation (MODSIM 2013) (S. 873-879). Adelaide, South Australia: Modelling and Simulation Society of Australia and New Zealand.European Commission - EuropeAid (2004). Project Cycle Management Guidelines, Volume 1. Cooperation Office.

Dirks, B., 2006. *Management des Massenfalls von Verletzten/Erkrankten durch den Leitenden Notarzt.* Notfall + Rettungsmedizin, (9), 333-346.

Donner A., Adler C. (2013): *Patientenregistrierung im Massenanfall.* Zukünftige Anforderungen an ein elektronisches Dokumentationssystem, in: Notfall + Rettungsmagazin 7/2013, Springer Verlag, Berlin/ Heidelberg, S. 549-555.

Dugdale, J., N. Bellamine-Ben Saoud, B. Pavard und N. Pallamin, (2014): *Simulation and Emergency Management*, 229. In: Van De Walle, Bartel, Murray Turoff, and Starr Roxanne Hiltz. Information systems for emergency management. Routledge, 2014.

Ellebrecht, N., & Kaufmann, S. (2014): *Boosting Efficiency Through the Use Of IT?: Reconfiguring the Management of Mass Casualty Incidents in Germany*. International Journal of Information Systems for Crisis Response and Management (IJISCRAM), 6(4), 1-18. Available on: doi:10.4018/IJISCRAM.2014100101

German Red Cross. (2012). *Zukünftige Schwerpunkte und Forschungsbedarfe im Deutschen Roten Kreuz (Prospective emphases and needs for research in the German Red Cross),* Newsletter – Neues aus der Sicherheitsforschung, 2012.

google.com (2015). *Website „Google Maps for Work, Google Maps APIs“:* https://www.google.com/intx/en_uk/work/mapsearth/products/mapsapi.html, Accessed October 9th, 2015.

Havlik, D., Dihé, P., Schlobinski, S., Heikkilä, A.-M., Polese, M., Taveter, K., et al. (2015a). *Modelling crisis management for improved action and preparedness.* Espoo, Finland: VTT Technology 228.

Havlik, D., Deri, O., Rannat, K., Warum, M., & Rafalowski, C. (2015b). *Training Support for Crisis Managers with Elements of Serious Gaming.* In R. Denzer, R. M. Argent, G. Schimak, & J. Hrebícek, Environmental Software Systems: Infrastructure, Services and Applications (S. 217–225). Springer.

Max, M. and Sautter, J. *Analysis of a German First Responder Exercise: Requirements for Exercise-Support and Simulation.* In: ISCRAM 2013, S. 923-924. Available on: http://www.iscramlive.org/ISCRAM2013/files/245.pdf

Meriste, M.; Helekivi, R.; Kelder, T.; Marandi, A.; Motus, L.; Preden, J. (2005): *Location Awareness of Information Agents*. In: Eder, J; Haav, H. M.; Kalja, A.; Penjam, J. (Eds.): Advances in Databases and Information Systems, Proceedings: 9th East European Conference on Advances in Databases and Information Systems, ADBIS2005. Tallinn, 12-15 September 2005. Springer, pp. 199–208.

Nestler, S., (2014). *Evaluation der Mensch-Computer-Interaktion in Krisenszenarien / Evaluating human-computer-interaction in crisis scenarios.* In Ziegler, J. (Hrsg.): i-com: Vol. 13, No. 1. Ber-lin: De Gruyter. S. 53–62.

Nielsen, J. Thinking Aloud: *The #1 Usability Tool* (2012). [Accessed on: 16th September 2015]. Available on: http://www.nngroup.com/articles/thinking-aloud-the-1-usability-tool/

Pel, A.J., Bliemer, Michiel C. J. und S.P. Hoogendoorn, (2012). *A review on travel behaviour modelling in dynamic traffic simulation models for evacuations* [online]. Transportation, 39(1), 97-123. ISSN 0049-4488. Available on: doi:10.1007/s11116-011-9320-6

Railsback, S.F. und V. Grimm, (2012). *Agent-based and individual-based modeling. A practical introduction.* Princeton: Princeton University Press. ISBN 978-0691-13674-5.

Reuter, C., T. Mentler, S. Geisler, M. Herczeg, T. Ludwig, V. Pipek, S. Nestler und J. Sautter, (2015). *Proceedings des Workshops „Mensch-Computer-Interaktion und Social Computing in sicherheitskritischen Systemen" (KritischeMCI)*. Workshop der Fachgruppe Mensch-Maschine-Interaktion in sicherheitskritischen Systemen (www.fg-mmi-sks.de) des GI-Fachbereichs Mensch-Computer-Interaktion im Rahmen der Konferenz Mensch & Computer 2015 am Di. 8.9.2015 in Stuttgart. Mensch & Computer 2015 – Workshopband. Oldenbourg-Verlag.

Rosqvist, T., Meriste, M., & Havlik, D. (2015). *A reference decision model for simulation of situational awareness related to first response.* ITEC, (S. 15). Prague.

Schneider, F., U. Kippnich, C. Siebel, J. Sautter, M. Kippnich und P. Sefrin, (2015). *Handlungsempfehlungen für die Durchführung und Auswertung von Übungen des Massenanfalls von Verletzten (MANV) aus Sicht des DRK* [online]. Der Notarzt, 31(02), 76-81. ISSN 0177-2309. Available on: doi:10.1055/s-0034-1387584

Sefrin, P., (2012). *Sichtung – zentrales Element zur Bewältigung eines Großschadensfalls und einer Katastrophe* [online]. Der Notarzt, 28(05), 194-202. ISSN 0177-2309. Available on: doi:10.1055/s-0032-1305296

Sefrin, P., (2013). *Handlungsfelder und Handlungserforderinisse auf der Ebene professioneller Akteuere bei MANV* [online] [Zugriff am: 21. September 2015]. Available on: http://www.schutzkommission.de/SharedDocs/Downloads/SK/DE/Fachgespraech%20Vortraege/Sefrin_MANV.pdf?__blob=publicationFile

stuttgarter-zeitung.de, 2011. Jörg Nauke: *"Wissenschaftler werfen Bahn Trickserei vor."* Stuttgarter Zeitung Verlagsgesellschaft mbH, Accessed April 03, 2015.

Saoud, N.B.B., T.B. Mena, J. Dugdale, B. Pavard und M. Ben, (2006). *Assessing large scale emergency rescue plans: an agent based approach.* International Journal of Intelligent Control and Systems, 11(4), 260-271.

Sautter, J., Böspflug, L. & Schneider, F. (2015). *Entwicklung eines Interaktionskonzeptes zur Simulation und Analyse von MANV-Einsätzen.* In: Proceedings des Workshops „Mensch-Computer-Interaktion und Social Computing in sicherheitskritischen Systemen" (KritischeMCI), Mensch & Computer 2015 – Workshopband. Oldenbourg-Verlag.

Sautter, J.; Hofer, J.; Wirth, S.; Engelbach, W.; Max, M.; Tenso, T. und Bracker, H. (2014a). *Local-specific resource planning for mass casualty incidents.* Proceedings of the 11th International ISCRAM Conference – University Park, Pennsylvania, USA, May 2014. Available on: http://www.iscramlive.org/ISCRAM2014/papers/p152.pdf

Sautter, J., M. Habermann, S. Frings, F. Schneider, B. Schneider und H. Bracker, (2014b). *Übungsunterstützung für Einsatztrainings des Massenanfalls von Verletzten (MANV).* Gesellschaft für Informatik -GI-, Bonn: Informatik 2014. Big Data - Komplexität meistern. CD-ROM : Tagung der Gesellschaft für Informatik, 22. - 26. September 2014 in Stuttgart, Deutschland, Bonn: Köllen, 2014 (GI-Edition - Lecture Notes in Informatics (LNI) - Proceedings 232).

Sautter, J., Engelbach, W. & Frings, S. (2012). *User-Centered Elaboration of an Integrated Crisis Management Modeling and Simulation Solution.* In Aschenbruck, N.; Martini, P.; Meier, M. & Tölle, J. (Hrsg.): 7th Security Research Conference, Future Security 2012, Berlin, Germany: Springer.

Ständige Konferenz für Katastrophenvorsorge und Bevölkerungsschutz, (2010). *Empfehlungen für Taktische Zeichen im Bevölkerungsschutz* [online] [Zugriff am: 21. September 2015]. Available on: http://www.bbk.bund.de/SharedDocs/Downloads/BBK/DE/FIS/DownloadsInformationsangebote/NeueBuecher/EmpfehlungenfuerTaktischeZeichenimBevoelkerungsschutz.pdf?__blob=publicationFile

SMA und Partner AG. (2011). *"Audit zur Betriebsqualitätsüberprüfung Stuttgart 21: Schlussbericht."*.

Tisue, S.; Wilensky, U. (2004): NetLogo: *Design and implementation of a multi-agent modeling environment*. In: Design and implementation of a multi-agent modeling environment. Proceedings of the Agent 2004 Conference on Social Dynamics: Interaction, Reflexivity and Emergence, Chicago, IL.

Towards Virtual Reality Crisis Simulation as a Tool for Usability Testing of Crisis Related Interactive Systems

Kristian Rother, Hamm-Lippstadt University of Applied Sciences, Lippstadt, Germany

Inga Karl, Hamm-Lippstadt University of Applied Sciences, Lippstadt, Germany

Simon Nestler, Hamm-Lippstadt University of Applied Sciences, Lippstadt, Germany

ABSTRACT

Usability testing is expensive in some domains due to the resource requirements that go hand in hand with taking a complex context of use into account. Crisis-related research is one such domain, typically requiring the reenactment of an extensive crisis scenario. To lessen the resource requirements and provide a more flexible setup geared towards testing, crisis scenarios can be reconstructed as virtual reality simulations. This paper outlines the development of an initial prototype of such a simulation following the design science method. The prototype is used to test if injecting an item that will be tested into the simulation affects the realism of the virtual reality crisis simulation. The realism was measured in a within-subject experiment and equivalence tests showed that injecting a representation of a simple app had no significant influence on the realism of the simulation.

Keywords

Virtual reality, usability testing, crisis management, design science, interactive systems

1 INTRODUCTION AND METHOD

This paper outlines the development of a virtual reality crisis simulation (VRCS) prototype to enable a novel form of usability testing for crisis-related interactive systems. The nature of the research, namely the development of an artifact (instantiation) that solves a previously unsolved problem, suggests a design science (DS) approach (Hevner, March, Park, & Ram, 2004). While DS has mostly been discussed in general information systems research during the last ten years (Hevner et al., 2004; Peffers, Tuunanen, Rothenberger, & Chatterjee, 2007; Offermann, Levina, Schönherr, & Bub, 2009; Österle et al., 2011) it is equally applicable for human-computer interaction research projects (Hevner & Zhang, 2011; Tarantino &

Spagnoletti, 2013) and in crisis contexts (Schryen & Wex, 2015). The design science process model (DSPM) suggested by Peffers et al. was chosen because it synthesizes different previous models and "defines a mental model for presenting and evaluating DS research" (2007). The remainder of this paper is structured according to the DSPM. Figure 1 shows the adapted process.

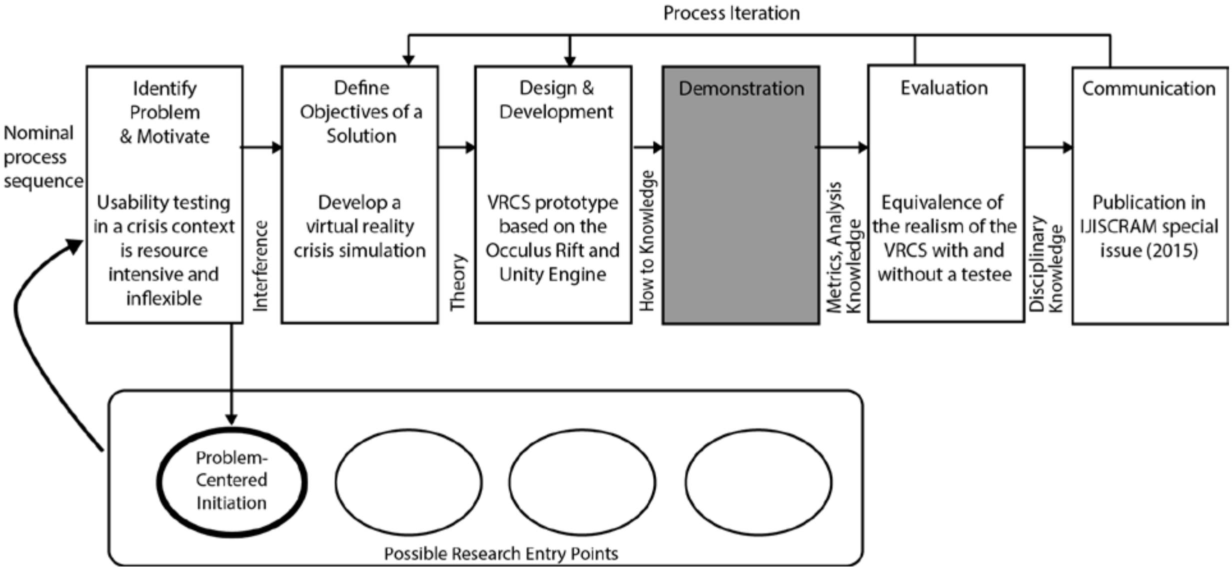

Figure 1. *Adapted design science process model according to Peffers et al. (2007).*

The research can be classified as a *problem-centered initiation* because the construction of the artifact was motivated by an identified problem, namely that usability testing based on real crisis simulations is resource intensive and inflexible. The activities *problem identification and motivation*, *definition of objectives of a solution* and *design and development* were conducted in sequential order. While a general problem and general objectives for a solution were identified the research question of this paper relates to the identified sub-problem that injecting an item into the VRCS for testing purposes can influence the realism of the VRCS. Accordingly, the *evaluation* activity is not aimed at the identified general problem but rather at advancing the prototype to a stage where that problem can eventually be tackled. To reach that stage the evaluation conducted in this paper is aimed at the identified sub-problem. The *demonstration* activity was not conducted because the prototype is still at an early stage and cannot be used to solve concrete problems yet. The publication of this paper and the anticipated discussions serve as the beginning of the *communication* activity.

2 PROBLEM IDENTIFICATION AND MOTIVATION

Professionals (emergency medical services, fire and rescue service, police) use crisis-related interactive systems during their work processes. Citizens can uses crisis-related interactive systems like apps or web applications to help them prepare for crises or in case a crisis breaks out. However, crisis situations are a complex domain. In complex domains, the context of use has to be taken into account for usability testing (DIS, 2009; Redish, 2007). Consequently, usability testing of theses systems in the lab is necessary but not sufficient. Human-computer interaction methods that focus on the context of use such as contextual inquiry (Holtzblatt & Jones, 1993) and field research methods (Kantner, Sova, & Rosenbaum, 2003; Rosenbaum & Kantner, 2007) are typically conducted during common work processes or day to day activities. Unmodified, these methods by themselves are not suitable for crisis-related interactive systems because a crisis happens unexpectedly and is not part of the routine work or typical daily activities. Even if a crisis would occur while these methods are used they could negatively affect the outcome of the crisis, for example by disturbing domain experts during their tasks. Therefore, these activities should be stopped immediately if a crisis breaks out.

Due to the outlined problems, field exercises also known as crisis simulations (Boin, Kofman-Bos, & Overdijk, 2004; Kleiboer, 1997) are used for usability testing of crisis-related interactive systems (Nestler, 2014). These *real crisis simulations*[9] are resource intensive because they require actors, extras, vehicles, equipment and space (see Figure 2). Additionally, changing variables during real crisis simulations, which is often desired for usability testing purposes, is not easy.

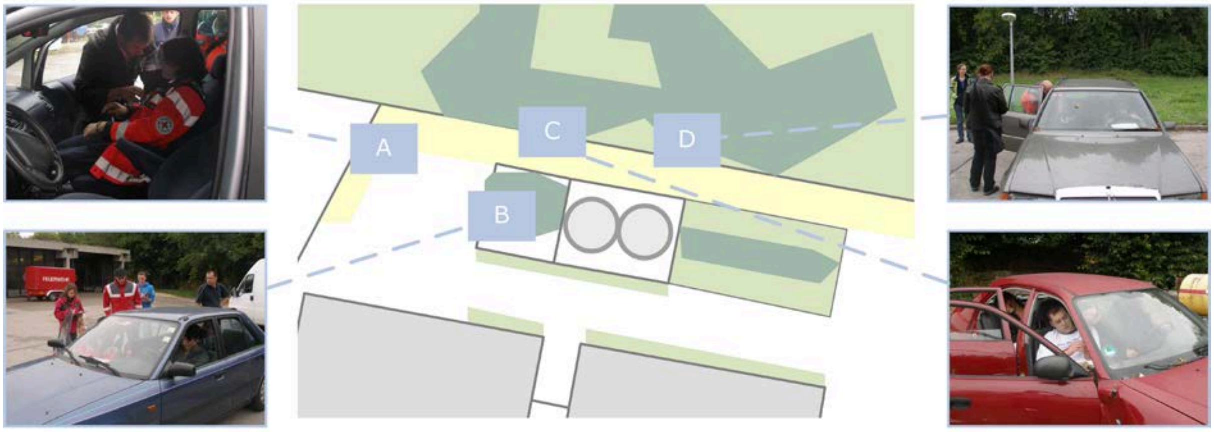

Figure 2. *Excerpt of the overview of a crisis simulation (Nestler, 2014) which shows some of the required vehicles and indicates the space requirements.*

During the ongoing research project INTERKOM[10] the outlined problem of taking a complex context of use into account became evident while prototyping a mobile app for the communication between citizens and crisis-professionals. This motivated the outlined research.

3 DEFINITION OF THE OBJECTIVES FOR A SOLUTION

To counteract the resource requirements of real crisis simulations these simulations can be transferred into virtual worlds. The resulting simulations are *virtual reality crisis simulations (VRCS)*. The development and use of VRCS is associated with costs. To provide a benefit for usability testing these costs have to be lower than the resources saved by using the VRCS. It is currently assumed as a working hypothesis that this can be achieved. Under this assumption objectives can be identified based on the initial conditions of the usability testing setup (i.e., are real crisis simulations already used or are they not used at all so far).

1. Real crisis simulations are not used for usability testing yet.
   - Problem: Real crisis simulations are too resource intensive and as a result at most lab based usability tests are conducted. The crisis context is not taken into account.

---

[9] Throughout the paper, we use the term real crisis simulation to make the distinction between these simulations and the virtual reality crisis simulations more clear.

[10] See acknowledgements for more details.

- *Objective 1*: If some additional resources are available but not sufficient to conduct an entire real crisis simulation they can be used to conduct VRCS and as a result the crisis context is taken into account.

2. Real crisis simulations are already used for usability testing.

   - Problem: Due to the resource requirements of running an entire real crisis simulation both the number of design solutions that can be tested and the scenarios in which they can be tested are limited.
   - *Objective 2*: VRCS can serve as a pre-test to reduce the number of design solutions that have to be tested in the real crisis simulation. VRCS can also be used to pre-configure the real crisis simulation to fit the testing needs.
   - *Objective 3*: VRCS replace the real crisis simulations entirely. Due to the reduced resource requirements more scenarios can be tested or scenarios can be tested more in depth and varied easily.

Since real crisis simulations are common practice and accepted as useful as a general tool outside the realm of usability testing objective 3 is excluded as a candidate. The initial goal is to develop a prototype that can eventually fulfill objective 1 or objective 2.

The development of the VRCS and its integration into the usability testing process should be *possible* and *feasible* (Peffers et al., 2007). It is possible in principle because virtual reality has been used successfully for other purposes like training in different domains (Orr, Mallet, & Margolis, 2009; Seymour et al., 2002) therapy (Riva, 2005) and way finding (Tang, Wu, & Lin, 2009). Furthermore, virtual prototypes (Kuutti et al., 2001) and virtual worlds have been suggested as potential tools for usability testing (Chalil Madathil & Greenstein, 2011). However the representation of the interactive system for which the usability test will be conducted in the VRCS (henceforth referred to as *testee*) could influence the realism of the simulation. Therefore, a necessary first step is to conduct a suitable evaluation to make sure that the presence of the testee doesn't influence the realism of the VRCS. Thus, the initial prototype was built with this goal in mind and serves as tool to conduct the required equivalence tests. Consequently, the research question of this paper is: "Can a testee be injected into a VRCS without influencing the realism of that VRCS?"

To ensure that the development of the VRCS is feasible the scope was limited by concentrating on a single crisis scenario and by creating this scenario ad hoc without the direct consultation of domain experts. The selected scenario was a *prolonged power outage* because it is described in literature (Petermann, Bradke, Lüllmann, Poetzsch, & Riehm, 2014) and the scenario is used in the INTERKOM research project. This ensures access to domain experts for future iterations of the VRCS. Limiting the testee to a simple virtual recreation of a mobile app inside the VRCS further reduced the scope.

4 DESIGN AND DEVELOPMENT

The developed prototype served as a basis to test the influence of the testee on the realism of the simulation and to get a general feeling for the feasibility of creating a VRCS. The two major design decisions were the transformation of the crisis scenario into a VRCS and the representation of the testee. The simulation was limited to a small city that was constructed from scratch by using preexisting city components such as buildings and streets. The city is in a state of power outage during the entire simulation with limited sound effects where appropriate and additional small visual indications of the power outage such as garbage that wasn't picked up. Obstacles that strategically limit the route to a predetermined one were used which means that one essentially walks from start to finish within the city while still retaining a feeling of free movement. This feeling of free movement was not measured as part of the experiment and only confirmed informally in talks when the VRCS was shown to another group of students later as a technology demo (i.e. not in an experimental setting).

With one exception, buildings cannot be entered. A playback component for a before-after effect of ten identified events, like increased accidents due to the lack of working traffic lights, was also added. These effects are triggered upon entering certain zones. A scene from the VRCS that shows that people will resort to open fires due to the lack of electric heating is depicted in Figure 3. The testee was prototyped as a simple virtual recreation of a mobile app inside the VRCS. A tablet and a virtual hand that holds it fade in at the bottom of the simulation when a trigger points is passed. There is no interaction with the virtual tablet. The device simply shows text related to the ongoing crisis. For example, when the trigger point for a burning apartment is passed, the tablet fades in and shows a note that explains that open fires are used for cooking and heating due to the power outage and as a result more fires break out (this is depicted in Figure 4). The German text translates to "Because electric heating and kitchen appliances cannot be used without electricity the use of open fires for cooking and heating increases. This leads to an increased risk of fires and corresponding increases in fire fighter deployments."

Figure 3. *A scene from the VRCS depicting a power outage.*

Figure 4. *A scene with the virtual tablet (testee) from the VRCS depicting a power outage.*

The two technology choices for the development of the VRCS were (a) picking the virtual reality hardware and (b) picking a 3D-engine. While there are many possible virtual reality hardware combinations an approach based on the Oculus Rift Development Kit 2 and an Xbox 360 controller was selected because this hardware was already available and integrated into the teaching process[11]. Furthermore, this setup can be used with a laptop, which makes the solution portable. Likewise there are many different 3-D engines. The Unity Engine was

[11] The fact that the technology is integrated into the teaching process corresponds to the Humboldtian model of higher education of integrating research and studies.

selected because it is free, wide spread, supports direct rendering of Oculus VR views and is already used in other projects at the Hamm-Lippstadt University of Applied Sciences.

5 EVALUATION

To test if the injection of a testee influences the realism of the VRCS, the realism was measured for the VRCS with and without the testee. This chapter outlines the experiment and the equivalence tests that were conducted to answer the research question.

5.1 PARTICIPANTS

32 participants were recruited from undergraduate students of the Hamm-Lippstadt University of Applied Sciences by asking for participation during their lectures. 26 participants were male and 6 participants were female. The age of the participants was between 18 and 29 (M = 23.28, SD = 2.67). The convenience sampling of the participants lead to a participant pool that has a high pre-education in the field of virtual reality as it is part of their studies (47% of the participants had previous knowledge about VR).

The participants were randomly assigned to two groups of 16 members each without any pretests or matching. No power-analysis to determine the required sample size was conducted prior to the experiment since the sample-size was limited to the available students regardless.

5.2 VARIABLES

The nominal-scale variable *simulation type* (with the two levels “without testee” and “with testee”) is the treatment variable. The four variables *scene realism*, *audience behavior*, *sound realism* and *realism of the VR-application* are the dependent variables. They are interval scaled from 1 (very low realism) to 5 (very high realism). The dependent variables are grand means of corresponding sub-items from the questionnaire that was used.

To control for external factors the experiment was conducted in the same conditions with each participant. All participants used the same equipment and computer and were tested in the same room under the same lighting and sound conditions. The individual characteristics of the participants are treated as random variables.

5.3 INSTRUMENTS AND MATERIALS

The experiment was conducted in a dedicated laboratory with constant lighting and no disturbing sounds. The same computer and hardware (Oculus Dev Kit 2, X-Box-Controller, 3D-Headphones) was used for all participants. A simple self-made questionnaire to collect demographic information was used.

The realism questionnaire that was used for the evaluation[12] is based on the Simulation Realism Scale (Poeschl & Doering, 2013) which is in turn based on the presence questionnaire by Witmer and Singer (1998). The Simulation Realism Scale was adapted to meet the needs of this evaluation in the following manner:

[12] Since the experiment was conducted in Germany, the German version of all mentioned questionnaires was used if available. Otherwise the questions were translated.

- The items relating to Audience Appearance were removed since Audience Appearance showed insufficient reliability in the original study by Poeschl and Doering and is not deemed essential for this research.
- Additional sound items were added as suggested by Poeschl and Doering. For the extension the sound items from the revised presence questionnaire (UQO Cyberpsychology Lab, 2004) were used.
- The realness items from Schubert (2003) were added.
- All items were adapted to five levels if necessary.

The resulting questionnaire contains a total of 17 items in 4 categories. Each category represents one of the dependent variables. The questionnaire is a summated rating scale. All items except the original sound item from Poeschl and Doering have five levels ordered from least agreement (left) to most agreement (right). Consequently, that sound item was collected but not used for the calculation of the grand mean for *sound realism*[13].

5.4 EXPERIMENT DESIGN AND PROCEDURE

Due to the limited number of participants, the experiment was conducted as a within-subject design. To avoid an ordering effect, a counterbalanced design in which participants were randomly assigned to one of the two groups was chosen. Each group consisted of 16 participants. Following Campbell, Stanley, and Gage (1963) the design is depicted in Figure 5. All sessions were conducted individually. Participants who were assigned to group A started with the *simulation type* set to "without testee" (X_1) followed by *simulation type* set to "with testee" (X_2). The reverse setup was used for group B. O_D depicts when the socio-demographic questionnaire was conducted, O_R depicts when the realism questionnaire was conducted and CD depicts when the cool down period happened. The length of the lines indicates the duration of the exposure to the VRCS and the cool down time respectively. The cool down time was set at five minutes. Unfortunately the exact exposure time wasn't collected. On average it was 10 minutes for X_1 and X_2 for a total of 20 minutes of exposure with the cool down break in between (this is indicated by the length of the lines in relation to each other).

Group A: O_D X_1____________O_R CD______X_2____________O_R

Group B: O_D X_2____________O_R CD______X_1____________O_R

Figure 5. *Design of the experiment following (Campbell et al., 1963).*

The same experimental procedure was followed for each participant. The participants were seated during the entire experiment. The experimenter greeted each participant and explained the health risks of the VRCS[14]. Afterwards a socio-demographic questionnaire was handed out and upon completion the VRCS was explained to the participant. After making sure that the HMD was set up properly and that the participant understood how to navigate the VRCS the

---

[13] The original sound item has the levels way too quiet, too quiet, right, too loud, way too loud. Alternatively this could be mapped as a 1,3,5,3,1 scoring.

[14] An additional written explanation was given as well and a warning text was shown within the VRCS at the beginning of the simulation.

first run through the VRCS begun. Upon completion of the first run, the participant filled out the realism questionnaire, which was collected upon completion. After a cool down period of five minutes the *simulation type* was switched and the participant conducted a second run through the VRCS. Upon completion of the second run a second realism questionnaire was filled out and the experimenter collected the questionnaire and thanked the participant.

5.5 MEASURES

Table 1 lists the descriptive statistics of the dependent variables for the conducted experiment as taken from the realism questionnaires on a scale from 1 (very low realism) to 5 (very high realism).

Table 1. Descriptive statistics of the realism questionnaire

Variable	*N*	*M*	*SD*	*Min*	*Max*
Scene Realism (without testee)	32	3.92	0.54	2.60	5.00
Scene Realism (with testee)	32	3.84	0.54	2.40	5.00
Audience Behavior (without testee)	32	3.42	0.85	1.50	4.75
Audience Behavior (with testee)	32	3.47	0.80	1.25	4.75
Sound Realism (without testee)	32	4.38	0.63	2.33	5.00
Sound Realism (with testee)	32	4.40	0.60	2.67	5.00
Realism of the VR-Application (without testee)	32	2.67	0.72	1.25	4.50
Realism of the VR-Application (with testee)	32	2.61	0.69	1.50	4.25

Since the objective of the evaluation was to see if adding a testee to the VRCS leaves the realism equivalent to the VRCS without the testee an equivalence test (Kirkwood & Westlake, 1981; D. L. Schuirmann, 1981) was conducted. The formulated research hypothesis (equivalence assumption) is "after injecting the testee into the VRCS, the realism of the VRCS is equivalent to the realism of the VRCS without the testee" which can be formulated for the scene realism, audience behavior, sound realism and the realism of the VR-application. The corresponding null hypotheses were tested with the Two One-Sided Tests procedure (TOST) (D. J. Schuirmann, 1987) for the four dependent variables *scene realism*, *audience* *behavior*, *sound realism* and *realism of the VR-application.* Following Wellek (Wellek, 2010, p. 11), the null hypothesis of nonequivalence has the general form

$$H: \theta \leq \theta_{\circ} - \varepsilon_1 \text{ or } \theta \geq \theta_{\circ} + \varepsilon_2$$

While the equivalence assumption has the general form

$$K: \theta_{\circ} - \varepsilon_1 < \theta < \theta_{\circ} + \varepsilon_2$$

The chosen epsilon value was 0.25 as this represents the suggested strict value for paired t-tests setups (Wellek, 2010, p. 16). The degree of dissimilarity θ was chosen to be the difference between the dependent variable before and after the independent variable was changed[15]. The reference value $\theta_{\circ}$ was set to zero as this represents the case when the distributions under investigation are equal. Table 2 summarizes the results of the equivalence tests for all dependent variables.

Table 2. Results of the equivalence tests

Dependent Variable	Mean of the Difference	Standard Error of the Difference	Confidence Interval (1-α)	TOST-Confidence Interval (1-2α)	p-value
Scene Realism	-0.081	0.063	[-0.188, 0.025]	[-0.170, 0.007]	.006
Audience Behavior	0.047	0.110	[-0.140, 0.233]	[-0.108, 0.202]	.037
Sound Realism	0.021	0.047	[-0.060, 0.101]	[-0.046, 0.088]	< .001
Realism of the VR-Application	-0.063	0.070	[-0.181, 0.056]	[-0.161, 0.036]	.006

Note. The alpha level was .05 and an epsilon of .25 was chosen. The order for the mean of the difference and standard error was kept constant. It was set to be the value of the case "with testee" minus the value for the case "without testee".

5.6 DISCUSSION

Since all TOST-Confidence Intervals fall within the range of [-0.25; 0.25] the null hypothesis of nonequivalence can be rejected for all four cases. Thus, the VRCS with and without the testee is equivalent regarding all relevant realism measures. This indicates, that it is possible to add a simple virtual app to the developed VRCS without disturbing the realism. This result is a first step towards being able to test said app in the VRCS.

It was assumed that the constructed questionnaire measures the realism of the VRCS reliably and that realism is a good base measure for a VRCS. The idea behind the latter assumption is that if the VRCS is perceived as real, the results of usability tests conducted within the VRCS could be transferable to the real world. Existing research of the applicability of VR learning to

[15] The order was kept constant. The degree of dissimilarity was always set to the value of the dependent variable for the case "with testee" minus the value for the case "without testee".

the real world (Alexander, Brunyé, Sidman, & Weil, 2005) could be a good starting point to justify this assumption. However, the potential gap between the general realism of the VRCS and the realism of the crisis scenario was not addressed. Experiential Design applied to Virtual Environments (Chertoff, Schatz, McDaniel, Bowers, & others, 2008) in conjunction with domain experts would be a viable approach. Lastly it is necessary to construct and validate a more sophisticated questionnaire or other means of measuring the realism of a VRCS while taking the realism of the scenario into account.

6 OUTLOOK

This paper outlined the general motivation for the development of a VRCS prototype as a means to solve the problem of taking the crisis context into account in a less resource intensive way than relying solely on real crisis simulations. It defined objectives for a solution and identified the sub-problem that injecting a testee into the VRCS could influence the realism of the VRCS. A high level view of the design and technology choices was sketched.

To answer the research question “Does the injection of a testee into a VRCS influence the realism of that VRCS?” equivalence tests with regards to the realism of the VRCS were conducted. The tests showed that the VRCS with and without the virtual app were equivalent with regards to *scene realism, audience behavior, sound realism* and *realism of the VR-application.*

While it proved to be feasible to build the prototype within a reasonable timeframe the construction of the first version of the VRCS and the conducted experiment have already revealed some defects and ideas for further improvements. Thus, the next step is to iteratively improve the VRCS before eventually moving on towards the goal of conducting usability tests inside the VRCS. Input from both domain experts in crisis management and human-computer interaction (HCI) specialists is needed and welcome to achieve this. To kick-start this communication activity (see Figure 1) we list some identified weaknesses and some of our own ideas for further discussion.

Cybersickness: A major drawback is that the well-known problem of cybersickness (Davis, Nesbitt, & Nalivaiko, 2014; McCauley & Sharkey, 1992) occurred during the early stages of prototyping the VRCS. Frame rate improvements offset the initial issues and none of the participants of the experiment reported any problems with cybersickness. However there is no guarantee that the issue is fully solved and further tests with a more heterogeneous group of participants are needed. The next iteration of the prototype will focus on following the best practices (Yao et al., 2014) that lead to a reduction in cybersickness even more in depth. Even if this problem can be reduced it may still have influence on the design choices of future experiments as cybersickness gets worse with prolonged exposure (Kennedy, Stanney, & Dunlap, 2000). For example, within-subject designs require a longer exposure to the VRCS than between-subject designs, which could lead to a higher number of subjects dropping out during the experiment due to the experienced sickness.

Relationship between the VRCS and the interactive system that will be tested: The exact specifications of the mobile app that will be tested within the VRCS are currently being developed in the INTERKOM research project. For now a simplified virtual tablet served as a placeholder and proved useful for equivalence testing. However the actual app that will be tested influences the design of the VRCS scenario and as such knowing the testee is a precondition for further advances. Additionally, the equivalence results cannot be generalized and a similar experiment needs to be conducted for every VRCS-testee pair that one designs.

App representation: There are multiple possible ways of representing an app in a VRCS. Mirroring the screen of the actual device onto a virtual representation of the device or a recreation of the app within the VRCS (as was done in a simplified manner for this version of the VRCS) are two examples. One of the key problems is that it is hard to impossible to use the mobile device while wearing a head-mounted display (HMD). Even if that wasn't the case the interaction with the device provides interesting challenges. A transfer of ideas from the use of touch- or device-based gesture control (Turk, 2015) could prove fruitful. The problem of interacting with the mobile device can be mitigated by moving form a HMD to a CAVE (Cruz-Neira, Sandin, & DeFanti, 1993). Even if a CAVE is used, a HMD based VRCS can serve as a prototyping environment for the CAVE as long as the underlying technology (e.g. 3D-Engine) is compatible.

Crisis representation: The selected crisis scenario was built ad hoc without the input of domain experts based on the scenario description found in Petermann et al. (2014). Since most test subjects will not have experienced this crisis situation it is hard to measure how realistic the reconstruction actually is. The next iteration will involve domain experts and rely on their feedback about the realism of the VRCS. Three crisis scenarios (prolonged power outage, pandemic and bio terrorism) are currently being developed in cooperation with domain experts in the INTERKOM research project. Other alternatives are seeking subjects that have lived through the specific crisis and relying on their memory of the past experiences (which is limited to types of crises that have already happened) or developing a generic questionnaire to evaluate if the crisis scenario felt real. The questionnaire by Chertoff, Goldiez, and LaViola Jr (2010) could be a good starting point. Additionally, content development was an afterthought and mostly based on what was available for free and some intuition regarding the construction of the city. A more rigorous approach following established principles (Isdale, Fencott, Heim, & Daly, 2002) is planned for a future iteration. Another challenge is the potential use of real-time data in the VRCS. Wang, Bishop, and Stock (2009) provide an overview of a framework for the integration of real-time data in collaborative virtual environments.

Lack of interaction: Currently users can only walk through the city by using a gamepad or keyboard in combination with the direction they look in. The simulation ends when the final destination is reached which leads to a fade to black. While this is acceptable for a first prototype the next steps need to focus on actual actions that are taken during a crisis. These interactions depend on both the testee and the crisis scenario, which have to be developed. In the future, the crisis scenario could be split into smaller units that can be used to measure the performance during concrete tasks within the VRCS like using the app to navigate to collection points, getting warned by the app when near an exclusion zone or using the app to communicate with the rescue service via text message. The measurements of performance can be based on the work done by Lampton, Bliss, and Morris (2015). The addition of a walking device like the Virtuix Omni as a replacement for the need to walk via a gamepad could be considered.

Usability testing of the VRCS: From an HCI point of view we jumped straight into the development step of the EN ISO 9421-11 process (2009). While this is a good compromise when developing software for your own use or to quickly see how much time it takes to build a prototype, a usability test of the VRCS itself has to be conducted especially if it is to be used by other researchers. Bowman et al. (2002), Gabbard et al. (1999) and Tromp et al. (2003) provide some insight into how this could be done. Sutcliffe and Gault (2004) provide some useful heuristics.

Comparison of VRCS and other methods of generating a crisis context: To test the assumed working hypothesis of resource savings VRCS have to be compared to other methods of creating a crisis context like non-VR 3D simulations, storytelling, paper based descriptions, low-fidelity crisis-simulation and real crisis simulations.

ACKNOWLEDGEMENTS

This research is supported by a grant from the German Federal Ministry of Education and Research (BMBF) as part of the INTERKOM project (No. 13N1005, 01/2014 – 12/2016). The paper is an enhanced and improved version of a paper presented at the 2015 Workshop "KritischeHCI" (Rother, Karl, & Nestler, 2015). We would like to thank Alexander Giesbrecht, Sandra Jürgensmeier, Inge Kling, Sinan Mert and Dennis Ziebart for their contributions.

REFERENCES

Alexander, A. L., Brunyé, T., Sidman, J., & Weil, S. A. (2005). From gaming to training: A review of studies on fidelity, immersion, presence, and buy-in and their effects on transfer in pc-based simulations and games. DARWARS Training Impact Group, 5, 1–14.

Boin, A., Kofman-Bos, C., & Overdijk, W. (2004). Crisis simulations: Exploring tomorrow's vulnerabilities and threats. Simulation & Gaming, 35(3), 378–393.

Bowman, D. A., Gabbard, J. L., & Hix, D. (2002). A Survey of Usability Evaluation in Virtual Environments: Classification and Comparison of Methods. Presence: Teleoperators and Virtual Environments, 11(4), 404–424. http://doi.org/10.1162/105474602760204309

Campbell, D. T., Stanley, J. C., & Gage, N. L. (1963). Experimental and quasi-experimental designs for research. Houghton Mifflin Boston.

Chalil Madathil, K., & Greenstein, J. S. (2011). Synchronous remote usability testing: a new approach facilitated by virtual worlds. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (pp. 2225–2234). ACM.

Chertoff, D. B., Goldiez, B., & LaViola Jr, J. J. (2010). Virtual Experience Test: A virtual environment evaluation questionnaire. In Virtual Reality Conference (VR), 2010 IEEE (pp. 103–110). IEEE.

Chertoff, D. B., Schatz, S. L., McDaniel, R., Bowers, C., & others. (2008). Improving presence theory through experiential design. Presence, 17(4), 405–413.

Cruz-Neira, C., Sandin, D. J., & DeFanti, T. A. (1993). Surround-screen projection-based virtual reality: the design and implementation of the CAVE. In Proceedings of the 20th annual conference on Computer graphics and interactive techniques (pp. 135–142). ACM.

Davis, S., Nesbitt, K., & Nalivaiko, E. (2014). A Systematic Review of Cybersickness. In Proceedings of the 2014 Conference on Interactive Entertainment (pp. 8:1–8:9). New York, NY, USA: ACM. http://doi.org/10.1145/2677758.2677780

DIS, I. (2009). 9241-210: 2010. Ergonomics of human system interaction-Part 210: Human-centred design for interactive systems. International Standardization Organization (ISO). Switzerland.

Gabbard, J. L., Hix, D., & Swan, J. E. (1999). User-centered design and evaluation of virtual environments. Computer Graphics and Applications, IEEE, 19(6), 51–59.

Hevner, A. R., March, S. T., Park, J., & Ram, S. (2004). Design science in information systems research. MIS Quarterly, 28(1), 75–105.

Hevner, A. R., & Zhang, P. (2011). Introduction to the AIS THCI Special Issue on Design Research in Human-Computer Interaction. AIS Transactions on Human-Computer Interaction, 3(2), 56–61.

Holtzblatt, K., & Jones, S. (1993). Contextual inquiry: A participatory technique for system design. Participatory Design: Principles and Practices, 177–210.

Isdale, J., Fencott, C., Heim, M., & Daly, L. (2002). Content design for virtual environments. In K. Hale & K. Stanney (Eds.), Handbook of virtual environments: Design, implementation, and applications (2nd ed., pp. 519–532). Boca Raton, FL: CRC Press.

Kantner, L., Sova, D. H., & Rosenbaum, S. (2003). Alternative methods for field usability research. In Proceedings of the 21st annual international conference on Documentation (pp. 68–72). ACM.

Kennedy, R. S., Stanney, K. M., & Dunlap, W. P. (2000). Duration and exposure to virtual environments: Sickness curves during and across sessions. Presence: Teleoperators and Virtual Environments, 9(5), 463–472.

Kirkwood, T. B., & Westlake, W. J. (1981). Bioequivalence testing–a need to rethink. Biometrics, 589–594.

Kleiboer, M. (1997). Simulation methodology for crisis management support. Journal of Contingencies and Crisis Management, 5(4), 198–206.

Kuutti, K., Battarbee, K., Sade, S., Mattelmaki, T., Keinonen, T., Teirikko, T., & Tornberg, A.-M. (2001). Virtual prototypes in usability testing. In Proceedings of the 34th Annual Hawaii International Conference on System Sciences, 2001 (p. 7 pp.–). http://doi.org/10.1109/HICSS.2001.926545

Lampton, D. R., Bliss, J. P., & Morris, C. S. (2015). Human performance measurement in virtual environments. In K. Hale & K. Stanney (Eds.), Handbook of virtual environments: Design, implementation, and applications (2nd ed., pp. 749–780). Boca Raton, FL: CRC Press.

McCauley, M. E., & Sharkey, T. J. (1992). Cybersickness: Perception of self-motion in virtual environments. Presence: Teleoperators and Virtual Environments, 1(3), 311–318.

Nestler, S. (2014). Evaluation der Mensch-Computer-Interaktion in Krisenszenarien / Evaluating human-computer-interaction in crisis scenarios. I-Com, 13(1), 53–62. http://doi.org/10.1515/icom-2014-0008

Offermann, P., Levina, O., Schönherr, M., & Bub, U. (2009). Outline of a design science research process. In Proceedings of the 4th International Conference on Design Science Research in Information Systems and Technology (p. 7). ACM.

Orr, T. J., Mallet, L. G., & Margolis, K. A. (2009). Enhanced fire escape training for mine workers using virtual reality simulation. Mining Engineering, 61(11), 41.

Österle, H., Becker, J., Frank, U., Hess, T., Karagiannis, D., Krcmar, H., … Sinz, E. J. (2011). Memorandum on design-oriented information systems research. European Journal of Information Systems, 20(1), 7–10. http://doi.org/10.1057/ejis.2010.55

Peffers, K., Tuunanen, T., Rothenberger, M. A., & Chatterjee, S. (2007). A design science research methodology for information systems research. Journal of Management Information Systems, 24(3), 45–77.

Petermann, T., Bradke, H., Lüllmann, A., Poetzsch, M., & Riehm, U. (2014). What Happens During a Blackout: Consequences of a Prolonged and Wide-ranging Power Outage. BoD–Books on Demand.

Poeschl, S., & Doering, N. (2013). The German VR Simulation Realism Scale–psychometric construction for virtual reality applications with virtual humans. Stud Health Technol Inform, 191, 33–37.

Redish, J. (2007). Expanding usability testing to evaluate complex systems. Journal of Usability Studies, 2(3), 102–111.

Riva, G. (2005). Virtual reality in psychotherapy: review. Cyberpsychology & Behavior, 8(3), 220–230.

Rosenbaum, S., & Kantner, L. (2007). Field usability testing: method, not compromise. In Professional Communication Conference.

Rother, K., Karl, I., & Nestler, S. (2015). Virtual Reality Crisis Simulation for Usability Testing of Mobile Apps. In A. Weisbecker, M. Burmester, & A. Schmidt (Eds.), Mensch und Computer 2015–Workshopband (pp. 69–76). Stuttgart: De Gruyter Oldenbourg.

Schryen, G., & Wex, F. (2015). Risk Reduction in Natural Disaster Management through Information Systems: A Literature Review and an IS Design. Transportation Systems and Engineering: Concepts, Methodologies, Tools, and Applications, 79.

Schubert, T. W. (2003). The sense of presence in virtual environments: A three-component scale measuring spatial presence, involvement, and realness. Zeitschrift Für Medienpsychologie, 15(2), 69–71.

Schuirmann, D. J. (1987). A comparison of the two one-sided tests procedure and the power approach for assessing the equivalence of average bioavailability. Journal of Pharmacokinetics and Biopharmaceutics, 15(6), 657–680.

Schuirmann, D. L. (1981). On hypothesis testing to determine if the mean of a normal distribution is contained in a known interval. In Biometrics (Vol. 37, pp. 617–617). Washington, DC: International Biometric Society.

Seymour, N. E., Gallagher, A. G., Roman, S. A., O'Brien, M. K., Bansal, V. K., Andersen, D. K., & Satava, R. M. (2002). Virtual Reality Training Improves Operating Room Performance. Annals of Surgery, 236(4), 458–464.

Sutcliffe, A., & Gault, B. (2004). Heuristic evaluation of virtual reality applications. Interacting with Computers, 16(4), 831–849. http://doi.org/10.1016/j.intcom.2004.05.001

Tang, C.-H., Wu, W.-T., & Lin, C.-Y. (2009). Using virtual reality to determine how emergency signs facilitate way-finding. Applied Ergonomics, 40(4), 722–730.

Tarantino, L., & Spagnoletti, P. (2013). Can Design Science Research Bridge Computer Human Interaction and Information Systems? In Organizational Change and Information Systems (pp. 409–418). Springer.

Tromp, J. G., Steed, A., & Wilson, J. R. (2003). Systematic usability evaluation and design issues for collaborative virtual environments. Presence: Teleoperators and Virtual Environments, 12(3), 241–267.

Turk, M. (2015). Gesture recognition. In K. Hale & K. Stanney (Eds.), Handbook of virtual environments: Design, implementation, and applications (2nd ed., pp. 211–231). Boca Raton, FL: CRC Press.

UQO Cyberpsychology Lab. (2004). PRESENCE QUESTIONNAIRE Revised by the UQO Cyberpsychology Lab. Retrieved from http://w3.uqo.ca/cyberpsy/docs/qaires/pres/PQ_va.pdf

Wang, P., Bishop, I. D., & Stock, C. (2009). Real-time data visualization in Collaborative Virtual Environments for emergency response. In Proceedings: Spatial Sciences Institute Biennial International Conference.

Wellek, S. (2010). Testing statistical hypotheses of equivalence and noninferiority. CRC Press.

Witmer, B. G., & Singer, M. J. (1998). Measuring presence in virtual environments: A presence questionnaire. Presence: Teleoperators and Virtual Environments, 7(3), 225–240.

Yao, R., Heath, T., Davies, A., Forsyth, T., Mitchell, N., & Hoberman, P. (2014). Oculus VR Best Practices Guide. Oculus VR. Retrieved from http://treyte.ch/oculus/tools/0.4.2/documentation/OculusBestPractices.pdf

Kristian Rother studied Business Information Systems at the University of Duisburg-Essen, Germany (Dipl.-Wirt.Inf.). Before entering academia he worked as a programmer, project manager and VP of marketing at a software company. He was a researcher at the University of Duisburg-Essen in the field of Artificial Intelligence. Currently, he is a researcher at the Hamm-Lippstadt University of Applied Sciences with a focus on Human-Computer Interaction, Virtual Reality, Augmented Reality and Crisis-Related Interactive Systems.

Inga Karl studied Applied Cognitive and Media Science at the University of Duisburg-Essen, Germany (M.Sc.). Currently she is a researcher at the Hamm-Lippstadt University of Applied Science in the project INTERKOM with a focus on Crisis-Related Interactive Systems. Further research focuses on Human-Computer-Interaction, Usability and Social Media.

Simon Nestler studied Computer Science (Dipl. Inf.) at the Technische Universität München, Germany (TUM) and received a PhD for his work on Human-Computer Interaction in life threatening, time critical and instable situations (Dr. rer. nat.) from the TUM. Currently, he holds a professorship at the Hamm-Lippstadt University of Applied Sciences and leads the Human-Computer Interaction research group. His research interests include all topics in Human-Computer Interaction, Social Media, Mobile Computing, Virtual Reality and Augmented Reality, especially with a focus on Crisis-Related Interactive Systems. Simon Nestler is a member of the German UPA and the German Informatics Society.

Should I try turning it off and on again?

Outlining HCI Challenges for Cyber-Physical Production Systems

Thomas Ludwig, Institute for Information Systems, University of Siegen, Siegen, Germany
Christoph Kotthaus, Institute for Information Systems, University of Siegen, Siegen, Germany
Volkmar Pipek, Institute for Information Systems, University of Siegen, Siegen, Germany
firstname.lastname@uni-siegen.de

ABSTRACT

The flexible production and process designs of complex and automated manufacturing systems – called Cyber-Physical Production Systems (CPPS) – lead to enormous challenges for the machine operator with regard to understanding their "behavior" and therefore their technical controllability. One way to face these challenges is to foster the operator's appropriation of highly complex hardware-centered ICT-systems. Based on the historical development of CPPS and a short excursion into a study about the appropriation of 3D printers, we will adapt the concept of sociable technologies, as hardware-centered appropriation infrastructures, to CPPS.

1 INTRODUCTION

Globalization and the resulting larger markets, better purchase conditions and cheaper production possibilities could offer a lot of potential to industrial companies, but it is often accompanied by a number of challenges too. A global market means global competitors. For long-term survival on international markets, industrial companies need to adapt their products to market trends at even shorter intervals and market positions must be kept or even expanded with new, technologically more advanced products offering higher quality at competitive prices. Companies find themselves in an area of conflict between customer-driven cost pressure, quality demands and features expected of the products as well as services that customers request; customers who, if left dissatisfied, might otherwise shift to other companies offering similar products. The steadily increasing demand for individual and customized manufacturing products is leading to an increased number of product variations, which generally means higher set-up times. This in turn leads to lower quantities and the result is higher costs per piece compared to traditional mass production.

Complex manufacturing systems offer a solution to these expectations and challenges. Modern manufacturing processes of shaping or cutting, separating or joining operations consist of a large variety of process parameters and resources needed to complete a product. Various mechanical functions of a machine and a range of ICT tools are brought together in the manufacturing process, resulting in a wide range of machine states and dependent process parameters. In the light of this complexity, the implicit pressure exerted by customers through their demands for increased variety, smaller batch sizes and more product complexity makes the monitoring and control of fully-automated manufacturing machines increasingly confusing and opaque. The rise of complexity with problems of operating such systems could also be found in other application fields like crisis management (Comes et al., 2011)

Despite of a more flexible production and process design, these complex and automated manufacturing systems still present enormous challenges for the machine operator with regard to their availability and technical controllability (Munir et al., 2013). A particular challenge is presented by the intra- and inter-organizational gathering and analyzing of relevant factors of the machine with regard to the real-time-based complex production processes. This is especially critical if errors or incidents within the highly complex automated production process occur as the machine operator is often not fully aware of a hardware-related machine failure (Ludwig et al., 2014). The capability of the production machines to report internal and external critical situations systematically and to present the production process to the machine operators is often limited; thus machine operators are often hindered in appropriating the complex production process. In other words: If an error in the machine – which is usually automated – occurs, the machine operator does not always know why it fails nor how to fix it, because the state of the machine depends on too many parameters both inside, but also outside the machine itself (Ludwig et al., 2015). This has become especially critical since modern complex production systems often operate within an entire value-added chain; so, if an error occurs within a previous company, it can have fatal consequences within one's own systems.

Within this paper, we outline current challenges in the field of Human-Computer-Interaction (HCI) and Computer-Supported Cooperative Work (CSCW) that deal with the question of how machine operators could be supported in appropriating the modern complex production machines known as cyber-physical production systems (CPPS). Based on a historical perspective on the development of CPPS (section 2), we will provide an excursion into a study, in which we empirically examined the appropriation of 3D printers as modern and complex machines in the field of additive production (section 3). Based on this study, we will outline design challenges for the appropriation of CPPS in the field of industrial production (section 4).

2 HISTORICAL PERSPECTIVE ON THE DEVELOPMENT OF CYBER-PHYSICAL PRODUCTION SYSTEMS (CPPS)

Based on their focus, we can divide current research and industrial approaches in the field of industrial production design into three areas: (1) data-centered, (2) technology-centered and (3) process-oriented (Birkhahn, 2007). We will present the development of CPPS as a combined approach of all three areas.

2.1 DATA-CENTERED APPROACHES

Data-centered approaches mainly encompass Computer Integrated Manufacturing (CIM). Beginning with initial digital support systems in the design (CAE, CAD), work process planning (CAP) and manufacturing (CAM, CAQ), then adding the operation of production planning and control systems, CIM encompasses an integrated approach for information processing in industrial companies in the manufacturing sector. More comprehensive approaches of CIM – under the concept of Computer Integrated Business (CIB) – include the inter-organizational information flows within the production networks (Becker & Rosemann, 1993; Geitner, 1990). The basic idea of CIM is to improve the consistency, timeliness and quality of enterprise data via computer-supported technologies to contribute to the process improvement within the company (Birkhahn, 2007). The concept of 'digital factory' describes a comprehensive network of digital models, methods and tools through the assimilation of integrated data management. The aim is for all the actors involved in the planning process to be able to access a digital model and the stored data base with the support of software tools (Westkämper & Jendoubi, 2003).

Pure data-oriented approaches such as the introduction of CIM tools or the design of a digital factory have however not led to the success anticipated (Birkhahn, 2007). Goals such as the shortening of run-through times, increasing product quality or reducing personnel in the production and management area were not achieved satisfactorily due to the often user-unfriendly handling and the resulting high training costs implied (Becker & Rosemann, 1993; Büring, 1997) .

2.2 TECHNOLOGY-CENTERED APPROACHES

The development and advancement of technologies has resulted in a number of technology-oriented approaches such as 'Smart Factory' or 'Smart Object' for use in industrial production systems. Smart objects are hybrid products comprising a physical and a data processing component (Fleisch, 2001). The data processing of a 'smart thing' is hidden in the background and cannot be directly perceived by the user. Examples of applications for smart objects can be found, for example, in logistics as part of the equipment of goods with wireless radio chips (e.g. RFID) which transfer data directly to ICT systems. In the industrial context, the 'Smart Factory' tries to close the gap between digital planning and the actual process (Westkämper & Jendoubi, 2003), creating a transparent, optimized production resource management system, in which highly dynamic sensor data is integrated within the contextual environment model (Bauer et al., 2003).

2.3 PROCESS-CENTERED APPROACHES

The flexibility with which companies must react to global market changes leads to process-centered approaches, which can be found in early concepts of 'Lean Production'. One characteristic of 'Lean Production' is that production planning does not primarily optimize machine capacity but is geared towards customer demands (Womack et al., 1990). 'Lean Production' offers new options for the physical process design. The changes brought about by 'Lean Production' are so far-reaching that they signify a paradigm shift – especially in European and American production companies. More recently, the concept of 'Lean Production' has been expanded towards a socio-technical system that integrates the entire company, the customers, suppliers, maintenance and process control as well as appropriate feedback loops (Shah & Ward, 2007).

2.4 COMBINED APPROACHES: CYBER-PHYSICIAL PRODUCTION SYSTEMS

The concept of a 'Smart Production System' is an approach which aims to meet the challenges currently facing production, in which the gap between data, technology and process-centered production design approaches is closed. The basic idea is to use 'knowledge-integrated objects' within the production process to make the processes transparent at all times, thus ensuring the efficiency and flexibility of the associated production system. The ‘knowledge-integrated objects’ represent production items. These, in addition to their actual function, also possess information technology functions by storing as well as providing data (Birkhahn, 2007). Today the ‘knowledge-integrated objects’ are mainly described under the comprehensive concept of cyber-physical systems (CPS) – and, when used within industrial production companies, as cyber-physical production systems (CPPS). CPPS are distributed, networked smart objects that connect embedded systems with internet-based technologies and capture sensor data by means of which they regulate materials, goods, and information flows (Rajkumar et al., 2010).

Manufacturing companies in countries with a high wage level compete with Asian manufacturers, and especially with the Chinese (Eisenhut et al., 2011). For the middle and upper quality and price segments however, CPPS provide a good opportunity for the producers to provide competition-related value; i.e. by offering additional services to their customers (Geisberger & Broy, 2012). Voluntary commitments such as ISO 9000 or legal liability regarding products and processes force European companies in particular to control and document their production processes themselves (Bundesministeriums der Justiz, 2004). However, the complexity of CPPS, the rapid technical progress and the close link between hardware and software in the field of industrial production means the staff and end-users of such complex production technologies are faced with major challenges when dealing with them. New user interfaces and support tools are therefore required which would enable users to keep pace and to work both effectively and efficiently.

2.5 APPROPRIATION AND APPROPRIATION INFRASTRUCTURES

Given the complexity and the socio-technical orientation of such new forms of production systems, issues from the field of HCI are of particular importance (Balka & Wagner, 2006; Dourish, 2003; Mackay, 1990; G Stevens et al., 2010). Within the field of HCI, the concept of appropriation is emphasized (Pipek, 2005), as well as further research being conducted on appropriation within the areas of HCI and CSCW. Following Pipek (2005), *appropriation* is the discovery and sense-making of an artifact while using it in practice. This understanding has its roots in established CSCW and HCI literature, where appropriation is associated with the process of fitting new technologies in users’ practices in situ by adoption as well as adaptation of those technologies (Balka & Wagner, 2006; Dourish, 2003; Mackay, 1990; Gunnar Stevens et al., 2009). The concept of appropriation goes deeper than that of customization or tailoring of software in that it can encompass fundamental changes in practice and embraces the possibility of users adopting and using the technology in ways not anticipated by the designer (Pipek, 2005). Furthermore, it should be noted that appropriation is associated with processes of exchange and interaction in networks of co-users where experiences and stories are shared between actors involved in the appropriation process (Gantt & Nardi, 1992; Mackay, 1990; Pipek & Kahler, 2006; Pipek, 2005).

Pipek (2005) focused on developing appropriation support functionalities for connecting users of one tool, while both Star & Bowker, (2002) and Stevens et al. (2009) looked at ensembles of tools and suggested an appropriation framework that would also address the developer’s interest in improving the technology. Aside from the core features of an interactive system (e.g. a CAD tool, an IDE or a printer), this framework adds second-level-functionality to support all associated appropriation activities. Examples for appropriation frameworks for software-centered domains include the development and integration of a participative feedback tool into the Eclipse IDE (Draxler et al., 2012; Draxler & Stevens, 2011) or attempts at formalizing a theoretical appropriation model focused on software (Belin & Prié, 2012).

The integration of appropriation frameworks directly into the IS which it is intended to support has been thoroughly investigated and tested, and seems to have merit (Pipek, 2005; Gunnar Stevens et al., 2009; Yetim et al., 2012). Traditionally, whenever hardware is involved in such studies, it is mostly considered in a systemic way in conjunction with software (Dalton et al., 2012; March et al., 2005). Generally speaking, this makes sense since complex hardware usually also has software components. However, given the discrepancy between the scientific approaches with regard to software vs. hardware appropriation, we argue it is necessary to focus on hardware aspects in order to bring both sides to an even synthesis.

3 HARDWARE-CENTERED APPROPRIATION INFRASTRUCTURES

Summarized under the concept of sociable technology as ‘highly hardware-centered appropriation infrastructures’, Ludwig et al. (2014) have outlined several design implications for deploying an appropriation infrastructure to the machine itself. As their application field, they used 3D printing. Unlike traditional “plug-and-play”-printers from the “2D world”, there are only a handful of previous practices which users can relate to while handling 3D printers. Unexpected errors and breakdowns as well as complex configurations lead to difficulties in understanding and appropriating these machines for existing practices of ‘making’. The same could be interesting for modern CPPS because technology changes the current work practices of industrial manufacturing.

No.	Empirical Findings	Challenges and Design Implications
Current practices and usage behaviors during 3D printing		
1	The 3D printer itself is a black box for the users and lacks in methods to see and grasp how it really works	Sensor based capturing and visualizing of context and printer information to support a better understanding of the machine
2	General orientation of learning-by-doing and experimenting instead of an extensive literature research	Context-related ambient learning through software- and sensor-based hints / tutorials / best practices
3	Identifying and locating problems is an problem itself due to the high context-dependence of those problems	Sensor based capturing of environmental variables and mapping them to possible printing problems. Detailed visual presentation
4	The entire 3D printing process is very time-consuming because the users must always be close to the printer	Providing web-based and in-situ options for monitoring and managing the printer as well as communicating with it remotely
Documentation and knowledge sharing		
5	The printer settings with regard to the model, material and individual print are forgotten regularly	Integrated print history with printer settings, material data, errors, etc. Recommendations for current prints based on the history
6	Individual documentation and sharing of 3D printing experiences is very cumbersome and involves multiple systems which keeps users from doing it	Print history from 5. should be presented to the user together with easy to use tools to add more information
7	Difficulties in asking for help because often, not enough contextual information can be provided.	Data from steps 5 and 6 should easily be postable to 3D Printing communities and social networks
8	Knowledge, tips and hints in sharing communities are scattered and not really searchable / indexed	Establishing an orderly, searchable data structure (format) for the data from the previous steps
9	Community-specific terminology hampers appropriation	Community-maintained dictionary and automated “translator”
10	Technical validation (manifoldness, etc.) has to be done manually by the users and is not standardized.	Integrated validation tool checking model specifications and matching them to the printer’s characteristics.

Table 2: Empirical Study-based Design Implications for 3D printers as Sociable Technologies (Ludwig et al., 2014)

Ludwig et al. (2014) pointed out different design ideas for functionalities which support infrastructuring activities (Table 1). They build on previous work for software infrastructures (Dalton et al., 2012; Draxler & Stevens, 2011; Lazar & Preece, 2002; Mackay, 1990). However, the physical/material conditions in relation to the machine, printing material and artifacts also suggest enhancing those activities with additional sensors and visualizations of printing processes, printer environments and the tasks/structures/workflows the printing is embedded in, as well as by incorporating in-situ and remote tools for those purposes. They have shown that most infrastructuring measures were communicative or collaborative activities involving not only technology manipulations and combinations of various kinds, but also articulations of usages or breakdowns that referred to the technologies at hand and their context.

Studies on these kinds of communication are not completely new, but current practices deserve a second look. The practices of communication evolve along with the communication infrastructures users change with the developments of miniaturization, mobile and ubiquitous computing. The argument now is to use this ubiquitous interconnectedness of devices to make more technologies 'sociable', meaning that the support now available to users outside the technology itself – e.g. at hand in the internet in general, in community forums or in neighboring offices – should be integrated into the technologies themselves. Conceptually, these activities have been referred to as 'appropriation activities' if they consist of user-user interaction, or as 'infrastructuring activities' if they also relate to other actors of technology production and use, or to the further development of technologies and their foundations. A functionality to support all these practices within the existing infrastructure needs to address not only interoperability issues as they arise, e.g. by defining standardized interfaces between various infrastructural layers; it must also allow for – and actively support – the negotiation of the socio-material aspects of emerging new practices connected to these technologies.

Ludwig et al. (2014) showed that the ability to articulate and discuss usage and configuration issues would benefit from sociable technologies that describe themselves on three context levels, potentially using additional sensors, and providing visualizations and tools in three dimensions: (1) Internal context. At this level, information about the inner workings of a machine, including its current state as well as behavioral structure, should be provided; (2) Socio-material context, providing e.g. location and surroundings, environmental data such as room temperature, maintenance and user/usage data; and (3) Task/process context, affording information on e.g. the technologies used to build or prepare models, the position in a production chain or process, purpose and goal of machine usage.

4 DESIGN CHALLENGES FOR THE APPROPRIATION OF CPPS

Ludwig et al. (2014) have shown that most of the activities constituted around the appropriation of 3D printers were collaborative activities involving the configuration of a technology as well as the articulation of usages and their context. However, the complexity of CPPS does not only result in its ability to capture and process environmental data and to adapt its current state to those parameters in real-time in just *one* production process (vertically). Instead, CPPS aims to connect customers and suppliers along the *entire* value-added chain by exchanging information or even influencing business processes within the company itself (horizontally). This characteristic distinguishes CPPS from 3D printers or similar complex machines, which are used mainly in private contexts or within the maker community and thus demand a reconsideration of appropriation requirements. Manufacturing and delivery time, cost efficiency, quality standards, legal liability of products and processes or protection of business secrets are much more relevant to commercial than to private manufacturers. CPPS is highly dependent on the basic (network) infrastructure. These aspects, in combination with increasing process automation, hamper the operators' understanding of the machine. This leads to an enormous complexity which in turn demands design implications of CPPS to support users along the entire value-added chain from an HCI as well as CSCW perspective.

Based on the example of 3D printers, Ludwig et al. (2014) outlined ten design implications for hardware-centered appropriation, which might possibly also be adapted to CPPS. To examine how the design implications could be adapted, we conducted a workshop with several experts from the field of HCI with a proper understanding of both 3D printers as well as of manufacturing processes within enterprises. We discussed each design implication outlined by Ludwig et al. (2014) with regard to its potential adaption for CPPS. Then we tried to either outline its transferability or to sketch amendments. Our examination of the transferability of the design implications of 3D printers towards CPPS was aimed neither towards general validity nor comprehensive results. Instead, based on a discussion about the concept of sociable technologies by Ludwig et al. (2014), we wish to outline new thoughts on the appropriation of CPPS that could be taken up by HCI designers or system developers.

1. "*Sensor based capturing and visualizing of context and printer information to support better understanding of the machine*"

CPPS are based on sensor data to perform their tasks (Rajkumar et al., 2010). The sensors deliver all the relevant data processed within the machine itself or transmitted to other nodes for further processing. These processes and dependencies are hard to comprehend for machine operators; thus it is almost impossible for them to solve or even understand problems regarding the machines (Munir et al., 2013). The horizontal dimension of CPPS compounds this issue, as information might also influence the machine state that does not originate from within the company. Capturing and visualizing machine data and context information in-situ, as proposed by Ludwig et al. (2014), is therefore an essential design issue for CPPS. Access to this kind of information is promoted by the functionality of CPPS and is thus easy to acquire, given the necessary interfaces. A dashboard visualizing all relevant data about the product, machine and process should be presented to the machine operator on a display individually suitable for each operator, machine or process respectively. In addition to the proposed high-resolution display mounted on the machine, other displays need to be considered in the CPPS context. Machine operators monitoring a number of distributed machines during a shift benefit from portable displays, such as tablets, smartphones, data glasses and augmented reality glasses. These devices should render access to all the relevant information from every machine for which the operator is responsible during his or her shift. The dashboard should emphasize information related to the current operator's position. If s/he works at one specific machine, all the relevant information regarding this machine, the product(s) inside and the process should be displayed and all other information should be minimized and condensed to relevant figures or warnings, otherwise the operator could be overloaded with information.

2. "*Context-related ambient learning through software- and sensor-based hints / tutorials / best practices*"

Experimental learning approaches such as learning-by-doing, as occur when appropriating 3D printers, can – in the best case – only supplement formal learning methods such as professional courses or professional instructions in production companies. Training sessions are often organized only once following the acquisition of a machine, and are often included in the purchase price (even if new employees are taken on). This does not apply to safety-critical machines such as x-ray apparatus, where periodical training sessions have to be absolved by the operators. From a business point of view, CPPS can be considered critical, as incorrect operation might cause a chain reaction of errors possibly leading to economic damage. However, a mixture of context-related ambient learning such as additional hints or tutorials as well as formal learning, as proposed by Ludwig et al. (2014), could be applied to CPPS appropriation too, especially if formal training sessions only take place once. Due to the horizontal dimension of CPPS, these measures have to focus strongly on intra- and inter-organizational process information. First steps towards the use of augmented reality for supporting the manufacturing processes based on complex machines are already in place (e.g. Nee et al., 2012; Perey et al., 2014).

3. "*Sensor based capturing of environmental variables and mapping them to possible printing problems. Detailed visual presentation*"

This design implication strongly correlates with the first issue (capturing and visualizing). CPPS are equipped with all sensors necessary for performing their tasks and should therefore have detailed information on their actual state as well as relevant environmental data, including data provided by either suppliers or customers. However, this might not always be the case as circumstances not anticipated by the CPPS designers might affect functionality. Thus the integration of additional sensor information should be provided to assist the machine operator. Visualization should be integrated in the situations and devices mentioned in 1.

4. "*Providing web-based and in-situ options for monitoring and managing the printer as well as communicating with it remotely*"

As mentioned above, it is feasible that machine operators might have to watch several distributed CPPS during their shift, or the operators themselves might not even be located at the production site (miscellaneous sites, various time zones, working from home etc.). To provide support in these scenarios, both, monitoring as well as remote control functionality, are necessary, as Ludwig et al. (2014) proposed. Operators should have access to the relevant information regarding the portable devices mentioned above; or to a computer or monitor in the office or at home, respectively. They should be in a position to perform non-physical tasks remotely (machine restart, change of parameters, etc.). Although one might think that nowadays all machines can be operated remotely, especially in the manufacturing sector, this is not true: machines are often isolated applications. Of course, the suggested approach also presents a number of obstacles, e.g. establishing a secure connection or lowering the level of binding between operator and machine which in turn probably lowers the feeling of responsibility.

5. "*Integrated print history with printer settings, material data, errors, etc. Recommendations for current prints based on history*"

The vision of CPPS is that it can set up automatically for each related product and process, retrieving all the necessary information from the 'smart product', CAD or ERP. Thus, the issues pertaining to forgotten settings, or materials used for private 3D printing, do not apply to professional CPPS. However, logging data relevant to the machine, product and process as well as additional environmental data could definitely benefit companies, in terms of quality control and liability matters, as well as machine operators by supporting them in-situ. Particularly when errors occur, data history could be indispensable in speeding up the recovery process. Thus the proposed logging and visualization of the above information should be displayed optionally on the mentioned displays when requested; or automatically, in the case of an error, to help speed up the recovery process. This might be especially helpful if the error was caused by process data provided by parties in the value-added chain rather than by the machine.

6. "*Print history from 5. should be presented to the user together with easy to use tools to add more information*"

Ludwig et al. (2014) propose this feature further to support the user's memory regarding knowledge capturing and sharing. As mentioned in 5, CPPS retrieve all the necessary data from distinct sources. There would seem to be no need to add information to the data logged during a manufacturing process and relate it to the machine operator. However, if an error occurs, this functionality could be useful for adding information that might not have been captured by sensors or other data sources. It could also be used to help point out relevant events that obviously occurred but would have to be elaborately extracted from the raw or even aggregated data. These annotations could support the process quality and also the product ex post. Referring to the operator's working context, it should be easy to complete the annotations using the portable or stationary devices either onsite or remote. Due to the almost real-time character of CPPS processes, audio or video notices should be supported in addition to written notices.

7. "*Data from steps 5 and 6 should easily be postable to 3D Printing communities and social networks*"

This design implication that focuses on sharing process information with online communities or social networks has to be discussed ambivalently. Sharing the information from 5 and 6 is mainly a matter of data protection. This information may contain company secrets and cannot be shared to open access online communities, nor oftentimes even to closed online groups. Usually, companies conclude a contract with a CPPS producer which includes maintenance and support or even the machine's functionality as a service – one of the CPPS visions. Such business partners have to clearly negotiate issues regarding law and data protection by at least concluding a non-disclosure agreement. Based on these formal as well as technical perquisites, sharing this kind of information, e.g. to rectify an error cooperatively, might be a responsible scenario. Such information sharing could be established within closed communities of practices – people that share a common practice – within one company.

This does not apply to open communities or social media the same way, as obviously such contracts cannot be conducted with e.g. Facebook users in a legally acceptable way. However, not all CPPS are forced to be so complex; or professional support might not be available, or too expensive. In order to motivate the formation of an online community at all, another requirement is that the CPPS are nearly of the same kind. Given this context, sharing this kind of information in open online communities – as Microsoft administrators do to resolve Windows Server or Exchange issues, for example – could be helpful for machine operators as well to enable them to access help when malfunctions arise. To support this feature, help should be available to machine operators, allowing them to revise the information before sharing. Business secrets must be removed or made unrecognizable but in a way that does not surrender too much information. There should be the opportunity to set up an approval process before finally sending data to online communities. This way, machine operators are not solely responsible and thus business secrets will unlikely leave the company accidently. But there is still the matter of insurance and quality issues which must be addressed in future. One such issue might be the question of who is responsible for damages to the machine due to bad advice. This has to be considered selectively. On the one hand, machine operators would be responsible for any advice followed from (anonymous) open online communities. On the other hand, if damage were caused by the advice given by providers or machine manufacturers, the responsibility would lie with these contractors.

8. "*Establishing an orderly, searchable data structure (format) for the data from the previous steps*"

As mentioned above, industrial companies are not inclined to share detailed process or product information in open online groups as such data generally incorporates critical business secrets. A searchable data structure of this kind of information is not very feasible and will not be regarded further. However, it would be desirable if such a data structure were internally accessible within the company to enable the inclusion of knowledge from processes implemented in the past. In view of the requirements mentioned in 7, an error-related data structure would be valuable for both CPPS producers and open online communities. Taking the possibly large extent of context information regarding an error into consideration, the need for "[…] *a standardized, indexed and especially searchable data structure for the enriched information […]*" (Ludwig et al., 2014) for the machine operators is necessary. As CPPS usually work under nearly real-time circumstances, the fast retrieval of valuable information on errors saves time and can help prevent such consequences as missing a delivery date or even bringing a whole production chain to a full stop. Based on this data format, an API should therefore be provided by the data base to enable suggestions based on certain error parameters. This should help the machine operator to find a solution quickly or at least be able to work around the issue.

9. "*Community-maintained dictionary and automated 'translator'*"

CPPS are often much more complex than 3D printers. It is essential that machine operators have an adequate clarity of expression at their command in order to articulate questions or describe errors precisely. The proposed integrated dictionary and translator would support this in both open and closed online communities, as discussed before. The dictionary and translator would provide correct terms for the different machine components, thus providing valuable assistance to operators on the one hand and supporting a data-base pre-search by CPPS on the other.

This type of dictionary could also prove useful to service providers or producers, especially of customer-specific CPPS, who should be equipped with corresponding data bases to enable issues to be resolved quickly.

In both cases, due to the ability of CPPS to determine internal data, states and other information, the machine operator or support hotline should have at their disposal a meaningful error expression (like 3), but *including the correct terminology*. Additionally, the CPPS should present its components or processes and it should be included into and be easily accessible directly within the CPPS. This could be provided by a 3D model of the CPPS including all relevant terms and descriptions.

10. "*Integrated validation tool checking model specifications and matching them to the characteristics of the printer*"

This design implication is very specific to 3D printers and cannot easily be transferred to CPPS in the context of commercial companies. Issues regarding specific products and processes to produce them efficiently are business secrets and as such will most likely not be shared and discussed publicly. Affected companies are more likely to consult the CPPS producer or provider should any physical limitations arise.

5 CONCLUSION

For long term survival on the international market, industrial companies must adapt their products to changes in market trends at even shorter intervals, maintaining and expanding market positions with new, technologically more advanced, higher quality products at competitive prices. One suggested technical approach to respond to these challenges is the concept of cyber-physical production systems as distributed, networked smart objects to connect embedded systems with internet-based technologies (Rajkumar et al., 2010). Taking the complexity of CPPS and their dependency on several parameters into account, a number of obstacles appear when putting the technology into practice – especially from the machine operator’s perspective (Munir et al., 2013). The concept of sociable technologies might be one approach to resolve these issues as they encompass the machine operator’s appropriation of a machine directly into the hardware itself.

Ludwig et al. (2014) outlined ten design challenges when trying to design 3D printers as sociable technologies. We have adapted these design challenges to CPPS and, based on an expert workshop, we have outlined new design directions that need to be addressed when trying to apply the concept of sociable technologies to CPPS. We assume that, in comparison to 3D printers, the horizontal perspective towards the entire manufacturing process and the related supply chain, deserve particular attention. Most of the above listed design implications to support the appropriation of CPPS address vertical issues mainly regarding individual companies and do not focus on networked machines. CPPS are, however, not only smart production systems within the production line of a *single* company, but also span over entire value-added supply chains consisting of *different* companies to add even more efficiency to production processes. Ludwig et al. (2014) do not explicitly focus on this aspect and thus further research is needed to determine design implications for sociable technologies in the horizontal perspective of CPPS.

We are currently in touch with several small and medium enterprises that are interested in applying the concept of sociable technologies to their manufacturing process. These enterprises in particular often rely on the knowledge of their employees; integrating fully-automated systems to their practice will not always lead the companies towards successful production. As future work, we aim to examine how such companies might be able to use sociable technologies by applying human-centered approaches towards the adaption of CPPS and by including their employees in the entire process of implementation. During this deployment across the supply chain, we also will try to address the legal perspective of CPPS. For example, the field of CPPS does not focus on questions concerning who is responsible for (data) errors, or how errors can be determined in such a complex system comprised of many legally independent actuators. We will further move the concept of sociable technologies to other application fields like the design of medical technology.

6 REFERENCES

Balka, E., & Wagner, I. (2006). Making things work: dimensions of configurability as appropriation work. In *Proceedings of the 20th anniversary conference on Computer supported cooperative work* (pp. 229–238). ACM New York. doi:10.1145/1180875.1180912

Bauer, M., Jendoubi, L., & Siemoneit, O. (2003). Grundlagen ubiquitärer Systeme und deren Anwendung in der „Smart Factory“. *Industrie Management – Zeitschrift für den industriellen Geschäftsprozess*, *19*(6).

Becker, J., & Rosemann, M. (1993). *CIM und Logistik: Die effiziente Material- und Informationsflussgestaltung im Industrieunternehmen*. Springer-Verlag Berlin Heidelberg.

Belin, A., & Prié, Y. (2012). DIAM: Towards a model for describing appropriation processes through the evolution of digital artifacts. In *Proceedings of the Designing Interactive Systems Conference* (pp. 645–654). Newcastle, UK: ACM New York. doi:10.1145/2317956.2318053

Birkhahn, C. (2007). Smart Production Systems - intelligente Konzepte zur Gestaltung von Produktionssystemen. Kaiserslautern. doi:10.1007/978-3-662-45302-5

Bundesministeriums der Justiz. (2004). *Gesetz über technische Arbeitsmittel und Verbraucherprodukte (Geräte- und Produktsicherheitsgesetz - GPSG).*

Büring, E. (1997). *Anspruch und Realität computerintegrierter Produktionssysteme und Fertigungssteuerungskonzepte*. Duncker & Humblot.

Comes, T., Wijngaards, N., Hiete, M., Conrado, C., & Schultmann, F. (2011). A Distributed Scenario-Based Decision Support System for Robust Decision-Making in Complex Situations. *International Journal of Information Systems for Crisis Response and Management (IJISCRAM)*, *3*(4).

Dalton, N., MacKay, G., & Holland, S. (2012). Kolab: Appropriation & Improvisation in Mobile Tangible Collaborative Interaction. In *Proceedings of the Designing Interactive Systems Conference* (pp. 21–24). Newcastle, UK: ACM New York. doi:10.1145/2317956.2317960

Dourish, P. (2003). The Appropriation of Interactive Technologies: Some Lessons from Placeless Documents. *Journal Computer Supported Cooperative Work*, *12*(4), 465–490. doi:10.1023/A:1026149119426

Draxler, S., & Stevens, G. (2011). Supporting the Collaborative Appropriation of an Open Software Ecosystem. *Journal Computer Supported Cooperative Work*, *20*(4-5), 403–448. doi:10.1007/s10606-011-9148-9

Draxler, S., Stevens, G., & Stein, M. (2012). Supporting the social context of technology appropriation: on a synthesis of sharing tools and tool knowledge. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 2835–2844). Austin, Texas: ACM New York. doi:10.1145/2207676.2208687

Eisenhut, M., Lässig, R., & Liedl, J. (2011). *Production Systems 2020*. Roland Berger Strategy Consultants.

Fleisch, E. (2001). Betriebswirtschaftliche Perspektiven des Ubiquitous Computing. In H. U. Buhl, A. Huther., & B. Reitwiesener (Eds.), *Information Age Economy*. Heidelberg: Physica-Verlag.

Gantt, M., & Nardi, B. (1992). Gardeners and gurus: patterns of cooperation among CAD users. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 107–117). Monterey, CA: ACM New York. doi:10.1145/142750.142767

Geisberger, E., & Broy, M. (2012). *agenda CPS - Integrierte Forschungsagenda Cyber-Physical Systems*. *acatech STUDIE*. doi:10.1007/978-3-642-29099-2

Geitner, U. H. (1990). Die CIM-Konzeption. In U. H. Geitner (Ed.), *CIM-Handbuch* (pp. 3–41). Braunschweig.

Lazar, J., & Preece, J. (2002). Social considerations in online communities: Usability, sociability, and success factors. In H. Van Oostendorp (Ed.), *Cognition in the Digital World* (pp. 1–46). Lawrence Erlbaum Associates Inc. Publishers.

Ludwig, T., Stickel, O., Boden, A., & Pipek, V. (2014). Towards Sociable Technologies: An Empirical Study on Designing Appropriation Infrastructures for 3D Printing. In *Designing Interactive Systems* (pp. 835–844). Vancouver, Canada. doi:10.1145/2598510.2598528

Ludwig, T., Stickel, O., Boden, A., & Pipek, V. (2015). Appropriating Digital Fabrication Technologies – A comparative study of two 3D Printing Communities. In *iConference 2015 Proceedings*. Newport Beach, California.

Mackay, W. E. (1990). Patterns of Sharing Customizable Software. In *Proceedings of the 1990 ACM conference on Computer-supported cooperative work* (pp. 209–221). Los Angeles, CA: ACM New York. doi:10.1145/99332.99356

March, W., Jacobs, M., & Salvador, T. (2005). Designing technology for community appropriation. In *CHI 05 extended abstracts on Human factors in computing systems CHI 05* (pp. 2126–2127). Montreal: ACM New York. doi:10.1145/1056808.1057120

Munir, S., Stankovic, J. a., Liang, C.-J. M., & Lin, S. (2013). Cyber Physical System Challenges for Human-in-the-Loop Control. In *The 8th International Workshop on Feedback Computing*. San Jose, California, USA.

Nee, A. Y. C., Ong, S. K., Chryssolouris, G., & Mourtzis, D. (2012). Augmented reality applications in design and manufacturing. *CIRP Annals - Manufacturing Technology*, *61*(2), 657–679. doi:10.1016/j.cirp.2012.05.010

Perey, O. C., Community, a R., Alliance, E., & Wild, F. (2014). Advanced Manufacturing with Augmented Reality. In *IEEE International Symposium on Mixed and Augmented Reality (ISMAR)*. Munich, Germany.

Pipek, V. (2005). *From Tailoring to Appropriation Support: Negotiating Groupware Usage*. *Processing*. University of Oulu.

Pipek, V., & Kahler, H. (2006). Supporting Collaborative Tailoring. In *End-User Development* (pp. 315–345).

Rajkumar, R., Lee, I. L. I., Sha, L. S. L., & Stankovic, J. (2010). Cyber-physical systems: The next computing revolution. *Design Automation Conference (DAC), 2010 47th ACM/IEEE*. doi:10.1145/1837274.1837461

Shah, R., & Ward, P. T. (2007). Defining and developing measures of lean production. *Journal of Operations Management*, *25*, 785–805. doi:10.1016/j.jom.2007.01.019

Star, S. L., & Bowker, G. C. (2002). How to Infrastructure. In L. A. Lievrouw & S. Livingstone (Eds.), *Handbook of New Media: Social Shaping and Social Consequences of ICTs, Updated Student Edition* (pp. 151–162). London, UK: SAGE Pub.

Stevens, G., Pipek, V., & Wulf, V. (2009). Appropriation Infrastructure: Supporting the Design of Usages. In *Proceedings of the 2nd International Symposium on End-User Development* (pp. 50–69). doi:10.1007/978-3-642-00427-8_4

Stevens, G., Pipek, V., & Wulf, V. (2010). Appropriation infrastructure: Mediating appropriation and production work. *Journal of Organizational and End User Computing*, *22*(2), 58–81. doi:10.4018/978-1-4666-0140-6.ch012

Westkämper, E., & Jendoubi, L. (2003). Smart Factories - Manufacturing Environments and Systems of the Future. In *Proceedings of the 36th CIRP International Seminar on Manufacturing Systems*. Saarbruecken.

Womack, J. P., Jones, D. T., & Roos, D. (1990). *The Machine that Changed the World: The Story of Lean Production*. *World*. doi:10.1016/0024-6301(92)90400-V

Yetim, F., Draxler, S., Stevens, G., & Wulf, V. (2012). Fostering Continuous User Participation by Embedding a Communication Support Tool in User Interfaces. *AIS Transactions on Human-Computer Interaction*, *4*(2), 153–168.

Thomas Ludwig studied Information Systems at the University of Siegen (Germany) and University of Newcastle (Australia). Currently, he is a research associate and PhD student at the Institute for Information Systems at the University of Siegen. He finished his study on information systems in 2012. During his study, he worked as a student assistant in the research project 'INFOSTROM' dealing with IT-support for inter-organizational crisis management. Now he works in the research project 'EMERGENT', which deals with the impact of citizen-generated content of social media in crisis management and he leads the research project 'KOKOS' that deals with the integration of citizens into the official crisis response work. He further examines HCI issues of complex as well as critical software and hardware systems and researches how the users' appropriation of those systems can be supported by technology.

Christoph Kotthaus studied information systems at the University of Siegen (Germany). His research interest concerns mobile and ubiquitous computing. As a student assistant he worked in a research project called 'INFOSTROM', in which he was significantly involved in the development of a geo information system. He wrote his diploma theses about "Concepts for Mobile Device Management", in which he developed application possibilities, introduction and integration of mobile devices (smartphones, tablets) into the infrastructure of (industrial) companies inside a rail technology company. After his diploma thesis he worked as project manager in this company until he went back to the University of Siegen as a research associate in the field of computer supported cooperative work and social media at the Institute of Information Systems.

Volkmar Pipek, Prof. Dr., chairs the group of Computer-Supported Cooperative Work (CSCW) and Social Media at the University of Siegen, Germany. CSCW is an interdisciplinary field of research which includes not only methodology and contents of Computer Science and Information Systems, but also disciplines of business administration, organizations theory, ergonomics, sociology, psychology and anthropology/ethnography. Particularly the research areas deal with questions of the arrangement and acquirement of cooperative software systems in organizations, questions about communication based knowledge management and also with the support of communities. His current research focus lies on Infrastructuring, the analysis and design of infrastructure development processes that integrates professional methods and creativity patterns of designers and domain experts as well as Sociable Technologies as the part of IT product design that helps supporting these processes. Among other domains, this thinking is currently also applied to cyber-physical systems as well as crisis management.

Towards Efficient Security

Business Continuity Management in Small and Medium Enterprises

Christian Reuter, Institute for Information Systems, University of Siegen, Siegen, Germany

ABSTRACT

Business Continuity Management (BCM) is an integral part of civil security in terms of corporate crisis management. According to the ISO 22301 (2014) BCM is defined as a holistic management process which identifies potential threats to an organization and the impacts those threats might have on business operations. Looking at the current situation of studies conducted in this field it seems to be obvious that the use of BCM in Small and Medium Enterprises (SME) is underrepresented and that the security level is partially located in an uneconomical range. This paper presents a literature research on the use of BCM in SME and discusses research findings concerning this matter. Based on this a matrix for possible impacts vs. quality of the crisis management for different actors is derived. The article concludes with the presentation of lightweight und easy to handle BCM security solutions in form of Smart Services, as a possible solution for the increasingly IT relaying industry 4.0.

1 MOTIVATION AND INTRODUCTION

The power failures in India 2012 (670 million affected people), in Brazil and Paraguay 2009 (87 million affected people), in Europe 2006 (10 million affected people) and in the USA and Canada 2003 (55 million affected people) show that major unintended interruptions of the electrical power supply can still happen everywhere on the planet, even today (Reuter & Ludwig, 2013). The German parliament (2011) analyzed the threats for modern societies using the example of a long and large-scale breakdown of the power supply and came to the conclusion that based on the almost complete pervasion of the living and work environment with electronic driven devices the consequences can add up to a critical situation of outstanding quality.

Besides power failures there is a range of additional possible reasons - like the hurricane Kyrill in Europe 2007; the tsunami and earthquake disaster in Japan 2011; the hurricane Sandy in the USA 2012; and even events which seem slightly smaller. Some studies indicated that over the last decades the frequency and intensity of natural disasters increased (Berz, 1999). The consequences can be so large-scale that the security of the citizens is not only concerned in their private but even in their work environment. The negative influence on the continuous economic practice of enterprises is another possible consequence of a breakdown.

This can lead to problems in business processes - for example if workflow-management components fail (Reuter & Georg, 2008) and cause additional extensive damage.

Since the third industrial revolution (digital revolution) - the usage of electronic and IT for automation of the production - and at least since the upcoming fourth industrial revolution - the merging of the real and the virtual world to become an internet of things which is being discussed as the future project of “industry 4.0” (Bundesministerium für Bildung und Forschung, 2015) - enterprises increasingly depend on the continuous use of IT.

However, due to the relative low chance e.g. of power failures in Western Europe the overall preparations are not optimal (Birkmann, Bach, Guhl, Witting, et al., 2010). The German Federal Ministry of the Interior (Bundesministerium des Inneren, 2009) calls this fact *vulnerability paradox*: In the dimension in which the supply performance of a country is less accident-sensitive, the effect of an accident is even stronger. Especially societies which use high industrialized and very complex technologies react more sensible to accidents because they are used to very high security standards and high supply reliability. Because of an increasing robustness and a lower accident-sensitivity it is possible that an illusory feeling of safety evolves. This can lead to the consequence that the impact of an accident which happens despite that is disproportionately high (Bundesministerium des Inneren, 2009, p. 10).

Conversely there exists a trend that public and even more private infrastructure carriers are in the area of conflict between consistently basic service and economic optimization (Kloepfer, 2005, p. 17). Therefore there is a risk that the availability of infrastructure is reduced to the contractual and businesslike minimum. Due to the resources we assume that the arising gap can at best be compensated by large enterprises, partially by SME and not at all by individuals.

BCM should contribute to the maintenance of the supply of production and/or service processes of an organization in previously defined levels; for those who would fail in case of an incident that causes a business interruption (Bundesamt für Sicherheit in der Informationstechnik, 2008). The safety of SME is essential for the European economy because they represent 99% of all enterprises (Thiel & Thiel, 2010). In this paper we aim to answer the research question if and how BCM can, could or should be used in SME.

Using the scientific literature databases available at the university a search for “BCM and SME” (abbreviated and unabbreviated) has been performed. We summarize the state of the art, propose a model for possible impacts vs. range and quality of the crisis management for different actors, and derive suggestions how to move towards efficient security.

2 DEFINING CONTINUITY MANAGEMENT

Business Continuity Management (BCM) is defined by the ISO 22301 (2014) as a “holistic management process that identifies potential threats to an organization and the impacts to business operations those threats, if realized, might cause.“ BCM “provides a framework for building organizational resilience with the capability of an effective response that safeguards the interests of its key stakeholders, reputation, brand and value-creating activities“. According to the German Federal Office for Information Security (BSI, 2008) BCM is a “management process with the goal to discover fatal risks for an institution that could endanger the viability at an early stage and establish methods against them.”

BCM as a kind of crisis management has evolved since the 1970s as a reaction to technical and operational risks concerning enterprises (Herbane, 2010a). The first international valid standard for BCM was only published back in 2012 in form of the ISO 22301 (2012) (in German: ISO 22301, 2014). The standard specifies requirements to plan, establish, realize, run, monitor and review a continuity management system and to improve it continuously. It replaced the previously existing British Standard BS 25999 (2007). More international standards are the US-American NFPA 1600: Standard on Disaster/Emergency Management and Business Continuity Programs (2013) as well as the Canadian CSA Z1600: Essential Emergency Management and Business, based upon it.

The German BSI-standard 100-4 (2008) for emergency management in enterprises shows a systematic way to ensure the continuity of business operations. Challenges for an emergency management are therefore to increase the reliability and to adequately prepare the institution for emergencies and crises, so that the important business operations can be quickly resumed. It is the goal to minimize damages caused by emergencies and crises and to secure the existence of the government agency or the enterprise even in major critical situations.

There are many reservations about emergency management (Bundesamt für Sicherheit in der Informationstechnik, 2014): the denial of possible risks, the fear, that the necessary activities and the measures to implement for emergency prevention are only going to complicate the processes in the organization, a certain carelessness (“Things always worked out fine before”), the exclusive treatment of this topic from the angle of costs, or the aversion to deal with this task without any direct external force. But also if more open mindedness for this topic existed, it wouldn’t necessarily lead to actually doing more for emergency prevention. These are declarations of intents, which however take a back seat quickly in the daily business. Furthermore an institution leaves it at isolated technical measures (“better data protection”) without examining, if these measures are sufficiently effective in emergency situations or crises.

Examples are easy to find: In 2006 the transfer of the ocean liner Norwegian Pearl from the shipyard at the Ems to the North Sea could entail power failure up to North Africa (in consequence of the selective shutdown of a small part of the grid in order to facilitate the safe transfer of the Norwegian Pearl, and a concatenation of unfortunate circumstances). In October 2008 because of the failure of a substation in Hannover in about 150 banks the cash machines, bank statement printers and the Online-Banking couldn‘t be used anymore throughout whole Germany. In January 2009 faultily performed maintenance work in a computer center resulted in the fact, that no rail tickets could be sold throughout Germany for hours, the trains had substantial delays or were cancelled and furthermore in many places several customers complained about the, from their perspective, insufficient information from the concerned transport company. The volcanic eruption of Eyjafjallajökull in April 2010 (Reuter et al., 2012) in Iceland, could lead to a nearly complete standstill of the air traffic in Europe for days. This for example raised the fear of production interruptions in several companies because of delayed supplies.

The examples have in common, that ostensible local events brought along unexpected broad effects and considerable damages. The instances show how cross-linked, and thus simultaneously vulnerable modern industrial countries and their institutions are.

3 RESEARCH FINDINGS ON THE PERCEPTION OF INFRASTRUCTURE BREAKDOWNS

Remarkably, power failures as examples for causes, are hardly perceived as a real threat in the population (Lorenz, 2010). According to a survey on a London power failure in 2003, many respondents reacted surprised by the fact, that failures like this can happen at all (Brayley et al., 2005). The lack of the power supply is not combined with fear or concerns. If devices necessary for the household, like a refrigerator or stove or even the computer are not working anymore, it is accepted in the first place. However, according to the respondents, longer-term failures would quite be noticed, in particular the absence of critical infrastructures. Furthermore, the fact, that the supra-regional media report little about power failures, leads to a lower risk perception among the population (Lorenz, 2010). According to Lorenz (2010, p. 29) certain information is not aware in the population and cannot be adequately implemented until it is integrated in a broad dialogue about possible dangers because of power or infrastructure failures. Therefore the Federal Ministry for nutrition gives the advice to get a stock of food lasting for 14 days, to be capable of acting in emergency situations (Bundesministerium für Ernhährung, 2010).

Necessarily the question arises whether solely the communication throughout the population should be supported in an infrastructure failure or if moreover possibilities should be worked out to meet the information needs among the population already before the failure (Reuter, 2014a). Furthermore the capacity for self-help of the population is the most important factor to determine, how much time goes by from the beginning of the catastrophe to the irreversible destruction of social structures (Lorenz, 2010, p. 34). This capacity for self-help implies that people are able to communicate with each other in a crisis and receive or share crisis-relevant information.

In many cases the population is just seen as a passive and needy receiver of help, which at best takes thankfully and at worst complicates the organizational processing of the problem situation by professional actors due to its conduct (Lorenz, 2010). In other words the population is assigned a victim role (Hunt, 2003). These conclusions turn out to be premature. On the contrary the population has to play the role of an important participant during a crisis. Thus many citizens use their social groups and networks to help each other and receive or share information (Drabek, 2013; Murphy, 2004). Quarantelli (1993, p. 73) describes that population groups immediately try to tackle the problems caused by a crisis in such situations. Moreover the population names coordination and a decentralized decision making as the most effective ways to react to a crisis. “Contrary to what is often portrayed, local citizens are the true ‘first responders’ in emergency situations”, Palen, Hiltz, & Liu (2007, p. 54) wrote and emphasized that citizens often act as first-aiders and bring victims or injured people to the hospitals. Coombs (2009) demands so-called *Instructing Information*, which points out how affected persons can protect themselves and behave before or in a crisis. When an exceptional situation already occurred such information must also be provided to supply the persons, which haven’t received these information before the crisis (Reuter, 2014a). The importance of the population as a participating actor to react to a crisis therefore implies appropriate possibilities for the acquisition and dissemination of relevant information.

The necessity of communication during a crisis scenario is also the result of the information needs of the individual (Reuter, 2014a). A power failure which endures for longer than 24 hours could already have serious consequences for the patients in a hospital. The UPS (uninterruptible power supply) ensures an emergency operation in the first 24 hours. Individual organizational areas, like the administration are already restricted. After 24 hours the failure of the UPS leads to the point that certain medical devices no longer function or medical products cannot be cooled anymore (Hiete et al., 2010). The power failure in the Münster region entailed the situation, that 20.000 people couldn’t be supplied with power up to four days later (Birkmann, Bach, Guhl, & Witting, 2010). The scenario of a hospital without access to electricity for a longer time is thus quite realistic and dangerous. Hence information needs exist in particular for the population outside the hospital, because the patients on-site can be informed by the employees. In the Münster region the power failed because of the storm Torsten due to a low pressure area, which is kind of a crisis before the crisis (Birkmann, Bach, Guhl, & Witting, 2010). Information about hospitals with emergency power supplies can be vital for persons, which for example were injured due to falling trees landing on their motor vehicles and thus must be treated urgently, because they possibly can't get the needed treatments without the information.

4 RESEARCH FINDINGS ON THE USE OF BCM IN SME

BCM is dedicated for all kinds of enterprises regardless of its size. According to the definition of the EU-Commission (2003) an enterprise belongs to the SME if it does not have more than 249 employees and annual sales not higher than 50 million Euro or a total asset of 43 million Euro at most. The safety of SME is essential for the European economy because they represent 99% of all enterprises (Thiel & Thiel, 2010) and SME are sometimes considered to be most vulnerable to the impacts from various disruptions. Therefore the need for SME to implement effective coping mechanisms to manage the effects of extreme weather events is increasing (Wedawatta et al., 2010).

However, according to a study of the Network Electronic Trading only every fifth SME prepares an emergency plan for IT and every fourth SME lacks in a standardized procedure for dealing with IT emergencies as quickly as possible (Duscha, 2009). Other studies discovered that 45% of the US-American and European SME could not show a BCM concept (ENISA, 2009). Another study in Great Britain shows that BCM is significantly less present in SME (Musgrave & Woodman, 2001). Furthermore rather 41% of the enterprises do not plan for crises of all kind at all (Semantec, 2011).

Herbane (2010b) empathized the economically meaning and vulnerability of SME. Through the comparison of research literature in the area of SME research and crisis management he summarizes that more attention towards a combined observation of both areas is necessary. Especially the use of BCM in and for SME was not much examined yet (Herbane, 2013). Other studies indicate that the security level in SME is significantly lower than in large enterprises (Duscha, 2009; European Network and Information Security Agency (ENISA), 2009; Musgrave & Woodman, 2001). A questionnaire survey, conducted as part of a "Community Resilience to Extreme Weather" research project, identified that SME mostly rely on "generic business continuity strategies as opposed to property level protection measures" (Wedawatta et al., 2010). A case study investigated five SME' actual crisis management practices. The results show that "SME, in spite of their resources constraints and relatively weak market positions, display resilient market responsiveness" (Hong et al., 2012).

An essential reason against the introduction of BCM in SME is the effort to implement abstract and generic described safety precautions in the working practice (ENISA, 2009). The complexity of BCM was identified as a problem for SME: Guidelines have to be translated into an individually fitting and understandable language; this step is hard to do for a SME (Thiel & Thiel, 2010). According to the European Network and Information Security Agency (ENISA, 2009) there is a huge need for simplified approaches regarding safety und crisis management. The *natural disaster syndrome,* as indicated by Hurricane Katrina is another observation: "Prior to a disaster, individuals in hazard-prone regions do not voluntarily adopt cost-effective loss reduction measures. The federal government then comes to the rescue with disaster assistance even if it claimed it had no intention of doing so prior to the event" (Kunreuther, 2006).

5 MODEL: (IN-) EFFICIENT SECURITY

Taking the research findings of the previous chapter into consideration some conclusions are obvious: The security level in SME is lower than in large enterprises; BCM is also not as common in SME as in large enterprises; however, also SME have risks.

It is possible to turn these observations in a descriptive model (Figure 1): The x-axis of the graph shows the possible impact, the y-axis the quality of emergency management.

- *Individuals* (on the bottom left in Figure 1) normally do not have a dedicated safety management in terms of BCM and little safety engineering with normally little consequences in case of a breakdown. Reasons why individuals do not protect themselves prior to a disaster are that they "underestimate the likelihood of a future disaster, often believing that it will not happen to them; have budget constraints; are myopic in their behavior; and/or do not want to be the only one on the block modifying their structure" (Kunreuther, 2006).
- Large *enterprises* deal with this intensively by high economic consequences at the same time (e.g. production breakdowns, process interruptions).
- But particular *SME* – which have been shown in the previous sections - have a undersupply in this area in relation to the possible consequences, as mentioned above (e.g. Duscha, 2009; ENISA, 2009; Thiel & Thiel, 2010). Therefore it is needed to deduce approaches for enhancing the quality of the emergency management.

The position of the different groups is based on the findings discussed in the literature review – however it needs to be evaluated with empirical data explicitly observing the possible impact and the quality of emergency management, also to quantify the corridor of efficient security, which currently is just defined as the meaningful measure between potential risk and protection. Rather clear from the perspective or other studies is that most SME are not optimal protected – and it is agreed, that the level of security needs to be improved while avoiding high investments, but by providing SME appropriate solutions.

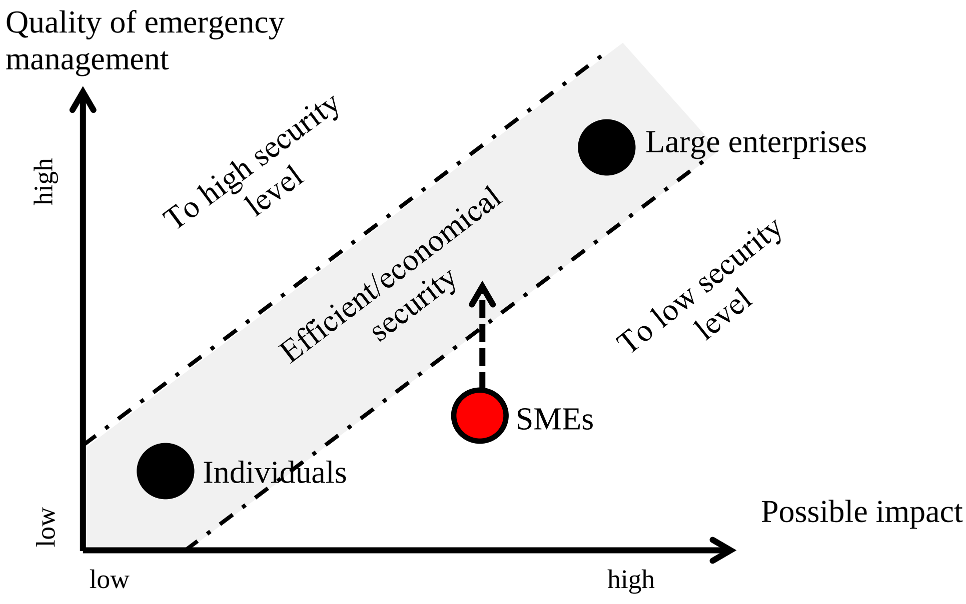

Figure 5: Efficient Security: Individuals, SME and large enterprises regarding impact vs. quality of the emergency management.

It has to be considered that the matrix looks different for different industries – and the aim is not to highlight all those differences, but to make aware that according to many articles SME are more likely to be in the corridor of non-efficient security. Still, some industries (including SME) are very security relevant (e.g. chemical industry) – therefore there are high requirements on BCM by law. Using the example of Germany, according to an emergency regulation - § 10 Störfallverordnung (Bundesrepublik Deutschland, 2015) - for some operation areas a safety report is required and the responsible emergency response authority has to create an external emergency plan as well, where the data related to the operating range (prepared) measures of emergency authority are described.

6 TOWARDS EFFICIENT SECURITY: APPROACHES FOR BCM IN SME

Besides the descriptive nature of the model (position of individuals/SME/enterprises) the model also contains a normative aspect on the intention to move SME towards efficient security.

Even if there was not too much research conducted in this area yet there already exist some approaches to improve BCM in SME: As Sullivan-Taylor & Branicki (2011) notice in their fittingly named article “why one size might not fit all”, enterprises of different sizes are leading to varying requirements for the use of BCM-systems. BCM for SME should consider the conditions of SME, like providing low personal resources, a lack of expert knowledge in risk management, and support for IT layman (Thiel & Thiel, 2010).

Based on a survey and interview study with 59 SME and resulting benchmarks Thiel & Thiel (2010) present a guideline of enterprise specific BCM for the implementation in SME which includes the individual SME characteristics, and which acts as a translator in the form of breaking the complex requirements down to the practice of SME. Another approach by Wedawatta & Ingirige (2012) suggests a combination of object-based safety measurements und generic BCM-measurements to strengthen the resilience of SME. Li et al. (2015) focus on the development of an agent-based model for simulating and deducting solution strategies for SME in case of a flood. Lee & Jang (2009) emphasize the information safety as a special aspect of BCM and develop an information security management system model for SME. Horváth (2013) also presents an integrated system for merging BCM with information security management activities. The tool, developed by Sapateiro et al. (2011), emphasizes the collaborative BCM activities and could be called a lightweight BCM solution, independent of the size of the enterprise which addresses the collaboration, the knowledge management, the team performance and the awareness of the situation.

Lightweight, simple and efficient BCM as a service for SME currently still represents a gap in research and development. The development of new business models and hybrid value chains for lightweight and easy to handle BCM security solutions for SME should support the phase before the crises (identification of important data, processes and workplaces, risk evaluation, action plans, exercises, measurement of the effectivity und efficiency of the actions) as well as the phase after the occurrence of the crises to enhance the level of the safety management. Smart services - services that are integral part of a product (Allmendinger & Lombreglia, 2005) - could reduce the necessary level of investment and complexity for SME.

While looking at specific security relevant industries, advanced BCM and security solutions are already implemented. Also insurances reward the use of BCM and security preparations – as long as their risk is reduced as well. Some insurance companies already provide services, such as weather warnings for free for their clients[16] and it is obvious that such services can also reduce the risk for the insurance company. Concerning SME, advanced services – besides consulting and insurance – might help them to move their behavior towards the area of efficient security.

According to the German Federal Office for Information Security SMEs use more and more virtualization technologies and cloud services to protect their IT based business processes against failure (Bundesamt für Sicherheit in der Informationstechnik, 2013). According to a recent study by BITKOM, however, the demand for cloud services will continue to grow worldwide. In 2014 the market for cloud computing rose by 46 percent to 6.4 billion euros. Until 2018, an increase of the cloud market is forecast at 19.4 billion euros, stating an annual growth rate of 35 percent (BITKOM, 2014)

7 CONCLUSION AND SUMMARY

The need to implement BCM for SME is incontrovertible. Apart from reasons such as ensuring the productivity and the continuation of the firm, different laws require the use of BCM.

Much prior research – as indicated by Herbane (2010b) – has focused on SME or crisis management, however a combination has seldom be considered. In order to review the few work that has been done in this field this article investigated the current research situation in the area of the business continuity management (BCM) in small and medium enterprises (SME) and has deduced a matrix for the positioning of SME in relation to possible impacts vs. quality of crisis management. The matrix provides a decent visualization of why research in this area is valuable and necessary.

The reviewed research findings lead to the conclusion that the use of BCM in SME seems to be low (Duscha, 2009). Other articles claim that exact findings are still missing (Herbane, 2013). It became especially obvious that SME have other requirements for the range of a solution, matching their individual risk and enterprise size (Sullivan-Taylor & Branicki, 2011). In order to address the specifics of SME lightweight and easy to handle BCM solution for SME as smart services are required and need to be researched.

Considering the *IT usage in emergent situations* that are dynamic and not predictable (Reuter, 2014b) as well as the need for an *uninterruptible IT use* in the industry 4.0 – this therefore provides a research gap. In future work studies about the use of BCM in SME combined with lightweight BCM services might contribute to the available knowledge in this field.

8 REFERENCES

Allmendinger, G., & Lombreglia, R. (2005). Four strategies for the age of smart services. *Harvard Business Review*, *83*(10). doi:10.1225/R0510J

Berz, G. (1999). Naturkatastrophen an der Wende zum nächsten Jahrhundert – Trends, Schadenpotentiale und Handlungsoptionen der Versicherungswirtschaft. *Zeitschrift für die gesamte Versicherungswissenschaft*, *88*(2-3), 427–442.

Birkmann, J., Bach, C., Guhl, S., & Witting, M. (2010). State of the Art der Forschung zur Verwundbarkeit kritischer Infrastrukturen am Beispiel Strom / Stromausfall. Risk Management. In *Forschungsforum öffentliche Sicherheit*.

[16] https://www.provinzial.de/web/html/privat/service/wind_und_wetter/

Birkmann, J., Bach, C., Guhl, S., Witting, M., Welle, T., & Schmude, M. (2010). *State of the Art der Forschung zur Verwundbarkeit Kritischer Infrastrukturen am Beispiel Strom / Stromausfall*. *Risk Management*. Berlin, Germany. Retrieved from http://www.sicherheit-forschung.de/schriftenreihe

BITKOM. (2014). Markt für Cloud Computing wächst ungebrochen. Retrieved from http://www.bitkom.org/de/presse/81149_80724.aspx

Brayley, H., Redfern, M. a., & Bo, Z. Q. (2005). The Public Perception of Power Blackouts. *2005 IEEE/PES Transmission & Distribution Conference & Exposition: Asia and Pacific*, 1–5.

British Standards Institution. (2007). *British Standard BS 25999: Business Continuity Management*.

Bundesamt für Sicherheit in der Informationstechnik. (2008). *Notfallmanagement – BSI-Standard 100-4*. Bundesanzeiger Verlag. Retrieved from https://www.bsi.bund.de/cae/servlet/contentblob/471456/publicationFile/30746/standard_1004.pdf

Bundesamt für Sicherheit in der Informationstechnik. (2013). Notfallmanagement mit der Cloud für KMUs. Retrieved from https://www.bsi.bund.de/SharedDocs/Downloads/DE/BSI/Mindestanforderungen/Notfallmanagement_mit_der_Cloud_KMUs.pdf?__blob=publicationFile

Bundesamt für Sicherheit in der Informationstechnik. (2014). *Webkurs Notfallmanagement auf Basis von BSI-Standard 100-4*. Retrieved from https://www.bsi.bund.de/DE/Themen/ITGrundschutz/ITGrundschutzSchulung/Webkurs1004/0_Startseite/StartseiteWebkurs_node.html

Bundesministerium des Inneren. (2009). *Nationale Strategie zum Schutz Kritischer Infrastrukturen (KRITIS-Strategie)*. Berlin.

Bundesministerium für Bildung und Forschung. (2015). Zukunftsprojekt Industrie 4.0. Retrieved from http://www.bmbf.de/de/9072.php

Bundesministerium für Ernhährung. (2010). Private Vorsorge: Notvorrat.

Bundesrepublik Deutschland. (2015). Zwölfte Verordnung zur Durchführung des Bundes-Immissionsschutzgesetzes (Störfall-Verordnung - 12. BImSchV). Retrieved from http://www.gesetze-im-internet.de/bundesrecht/bimschv_12_2000/gesamt.pdf

Coombs, W. T. (2009). Conceptualising Crisis Communication. In R. L. Heath & D. O'Hair (Eds.), *Handbook of Risk and Crisis Communication* (pp. 99–118). New York.

Deutscher Bundestag. (2011). *Gefährdung und Verletzbarkeit moderner Gesellschaften – am Beispiel eines großräumigen und langandauernden Ausfalls der Stromversorgung*. (T. Petermann, H. Bradke, A. Lüllmann, M. Poetzsch, & U. Riehm, Eds.). Retrieved from dip21.bundestag.de/dip21/btd/17/056/1705672.pdf

Drabek, T. E. (2013). *The human side of disaster*. CRC Press.

Duscha, A. (2009). Netz- und Informationssicherheit in Unternehmen 2009. Studie des Verbundprojekts „Sichere E-Geschäftsprozesse in KMU und Handwerk". Retrieved from http://www.mittelstand-digital.de/MD/Redaktion/DE/PDF/studie-it-sicherheit-2009-pdf

Europäische Union. (2003). *Empfehlung der Kommission vom 6. Mai 2003 betreffend die Definition der Kleinstunternehmen sowie der kleinen und mittleren Unternehmen. (2003/361/EG). Artikel 2 des Anhangs*. Retrieved from http://eur-lex.europa.eu/legal-content/DE/TXT/PDF/?uri=uriserv:OJ.L_.2003.124.01.0036.01.DEU

European Network and Information Security Agency (ENISA). (2009). Assessing a simplified Information Security approach. Retrieved from http://www.enisa.europa.eu/publications/archive/assessing-a-simplified-information-security-approach

Herbane, B. (2010a). The evolution of business continuity management: A historical review of practices and drivers. *Business History*, *52*(6), 978–1002. doi:10.1080/00076791.2010.511185

Herbane, B. (2010b). Small business research - Time for a crisis-based view. *International Small Business Journal*, *28*(1), 43–64. doi:10.1177/0266242609350804

Herbane, B. (2013). Exploring Crisis Management in UK Small and Medium Sized Enterprises. *Journal of Contingencies and Crisis Management*, *21*(2), 82–95. Retrieved from http://onlinelibrary.wiley.com/doi/10.1111/1468-5973.12006/full

Hiete, D. M., Merz, M., & Trinks, C. (2010). *Krisenmanagement Stromausfall Kurzfassung - Krisenmanagement bei einer großflächigen Unterbrechung der Stromversorgung am Beispiel Baden-Württemberg*. (Innenministerium Baden-Würtemerg & Bundesamt für Bevölkerungsschutz und Katastrophenhilfe, Eds.). Stuttgart.

Hong, P., Huang, C., & Li, B. (2012). Crisis management for SMEs: insights from a multiple-case study. *International Journal of Business Excellence*, *5*(5), 535–553. doi:10.1504/IJBEX.2012.048802

Horváth, G. K. (2013). Information Security Management for SMEs: Implementating and Operating a Business Continuity Management System (BCMS) Using PDCA Cycle. In *Proceedings of FIKUSZ* (pp. 133–141). Budapest, Hungary.

Hunt, A. (2003). Risk and moralization in everyday life. In R. V. Ericson & A. Doyle (Eds.), *Risk and morality* (pp. 165–192). Toronto: University of Toronto Press.

ISO 22301. (2012). Societal security - Business continuity management systems - Requirements. Retrieved from http://www.iso.org/iso/catalogue_detail.htm?csnumber=50038

ISO 22301. (2014). *Sicherheit und Schutz des Gemeinwesens – Business Continuity Management System – Anforderungen (ISO 22301:2012); Deutsche Fassung EN ISO 22301:2014*.

Kloepfer, M. (2005). *Schutz kritischer Infrastrukturen*. Nomos.

Kunreuther, H. (2006). Disaster Mitigation and Insurance: Learning from Katrina. *The ANNALS of the American Academy of Political and Social Science*, *604*(1), 208–227. doi:10.1177/0002716205285685

Lee, W., & Jang, S. (2009). A Study on Information Security Management System Model for Small and Medium Enterprises. *Recent Advances in E-Activities, Information Security and Privacy*, 84–87.

Li, C., Coates, G., Johnson, N., & Mcguinness, M. (2015). Designing an Agent-Based Model of SMEs to Assess Flood Response Strategies and Resilience. *International Journal of Social, Education, Economics and Management Engineering*, *9*(1), 7–12.

Lorenz, D. F. (2010). Kritische Infrastrukturen aus Sicht der Bevölkerung. *Schriftenreihe Forschungsforum Öffentliche Sicherheit der FU Berlin*, *3*, 1–97.

Murphy, B. L. P. D. (2004). Emergency Management and the August 14th, 2003 Blackout. In *Institute for Catastrophic Loss Reduction* (pp. 1–9).

Musgrave, B., & Woodman, P. (2001). Weathering the storm - The 2013 Business Continuity Management Survey. *Airline Business*. doi:10.1111/j.1751-486X.2009.01490.x

National Fire Protection Association (NFPA). (2013). NFPA 1600: Standard on Disaster/Emergency Management and Business Continuity Programs. Retrieved from http://www.nfpa.org/codes-and-standards/document-information-pages?mode=code&code=1600

Palen, L., Hiltz, S. R., & Liu, S. B. (2007). Online forums supporting grassroots participation in emergency preparedness and response. *Communications of the ACM*, *50*(3), 54. doi:10.1145/1226736.1226766

Quarantelli, E. L. (1993). Community Crises: An Exploratory Comparison of the Characteristics and Consequences of Disasters and Riots. *Journal of Contingencies and Crisis Management*, *1*(2), 67–78. doi:10.1111/j.1468-5973.1993.tb00009.x

Reuter, C. (2014a). Communication between Power Blackout and Mobile Network Overload. *International Journal of Information Systems for Crisis Response and Management (IJISCRAM)*, *6*(2), 38–53.

Reuter, C. (2014b). *Emergent Collaboration Infrastructures: Technology Design for Inter-Organizational Crisis Management (Ph.D. Thesis)*. Siegen, Germany: Springer Gabler. Retrieved from http://www.springer.com/springer+gabler/bwl/wirtschaftsinformatik/book/978-3-658-08585-8

Reuter, C., & Georg, C. (2008). Entwicklung eines webbasierten Dokumentenmanagement-Systems für eine Fluggesellschaft. *Journal WIRTSCHAFTSINFORMATIK*, *50*(2), 142–145.

Reuter, C., & Ludwig, T. (2013). Anforderungen und technische Konzepte der Krisenkommunikation bei Stromausfall. In M. Hornbach (Ed.), *Informatik 2013 - Informatik angepasst an Mensch, Organisation und Umwelt* (pp. 1604–1618). Koblenz, Germany: GI-Edition-Lecture Notes in Informatics (LNI).

Reuter, C., Marx, A., & Pipek, V. (2012). Crisis Management 2.0: Towards a Systematization of Social Software Use in Crisis Situations. *International Journal of Information Systems for Crisis Response and Management (IJISCRAM)*, *4*(1), 1–16.

Sapateiro, C., Baloian, N., Antunes, P., & Zurita, G. (2011). Developing a Mobile Collaborative Tool for Business Continuity Management. *Journal of Universal Computer Science (j.ucs)*, *17*(2), 164–182.

Semantec. (2011). SMB Disaster Preparedness Survey. Retrieved from http://www.symantec.com/about/news/resources/press_kits/detail.jsp?pkid=dpsurvey

Sullivan-Taylor, B., & Branicki, L. (2011). Creating resilient SMEs: why one size might not fit all. *International Journal of Production Research*, *49*(18), 37–41. doi:10.1080/00207543.2011.563837

Thiel, C., & Thiel, C. (2010). Business Continuity Management für KMU. *Datenschutz und Datensicherheit - DuD*, *34*(6), 404–407. doi:10.1007/s11623-010-0114-3

Wedawatta, G., & Ingirige, B. (2012). Resilience and adaptation of small and medium-sized enterprises to flood risk. *Disaster Prevention and Management: An International Journal*, *21*(4), 474–488.

Wedawatta, G., Ingirige, B., & Jones, K. (2010). Coping strategies against extreme weather events: a survey of SMEs in the UK. In *COBRA 2010*. RICS.

Dr. Christian Reuter studied Information Systems at the University of Siegen, Germany and the École Supérieure de Commerce de Dijon, France (Dipl.-Wirt.Inf.; M.Sc.) and received a PhD for his work on (inter-)organizational collaboration technology design for crisis management (Dr. rer. pol.) with summa cum laude. He has worked as a web developer, consultant and researcher and has published more than 60 scientific articles. He is voluntary founding spokesman of the section "human computer interaction in security relevant systems" of the German Informatics Society.