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

Special Issue on Human Computer Interaction in Critical Systems I: Citizen and Volunteers

IJISCRAM, Volume 7, Issue 2

Christian Reuter, Tilo Mentler, Stefan Geisler (Eds.)

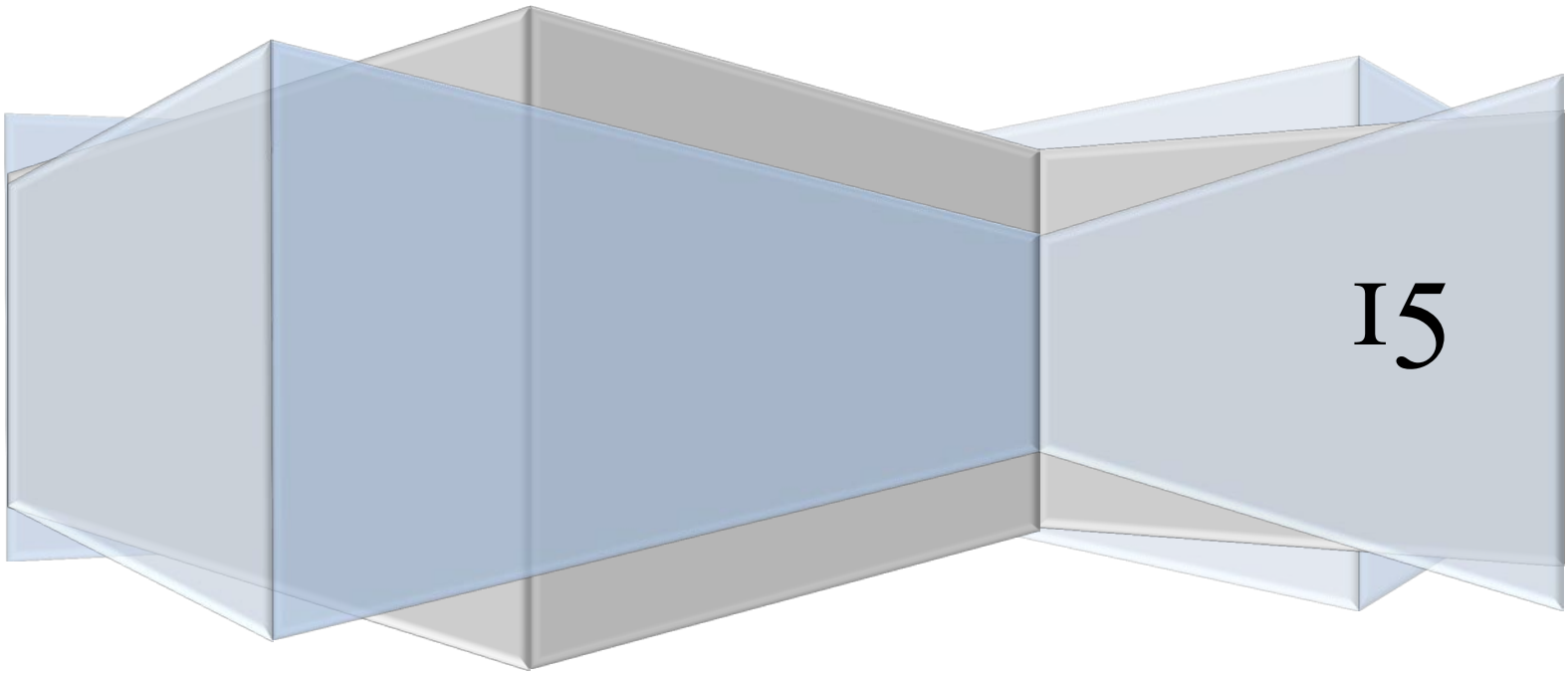


TABLE OF CONTENTS

GUEST EDITORIAL PREFACE

Special Issue on Human Computer Interaction in Critical Systems I:
Citizen and Volunteers

Christian Reuter, University of Siegen, Germany

Tilo Mentler, University of Lübeck, Germany

Stefan Geisler, University of Applied Sciences Ruhr West, 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 citizen and volunteers in emergencies.

Keywords: Citizens, Emergency, Human Computer Interaction, Security, Volunteers

1 INTRODUCTION

The usability of 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. Many areas are increasingly challenged through information processing, interactive, multimedia and real-time systems:

- Control systems for process control, for example, power plants (Herczeg, 2009), chemical plants

- Management of critical infrastructures, such network management, command and control centers (Rinaldi et al., 2001)
- Vehicle and traffic management, for example, motor vehicles (Geisler et al., 2012), railway engineering (Sautter et al., 2012), aerospace, nautical
- Production technology and business continuity management, e.g. operating rods
- Health care, medicine and medical technology (Klein et al., 2015)
- Security, for example, crisis management (Ludwig et al., 2015) and civil protection (Reuter, Ludwig, & Pipek, 2014)

This requires the development and discussion of new methods and approaches at the interface of man-machine systems engineering, human-computer interaction and usability and software engineering. An important trend is beyond: the further development of the relationship between human-machine towards collaboration in the sense that man and machine as a team collaborate on tasks and to exchange information about the current state of problem solving and on next steps. Increasingly, mobile devices and social networking contexts and must be included in the considerations.

The previously mentioned points become more and more important. The research in the area of human computer interaction in security relevant systems addresses several of the central challenges defined by the German Informatics Society. A so called *Grand Challenge* for computer science is "a general (fundamental) problem which solution (with the use of information technology) means a clearly noticeable progress in terms of economy, social life and society for all of us."[1] Three out of the five challenges will be addressed through this section:

- "Systemic Risks" (Challenge 3) are especially addressed by security relevant and time-critical systems which can lead to major consequences in case of a blackout.[2]
- "Ubiquitous human-computer interaction" (Challenge 4) has also found its way in here and its challenge is "to effortlessly use the by now ubiquitously available communication- and information offers and to [participate] in the social process."[3]
- "Reliability of software" (Challenge 5) is especially important in this context: "If software is rules our world, operates our cars and planes and leads our medical instruments, how can we prove that the software does exactly what it is supposed to do?"[4]

This significance is now also represented in the sections of the German Informatics Society (GI). Based on last year's workshop „human-computer interaction and social computing in emergency situations" (Reuter, Ludwig, Pipek, et al., 2014), in which related themes were considered, attempts were made to found a section out of the already existing research group. The intentions of the section are the scientific and thematic exchange and the connection of actors and thematically interested people. This special issue 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.

[1] http://www.gi.de/themen/grand-challenges-der-informatik.html

[2] http://www.gi.de/themen/grand-challenges-der-informatik/systemische-risiken.html

[3] http://www.gi.de/themen/grand-challenges-der-informatik/systemische-risiken.html

[4] http://www.gi.de/themen/grand-challenges-der-informatik/verlaesslichkeit-von-software.html

2 ACCEPTED ARTICLES

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 nine articles will be published; four in this issue and fife in the next issue:

Henrik Detjen, Stefan Hoffmann, Leonie Rösner, Stephan Winter, Stefan Geisler, *Nicole Krämer* and Gerd Bumiller's article "*Integrating Volunteers into Rescue Processes:Analysis of User Requirements and Mobile App Conception*" proposes a system that will give dispatchers the control centers additional options to allocate human resources on a voluntary basis. Volunteers can reduce the response time for medical help, provide technical resources or reduce workload for fire departments for exploring locations. The system is targeted for large-scale disaster situations and works with preregistered volunteers. It uses a mobile app for communication. First interviews with potential users revealed certain requirements such as trust, controllability of readiness status, privacy and data security, and need for training courses. Long-term motivation is another aspect that needs to be considered. These requirements will be implemented in a first prototype which will be evaluated with the target group in subsequent workshops.

In their article "*Crisis-related Apps – Assistance for Critical and Emergency Situations*", Inga Karl, Kristian Rother and Simon Nestler (Hochschule Hamm-Lippstadt) discuss the benefits of crisis-specific apps in terms of human behavior and challenges of crisis communication in time-critical and uncertain situations. They discuss the usage of apps as a communication tool that helps to reduce fear and uncertainty of affected people. Build upon a comparison of different crisis-related apps, the authors derive design implications for a mobile-based communication means for emergency services to improve and modernize the crisis communication with citizens. This article emphasizes a need for research in the field of mobile crisis communication with regard to behavioral aspects of affected people. This aspect is taken into account by the authors on subsequent research, in particular the collection of user requirements and the evaluation of the design concept.

Christian Reuter (University of Siegen), Thomas Ludwig (University of Siegen), Therese Friberg (University of Paderborn), Sylvia Pratzler-Wanczura (Fire Department of Dortmund) and Alexis Gizikis (European Emergency Number Association) highlight in their article "*Social Media and Emergency Services? Interview Study on Current and Potential Use in 7 European Countries*" the perception of emergency services on social media during emergencies. Within the European research project EmerGent, they therefore conducted an interview study with emergency service staff (N=11) from seven European countries and eight different cities. The results highlight the current and potential use of social media, the emergency service's participation in research on social media as well as current challenges, benefits and future plans.

Benjamin Weyers (RWTH Aachen University), Barbara Frank (Ruhr University Bochum), Kathrin Bischof (University of Duisburg-Essen), and Annette Kluge (Ruhr University Bochum) present in the paper entitled "*Gaze Guiding as Support for the Control of Technical Systems*" an approach on guiding user's gaze as support for the control of technical systems. Standard operating procedures, e.g. provided by paper-based manuals or decision trees, specify how a human operator should handle a specific situation occurring in the system control, which might also be safety-critical. The main contribution of this work is a concept of guiding users' gaze in such control scenarios of technical systems, which aims at preventing the user from having to leave the control context in order to consult such a paper-based

standard operating procedure. Instead, the presented approach fades in information into the control interface based on the current situation of the system and the intended procedure. This concept, called gaze guiding, has been implemented in a framework in which it can be applied to existing control interfaces. Its feasibility is demonstrated in a user study with 21 participants.

3 CONCLUSION

Human computer interaction in critical systems will continue to play a major role. This issue presented technologies for citizen and volunteers in emergencies. With special issue we want to contribute to help shape this development in a meaningful way.

Christian Reuter

Tilo Mentler

Stefan Geisler

Guest Editors

IJISCRAM

ACKNOLWEGEMENTS

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

REFERENCES

Geisler, S., Heers, R., & Wolter, S. (2012). Herausforderungen an zukünftige Bedienkonzepte und HMI Systeme im Automobil. In Mensch & Computer 2012: Workshopband (pp. 343–346).

Herczeg, M. (2009). Zusammenwirken von Mensch, Technik und Organisation in Kernkraftwerken. In Ministerium für Soziales; Gesundheit; Familie; Jugend und Senioren des Landes Schleswig-Holstein (Ed.), Zur Sicherheit von Kernkraftwerken (pp. 33–40). Kiel.

Klein, J. P., Kensche, M., Becker-Hingst, N., Stahl, J., Späth, C., Mentler, T., … Schweiger, U. (2015). Development and psychometric evaluation of the Interactive Test of Interpersonal Behavior (ITIB): A pilot study examining interpersonal deficits in chronic depression. Scandinavian Journal of Psychology.

Ludwig, T., Reuter, C., Siebigteroth, T., & Pipek, V. (2015). CrowdMonitor: Mobile Crowd Sensing for Assessing Physical and Digital Activities of Citizens during Emergencies. In Proceedings of the Conference on Human Factors in Computing Systems (CHI). Seoul, Korea: ACM Press.

Reuter, C., Ludwig, T., & Pipek, V. (2014). Ad Hoc Participation in Situation Assessment: Supporting Mobile Collaboration in Emergencies. ACM Transactions on Computer-Human Interaction (ToCHI), 21(5).

Reuter, C., Ludwig, T., Pipek, V., Herczeg, M., Mentler, T., Nestler, S., & Sautter, J. (2014). Editorial: Mensch-Computer-Interaktion und Social Computing in Krisensituationen. In M. Koch, A. Butz, & J. Schlichter (Eds.), Workshop-Proceedings der Tagung Mensch & Computer 2014 (pp. 101–104). München, Germany: Oldenbourg-Verlag.

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.

Rinaldi, S. M., Peerenboom, J. P., & Kelly, T. K. (2001). Identifying, Understanding, and Analyzing Critical Infrastructure Interdependencies. IEEE Control Systems Magazine, 11–25.

Sautter, J., Roßnagel, H., Kurowski, S., Engelbach, W., & Zibuschka, J. (2012). Interoperability for Information Systems in Public Urban Transport Security: The SECUR-ED Interoperability Notation. In Proceedings of the Information Systems for Crisis Response and Management (ISCRAM). Vancouver, Canada.

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.

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).

Stefan Geisler is Professor for Applied Computer Science and Human-Machine Interaction at Hochschule Ruhr West, University of Applied Sciences in Bottrop, Germany. After he received his Ph.D. he worked for several years in the industry, at Ford Werke GmbH in Cologne. There he worked in different automotive HMI projects from research to serial development. 2010 he was offered a professorship. In his research he continues working on automotive HMI, but also on usability of different kinds of technology in times of demographic change (User Interfaces for Ambient Assisted Living systems) and for safety-critical systems. He works with user-centered design processes following the goals of the Positive Computing paradigm.

Integrating Volunteers into Rescue Processes

Analysis of User Requirements and Mobile App Conception

Henrik Detjen, Computer Science Institute, Hochschule Ruhr West, University of Applied Science, Germany

Stefan Hoffmann, Computer Science Institute, Hochschule Ruhr West, University of Applied Science, Germany

Leonie Rösner, Institute for Social Psychology: Media and Communication, University Duisburg-Essen, Germany

Stephan Winter, Institute for Social Psychology: Media and Communication, University Duisburg-Essen, Germany

Stefan Geisler, Computer Science Institute, Hochschule Ruhr West, University of Applied Science, Germany

Nicole Krämer, Institute for Social Psychology: Media and Communication, University Duisburg-Essen, Germany

Gerd Bumiller, Computer Science Institute, Hochschule Ruhr West, University of Applied Science, Germany

ABSTRACT

Recently, rescue worker resources have not been sufficient to meet the regular response time during large-scale catastrophic events in every case. However, many volunteers supported official forces in different disaster situations, often self-organized through social media. In this paper, a system will be introduced which allows the coordination of trained volunteers by a professional control center with the objective of a more efficient distribution of human resources and technical equipment. Volunteers are contacted via app on their private smartphone. The design of this app is based on user requirements gathered in focus group discussions. The feedback of the potential users includes privacy aspects, low energy consumption, and mechanisms for long-term motivation and training. We present the results of the focus group analyses as well as the transfer to our app design concept.

1 INTRODUCTION

Due to new technologies, such as mobile phones, new opportunities for crisis communication are emerging (e.g., Starbird & Palen, 2011). The present research explores the potentials of a smartphone-based system that would assign medically or technically trained volunteers to emergencies in their direct environment. The idea of this system is to alert volunteers when it is foreseeable that regular emergency forces may not be able to arrive in the regular response time. The selection of volunteers will be automatically supported, but the decision remains with the dispatchers in the control center. This approach might be particularly helpful in cases of major catastrophic events, when the regular staff is drawn to operations that are connected to the disaster and therefore might not reach additional emergencies as quickly as necessary. The volunteers register online and will provide basic support (similar to first responders, see Timmons & Vernon-Evans, 2012).

In this article, we will discuss the current state of the art with regard to voluntary help and how mobile applications could help to integrate volunteers into official rescue processes. With the example of the research project "Automated Allocation of Volunteers in Major Disasters" ("Automatisiertes Helfer-Angebot bei Großschadensereignissen", AHA), we will analyze the motivation of potential volunteers and derive concepts for a mobile application. The project is a cooperation between the Hochschule Ruhr West, University of Applied Sciences, the University of Applied Sciences for Public Administration Duisburg, the University of Duisburg-Essen, the company CKS Systeme GmbH, developer of software for fire departments, and the Institute for Fire Department and Rescue Technology Dortmund (IFR).

In the following, we first describe the motivation (Chapter 1.1), then several related projects (Chapter 1.2) and introduce the AHA project in this context (Chapter 1.3). After this, a first user study is presented (Chapter 2): with an explanation of method (Chapter 2.1) and procedure (Chapter 2.1) and first results (Chapter 2.3). Afterwards requirements and functions for the volunteers' mobile app are derived (Chapter 3). Starting with an overview of possible functions (Chapter 3.1), followed by a more detailed look upon: data privacy and security (Chapter 3.2), a quiz function (Chapter 3.3), automated readiness (Chapter 3.4) and dashboard design (Chapter 3.5). Finally, conceptual challenges are summarized and a brief outlook is given (Chapter 4).

1.1 MOTIVATION

Eight, ten or twelve minutes, this is the legal response time for fire fighters or medical help in Germany, depending on the geographic region. During large-scale catastrophic events this time limit is not always met. In interviews, which we have conducted in preparation of this project, rescue workers mentioned that the resources of the emergency services had problems handling the number of incoming rescue and security tasks in a timely manner. New incidents could not be processed immediately, as all forces, including human resources and equipment, were already in rescue operation. Supra-regional help can be requested, however, it is common in major disasters that their forces are occupied as well.

The goal of the AHA project is to mobilize additional, qualified resources from the population and make them available for the dispatcher. Additional helpers from the region and technical aids are recorded, checked and registered in the system, in order to be available in case of an emergency. Their locations and availabilities can be determined and are shown to the dispatcher in the control center. The final decision whether to alert a volunteer or not, remains with the dispatcher and is not automated.

By means of quickly alerting additional qualified resources and assigning them to close-by operations where help is needed, the AHA system should cause a significant reduction of the response time. The realization of low investment and operating costs for fire departments and volunteers is a key objective.

1.2 RELATED WORK

Various other volunteer projects and spontaneously formed volunteer actions follow a collaborative approach (i.e., Reuter, Ludwig & Pipek, 2014), partly through social networks. Here, however, it is difficult for official rescue forces to obtain an overall picture of the situation and to decide how to make the best use of available resources. Thus, much potential is still unused because resources are not allocated to where their skills are needed most. A comprehensive overview on this topic is given in Reuter et al. (2015) and Reuter, Heger & Pipek (2013). The corresponding challenges are addressed by Kaufhold & Reuter (2014).

Due to the German century-flood in the summer 2013 the project "Hands2Help" was founded (Hofmann et al. 2014). Its aim is to organize the rather uncoordinated voluntary help in crisis situations with help of a mobile app. Like on a virtual pin board, incoming tasks can be entered into the system and other (ad hoc) registered helpers can take over suitable tasks. The algorithm uses the proximity to the incident (assessed with GPS) and the volunteers' suitability for the operation (e.g., required tools such as shovels). In this way, individual help is distributed to the right place at the right time and increases the efficiency of the voluntary help as a whole. There are interfaces which allow control centers to communicate with local helpers in order to send them further information about the operation and give them the opportunity to ask for further information.

The project "United Hatzalah" supports medical teams in lifesaving operations (Friedson, 2012). With more than 2500 registered helpers, it is the largest, independent voluntary organization of Israel in the medical field. The projects' core is a mobile application with the so-called "Life Compass System". Through the use of GPS technology, emergencies are passed to a nearby helper by the system. The most qualified helper receives the request. Over the last years, several small control centers that are coordinating the volunteers and resources were built up. The resources include defibrillators, scooters with medical equipment, even fully equipped ambulance cars. The self-reported average time to help based on past operations is 3.5 minutes.

There is a similar project in Germany named "Mobile Saviors" ("Mobile Retter") which is concerned with the support of medical rescue services by volunteers, too (Stroop, Strickmann & Kerner, 2015). Once the system receives an emergency call, a previously registered and nearby helper can be contacted via a mobile app. The project has been in the test phase since 2013 and currently more than 400 volunteers are registered. The helper obtains an appointment for a conference at the Mobile Savior association with her or his registration, where a special training course for the use of the system is conducted.

Another project is "Cooperation with Volunteers in Complex Damage Situations" ("Kooperation mit freiwilligen Helfern in komplexen Schadenslagen", KOKOS), which has been founded in 2015. The goal of KOKOS is to develop methods, IT-based concepts and tools that help to integrate the public into crisis management (KOKOS Projekt, 2015). Public displays, for instance, which are centrally located and provide crisis-relevant information from different sources (e.g. news, social media, local helpers). Via direct access to the display, helpers can share information with each other (Ludwig, Kotthaus & van Dongen, 2015).

In summary, the goals of the AHA project are similar to those of the mentioned projects: to shorten the period of help and to relief the rescue forces in a major incident. In contrast to pure community-based approaches, like "Hands2Help", the help will be coordinated and monitored by professional rescue forces, so that the potential help can be used purposefully. In order to achieve this, the control centers (i.e. fire department control centers) should handle the central coordination of the volunteers. Therefore, a goal of the AHA project is the integration of the smartphone-based volunteer system into the existing systems and processes in the control centers. The KOKOS project is about finding technical concepts and solutions for integrating non-professionals into rescue processes, while AHA focusses on persons with a certain qualification and a proofed identity, so that the dispatcher can rely on that, if he sends them onto a mission. In contrast to projects like "United Hatzalah" and "Mobile Saviors", the AHA project's scope is not limited to medical help scenarios, but covers also technical help cases and exploration missions, which are important tasks during a major disaster. At the same time, we examine how potential volunteers can be motivated to participate in such a system for a longer period of time, how their availability can be ensured in compliance with data protection requirements, and how the dispatchers can include those additional resources in stressful situations with the least possible additional load.

1.3 PROJECT OVERVIEW

The project has two main user groups: the control centers' dispatcher and the volunteer. Therefore the system has to provide interfaces for both sides. The dispatcher needs a system that receives, processes, and forwards information about additional resources. The interface has to be convenient to the existing control centers' software to guarantee a seamless integration (ISO 9241-110, 2006). The helpers' system needs to communicate with the control center. Suitable for this purpose is the use of mobile devices, due to the high prevalence and potentially high accessibility (Statista, 2015). The focus of this paper pertains to the helpers' side; we will however provide a short overview on the whole system in order to get a better understanding of the occurring challenges.

Figure 1 shows an overview in a draft sketch: In a major incident, a great amount of forces is already bound and not available for the dispatchers, while at the same time many urgent emergency calls come in. In consequence, the dispatchers are under very high pressure. The AHA systems' goal is to relieve dispatchers and offer additional forces in the form of volunteers. These are registered in advance via a website. The registration includes information about the helpers' person, his or her relevant qualifications, as well as potentially useful tools that she or he can offer. A verification staff evaluates the registration. Details about this staff are also part of the projects' research (e.g., law review of electronic certification processes and methods in public context), because such a unit competes with the goal of low operating costs.

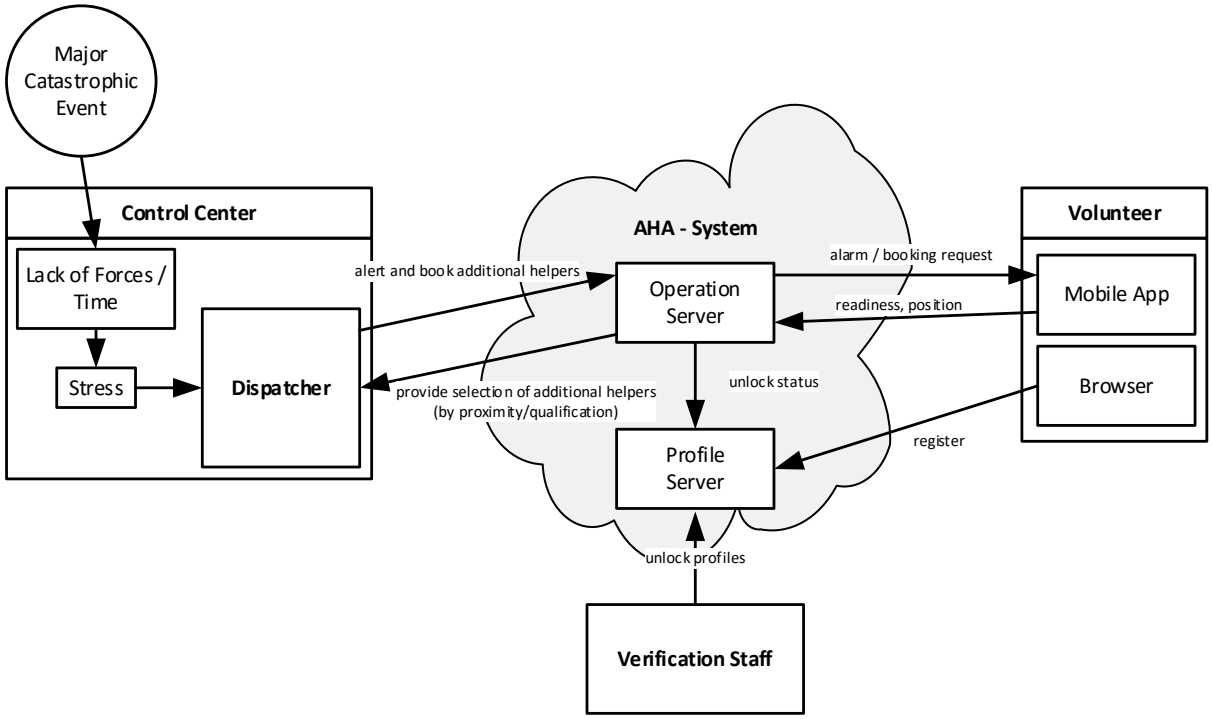


Figure 1: AHA Project Overview.

From a technical point-of-view, the server is separated in two logical units: profile server and operation server. This increases the personal data security, because operation-relevant data can be isolated from the personal data and personal data is only submitted once in the registration process. In operation processes, the user data consists of a pseudonymized, unique identifier connected to qualifications and tools.

The dispatcher can see the positions of potential helpers in his monitoring system's interface. For an operation, she or he can choose, based on different criteria (e.g. skills, distance, experience with disaster situations), and alert (with prioritization) suitable helpers. Background services on the mobile app send the current positions to the system and the helpers nearby an incident are displayed in the dispatcher interface. The helper gets a push-notification on her or his mobile phone with an alarm that provides abstract information about the scenario (e.g. type and distance). Detailed information (incident address, operation details) is only revealed when a helper accepts the request. In addition, a route to the incident scene is suggested by the mobile app.

Alternative concepts of the alarm process can be realized. For example: alarming coupled to the degree of forces' utilization, the overall level of emergency or "on-the-fly" requests with incoming emergency calls. In any case, the helper has to confirm her or his readiness status upon a certain state (e.g. on app start, automated, on request). Here, the trade-off is between the dispatcher's uncertainty (quote of rejection) and the tolerance of the helper (number of readiness requests). Several concepts will be tested and evaluated.

The system has three main application scenarios: Medical help, technical help and exploration. In the first use case, medical help, a volunteer with certain medical qualifications (e.g. emergency doctor, nurse, first aid course) is alarmed to get to a nearby rescue operation. As mentioned before, the volunteers' qualification must be suitable for the operations type. The dispatcher has to choose the first responders well-considered. Potentially, a volunteer can reach the location earlier than a professional rescue service could. In the second use case, technical help, a volunteer with certain equipment (e.g. tractors, submersible pumps) is

alarmed. She or he delivers the requested gear to where it is needed. The third use case is the exploration of incident scenes for the control center. A volunteer checks and updates the status of a queued emergency call. The dispatcher ensures that the incident scene is not critical for the volunteer's safety. If a swamped cellar has drained over time or people helped themselves, an intervention of the fire department might not be necessary anymore. Thus, empty drives can be avoided.

Besides technical challenges and process design, the use cases implicate to examine surrounding conditions, like organizational, legal and financial aspects. But one of the most important conditions is that there are no motivation hurdles for potential volunteers to use the system.

2 ANALYSIS OF THE VOLUNTEERS MOTIVATION

Vital to the success of the project is the attraction of a sufficiently large number of people who are willing and motivated to use the system and offer their help. In order to understand the motivation of prospective app users for their voluntary assistance and to identify specific incentives and objections relevant for their use of the app, we employed a qualitative approach building on focus group interviews.

A focus group is a group interview led by a moderator who sets the topics of the interview and guides the discussion of the group. The benefit of this method is that participants gain a deeper understanding of their own thoughts on a topic by discussing it with others in their own words. Moreover, group discussions typically yield more than one perspective on a topic and help to explore a research question from different angles (Kitzinger, 1995).

2.1 METHOD

Four semi-structured focus group sessions with 4-6 participants (N = 20 in total; 9 female, 11 male) were conducted in May 2015. Each group was chaired by a trained faculty member and led according to an interview guide. Smartphone users with basic knowledge of medical care were recruited for participation because participants should be familiar with the use of smartphone apps in order to give suitable feedback about the configuration and functions of the planned app and also have basic medical skills since first aid is the most central use case scenario for the application of the system. Participants' background and medical knowledge was mixed (e.g., medical students, members of the German Red Cross, employees and students of other fields), their age ranged from 22 to 56. The sessions lasted between 105 and 135 minutes and were audiotaped. Recordings were transcribed into plain text and transcripts were content analyzed pursuing an inductive approach, developing the coding scheme directly from the data (cf., Schreier, 2012).

2.2 PROCEDURE

Upon arrival, participants received detailed information about the study aim and instructions concerning the procedure and gave their consent to audio record their statements. Then they filled out a short questionnaire on their demographics before the group interview started with an introduction of participants and a short round of "warm-up" questions concerning their prior experiences with volunteer engagement. The main questions discussed in the focus groups referred to the evaluation of the project idea and the utility of the app with regard to different use cases, the motivational factors and potential incentives for using the app as well as perceived risks and concerns of its usage. A creativity technique was used to generate

concrete ideas for incentives that could assure long-term motivation and participation. The task for each participant was to write down two initial ideas for incentives on a sheet of paper. These sheets were then simultaneously passed on to the next person, who read the ideas and commented, extended or refined them before handing the sheet over to the next person. This procedure was continued until every person in the group had commented on every initial idea. Afterwards, participants' elaborations were discussed in the group and evaluated. The focus group sessions closed with discussing the most important aspect determining participants' motivation to use the app and to engage in voluntary assistance in this way. Afterwards, we passed around a sheet of paper and asked participants to leave their e-mail address if they were interested in participating as volunteers and wished to be informed when the app was available for use. After the session, participants had the opportunity to ask questions about the project and were compensated with 25€.

2.3 RESULTS

BENEFITS AND RISKS

The majority of participants expressed a positive evaluation of the main idea of the proposed application: They particularly appreciated the fact that it would make additional resources for first aid available, which might help to save time in emergency situations, and the opportunity to actively improve the emergency system. One interviewee (male, 24 years old, student with basic medical skills) said: "I think it is very motivating to achieve good things with the help of new technologies". Furthermore, participants said that the application might increase the salience of the topic of voluntary help in the general public. Most interviewees stated that money and other material incentives are not necessary to motivate volunteering and might even attract the "wrong" people.

In spite of the generally positive evaluation, participants also expressed reservations with regard to legal accountability, data security, and their own abilities to help in difficult situations as well as the qualifications of other volunteers. Legal concerns were mentioned in every focus group, especially with regard to accountability ("I think, if there was no legal certainty, this would be the greatest barrier", male, 30, medical student) and insurances ("What happens if I get injured and will not be able to work anymore?", male, 29, member of the German Red Cross). With regard to data security and privacy, participants would favor a low data volume and a reduced collection of position data (for instance, by only tracking volunteers' location if there is a high likelihood of a critical event). Interviewees who have basic knowledge in first aid but do not work in medical jobs expressed concerns that they might not have enough qualifications for complicated medical incidents. One participant (female, 26, paramedic) said: "I think people will feel bad if things don't turn out fine in such an event and if helping was not successful. Then one will feel guilty".

SUGGESTIONS FOR FEATURES AND INCENTIVES

Participants offered several suggestions for features that could alleviate the above mentioned concerns or could strengthen users' long-term motivations. In every focus group, the desirability of a sleep function was mentioned: Such a feature would allow volunteers to enter times in which they are not available so that they would not be visible in the system and would not be alerted. According to the interviewees, this could help to reduce the (potentially uncomfortable) feeling of permanent stand-by duty but would also accelerate the process of finding the right person who is available: "It is not only about feeling bad when one does not

respond to an emergency call – there are many scenarios in which people simply do not have the opportunity to help right now, for instance, if they cannot leave their baby alone at home" (male, 22, medical student). Furthermore, a classification of volunteers that matches the qualifications for different types of medical cases was suggested ("For instance, if there is a lot of blood, I would not be the ideal candidate", male, 30, student with basic medical skills). As general requirements, participants mentioned usability, low battery demands, and a design that stresses the credibility and trustworthiness of the application and the institutions ("There must be an official authority behind it", male, 30, medical student).

With regard to incentives that could increase long-term motivation, all focus groups came up with the idea of free courses and trainings for different skills. Furthermore, face-to-face meetings within the group of local volunteers and newsletters about successful cases in the system were mentioned. Most groups also suggested to include some kind of quiz within the application, for instance with questions about first aid topics and medical knowledge. This quiz might serve entertainment purposes and increase the visibility of the whole system (by playing the quiz, users "notice" the app even if there are no emergencies for a longer time) but can also be valuable to convey helpful information ("for instance, knowledge about first aid that might be useful. Maybe in a factual version for older users and a more gamified version for younger users", male, 29, member of the German Red Cross). Concerning the implementations of social media (e.g., by distinguishing very active volunteers on the Facebook profile), opinions were mixed: This might have a motivating effect and spread the idea of the system, but many participants criticized that this would lead to a feeling of "competition" between the volunteers.

In summary, respondents were favourable toward the general idea of volunteering with the help of new technologies (at the end of the discussions, 18 out of 20 participants entered their e-mail address to get more information when the application starts). However, they raised important concerns, for instance with regard to availability and security, and suggestions for long-term motivation that need to be addressed in the further design.

3 CONCEPT FOR A MOBILE APPLICATION

To reach the goals of high acceptance and long-term motivation, the app is developed using the user centered design process (ISO9241-210, 2010). This includes a good understanding of the users, the tasks and the environment of use. In this chapter, selected aspects of the first version will be presented, integrating the results from the focus group as well as general requirements, before they will be reviewed by user groups and discussed in workshops according to methods of participatory design in a next step (Muller, 2003).

3.1 SYSTEM REQUIREMENTS AND FUNCTIONS

Battery life is an important factor for most customers when choosing the next mobile phone. Against this background, it is obvious that the app needs to be technically designed in a way that the power consumption, due to the permanent activity of the app, is insignificant. To achieve this goal, the GPS positioning system should not be activated permanently. This matches the privacy requirement of data avoidance. Therefore, the exact position via GPS will only be determined and transmitted if a certain level of criticality in the control center is reached, meaning a low and decreasing number of available rescue forces or tools. In these situations the probability is high that help of the volunteer is needed. A wake-up signal is sent from the server to relevant smartphones to realize this.

The described approach is furthermore in line with research results from Barkhuus et al. (2003). Based on a classification by Snekkenes (2001), it was found that position-aware services create less privacy concerns than location-tracking services. Position-aware services are services which run on the mobile device only, while tracking services use external parties. As in our approach, GPS is only activated in the rare case of a critical situation and only in this case position data is transferred to the server, the app mainly runs in the user accepted position-aware mode.

As the interviews revealed, users raise the requirement not to be alarmed if the incident does not fit to their skills. A similar requirement was gathered from the control center dispatchers, who only want to interact with appropriate volunteers in an efficient manner. Therefore, during registration, a skill profile needs to be defined. As this is more or less a one-time event, which requires more complex options, this will not be integrated into the app but will be part of the web-based registration process. A drawback of this approach is a higher hurdle for spontaneous participation of additional volunteers.

A large number of participants requested a feature similar to a “sleep mode”. The app should offer the possibility to switch off the availability temporarily. It needs to be investigated whether an automatic reminder to switch it on again after some hours is acceptable for the users. This would prevent from being in off-mode longer than desired and maybe miss an alert. In addition to the manual switch, a first concept was developed to automatically turn availability on and off depending on time or location. This will be discussed in more detail in section 3.4.

Several persons suggested a quiz to train certain relevant skills. This would also address another issue: As the app will be activated only very rarely, users might forget about the purpose of the app. A quiz and regular information will serve as a reminder. The quiz will be discussed in more detail in section 3.3. A challenge to fulfill this requirement is not to provoke the feeling that the main purpose of the app is entertainment.

Another feature available for training purposes will be the possibility to start a test alarm. It will simulate the different steps of a real incident, so that users can get familiar with the app under normal circumstances and will become more efficient in the situation of a real alert.

3.2 MOBILE SECURITY

The disclosure of sensitive personal data was mentioned by several of the interviewees as a significant risk. Thus, it is important to tackle the challenges of information security not only from a pure juridical and technical point-of-view. The perspective of the potential user must be considered with a likewise high priority. The user's trust in the measures taken to protect her or his data must be ensured, especially in an official and safety-critical context.

The German Federal Data Protection Act (“Bundesdatenschutzgesetz”, BDSG) regulates the handling of individual-related data in information systems (Auernhammer, 2014). A basic requirement is that the data protection must be “state of the art” and with the highest security level that is feasible under the given technical conditions. The Düsseldorfer circle (“Düsseldorfer Kreis”, DK) is a committee that is responsible for guaranteeing a uniform application of these requirements. The DK gives concrete recommendations and instructions for data security in information systems (Düsseldorfer Kreis, 2014). It describes what is meant by “state of the art” security in this technical context.

To cover all of these aspects, the AHA system follows a holistic approach in terms of a comprehensive security concept that deals with both technical and non-technical security

issues. The following selection describes the most important aspects that are relevant for the potential helper's view.

DATA MINIMIZATION

Data minimization and avoidance are important aspects for the protection of personal data. It means that it is forbidden to collect more data than necessary to fulfill the specified task. As described in section 3.1, this implies for example that locations of the helpers may only be collected in case of certain alarm situations, but not continuously. When the alarm level is expired, the location-related data must be erased. The concept of data minimization and avoidance is given in § 3a of the BDSG (Auernhammer, 2014).

USER PSEUDONYMIZATION

It is clearly necessary to gather personal data of the user in the registration process, for instance, full name and address. This is required for a later legitimation. However, the concept of the AHA system includes a helper pseudonymization for certain cases. The dispatcher does not obtain the full personal data of the volunteer, just the data that is necessary for her or him (like qualifications). The helper identity is replaced by a randomized pseudonym.

ENCRYPTION

All connections between the mobile app and the AHA server are encrypted without any exception. The DK provides detailed instructions on the encryption algorithms and key sizes to use. It recommends the Transport Layer Security (TLS) protocol with strong ciphers (like AES) and a key size with at least 128 bits. The concrete cryptographic methods are taken from a recommendation by the German Federal Office for Information Security (BSI, 2014). Following these instructions, it is practically impossible for a third party to obtain the personal data of the users, even within an untrusted network.

SECURE DATA ERASURE

In case that a user wants to end her or his membership of the AHA system, the user's data must be erased. A normal deletion is not sufficient, the data must be erased by overwriting it. By this means it is impossible to recover data after the erasure. According to recent research results, a one-time overwriting pass with an arbitrary pattern is sufficient (Wright, Kleiman, & Sundhar, 2008).

SECURE PASSWORD

To protect the user account and its personal data, it is important to choose a strong password during the registration process. The AHA system gives an indication on the strength of the password that is selected by the user. Passwords that are too short are refused. Security requirements for passwords of different use cases are given in Eastlake, Schiller, & Crocker (2005). Also, the password entry will be masked by default to avoid over-the-shoulder attacks. Nevertheless, there is a tradeoff between security and usability: the longer a password gets, the harder it is to remember (Braz & Robert, 2006).

AFTER-THEFT PROTECTION

The AHA system provides data protection measures for the case that a helper's mobile device is stolen. First, with the data stored on the mobile device the thief is not able to access the full personal data of the user at the profile server. Second, the user can always block her or his account in order to prevent a thief to impersonate the user.

SECURITY STATEMENT

A clear and transparent security statement will be provided. It describes the processing and protection of personal data within the system in detail. The document addresses the whole range of potential users from people without any technical knowledge up to experts. The goal is that all users who are worried about the protection of their data can comprehend the measures taken in AHA to protect their data. As a consequence, the users' trust in the system should be increased.

3.3 QUIZ

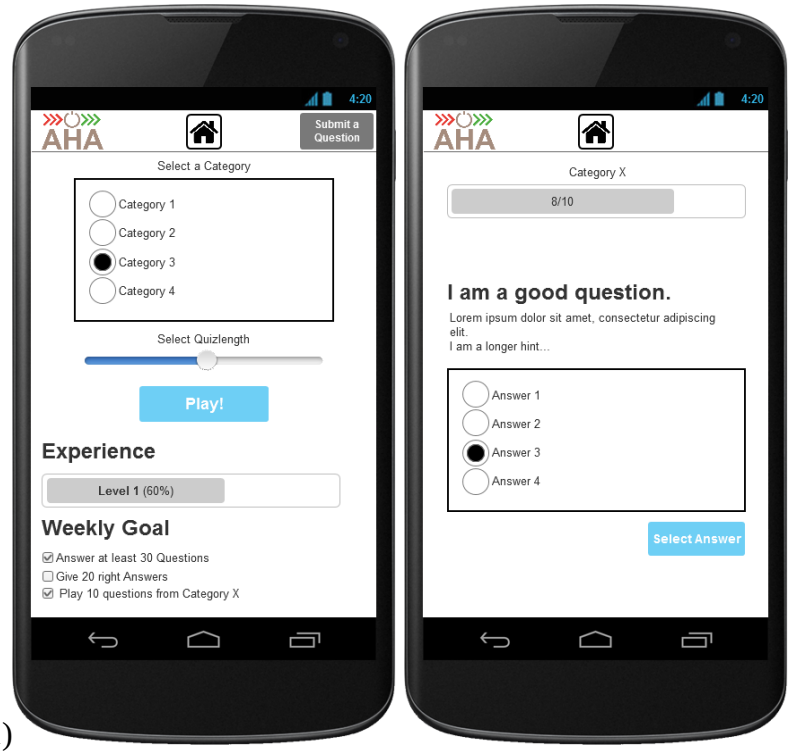
Survey participants also proposed a quiz function. A quiz could bring two essential benefits for app users: On the one hand, the quiz is an additional factor with potential for long time motivation. On the other hand, operation relevant knowledge can be conveyed to the helper, so that she or he can improve her or his existing knowledge or learn something new in a playful way. The suggestion of a more factual version for older people is discussable, because research shows that elderly people also enjoy games (e.g., Rottermanner, 2015). This gamification approach, the use of game elements in a non-gaming context (Deterding et al., 2011), is meant to motivate the helper to use the app in quiet phases.

A successful game has to find the right balance between challenge and motivation to provoke a flow experience. Three factors influence can influence the users' intention to play: her or his motivation, the skill to solve the task and the presence of an effective trigger (Fogg, 2009). The trigger could be a reminder via push notification that appears from time to time. The motivation and the skill to solve the questions should be no problem, since it was the request of the helpers to get a quiz function and the quiz will allow the choice of a category which is matching the user's knowledge field. The questions must neither be too easy nor too difficult (cf., Csikszentmihalyi, 2010), but it is hard to find the optimal level of difficulty (LoD) for a single user. A solution would be an adaptive system which automatically classifies the questions into a LoD (e.g., 1 / (right anwers / wrong answers)). For a user's individual quiz, the system would prefer questions whose LoD is corresponding to her or his own ratio of right to wrong answers.

The ARCS-model (Keller, 1987) describes an instruction design that improves the long term motivation based on attention, relevance, confidence and satisfaction of a user. In our quiz, attention can be achieved with a prominent place in the user interface and an inclusion of the quiz function in the app tutorial. The relevance can be obtained with content that fits to the emergency topic, the confidence with a balance between self-control (quiz can be ended at any time), adequate learning requirements (see LoD) and success (i.e. level-ups, stats). The user's satisfaction will be reached if the quiz is easy to use and the helpers' expectations are fulfilled.

As mentioned before, a categorization of the questions allows targeted training for different types of users, since the project has different use cases and therefore heterogeneous target audiences. A further helper survey will show which categories are suitable. Possible

categories would be medicine, first aid, disaster protection, operation security, public laws. Furthermore, the content must be administrated in order to occasionally provide new questions. A community approach would avoid current costs: Helpers could bring up their own questions and other helpers would rate the questions before they are published. After a few ratings, a question with positive evaluations will be accepted from the system and bad questions would be rejected. The quality of the rating should be assured through the qualification of the helpers.



(1) (2)

Figure 3: Quiz Mock-up.

Figure 3 shows a first design of the quiz interface. In the start view (1), the helper finds her or his progress to upcoming achievements and short statistics of her or his quiz history. A weekly goal, micro-achievements like “answer x questions from category y” can produce extra motivation for a repeated use (Zichermann & Cunningham, 2011). After a question category and amount have been chosen, the helper can start the quiz. The game view (2) is compact and reduced to the main elements: question, answers, progress, back button and restart button.

3.4 READINESS AUTOMATION

In the focus group, there was the demand for a “sleep function” which allows the user to define times in which she or he is inaccessible by the system (invisibility for the dispatcher / no alerts). Such a function would improve their perceived control and would make them feel more comfortable than being available all time. To reflect this in the app, three possible states are used in the user interface: “ready”, “not ready” and “automated”. The “ready” and “not ready” states are permanent, while the “automated” state is rule-based. When one sets her- or himself into permanent readiness, there will be a reminder which indicates that the user has now the duty to respond to incoming alerts at any times. Otherwise, if the user has chosen to be permanently not ready, she or he becomes a push-notification which notifies her or him that the status has not changed for a while.

For the “automated state”, the interviewees suggested a time based rule mechanism, but other mechanisms could be useful, too. In this state, the app follows the principles of context-aware systems meaning that it adapts its behavior depending on the context without user intervention (e.g., Baldauf et al., 2007, Schmidt et al., 1999). The user needs to be able to define a rule set in an intuitive way. Different sensors and available information (e.g., location via GPS, postal code, WLAN-SSID, “24 hours pause after being alerted”, certain entries in the calendar of the smartphone) will be tested in next research steps.

It is intended that the user can define the rules either in a positive way (“When it is between 2 p.m. and 4 p.m., set me to ready”) or in a negative way (“When it is between 2 p.m. and 4 p.m., set me to not ready”). As long as the number of rules is small, this is more comfortable than defining positive and negative rules in separated lists. A challenge that comes with the use of automation is to find the right level of automation (LoA). Automation use can be characterized as when operators engage automation in order to perform tasks they would otherwise perform manually. Its usefulness depends on workload, cognitive overhead, trust, self-confidence and risk (Lee et al., 2008). The workload reduction is a positive aspect of automation use, while the other factors are depending on the LoA and individual usage differences (Sanchez, 2009). According to (Sheridan & Verplanck, 1978), suitable automation levels for the “sleep function” would be between 5 and 8 (on a scale from 1 to 10; 1 = “computer offers no assistance, human must take all decisions”; 10 = “The computer decides everything, acts autonomously, ignores the human”). In the following, the LoA and the corresponding interaction design implications are derived:

- “5 Executes that suggestion if the human approves”: *Every time* the system changes the readiness status, the user is asked via push notification to *confirm the change*.
- “6 Allows the human a restricted veto time before automatic execution“: *Every time* the system changes the readiness status, the user is asked via push notification to *reject the change in a certain time.*
- “7 Executes automatically, then necessarily informs the human”: *Every time* the system changes the readiness status, the user is *informed about the change* via push notification.
- “8 Informs the human only if asked”: The user can *select in a checkbox* if she or he wants to receive push notifications about the status change.

A first prototype should vary and test the different automation levels of the “sleep function”. Furthermore, a tutorial should introduce the user into the functionality and show how one defines her or his state of readiness and the rules. It should be done with the app’s first use and be repeatable thereafter (e.g. in a help menu). The next question is how the function can be presented in the user interface.

3.5 DASHBOARD

The Dashboard of the mobile app will be the first thing the user sees when she or he starts the app. It contains access to relevant functions and information. The functions, as partly described in chapter 3.1, are: news, anonymized statistics, quiz, bonus status and a test alert. The potentially most frequently used function will be editing the user’s readiness state. Corresponding to the form follows function principle (Sullivan, 1896), a state switcher is placed on top of the dashboard. With large radio buttons, the three states of readiness can be switched: ready (“I am ready”), rule-based/automated (“Automated”) and not ready (“I am not ready”). In automated state, the state of readiness is dynamic and the user cannot see in which state her or his system is from radio button alone. To cope with that, an additional, red or

green colored indicator (traffic light metaphor) shows the current readiness state next above (next the control group label, see figure 2).

Figure 2 shows two mock-ups: As mentioned, the state switcher is always on top. Mock-up (1) is a tab menu with a dynamic panel underneath, which allows the user to change between functions. In the upper right corner, a link to edit the personal information (web link) and the help menu can be found. In (2), the navigation is in form of buttons which lead to a new view. The buttons metaphoric design is not final but in line with common representations. The advantage of (2) is a cleaner interface, but it also adds an extra navigation level, thus a return/home button is placed on top to navigate back.

(1) (2)

Figure 2: Start Screens.

Both dashboard approaches as well as the quiz and the different readiness automation levels will be implemented prototypically and have to be evaluated in a following user study to see, which one is more useful and which users find more fitting.

4 CONCLUSION

The proposed AHA system will give the dispatchers in the control centers additional options to allocate human resources on a voluntary basis. Volunteers can reduce the time until medical help will be at the location of the incident, provide technical resources or reduce workload for fire departments for exploring locations. In general, our results show a large potential of smartphone-based applications to integrate volunteers into rescue processes. A fundamental question is the integration of the volunteers and especially to generate a long-term motivation. To achieve a high motivation and alleviate concerns, it is important to provide additional functionality that brings benefits for users. The proposed system will use a mobile app-based approach for regular communication since nearly every person of the target group owns a smartphone and thus, no extra costs are generated. First interviews with

potential users revealed certain requirements such as trust, controllability of readiness status, privacy and data security, and need for training courses. These will be implemented in a first prototype which will be evaluated with the target group in subsequent workshops. Depending on the outcome, modifications will be integrated. Another important aspect is the ongoing communication between helper and dispatcher. As this needs to fit very well into the processes of the dispatcher, their requirements also need to be considered. For this reason additional investigations are required prior to this part of app design and will be discussed in a later article. In contrast to most other crisis management apps the AHA-system does not rely on self-organizing structures of spontaneously appearing volunteers, but on pre-registered person with well-known skills and equipment. Furthermore a detailed juridical and privacy concept for the practical use of the system will be elaborated to be in line with the current law. A further step is the integration into the software of the control center and future work will concentrate on this aspect, especially with a focus on workload and stress of the dispatchers. This will also affect the app design during the rescue operation. All further steps will be performed in close cooperation with relevant users and official organizations.

ACKKNOWLEDGEMENTS

The project AHA is government-founded in context of the program „Research for Civil Safety, Announcement Civil Safety - Protection and Rescue in Complex Operation Situations“ („Forschung für die zivile Sicherheit - Bekanntmachung Zivile Sicherheit - Schutz und Rettung bei komplexen Einsatzlagen“) by the Federal Ministry of Education and Research („Bundesministerium für Bildung und Forschung“) under the reference number 13N13220. This paper is a more detailed version of a paper which was presented in the workshop “KritischeHCI“ at the “Mensch and Computer” conference, see Detjen, Geisler & Bumiller (2015).

REFERENCES

Auernhammer, Herbert. (2014). *Bundesdatenschutzgesetz*. 4. Auflage. Carl Heymanns Verlag.

Barkhuus, L., & Dey, A. K. (2003, July). Location-Based Services for Mobile Telephony: a Study of Users' Privacy Concerns. In *INTERACT* Vol. 3, (pp. 702-712).

Baldauf, M., Dustdar, S., & Rosenberg, F. (2007). A survey on context-aware systems. In *International Journal of Ad Hoc and Ubiquitous Computing*, 2(4) (pp. 263-277).

Braz, C., & Robert, J. M. (2006, April). Security and usability: the case of the user authentication methods. In Proceedings of the 18th *International Conference of the Association Francophone d'Interaction Homme-Machine* (pp. 199-203). ACM.

BSI (2014). *Technische Richtlinie - Kryptographische Verfahren: Empfehlungen und Schlüssellängen*. Bundesamt für Sicherheit in der Informationstechnik.

Csikszentmihalyi, M. (2010). *Das flow-Erlebnis. Jenseits von Angst und Langeweile: im Tun aufgehen*. 10. Auflage. Stuttgart: Klett-Cotta.

Deterding, S., Khaled, R., Nacke, L. E., & Dixon, D. (2011, May). *Gamification: Toward a definition.* In CHI 2011 *Gamification Workshop Proceedings* (pp. 12-15).

Detjen, H., Geisler, S., & Bumiller, G. (2015). Nutzeranforderungen eines Systems zur automatischen Helferbereitstellung. In *Mensch und Computer 2015 proceedings.* Berlin: De Gruyter Oldenbourg.

Düsseldorfer Kreis (2014). *Orientierungshilfe zu den Datenschutzanforderungen an App-Entwickler und App-Anbieter*. Bayerisches Landesamt für Datenschutzaufsicht.

Eastlake, D., Schiller, J., & Crocker, S. (2005). Randomness Requirements for Security. *Request for Comments* (RFC) 4086.

Felice Friedson. (2012). Israel's fast, free and innovative way to save lives. In *Jewish Journal*.

Fogg, B. J. (2009, April). A behavior model for persuasive design. In *Proceedings of the 4th international Conference on Persuasive Technology* (p. 40). ACM.

ISO 9241-110. (2006). *Ergonomics of human-system interaction - pt. 110 : Dialogue principles.* International Organization for Standardization.

ISO9 241-210. (2010). *Ergonomics of System Interaction-Part 210: Human-centered design for interactive systems.* International Organization for Standardization.

Kaufhold, M. A., & Reuter, C. (2014). Vernetzte Selbsthilfe in Sozialen Medien am Beispiel des Hochwassers 2013/Linked Self-Help in Social Media using the example of the Floods 2013 in Germany. *i-com, 13(1),* 20-28. Keller, J. M. (1987). Strategies for stimulating the motivation to learn. *Performance+ Instruction*, 26(8), 1-7.

Keller, J. M. (1987). Strategies for stimulating the motivation to learn. *Performance+ Instruction,* 26(8), 1-7.

Kitzinger, J. (1995). Qualitative research. Introducing focus groups. In *BMJ: British medical journal,* 311 (pp. 299-302).

KOKOS Projekt. (2015). Retrieved October 16, 2015, from http://kokos-projekt.de/

Lee, J. D. (2008). Review of a pivotal Human Factors Article: "Human and Automation: Use, Misuse, Disuse, Abuse*". Golden anniversity special issue of Human Factors*, vol. 50, no. 3 (pp. 404-410).

Ludwig, T., Kotthaus, & van Dongen, S. (2015). Public Displays zur Koordinierung ungebundener Helfer in Schadenslagen. In A. Weisbecker, M. Burmester & A. Schmidt (Hrsg.): *Mensch und Computer 2015 Workshopband* (pp. 19-27), Stuttgart: Oldenbourg Wissenschaftsverlag

Muller, M. J. (2003). Participatory design: the third space. In *HCI. Human-computer interaction: Development process*, 4235.

Reuter, C., Heger, O., & Pipek, V. (2013). Combining Real and Virtual Volunteers through Social Media. In T. Comes, F. Fiedrich, S. Fortier, J. Geldermann, & T. Müller (Eds.), Proceedings of the *Information Systems for Crisis Response and Management* (ISCRAM) (pp. 780–790). Baden-Baden, Germany.

Reuter, C., Ludwig, T., & Pipek, V. (2014). *Ad Hoc Participation in Situation Assessment: Supporting Mobile Collaboration in Emergencies*. ACM Transactions on Computer-Human Interaction (ToCHI), 21(5).

Reuter, C., Ludwig, T., Kaufhold, M.-A., & Pipek, V. (2015). XHELP: Design of a Cross-Platform Social-Media Application to Support Volunteer Moderators in Disasters. In *Proceedings of the Conference on Human Factors in Computing Systems* (CHI). Seoul, Korea: ACM Press.

Rottermanner, G., Weißenböck, J., Sommer, S., Pflegerl, J., Doppler, J., Gruber, W., & Judmaier, P. (2015). *Mediengestützte Kommunikation für ältere Menschen.* Retrieved June 22, 2015, from http://ffhoarep.fhooe.at/handle/123456789/396.

Sanchez, J (2009). Conceptual Model of Human-Automation Interaction. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, October 2009, vol. 53 no. 18 (pp. 1403-1407).

Schmidt, A., Beigl, M., & Gellersen, H. W. (1999). There is more to context than location. In *Computers & Graphics, 23(6)* (pp. 893-901).

Schreier, M. (2012). *Qualitative Content Analyis in Practice*. Los Angeles, London: Sage Publications.

Sheridan, T.B., & Verplank, W. (1978). *Human and Computer Control of Undersea Teleoperators.* Cambridge, MA: Man-Machine Systems Laboratory. Department of Mechanical Engineering, MIT.

Snekkenes, E. (2001, October). Concepts for personal location privacy policies. In *Proceedings of the 3rd ACM conference on Electronic Commerce* (pp. 48-57). ACM.

Starbird, K., & Palen, L. (2011). "Voluntweeters": Self-organizing by digital volunteers in times of crisis. In *Proceedings of the ACM 2011 Conference on Human Factors in Computing Systems (CHI 2011).* Vancouver, CA.

Statista. (2015). *Anzahl der Smarthphone-Nutzer in Deutschland in den Jahren 2009 bis 2015 (in Millionen).* Retrieved October 8, 2015, from http://de.statista.com/statistik/daten/studie/198959/umfrage/anzahl-der-smartphonenutzer-in-deutschland-seit-2010/.

Stroop, R., Strickmann, B., & Kerner, T. (2015). Ersthelfer-Alarmierung per Smartphone. *Deutsches Ärzteblatt*, 112(24), 18.

Sullivan, Louis H. (1896). The tall office building artistically considered. In *Lippincott's Magazine*.

Timmons, S., & Vernon-Evans, A. (2012). Why do people volunteer for community first responder groups?. *Emergency Medicine Journal 30*.

Wright, C., Kleiman, D., & Sundhar, S. (2008). Overwriting Hard Drive Data: The Great Wiping Controversy. *Proceedings of 4th International Conference, ICISS 2008, Hyderabad, India, December 16-20, 2008* (pp. 243-257). Berlin Heidelberg: Springer.

Zichermann, G., & Cunningham, C. (2011). *Gamification by design: Implementing game mechanics in web and mobile apps*. O'Reilly Media, Inc.

Henrik Detjen studied Applied Cognitive and Media Science at the University Duisburg-Essen. His main interest are (model driven) software development, information visualization, networks and human computer interaction. In his master thesis he implemented a framework for the visualization of dynamic networks. Currently, he works as a research associate in HCI topics at the Hochschule Ruhr West, University of Applied Science, Germany.

Stefan Hoffmann received his Diplom (FH) in Electrical Engineering from Cologne University of Applied Sciences and his MSc in IT-Security from Ruhr-University Bochum. Now, he is working as a research assistant at the Computer Science Institute, Hochschule Ruhr West, University of Applied Science, Germany. His research interests include various aspects of security in information technology (especially cyber security in smart grids) and cryptography.

Leonie Rösner is a research assistant and doctoral student in social and media psychology at the University of Duisburg-Essen, in the department of Social Psychology: Media and Communication. She has earned her master's degree in Applied Cognitive and Media Science at the University of Duisburg-Essen in 2013 with a thesis on the effects of anonymity and group norms on aggressive language use in online comments. In her research she is interested in social influence processes in Web 2.0 settings, social media effects on social norm perceptions, and the usage of social and mobile media in risk and crisis communication.

Stephan Winter is a research associate in social and media psychology at the University of Duisburg-Essen, Germany. After working as a newspaper and radio journalist, he earned his PhD in 2012 with a thesis on selective exposure and information processing on online news sites. His current research interests include persuasion and credibility in online contexts, the role of social media in crisis communication, self-presentation in social networking sites, and laypersons' understanding of scientific knowledge.

Stefan Geisler is Professor for Applied Computer Science and Human-Machine Interaction at Hochschule Ruhr West, University of Applied Sciences in Bottrop, Germany. After he received his Ph.D. he worked for several years in the industry, at Ford Werke GmbH in Cologne. There he worked in different automotive HMI projects from research to serial development. 2010 he was offered a professorship. In his research he continues working on automotive HMI, but also on usability of different kinds of technology in times of demographic change (User Interfaces for Ambient Assisted Living systems) and for safety-critical systems. He works with user-centered design processes following the goals of the Positive Computing paradigm.

Nicole C. Krämer is professor for social psychology: media and communication at the University of Duisburg-Essen. She finished her PhD in 2001 and received the venia legendi for psychology in 2006 with a thesis on social effects of embodied conversational agents. Her current work focuses on social psychological aspects of Web 2.0 applications as well as on social effects of human-technology interaction.

Gerd Bumiller received the Diplom (Univ.) and the Ph.D. degrees in electrical engineering from the University of Erlangen-Nürnberg, Germany, in 1997 and 2009, respectively. Served in one medium-sized company in the area of development, project and research achievement (1997- 2011). In October 2011 he leaved industry and is currently a Professor on Energy and Information Engineering at the Institute of Computer Science of the University of Applied Sciences Hochschule Ruhr West at Campus Bottrop, Germany.

Crisis-related Apps
Assistance for Critical and Emergency Situations

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

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

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

ABSTRACT

In this paper we developed applications for apps in times of crises and critical situations. We analyzed how people act in these situations and how to mitigate their uncertainty and fears through situation-specific communication. Including these aspects as well as the general challenges of crisis communication, pros and cons of apps based on existing examples were discussed. The resulting requirements for an app for crises and dangerous situations should assist in designing a communication solution that strengthens the feeling of security of citizens in critical times, such as life-threatening situations. This solution is intended as an additional means of communication for emergency services to modernize crisis communication with affected people.

Keywords

Critical situation, life-threatening situation, apps, crisis behavior, crisis communication

1 INTRODUCTION

In life-threatening situations, such as unexpected dangerous conditions, many people feel uncertain. In such cases, these people are looking for help and feel confused: What is happening? What is the correct course of action? What should I consider? Who can help? The less information is available, the higher the anxiety, panic reactions and incorrect behavior. If people experience helplessness, a loss of control and uncertainty with the feeling of being in mortal danger, they are petrified with fear (Herzog, 2014). Renner and Gamp (2014) demonstrated that contextual information could help affected people to assess the situation and make informed decisions. Accordingly, the timely communication of current issues can affect the loss of control, thus reducing the feeling of insecurity.

Mobile devices such as smartphones afford a rapid exchange of information. They are handy, practical, can be used anywhere and provide access to various forms of content and functions in real time. More and more people own smartphones (Statista, 2015) and use numerous apps that accompany them reliably in their everyday life (Rademacher, 2012). The smartphones serve as a "digital nanny" for users, which reminds them of appointments, predicts the

weather or serves as a source of entertainment, thus they never get the feeling of being alone. Rademacher (2012) posited that the immediate availability of such information via apps creates a feeling of control because knowledge and the ability to influence ones living environment are available at any time, e.g. through communication with contacts and monitoring their status updates. This perceived control has a soothing effect on people (Rademacher, 2012).

Our research project deals with the design of communication networks that strength the sense of security of the citizens in crises situations. We aim to improve the communication between crisis actors and the affected so that important information can be exchanged at any time and for various conditions. In this context, the use of apps for crisis communication seems to be of great benefit. The technical possibilities, such as the immediate access to stored data or the mobile web and thus the access to current news, as well as the familiar handling of the technology and the associated confidence, can foster autonomous action and reduce perceived uncertainty among people. Considering these aspects, the following research question can be derived: Which factors are critical to design an efficient communication app for citizens in critical situations?

In order to design a concept for a successful solution, various aspects are considered in this paper. First, in the following chapter communication in critical situations is analyzed. There we consider the behavior of people during the different crisis phases in relation to the crisis communication of authorities and organizations with security tasks and examine the challenges of crisis communication. Then, various communication means are reflected in terms of their suitability for crisis and emergency scenarios. In the third chapter, we present different apps that have been developed for crisis situations in order to help people. We analyze the properties and functions of apps and discuss their advantages and disadvantages for critical scenarios. Based on the previous results, we derive requirements for an app that can be used for different critical situations and supports all user groups. In the conclusion we discuss this design concept and further steps of our research project.

2 COMMUNICATION IN CRISES AND EMERGENCY SITUATIONS

Insecurity and fear arise in situations that occur unexpectedly with unknown consequences. These include life-threatening events. To avoid panic, it is vital to provide citizens, particularly the affected, with relevant information. To reach people in crises there are different communication tools. Emergency services can use many different media, such as newspapers, websites, radio, flyers, local announcements and sirens to inform the citizens. Sometimes people do not know that this information is available. This often depends on the citizens themselves and the awareness of their own situation.

2.1 CRISIS PHASES AND HUMAN BEHAVIOR

As already pointed out, in crisis situations it is important to strengthen the sense of security of those affected so that they act properly. According to a theory by John Leach human behavior is not dependent on the type of a disaster, but on the perceived risk (Leach & Campling, 1994). Leach distinguishes three stages of a crisis and assigns each to a certain behavior. The crisis communication should be adjusted according to the appropriate behavior. The objectives of crisis communication can be assigned to the respective phases.

In the phase *before a crisis*, people are uninterested in potential crises and tend to ignore the facts and suggested precautions. Therefore, the crisis communication in this phase should

include informing the population. Trust and credibility in the source are crucial (Federal Ministry of the Interior, 2008). To avoid that the communicated information is ignored, it is important to highlight the personal relevance and usefulness for those affected (Downs, 2011). With a higher perception of risk the likelihood to remember important information increases (Brewer, 2011).

In Leach's phase *during a crisis*, people show reflexive and schematic behavior. They have no control over their emotions and information processing is inhibited. At this stage crisis communication should comprise an accurate assessment of the situation (Renner & Gamp, 2014). The assessment should be prompt, transparent, objective and truthful, even if the information is still uncertain (Federal Ministry of the Interior, 2008). This knowledge and an accurate assessment of the situation help choosing appropriate behavior patterns and making informed decisions.

In the third phase, *after the crisis*, people are aware of the impact and damage, but act very emotional trying to suppress the reality. At this stage there is no specific need for communication with the population (Federal Ministry of the Interior, 2008). Here crisis management reflects about previous events in order to gain new insights and to prepare for future crises. However, it can be assumed that the citizens have to deal with the particular experiences and thus require corresponding feedback and support in this phase.

Considering these behavioral strategies, it seems to be important to align the crisis communication according to the needs of citizens. It should be noted at which time information is necessary for citizens and when they would consider it. As already indicated, not all of the crisis media are known by the citizens or they are not accessible to them. However, it is important to bring information to the affected quickly and without gaps. In this context, it makes sense to adapt the information media to the needs of citizens, because according to Leach´s theory an adaptation of citizen's behavior in crises cannot be implemented (Vorst, 2010).

2.2 CHALLENGES OF CRISIS AND EMERGENCY COMMUNICATION

Successful crisis communication is also dependent on other factors besides the choice of suitable media. In this context, the communication source as well as the communicated content is important. Hagar (2010) demonstrated different information challenges in the context of information communication from the authorities to citizens (see Table 1). In that regard Hagar emphasized that it is relevant to understand the importance of information in the various stages of a crisis, to analyze complex information needs and information-seeking of the people and to get an understanding of the factors that impact the integration and coordination of information in a crisis.

These challenges vary depending on the situation. The specific crisis scenario and the relevant addressees must be distinguished, because people can have different roles in the scenarios, e.g. victim, volunteer, relative or observer. These factors are decisive for the investigation of technologies and human-centered approaches that support communities in crises (Hagar, 2010). To account for the challenges, the communication should provide personalized information for all persons. Hence the challenge is to reach individuals to address the relevant information needs. In order to provide customized information, their specific situation must be known. In addition to the information about the general situation and situation assessment, there will be situations that require certain actions. People have to be instructed to behave properly, if they are not able to do so of their own accord. These include situations that affect the person's own concern (e.g. car accident).

Table 1. Information challenges in a crisis (Adopted from Hagar, 2010)

Information Challenges in a Crisis
• Information overload or, conversely, lack of information • Changing information needs at various stages of a crisis: preparedness, warning, impact, response, recovery and reconstruction • The many diverse actors and agencies involved who increase the amount of information produced • The connection of informal and formal channels of information creation and dissemination • Information uncertainty • Trustworthy sources of information • Conflicting information • Getting the right information to the right person at the right time

In order to get adequate help, support and situation-related information in crises, the role of the persons concerned can be crucial. In relation to the various roles, different level of affection can be distinguished. Each level contains specific needs for information. On the other hand, people have a different perception of the situation on each level. In our view, four different roles or level of affection can be distinguished:

- First level of affection: Victims and people who can give first-hand information (e.g. how they feel), since they themselves are affected, and people who are affected themselves but cannot provide information. If they are able to act, they can search or call for help and they can help themselves.
- Second level of affection: Companions or direct helpers who are with or near victims and affected in critical situations. They can report second-hand information (e.g. reflect how others feel) and describe the situation in detail (e.g. what they see). They can search or call for help and they can help others.
- Third level of affection: Observers or indirect helpers who see or hear about critical situations but cannot report in detail. They could help others.
- Fourth level of affection: Messengers or public facilities who cannot see but tell that something has happened and where it is. They could help others.

In view of the challenges and the various forms of communication, the most vital requirement referring to Hagar (2010) is to get the right information to the right person at the right time.

2.3 MEANS OF COMMUNICATION

At first glance human-to-human communication appears to be the only option to receive personalized information. In this way, the own situation can be described and required information can be retrieved. Media such as radio, television, flyers or sirens are unsuitable, as an exchange between the communication parties is needed. Because direct communication from the authorities to citizens cannot detect the citizen's needs, if the backchannel to ascertain the needs is missing.

For a bi-directional exchange other communication methods seem to be more convenient. Probably the easiest way is a face-to-face conversation or a phone call. In this context, the set of acquaintances as well as appropriate experts (e.g. emergency personal) serve as sources of information and recommenders of actions or instructions (Whalen & Zimmerman, 1990). Possible limitations arise in this case if it is not possible to address or to call another person, for example, when the person got into a critical situation himself and is not able to make calls

or speak due to the circumstances. Social media represent another means of bi-directional exchange. In contrast to mass communication through traditional media, for the most part the receiver knows who the transmitter of information from social media is. These provide information on different areas in crises. First, the exchange between relevant persons can be carried out in real time and people can search for published news. In addition, various initiatives are launched through social networks in crises, e.g. to coordinate volunteer help and helping others to cope with the crisis (Kaufhold & Reuter, 2014). A big advantage of social media communication is the possibility to use it on the go anywhere. Among other things, a disadvantage is that the information in social media often does not come from authorized sources or security organizations.

Although the authorities provide many media for different situations, they must be taken to the citizens, because mostly they do not know that such media exist. According to Leach's theory (Leach & Campling, 1994), facing a crisis is difficult, because people do not deal with potential crises or dangerous situations before they occur. Accordingly, they must first identify the relevant information corresponding to the phase of the crisis and the person concerned. In crises people likely use the channels that they prefer to use otherwise (see schematic behavior *before crisis*). Social media offer access to content by various technologies that people already use a lot every day and on the go. Taking into account the mentioned aspects, mobile technologies offer a combination of different functions that can provide an attractive solution both in terms of the behavior of people in crises as well as the communication challenges.

2.4 MODERN CRISIS COMMUNICATION VIA SOCIAL MEDIA

The relevance of communication by the authorities to citizens through social media was highlighted in various works. In this context, studies focused on past crises to analyze the communicated content. St Denis, Palen, and Anderson (2014) found that authorities do not comply with the citizens communication needs and emphasized the potential of social media for crisis communication. Previous studies already stated the essentiality of mobile peer-to-peer communication in phases of crises (Palen, Vieweg, Liu, & Hughes, 2009). Ivarsson (2015) also emphasized the significance of the involvement of the public for crisis communication. Tapia and LaLone (2014) indicated the use of social media communication in the context of the Boston Marathon Bombing. Other studies emphasized a consideration of volunteers through social media, because in crises people tend to help each other and need to be coordinated (Condon & Robinson, 2014; Purohit et al., 2014; Van Gorp, 2014). Furthermore, Magnusson and Öberg (2015) stated that crisis training is a fundamental user need. Hence, this aspect should also be integrated into modern crisis communication.

In relation to the development of crisis-related social media, Hughes, St Denis, Palen, and Anderson (2014) identified design proposals for crisis communication analyzing past postings from social media. They propose to highlight important information related to a crisis so that it can be found quickly. This proposal can also be applied to the use of apps. In a crisis-specific app the attention to such information can be increased because of the crisis focus of the app. Relating to the thesis by Downs (2011) this would highlight the personal relevance and usefulness for affected people. Roos, van Buul-Besseling, Streefkerk, and Neef (2015) have derived success factors for crowdsourcing platforms. They describe motive alignment of the crowd as an important factor for the usage of such technologies. Choi, Choi, and Kim (2012) already considered motivational aspects of app usage and found a correlation between extrinsic motives and trust.

Research in the field of crisis context focuses increasingly on the use of apps to support the communication and interaction between victims and the helping actors (e.g. Bean et al., 2015; Cheng, Liang, & Leung, 2014; Reuter, 2014). Therefore, in the following, various apps are analyzed based on their features to outline their advantages and disadvantages for crisis communication.

3 USE OF APPS IN CRISIS AND EMERGENCY SITUATIONS

The numerous functions of smartphones including MTS, GPS, camera and data memory enable various application options. Location-based information can support people by promoting situational awareness. If MTS or GPS do not work people can still use preprogrammed instructions. Also people can participate and share vital information with others. Köllen (2015) described different crisis apps for weather or hazard warning (*KATWARN*[5]), search for objects that were buried by avalanches (*Galileo-LawinenFon*[6]), first aid instructions (*Malteser Erste-Hilfe-App*[7]) or current investigations of wrong-way drivers (*ANIKA* [8]). Moreover, there are apps to recruit and coordinate registered volunteers (*Hands2Help*[9]) whereas trained first aiders can register at *Mobile Retter*[10] and be alarmed in an emergency situation in their immediate vicinity, to get there faster than the ambulance. Depending on the context of a crisis or disaster, there are different objectives of communication. The crisis communication can be supported by the use of apps, whereby the uncertainty of affected people can be reduced.

3.1 CHARACTERISTICS OF CRISIS APPS

In the following, the mentioned apps (Köllen, 2015) and their functions will be presented to illustrate the possibilities for the use of apps in critical situations. To give a better overview, we present other apps that are similar to the already mentioned ones. These apps address different roles of affected people and their level of affection in various contexts. They promote an information gain, provide behavioral instructions, coordinate people in crises and provide useful support in other critical situations. It should be noted that the objective is not to investigate the apps to see if they are well designed or how popular they are. Furthermore, it should be noted that the featured apps exemplify an overview of the various areas of application for the discussed problems. There are many other areas for the use of apps for example in the context of security, such as location trackers for kinds or pets (*trax*[11]). The aforementioned apps can be considered in various operational scenarios.

APPS WITH ALARM FOR SITUATION AWARENESS

There are apps like *KATWARN* and *ubAlert*[12] that send messages or alerts to the users of the apps and thus inform them of the situation or a disaster, such as storms, epidemics or fires.

---

[5] http://www.katwarn.de (accessed: 27-May-2015)

[6] http://www.lawinenfon.eu/ (accessed: 01-September-2015)

[7] http://www.malteser.de/erstehilfeapp.html (accessed: 27-May-2015)

[8] https://www.tu-clausthal.de/presse/nachrichten/details/1621.html (accessed: 01-September-2015)

[9] http://informationsmanagement.wiwi.uni-halle.de/projekte/hands2help/ (accessed: 27-May-2015)

[10] http://www.mobile-retter.de (accessed: 27-May-2015)

[11] http://www.traxfamily.com (accessed: 01-September-2015)

[12] https://www.ubalert.com (accessed: 01-September-2015)

With *KATWARN* users are warned via push-notification by civil protection authorities, fire departments and by the German Weather Service (Fuchs-Kittowski & Faust, 2014). They can share the warnings and forwarding them via SMS. Similar to *KATWARN*, *ubAlert* allows users to indicate their residence to get location-specific information within a specified radius via email or SMS. However, users can also take action themselves by creating warnings and passing them on to the app (Ibrahim et al., 2013). Following a review of the relevance of the message by the operator, all registered users who are located within the warning area will be informed. The warnings are displayed graphically on a map and can be filtered by time, location, severity, credibility and category if required. There is also information about the state of the message (rumor vs. confirmed message). The app has a collaboration aspect as messages can be broadly shared and commented by users.

As another example of warnings via apps, the student project *ANIKA* from the University of Clausthal can be cited. Drivers on a highway can be warned faster by the app than by traffic reports that a wrong-way driver is located in their vicinity (ITS Niedersachen News, 2014). This works by transmitting the mobile data of all drivers to the roadway pillars, whereupon an evaluation of the data ensues. If a vehicle, which is traveling in the wrong direction, is detected, other drivers in the vicinity are alarmed within a second via message.

APPS FOR SENDING ALARMS AND ASKING FOR HELP

There are various forms of apps to submit alarms or emergencies. Avalanches represent a special scenario, where the person in distress can no longer ask for help actively. The app *iSis*[13] supports an automatic alarm if the user has an accident or is buried by an avalanche. Therefore, the *iSis* system recognizes the traveled distance, the height differences and the user's mobility in real-time (Floyer, 2013). Users who are conscious can also trigger a manual emergency alarm. In both cases the corresponding resorts, emergency services or registered users (favorites) are alerted via push notification. The user receives direct feedback about his or her call, wherein a first ring tone signals that a distress signal was sent, and a second ring tone indicates that the distress signal has been received. To use the app, an Internet connection or Bluetooth is required. The *Galileo-LawinenFon* uses satellite technology to locate the persons concerned (Meiboom, 2014). This way, a very accurate localization of the position of the device that sends an alarm is possible.

The emergency app *Malteser Notruf-App*[14] is an all-round alarm system and can be used anywhere. It is not specialized for any specific area. With this authorized app people can send emergency calls to predetermined representatives (by SMS) or to an emergency call center (automatic voice connection to the Malteser emergency central). The exact GPS based location and stored information such as pre-existing conditions are forwarded with the call. However the use of this app is fee-based.

APPS FOR BEHAVIORAL INSTRUCTIONS AND SUPPORT

Apps for behavioral instructions or step-by-step instructions in critical situations provide users with information to act independently in various scenarios. The first-aid app by Malteser (*Malteser Erste-Hilfe-App*) uses images and short texts to guide the user through important actions, based on simple guiding questions to situation-specific provisions (e.g. securing the

[13] http://www.isis-application.com/ (accessed: 01-September-2015)

[14] http://www.malteser-notruf-app.de (accessed: 01-September-2015)

accident scene) and first aid instructions (e.g. in cases of poisoning or wounds). This content was created based on training requirements for the Assistance Service and should therefore serve as a kind of first-aid training. In addition, the app contains a link to related courses.

The *St John Ambulance First Aid*[15] app also works with step-by-step instructions by pictures and brief descriptions for numerous issues, including asthma, drowning, cold and heat accidents. Some instructions differentiate between aid for adults, children and infants (e.g. resuscitation). Additional, auditioned guides can instruct the user by voice.

APPS FOR VOLUNTEERS

The app *TeamRedCross*[16] allows registered users to advertise posts for volunteers or respond to listings. Newly issued alerts that come up within the specified location of the user will be forwarded via push-notification. If the user is interested in the offer, he can prepare on the basis of bullet points, videos or simple quizzes in the app, e.g. he learns how a drowning child can be saved and what should be noted doing this. Then the user can decide whether he wants to accept the commitment. Operations are advertised for situations such as fires, floods, storms and other disasters. As an incentive for volunteering digital badges and achievements are awarded for numerous commitments. The app also allows forming a team with other registered users to be in direct contact with them. Further, alerts can be divided into social networks to inform other people and ask them to volunteer.

Another app for volunteer workers is *Hands2Help*. Using the app requests for assistance from citizens by authorities and support services can be captured spontaneously and routed to the right helpers. These are identified by their profiles and customizable criteria (e.g. skills, access routes and equipment) with the aid of an algorithm. Users are alerted via the app and get information after a certification about their commitment, e.g. for filling sandbags or providing supply to helpers (Hofmann, Betke, & Sackmann, 2014).

APPS FOR TRAINED FIRST AIDERS

Mobile Retter is an app that is based on a similar principle as *Hands2Help.* With the *Mobile Retter* app trained first aiders that are located in close proximity can be alarmed in parallel to emergency services. The proximity is checked via GPS by the control center. If the first aider accepts the call, he gives feedback to the central office via the app and gets the exact emergency location immediately so that he can move towards that location right way. Due to this physical proximity the mobile first aiders are often at the crash scene to initiate life-saving measures before the emergency services arrive (Stroop, Strickmann, & Kerner, 2015). This increases the chances of survival of the affected. To guarantee a high quality of aid, the access to the app is limited to registered first aiders with reviewed qualifications.

This app is different from the aforementioned ones. The other apps are used in the context of assistance and for information gain. *Mobile Retter* focuses on an effective deployment of people with trained skills in crises. Nevertheless, this app is an example of a sensible solution and effective communication in critical cases.

Taking into account the areas of application of the listed apps for critical and dangerous situations, it can be stated that apps provide a replacement opportunity for other

[15] https://www.sja.org.uk/sja/support-us/the-difference/helpless/mobile-phone-app.aspx (accessed: 01-September-2015)

[16] http://www.redcross.org/mobile-apps/volunteer-app (accessed: 01-September-2015)

communication means, both for one-way as well as for bi-directional communication. Moreover, in crisis situations various audiences can be addressed with apps and perform various actions with these apps. Table 2 shows a summary of the emphasized characteristics of the described apps.

Table 2. Characteristics of the sample of apps for critical situations

App Name	Communication Direction	Actions	Addressees	Level of Affection
KATWARN	Bi-directional	Consume and participate	Everyone	Any
ubAlert	Bi-directional	Consume and participate	Everyone	Any
ANIKA	One way	Consume	Drivers	2
Galileo-LawinenFon	Bi-directional	Participate	Anyone in avalanche zones	1 + 2
iSis	Bi-directional	Participate	Anyone in avalanche zones + climber	1 + 2
Malteser Notruf-App	One way	Participate	Everyone	1 + 2
Malteser Erste-Hilfe-App	One way	Consume	Everyone	Any
St John Ambulance First Aid	One way	Consume	Everyone	Any
TeamRedCross	Bi-directional	Consume and participate	Everyone	2 + 3
Hands2Help	Bi-directional	Consume and participate	Everyone	2 + 3
Mobile Retter	bi-directional	Consume and participate	Trained first aiders	4

Likewise, using apps facilitates a combination of different media. Information may be consumed by apps instead of using radio, television, or print media. Warning sirens or vehicles can be replaced by alerts via smartphones and behavioral instructions can be supplanted by using imagery and short text in apps. On the other hand apps also have specific restrictions that should be considered.

3.2 ADVANTAGES AND DISADVANTAGES OF APPS FOR CRITICAL SITUATIONS

The ideas and scenarios of the described apps show the variety of applications for different situations. To analyze the usefulness of the apps, they should be considered in terms of the crisis phases by Leach (Leach & Campling, 1994) and the communication challenges by Hagar (2010). Thus, the advantages and disadvantages of individual apps and their functions can be revealed.

RELATED TO CRISIS PHASES AND HUMAN BEHAVIOR

Mayer (2012) posited that the value of apps is determined by quick access to information and need-based services. An underlying advantage of mobile crisis communication is reflected in the prompt reporting. The short path of an announcement to a citizen via smartphone is clearly superior to other communication media such as newspapers, radio and television. It highlights the perceived topicality of information and immediately attracts the attention of users. For direct response apps support another useful function. Location-specific information transfer using detection by GPS can support the assessment of the situation and highlight the personal relevance, cf. Downs (2011). This supports the statement made by Renner and Gamp (2014), as this contextual information can help to asset the situation. For example, through warning services like *KATWARN* and *ubAlert* that issue location-specific information on danger spots such as major fires or storms, the own risk perception can be increased (see phase *before*). *ANIKA* provides effective situation specific real-time information because the message is directly reported and not relayed through third parties. *KATWARN* even adds behavioral advice to the warning information, so that the users can reduce the loss of control by seeing actual opportunities for action. As a result, the alertness to potential involvement and the motivation for protective measures can be increased (Al-Akkad & Floor, 2014).

On the other hand, using preinstalled information such as guidance documents (Reuter & Ludwig, 2013) can encourage the autonomous action of affected in critical situations (cf. schematic behavior in the phase *during*). The advantage of the apps in this case is that these documents can be used even without Internet and mobile connections. Apps like the first aid apps *Malteser* and *St John Ambulance First Aid* provide step-by-step instructions and serve as support against uncertainty (cf. phase *during*). This provides an advantage in terms of immediate availability compared to other communication media such as information flyers like the "Guide to emergency preparedness and right action in emergency situations" (BBK, 2013). The information can be accessed directly from the app and instruct the actors. Accessing preinstalled content may also satisfy an immediate need for information. If that is not sufficiently, there is the possibility to ask for help, e.g. with the app *Malteser Notruf-App*. This function is a known practice in accordance with the usual handling of calls and messages (cf. schematic behavior in phase *during*). The app also provides the benefit of stored personal data that is sent with the emergency call. If the affected is not able to ask for help, functions such as the implementation of the automated alarm and call for help are useful, e.g. *Galileo-LawinenFon* and *iSis*. With the localization function victims are rescued quickly, which is especially important if they are buried or unconscious.

After the crisis, people's behavior is characterized by their awareness of the crisis extent, but they cannot deal with the situation and suppress feelings. It was assumed that in this phase the citizens have to deal with the particular experiences and thus require corresponding feedback and support. To ask for help or to provide assistance the users can make announcements with apps, e.g. *Hand2Help* and *TeamRedCross*. Through the request for assistance and the related talk those affected cope better with the crisis, which can also be promoted by offering help.

RELATED TO INFORMATION CHALLENGES

Regarding the information challenges by Hagar (2010) mobile communication offers many useful approaches. The importance of information was shown by the detailed reflection of human behavior in crises. So the challenge of changing information needs at various stages of a crisis can be solved with the use of apps. But the needs of affected are not only related to the accessibility of information. The provided information must meet certain criteria.

In crises, it is important that information is quickly and easily accessible in order to avoid information overload (Cromdal, Osvaldsson, & Persson-Thunqvist, 2008; Turoff, Chumer, de Walle, & Yao, 2004). The *Malteser Erste-Hilfe-App* and *St John Ambulance First Aid* contain many details and have several navigation steps before the user reaches the desired information. Likewise, the user has to assess which information fits his or her needs best in the current situation. However, apps such as *KATWARN* may have the disadvantage that the necessary information cannot reach the user, since GPS does not work. Alternatively, it is possible that the user is suddenly confronted with a situation that has not yet been recognized by the authorities and therefore there is no notification about it. Thus, the user experiences helplessness.

The dissemination of information is facilitated by the ability to share it, e.g. *KATWARN* and *iSis*. Furthermore, many apps refer to the source of information contained within the app, so users can obtain content from entities such as government agencies and organizations they trust. However, apps do not provide benefits related to information uncertainty or conflicting information, because these challenges depend on the source of the information. Perhaps users may trust the information in the app and feel guided by its information if they trust the source.

The biggest advantage is the ability to get personalized information, due to location-based information in real time, filtering options (cf. *ubAlert*) and stored user profiles (cf. *Malteser Notruf-App*). Many apps help overcome the challenge to get the right information to the right person at the right time (Hagar, 2010). Another advantage is that a lot of information can be communicated and gathered in one place (cf. *KATWARN*). However, it seems to be rational to use several means of communication. To reach different audiences, apps should be considered as an additional option to communicate the relevant information because of the restrictions of smartphone usage.

GENERAL ADVANTAGES AND DISADVANTAGES

Considering the different featured apps, it is unfortunate that different apps for specific scenarios exist and there are already several solutions for each scenario. The user must decide which app is suitable for him, which can lead to uncertainty and fear of the wrong choice (Schwartz, 2004). This can be a problem especially if the person is in a crisis and the choice of the right app is overwhelming. In this context, it makes sense that the app is installed already before the crisis occurs. If the mobile device has a pre-installed app, there is no need to make a choice, which would promote confidence in the app (Rademacher, 2012). A further advantage of pre-installed apps is that registration and the collection of profile data can be handled before the crisis occurs, so this information is already present in a crisis situation.

If an app is only available commercially and thus costs money (e.g. *Malteser Notruf-App*) that is a disadvantage in comparison to other information channels. Likewise, it is disadvantageous if additional hardware is necessary, e.g. *Galileo-LawinenFon*. As already indicated, it can be assumed that the usage of some apps is not intuitive (see. *Malteser Notruf-App* and *St John Ambulance First Aid*), so users may resort to more familiar media or functions such as a phone. General limitations of the app usage in crises are battery life and GPS availability.

Based on the assumption that apps represent an additional means of communication in times of crises, many advantages may be recorded. In terms of the level of affection, various groups of people (cf. *KATWARN*) and roles (cf. *Mobile Retter*) can be addressed directly for different scenarios with apps. Another advantage is the ability to get the content and information personalized, e.g. filtering of relevant information in *ubAlert* and create profiles with *Malteser*

Notruf-App. Although a direct emergency call is to be preferred, in the case of reception problems a behavior instruction via app can be very helpful to reduce panic reactions. Likewise, it should be emphasized that information as a combination of image, text and language may support different users needs. Table 3 shows a summary of the advantages and disadvantages of the presented apps.

Table 3. Advantages and disadvantages of the presented crisis-related apps

Advantages	**Disadvantages**
Speed: • Short and quick route towards the notification of users (*ANIKA*) • Possibility to set an individual, automatic alarm, which sends an emergency call when users have lost the ability to send one by themselves (*Galileo-LawinenFon*, *iSis*)	Reliability: • The app usage depends on the battery life of the mobile phone and the GPS availability • Relevant information may not reach the user, if the GPS is malfunctioning (*KATWARN*) • Different information sources can conflict and undermine the trust in the provided information
Personalization: • Location-specific information can be send to the users to help them assess the current situation (*KATWARN*, *ubAlert*) • Custom tailored information based on predefined user profiles (*Malteser Notruf-App*) and filters (*ubAlert*) • Ability to send personal data embedded in the emergency call to speed up the dispatching process (*Malteser Notruf-App*)	Scope: • Users can not receive information for crisis situations, which have not yet been recognized by the authorities • Some apps are not free of charge or may require additional hardware to function, which reduces the number of potential users (*Malteser Notruf-App*, *Galileo-Lawinenfon*)
Flexibility: • There are apps for various roles and groups within a crisis (*KATWARN*, *Mobile Retter*) • Possibility to combine multiple channels within a single app • Preinstalled information can be accessed even when the user has no internet connection or GPS-signal (*Malteser*, *St John Ambulance First Aid*)	Confusion: • Usually multiple steps are needed to reach the desired information within an app (*Malteser Erste-Hilfe-App*, *St John Ambulance First Aid*) • There is an oversaturation of apps for specific scenarios, which may confuse potential users (*KATWARN*, *iSis*)

On the basis of the presented issues, the use of smartphones and its mobility constitute advantages for the basic crisis communication. However, only specific apps provide crisis-relevant and needs-oriented features. Compared to other crisis communication channels, the advantage that apps provide is that they allow for the combination of multiple channels. To successfully exploit these advantages, however, several aspects have to be considered.

4 REQUIREMENTS FOR CRISIS-RELATED APPS

As already pointed out, many people own a smartphone and can use apps. The trend is rising (Statista, 2015). More and more people own smartphones, which means that the daily life use of these devices also increases. The individually optimized offers of smartphones via apps promote the convenience of users, according to the principle "I need an app that tells me when to do some sports or how the weather will be today" (Rademacher, 2012). The desire for an everyday support and a certain basic trust in the capabilities of apps seem to be a good prerequisite for the use and success of mobile applications in a crisis context. Similarly, benefits of apps can be expected in terms of objectives of crisis communication. Therefore it can be assumed that apps provide a practical alternative and a meaningful additional media to convey relevant information to affected people in crises. In particular, benefits can be seen in terms of human behavior support.

In order to harness the advantages offered by such apps and to counteract the disadvantages, various requirements for a successful solution for mobile crisis communication must be considered. Thus, the coverage and consideration of different functions based on analyzed apps appears to be advisable. With regard to the featured apps it can be concluded that the communication solution should include all of the following functions, in order to present an effective communication and exchange solution for different levels of affection and thus problems during crises:

- The app should offer the option to *get information and news*, which should be done in real time. The information should be communicated to the users directly and attract their attention, e.g. by alerts.
- The ability to *inform oneself independently* about specific content, in the sense of guidance and best practices, provides another important function for the app. This would promote autonomous actions and impart a sense of control. Another important aspect is that such information must also be accessible without an Internet connection.
- The option to *share and disseminate information* is important. It should be possible to share the given information from within the app with friends, acquaintances or other stakeholders (in close proximity) form within the app and distribute crisis relevant content. Thereby people can be addressed who have not received the message, for example, those without the app. Just as well, the app should allow to convey the own status, which is important for the contacts as well as for authorities and helpers.
- Furthermore, the function to *ask for help* appears to be very useful for such an app. Distinction should be made between the ability to dispatch an emergency autonomously and the option of automatic emergency calls. This is helpful as a person can ask for help in a dangerous situation, or the system triggers an alarm if the person cannot do it by himself. The possibility of an automatic aid call is an important advantage of apps in crises.
- An additional function is the option to *offer help* and to become a helper. The app allows coordinating volunteers and deploying them at appropriate places. People may also be prompted to provide assistance through the app.

The various functions are important because all individuals and thus levels of affection must be addressed. For a uniform solution considering all of the affected groups is fundamental. Thus, the personal relevance can be increased, as their behavior can be addressed in different situations, even if their situation or level changes (c.f. Downs, 2011). The precondition is that the app can be used *location-specific* and functions can be *personalized*. Hence, the content should be customized, e.g. with personal details and preferences of usage. With regard to the

design and usability, the following aspects of the app should be considered. A combination of the functions and *links between the individual functions* should be added, so that other actions can occur directly from the various functions, e.g. information should animate to action and contain a forward to the appropriate behavioral instructions. In terms of the mentioned apps with behavior instructions, long navigation routes should be avoided to get the user to relevant content quickly by *referring to other important communication media* (radio, television etc.), so only the most important information is included in the app and available ad-hoc. Here, the reference to general emergency call numbers such as 911 (US) and 112 (Germany) appears to be particularly important.

For the success of a crisis app the following additional notes should be observed. It is essential that user have the opportunity to *receive feedback* from the system for all actions and functions. The fact that a user gets feedback enables him to assess the behavior and to get a feeling of security and control over his or her actions and the critical situation. Furthermore for a useful solution the content is as important as functioning technology. Thus, the emergency service or other sources of information must provide *up to date content*, so the affected have input at various stages of the crisis. Also the communication of uncertain content is important in order to obtain the trust of citizens and to keep them on the cutting edge of things. Taking into account the fact that people do not download such apps in advance of a crisis (c.f. *first phase*), the app should be *pre-installed on mobile devices*.

5 CONCLUSION

This paper discovers the possibilities of apps in relation to critical situations and the necessary functions. In response to the research question, the benefits and crisis-specific characteristics of apps with regard to behavior and communication challenges have been discussed. As factors for the design of an efficient communication app in critical situations different functions were derived based on the needs of people. The design solution addresses the need to be informed during crises, to be guided, to offer help and enable the exchange with other affected. Other crisis communication means can be supported by apps, as apps are used as an additional means of communication, if the user will not be confused by the variety of the available functions.

There is a need to investigate the acquired concept for a communication solution that meets the different requirements of a crisis communication app. Our next steps imply an analysis of user requirements for apps in critical situations. Using these requirements, we will develop a first demonstrator that should be used to establish whether the design concept is sufficient to be an efficient communication app.

Thus, this paper provides a first contribution to addressing behavioral factors in mobile support in crisis communication. The exposed advantages of apps based on a theory of human behavior as a function of perceived risk and taking account of objectives of crisis communications are to be viewed critically, as they serve as an initial theoretical basis and there is no empirical evidence. To determine the usefulness of apps as a reliable helper in a life-threatening situation and its acceptance, further research approaches should focus on the aspect of trust because trust is a relevant factor for the use of an app or smartphone (Rademacher, 2012).

ACKNOWLEDGEMENTS

We would like to thank Sandra Jürgensmeier, Marius Gördes and Dennis Ziebart for their research help and contributions. 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" (Karl, Rother, & Nestler, 2015).

REFERENCES

Al-Akkad, A., & Boden, A. (2014). Kreative Nutzung der verfügbaren Netzwerkinfrastruktur im Katastrophenfall/Creative usage of available network infrastructure in disaster situations. *i-com*, *13*(1), 45-52.

Bean, H., Sutton, J., Liu, B. F., Madden, S., Wood, M. M., & Mileti, D. S. (2015). The Study of Mobile Public Warning Messages: A Research Review and Agenda. *Review of Communication*, *15*(1), 60-80.

Brewer, N. T. (2011). Goals. In B. Fischhoff, N. T**.** Brewer, & J. S Downs (Eds.), *Communicating risks and benefits: An evidence-based user's guide.* Government Printing Office, 3-10.

Cheng, Y., Liang, J., & Leung, L. (2014). Social network service use on mobile devices: An examination of gratifications, civic attitudes and civic engagement in China. *new media & society*, 1461444814521362**.**

Choi, H., Choi, Y. J., & Kim, K. M. (2012, January). The understanding of building trust model on smartphone application: focusing on users' motivation. In *Proceedings of the International Conference on IT Convergence and Security 2011* (pp. 13-20), Springer Netherlands.

Condon, S. L., & Robinson, J. R. (2014). Communication Media Use in Emergency Response Management. In: *Proceedings of 11th International Conference on Information Systems for Crisis Response and Management (ISCRAM '14)*, University Park, PA, USA.

Cromdal, J., Osvaldsson, K., & Persson-Thunqvist, D. (2008). Context that matters: Producing "thick-enough descriptions" in initial emergency reports. *Journal of pragmatics*, *40*(5), 927-959.

Downs, J. (2011). Evaluation. In B. Fischhoff, N. T**.** Brewer, & J. S Downs (Eds.), *Communicating risks and benefits: An evidence-based user's guide*. Government Printing Office, 11-18.

Federal Ministry of the Interior (Bundesministerium für Inneres). (2008, July). *Krisenkommunikation. Leitfaden für Behörden und Organisationen*. Referat KM1, Berlin, 19-21.

Federal Office of Civil Protection and Disaster Assistance (Bundesamt für Bevölkerungsschutz und Katastrophenhilfe). (2013, August). *Ratgeber für Notfallvorsorge und richtiges Handeln in Notsituationen*, Bonn. Retrieved September 2, 2015, from http://www.bbk.bund.de/SharedDocs/Downloads/BBK/DE/Publikationen/Broschueren_Flyer/Ratgeber_Brosch.pdf?__blob=publicationFile

Floyer, J. (2013). Smartphone Avalanche Search Apps—A Review. *Canadian Avalanche Centre*.

Fuchs-Kittowski, F., & Faust, D. (2014, August). Architecture of Mobile Crowdsourcing Systems. In *Collaboration and Technology: 20th International Conference, CRIWG 2014, Santiago, Chile, September 7-10, 2014, Proceedings* (Vol. 8658, p. 121). Springer.

Hagar, C. (2010). Crisis informatics: Introduction. *Bulletin of the American Society for Information Science and Technology*, *31*(6), 6-10.

Herzog, G. (2004). *Psychologische Aspekte von Großschadensereignissen und Katastrophen*. Springer Vienna, 171-195.

Hofmann, M., Betke, H., & Sackmann, S. (2014). Hands2Help–Ein App-basiertes Konzept zur Koordination Freiwilliger Helfer/Hands2Help–An App-based Concept for Coordination of Disaster Response Volunteers. *i-com*, *13*(1), 29-36.

Hughes, A. L., St Denis, L. A., Palen, L., & Anderson, K. M. (2014, April). Online public communications by police & fire services during the 2012 Hurricane Sandy. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 1505-1514). ACM.

Ibrahim, L. F., Albatati, R., Batweel, S., Shilli, R., Bakeer, M., & Al Laban, T. A. (2013). Safety of natural disasters. In *Design, User Experience, and Usability. User Experience in Novel Technological Environments* (pp. 85-94). Springer Berlin Heidelberg.

ITS Niedersachen News. (2014). *Netzwerkpartner starten ANIKA Projekt – Intelligente Erweiterung von Notrufsäulen*. Retrieved September 15, 2015, from http://www.its-nds.de/media/newsletter/Journal_2_2014_Screen.pdf

Ivarsson, S. (2015). New method for evaluation of crisis communication in exercises–involve the public. In: *Proceedings of 12th International Conference on Information Systems for Crisis Response and Management (ISCRAM '15)*, Kristiansand, Norway.

Karl, I., Rother, K., & Nestler, S. (2015). Begleiter und Helfer in der Not-Apps für Krisen und Gefahrenlagen. In A. Weisbecker, M. Burmester, & A. Schmidt (Eds.), *Mensch und Computer 2015–Workshopband* (pp. 29–35). Stuttgart: De Gruyter Oldenbourg.

Kaufhold, M. A., & Reuter, C. (2014). Vernetzte Selbsthilfe in Sozialen Medien am Beispiel des Hochwassers 2013/Linked Self-Help in Social Media using the example of the Floods 2013 in Germany. *i-com*, *13*(1), 20-28.

Köllen, K. (2015, April 4). *Smartphone - So wird das Handy zum Lebensretter*. Wirtschaftswoche. Retrieved May 25, 2015, from http://www.wiwo.de/technologie/digitale-welt/smartphone-so-wird-das-handy-zum-lebensretter/11535966-all.html

Leach, J., & Campling, J. (1994). *Survival psychology*. Macmillan.

Magnusson, M., & Öberg, L. M. (2015). Crisis Training Software and User Needs–Research Directions. In: *Proceedings of 12th International Conference on Information Systems for Crisis Response and Management (ISCRAM '15)*, Kristiansand, Norway.

Mayer, A. (2012). App-Economy. *Milliardenmarkt Mobile Business*, München.

Meiboom, M. (2014). *Untersuchungen zum Einsatz von UAVs bei der Lawinenrettung*. Deutsche Gesellschaft für Luft-und Raumfahrt-Lilienthal-Oberth eV.

Palen, L., Vieweg, S., Liu, S. B., & Hughes, A. L. (2009). Crisis in a networked world features of computer-mediated communication in the April 16, 2007, Virginia Tech Event. *Social Science Computer Review*, *27*(4), 467-480.

Purohit, H., Bhatt, S., Hampton, A., Shalin, V., Sheth, A., & Flach, J. (2014). With Whom to Coordinate, Why and How in Ad-hoc Social Media Communities during Crisis Response. In *Proceedings of the 11th International Conference on Information Systems for Crisis Response and Management. University Park, Pennsylvania* (Vol. 12).

Rademacher, U. (2012). Treue Begleiter. Die Psychologie der App-Nutzung. *Research & Results*, *3*, 40.

Renner, B., & Gamp, M. (2014). Krisen- und Risikokommunikation. *Prävention und Gesundheitsförderung*, *9*(3), 230-238.

Reuter, C. (2014). 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., & Ludwig, T. (2013). Anforderungen und technische Konzepte der Krisenkommunikation bei Stromausfall. In *GI-Jahrestagung*, 1604-1618.

Roos, B., van Buul-Besseling, K., Streefkerk, J. W., & Neef, M. (2015). Recover Faster from Disaster: Success Factors for a Crowdsourcing Platform. In: *Proceedings of 12th International Conference on Information Systems for Crisis Response and Management (ISCRAM '15)*, Kristiansand, Norway.

Schwartz, B. (2004, January). The paradox of choice: Why more is less. New York: Ecco.

St Denis, L., Palen, L., & Anderson, K. M. (2014). Mastering Social Media: An Analysis of Jefferson County's Communications during the 2013 Colorado Floods. In *Proceedings of the Information Systems for Crisis Response and Management Conference (ISCRAM 20014)*.

Statista. (2015). *Anzahl der Smartphone-Nutzer in Deutschland in den Jahren 2009 bis 2015*. Retrieved October 5, 2015, from http://de.statista.com/statistik/daten/studie/198959/umfrage/anzahl-der-smartphonenutzer-in-deutschland-seit-2010/

Stroop, R., Strickmann, B., & Kerner, T. (2015). Ersthelfer-Alarmierung per Smartphone. *Deutsches Ärzteblatt, 112*(24), 18.

Tapia, A. H., & LaLone, N. J. (2014). Crowdsourcing Investigations: Crowd Participation in Identifying the Bomb and Bomber from the Boston Marathon Bombing. *International Journal of Information Systems for Crisis Response and Management (IJISCRAM), 6*(4), 60-75.

Turoff, M., Chumer, M., de Walle, B. V., & Yao, X. (2004). The design of a dynamic emergency response management information system (DERMIS). *Journal of Information Technology Theory and Application (JITTA), 5*(4), 3.

Van Gorp, A. F. (2014). Integration of Volunteer and Technical Communities into the Humanitarian Aid Sector: Barriers to Collaboration. In *Proceedings of the Information Systems for Crisis Response and Management Conference (ISCRAM 2014).*

Vorst, H. C. (2010). Evacuation models and disaster psychology. *Procedia Engineering, 3,* 15-21.

Whalen, M. R., & Zimmerman, D. H. (1990). Describing trouble: Practical epistemology in citizen calls to the police. *Language in society, 19*(04), 465-492.

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.

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.

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.

Social Media and Emergency Services?
Interview Study on Current and Potential Use in 7 European Countries

Christian Reuter, University of Siegen, Germany

Thomas Ludwig, University of Siegen, Germany

Therese Friberg, University of Paderborn, Germany

Sylvia Pratzler-Wanczura, Fire Department of Dortmund, Germany

Alexis Gizikis, European Emergency Number Association, Belgium

ABSTRACT

Social media is much just used for private as well as business purposes, obviously, also during emergencies. Emergency services are often confronted with the amount of information from social media and might consider using them – or not using them. This article highlights the perception of emergency services on social media during emergencies. Within our European research project EMERGENT, we therefore conducted an interview study with emergency service staff (N=11) from seven European countries and eight different cities. Our results highlight the current and potential use of social media, the emergency service's participation in research on social media as well as current challenges, benefits and future plans.

1 INTRODUCTION AND RELATED WORK

The need of emergency services to employ with social media has risen during the last years, as long as these kinds of media are used more and more – of course also during emergencies. Social media is thereby defined as a "group of Internet-based applications that build on the ideological and technological foundations of Web 2.0, and that allow the creation and exchange of User Generated Content" (Kaplan & Haenlein, 2010).

1.1 PREVIOUS CASES

Since now, the majority of research focuses on crises and emergencies in the USA and deals with Twitter (Reuter et al., 2012). Table 1 summarizes the literature in a structured way by providing an overview of studies with regard to their reference, the related case or scenario, a brief overview of the scientific contribution and a keyword. The cases are sorted by the year the event took place. They have been identified while searching in Google scholar for the keywords "social media", "emergency", "disaster", "crisis". However, due to the amount of studies, only the most project-related have been selected to provide an appropriate overview.

Reference	Case	Contribution	Keyword
(Liu et al., 2008)	2004 Indian Ocean tsunami	Photo repository sites were used by citizens to exchange information.	Photo Sharing
(Murphy & Jennex, 2006)	2005 Hurricane Katrina	PeopleFinder and ShelterFinder	Finding
(Endsley et al., 2014)	2005 Hurricane Katrina, 2010 volcano Eyjafjallajökull in Iceland	Indicates that the perceived credibility of Social Media information is less than of printed, official online or televised news and information from family, relatives or friends.	Information Credibility
(Shklovski et al., 2008)	2007 Southern California wildfires	Photo repository sites were used by citizens to exchange information.	Backchannel communicatio n
(Amanda Lee Hughes & Palen, 2009)	2008 hurricanes Gustav and Ike	Depicts differences between the use of Twitter in crises and the general use.	Microblogging
(Qu et al., 2009)	2008 Sichuan earthquake	Outlines that people gather and synthesize information.	Information synthesis
(Sutton, 2010)	2008 Tennessee River technological failure	Outlines the phenomena of broadcasting.	Broadcasting
(Heverin & Zach, 2010)	2009 attack on four police officers in Lakewood, Washington	Shows the ability of Twitter to organize and disseminate crisis-related information.	Types of Tweets
(Latonero & Shklovski, 2011)	2009 Los Angeles Fire Department	Public Information Officers highlight the importance of the information evangelist within organizations.	Information Evangelism
(Starbird & Palen, 2010)	2009 Oklahoma Fires	Highlights the role of retweeting.	Collective Intelligence
(Vieweg et al., 2010)	2009 Red River Floods	Highlights broadcasting by people on the ground as well as activities of directing, relaying, synthesizing, and redistributing.	Situational Awareness
(Birkbak, 2012)	2010 Bornholm blizzard	Shows that the geographical location and self-selection into groups create different views of a crisis situation	Emergent Groups
(Starbird & Palen, 2011)	2010 Haiti earthquake	Was analyzed with the help of translators and reveals the phenomenon of "digital volunteers".	Digital Volunteers
(Starbird, 2013)	2010 Haiti earthquake	Examines collective intelligence as transformations of information through activities.	Collective Intelligence

Reference	Case	Contribution	Keyword
(Reuter et al., 2012)	2010 mass panic at the Love Parade music festival in Germany, 2010 volcano Eyjafjallajökull in Iceland	Outlines the need for duplex communication.	Crisis Management
(Nagy et al., 2012)	2010 San Bruno Californian gas explosion and fire disaster	Analysis for identifying and extracting subjective information by using language processing and linguistic approaches	Sentiment Analysis
(Starbird & Palen, 2012)	2011 Egyptian uprising	Shows how the crowd expresses solidarity and does the work of information processing through recommendation and filtering.	Information contagion and diffusion
(Wilensky, 2014)	2011 Great East Japan Earthquake	Emphasizes the use of Twitter to provide emotional support and mentions the problem of widely publishing obsolete or inaccurate information.	Commuters
(Perng et al., 2012)	2011 Norway attacks	The notion of peripheral response has been developed in relation to emergent forms of agile and dialogic emergency response.	Peripheral response
(Jennex, 2012)	2011 San Diego / Southwest Blackout	The availability of Social Media illustrates that “contrary to expectations, the cell phone system did not have the expected availability”.	Availability of Social Media
(St. Denis et al., 2012)	2011 Shadow Lake fire	Shows the deployment of trusted digital volunteers as a virtual team to support a incident management team.	Trusted Volunteers
(Reuter et al., 2013)	2011 Super Outbreak	Distinguishes groups of twitterers, such as helpers, reporters, retweeters, and repeaters.	Volunteers
(Wulf et al., 2013)	2011 Tunisian revolution	Social media linked the young activists with actors in other cities.	Political
(Yang et al., 2013)	2012 hurricane Isaac	Leads to knowledge which classification algorithms work best in each phase of emergency.	Four Phases of Emergency Management
(Amanda L. Hughes et al., 2014)	2012 hurricane Sandy	Shows that few departments used online channels in their response efforts and that communication differed between fire and police departments and across media types.	Officials Social Media use
(American Red Cross, 2012a)	2012 Online and Telephone Survey	States that 25% of the participants will download an emergency app and 12% of the general public used Social Media in crises.	Aid Organization
(Bergstrand et al., 2013)	2012 Analyses the Social Media use of government authorities	Presents an account type typology containing high-level organizational accounts, accounts for formal functions and roles, formal personal accounts and affiliated personal accounts.	Emergency Response
(Fuchs et al., 2013)	2013 European Flood in Germany	Confirms the potential of Twitter as a distributed ‘social sensor’ but at the same time highlights some caveats in interpreting immediate results.	Visual Analytics

Reference	Case	Contribution	Keyword
(Reuter et al., 2015)	2013 European Flood in Germany	Identifies challenges (1) clarity and representation of relevant content, (2) moderation and autonomous work, (3) feedback and updates in interaction relationships and (4) integration of technologies and interaction types.	Moderators and Design Challenges
(Cobb et al., 2014)	2013 Investigates the current tools, work practices and ad hoc collaboration of distributed digital volunteer teams	Identifies design implications for integrating the activities of distributed volunteers.	Digital Volunteers
(Gorp, 2014)	2014 Investigation of V&TCs and aid organizations	Categorizes Volunteer and Technical Communities into software platform development communities.	Volunteer and Technical Communities (V&TCs)

Table 1: Overview of Selected Cases in Literature

1.2 PREVIOUS SURVEYS WITH CITIZENS

Beside the several studies about the use of social media with regard to emergencies, just a few surveys on the perception of social media exist: With over 1,000 participants, a comparative study of the Canadian Red Cross (2012) aimed to figure out to what extent Canadian citizens use social media and mobile devices in crisis communication and what they expect from the emergency services both, currently and in the future. The American Red Cross (2012b) also studied citizens' use of social media during emergencies, with 1,017 online and 1,018 telephone survey respondents. However, these surveys only focus on citizens and not on professional emergency services.

1.3 PREVIOUS SURVEYS WITH EMERGENCY SERVICES

Another comparative study published by the American National Emergency Management Association (NEMA) contains the results of a survey conducted in 2012 among members of emergency services from 50 Federal States of the US (San et al., 2013). The survey, which involved 505 respondents, focused on the current degree of use of social media in crisis situations by emergency services and the future development of the organizations in respect of possible use. Additional questions were asked regarding general opinions of social media and the trustworthiness of citizen-generated information. Although the respondents indicated a positive attitude towards social media in general and valued its suitability for information dissemination, 75% mentioned the requirement of verifying citizen-generated content, and otherwise questioned its credibility. However, the main barrier identified, was the lack of personnel, experience and knowledge to take on additional responsibilities. However, they argued that the "largely untapped resource" of digital volunteers could "help to alleviate some personnel issues". The study revealed that 85% of US authorities already use social media.

A further survey of 241 US emergency managers at the county level in 2014 shows that only about half of these agencies use social media (Plotnick et al., 2015). Most of them do not have any formal policies to guide their use. Of those that do have formal policies, about one quarter actually forbid the use of social media. As main barriers for communication from authorities to citizens a lack of staff, guidance and skills have been identified; main barriers for the other

way around (from citizens to authorities) are staff, trustworthiness and information overload. The authors conclude that "the agencies and their representatives are not yet ready to embrace social media and use it to its fullest potential. For the most part, current social media use is for dissemination of information, not the collection of it". Furthermore "in addition to technological advances, policy and management changes are needed as well, to remove the "red tape" (lack of guidelines or even prohibitions against use) that impedes the effective use" of social media (Plotnick et al., 2015).

Flizikowski et al. (2014) present a survey within Europe, conducted among citizens (317 respondents) and emergency services (130 respondents plus 33 interviews from Finland, France, Portugal, Norway, Ireland, Great Britain and Poland). The study focuses on the identification of user needs concerning crisis management with the support of social media and mobile devices. The main goal of the study was to identify possibilities and challenges of social media integration into crisis response management. Generally the participants had a positive attitude towards social media. During the study, both citizens and emergency services identified the same challenges, such as a lack of knowledge, personnel issues, and uniform terms of use, credibility of citizen-generated content, and accessibility for older generations.

1.4 RESEARCH GAP

As seen some of this related work is focusing on citizens' perception. Other work focuses on the perception of emergency services in the US. Just Flizikowski et al. (2014) focuses on European emergency services. However they study the current state and challenges, but did not explicitly focus on future plans and the activities in research. This gap is going to be addressed within this paper by our interview study. Our research question therefore was:

What is the use of social media by emergency services in Europe?

In order to answer this question the sub questions of (a) current use, (b) potential use, (c) participation in research, (d) benefits, (e) challenges and (f) future plans will be studied.

2 METHODOLOGY OF DATA COLLECTION

To collect information about the different types of authorities' users and their motivation and attitudes in the use or potential use of social media in emergencies, a number of interviews with authorities' professionals were conducted.

2.1 METHODOLOGY AND DETAILS OF QUESTION ASKED

It was agreed to focus on qualitative rather than quantitative data, and in this respect, the interviews followed a semi-structured form. The openness provided by this kind of form, in comparison to a strictly form, is deemed to provide the opportunity for more direct communication between the interviewer and the interviewee. This approach allows a more in-depth exploration of the issues being covered, which provides a richer set of results due to ideas and topics brought up during the interview. Additionally, this form allows the interviewer to ask questions in ways more appropriate to each interviewee based on his/her background (see also Baxter & Courage, 2005). Before the conduction of the interviews, all participants were briefed about the general project idea and the purpose of the interviews (including the grant of the EmerGent). We also prepare a guidance document to ensure that interviewers explored the same topics in a similar way. The guidance document contains a framework of questions outlined in Annex A, with free answers or in some cases multiple choice answers or rating scale answers.

The interview covered different topics, structured in six sections:

A Introduction to the organization
B Information about the PSAP and/or emergency dispatching center
C Technical information about the PSAP and/or emergency dispatching center
D The use of social media in emergencies
E Challenges and benefits of the use of social media in emergencies
F Future plans

2.2 COLLECTION OF RESULTS

Members of the project EMERGENT conducted interviews during May 2014, in face-to-face or telephone sessions. The results were usually collected offline and were later added by each interviewer to an online tool for consistency and further analysis. The results are provided in the following sections anonymously and neither with an indication of the country nor the interviewee. The sections provide a detailed analysis of the data collected during the interviews and describe the current and potential future use of social media in emergency management, by taking into account participant perceptions and experiences so far.

Overviews of the collected responses are presented in tables. Conclusions and important highlights of the analysis of results are provided within each section. The first sections are focused on presenting the profile and operational characteristics of the respondents and their organizations (section 3), their media use for operations and communication (section 4) while the remaining section focus on social media use (section 5).

3 ORGANIZATION PROFILE

3.1 PARTICIPANTS (QUESTION A4)

The selection criteria focused on collecting responses from a wide range of authorities and emergency services. Interview participants were selected across the networks of consortium partners and from a variety of Public Safety Answering Points (PSAPs) and emergency dispatch centers. Here, the aim was to cover all types of authorities relevant for the project. While the interviews collected responses from authorities across different countries, the selection criteria were not explicitly based on the geographical location. Similarly, use of social media was not a prerequisite for participating in the study, but on the contrary responses from both authorities using and not using social media were welcome.

Due to the nature and wide range of the topics covered, for example operational and technical topics, in some cases more than one person from the same organization contributed to the interview. In total, eleven interviews with 19 participants were conducted. The participants come from seven European countries and eight different cities, including five national capital cities, both represented within the consortium of the project and outside it. The exact locations of the interviews are not provided in this article to ensure the anonymity of the respondents.

3.2 TYPE AND SIZE OF ORGANIZATION (QUESTION A1)

A wide range of authorities, such as police, fire departments, emergency medical and governmental authorities participated in the study, in addition to respondents who were responsible for directly receiving and answering emergency calls (PSAPs). The conducted interviews involve organizations that operate on all administrative levels at local, regional and

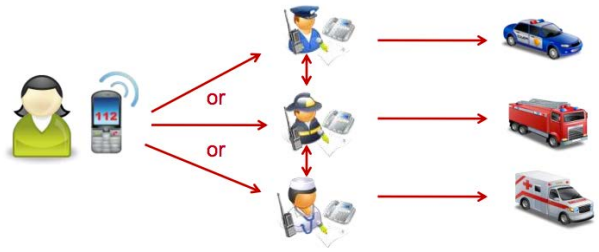
national level, while most of them operate locally. The case of service providers not directly responsible to handle emergencies, such as a police information service, was also studied as such types of providers are directly related to emergencies, collaborate during emergencies with the emergency services and also use social media in their daily activities.

3.3 PSAP MODELS (QUESTION A2)

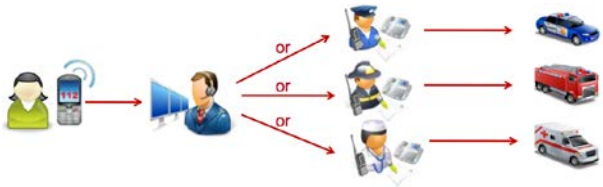
A list of different models (Machado, 2014) was used as the common basis for reporting and comparing the conducted interviews. While this list is not exhaustive and does not cover the entire call handling model or all possible models available worldwide, it was found sufficient for this study, because it helped quickly and easily refer to the major characteristics of operation amongst the respondents. The majority of PSAP model of operation was represented in the study. The participants from PSAPs followed mainly four models:

- Model 1: Emergency Response Organizations handling emergency calls
- Model 2: Filtering stage 1 PSAP and resource dispatching stage 2 PSAPs
- Model 3: Data gathering by stage 1 PSAP, resource dispatching by stage 2 in an integrated control room. In model 3 all involved emergency services use the same infra-structure (hardware / software), in contrast to model 2, where emergency services use the different infra-structure and interoperability can be a major issue.
- Model 4: Emergency Response Organizations independent PSAP

Each model is depicted in the following figures (Figure 1).



Model 1: Emergency Response Organizations handling emergency calls



Model 2: Filtering stage 1 PSAP and resource dispatching stage 2 PSAPs

Model 3: Data gathering by stage 1 PSAP, resource dispatching by stage 2 in an integrated control room

Model 4: Emergency Response Organizations independent PSAP

Figure 1: PSAP MODELS (Machado, 2014)

Table 2 provides an overview of the participants' organizational profile in terms of the PSAP model they follow and their operational level.

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10	Case 11
PSAP	X	X	X	X	-	X	-	-	X	X	X
PSAP Model	1	3	3	4	n/a	2	n/a	n/a	2	2	2
Operation level	loc	loc	reg	loc	nat	loc, reg	loc, nat	loc, reg, nat	loc	loc	loc

loc = local; reg = regional, nat = national

Table 2: Organization Profile (Source: May 2014 Survey of authorities)

3.4 PARTICIPANT POSITION AND FUNCTIONALITIES (QUESTION A3)

Participants in the interviews came from different professional backgrounds, including operations, communications, technical etc. Since in most cases, more than one participant contributed to each of the eleven cases, 19 professionals with senior positions participated in this study, including:

- Senior specialist in crisis communications
- Head of the Communication Centre
- Head of the Centre
- Commander
- PSAP leader
- Technical team leader
- Head of training department

Their responsibilities in their organizations included dispatch planning, field support, logistics, communication management, team coordination, crisis management, technical administration, exercise preparation etc.

This data is provided to help understand the perspectives on the use of social media in relation to the operational/organizational responsibilities. It was important all participants, regardless of their position and background, acknowledged the importance of social media in emergencies, considered it an interesting topic that they like to follow and agreed it cannot be overlooked despite the difficulties currently encountered.

3.5 RISKS, VULNERABILITIES AND OPERATIONAL SIZE (QUESTIONS A5-A8)

The following table (see Table 3) aims to highlight among others the likelihood and intensity of bilateral communication needs, i.e. from citizens to authorities and vice-versa that results out of the characteristics of population, given risks, hazards and vulnerability as well as the current calls/missions.

	Case 1	Case 2	Case 3	Case 4 and 5	Case 6	Case 7	Case 8	Case 9	Case 10	Case 11
Region										
Population in thousands	500 – 1000	≤ 500	500 - 1000	> 1000	≤ 500	≤ 500	≤ 500	> 1000	≤ 500	500 - 1000
Risks, Hazards and Vulnerability										
High population density	X	X	X		-	-	X		X	X
Large industrial sites	-	X	X	X	X	X	X		X	X
Harbors	X	X	X	X	-	-	-	X		X
Railways	X	X	X	X	X	X	X	X	X	X
Tunnels	X		X	X						
Major motorways	X	X	X	X	X	X	X	X		
Earthquakes				-	X	X	X			X
Storms / bad weather conditions	X			-	X	X	X		X	
Water catchment area	-	X		X	-	n/a	n/a			
Flooding	X	X		X	-	X	X		X	X
Cultural heritage, old cities		X	X	X	X	n/a	n/a	X	X	X
Touristic attraction	X	X	X	X	-	X	X	X		
Cultural Events	X		X	X						
Calls / Missions	17135	19500	1432	3942	1467	59458	0	1700000	240000	140000

Table 3: Characteristics of the analyzed interviews (Source: own elaboration)

4 MEDIA FOR OPERATIONS AND COMMUNICATION

4.1 OPERATIONAL TASKS (QUESTION B1-B3)

All participants share the task of responding to the public, or have a direct role in responding to emergency incidents. Case 5 is an exception to this as it holds a higher level role in emergency management. With the exception of case 7, most of the participants are involved in notifying the public and providing information. Similarly, case 10 is the only organization in the study, not directly responsible for receiving emergency calls. Table 4 summarizes the results.

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10	Case 11
Receiving urgent calls from 112	X	X	X	-	-	X	X	X	n/a	-	X
Receiving direct urgent calls	X	X	X	X	-	X	X	X	X	-	X
Notification	X	X	X	X	-	X	-	X	X	X	X
Providing information	X	X	X	-	-	X	-	X	X	X	X

Table 4: Operational Tasks (Source: own elaboration)

Table 5 identifies how each participant is involved in the four stages of the emergency management cycle[17].

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10	Case 11
Prevention	n/a	-	X	n/a	n/a	X	-	-	X	X	X
Preparedness	n/a	-	X	n/a	n/a	X	X	-	X	X	X
Response	n/a	X	X	n/a	n/a	X	-	X	X	-	X
Recovery	n/a	-	n/a	n/a	n/a	-	-	-	X	-	X

Table 5: Participant involvement in four stages of an emergency (Source: own elaboration)

4.2 INBOUND COMMUNICATION (QUESTION B4)

The communication channel most frequently reported and used as a source of input messages from citizens is the telephone. Another frequently reported channel is SMS, which in some cases is also used by people with hearing disabilities. Social media is usually not reported as an inbound message source, with the exception of two cases. In the first case, it is reported that social media is so tightly integrated in our daily life and communication channels, that is too important to ignore nowadays and it would be unthinkable not to respond to it. In the second case – although social media is not officially acknowledged as an inbound message source – messages are received, read and certainly taken into account. In both cases and in the context of this study, social media is used as a communication channel for inbound information in practice, while officially it is not acknowledged or promoted as an information channel. Other communication channels reported: Case 1 and 3: fax (deaf and persons hard of hearing); case 2 is planning to implement SMS and email channels in the near future, as it is important to widen the ways to reach the 112 PSAP; case 8: WAP, Video Call. Table 6 summarizes the results of all cases.

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10	Case 11
Telephone calls	X	X	X	X	n/a	X	X	X	X	X	X
SMS	-	-	-	-	n/a	X	-	X	X	-	-
Paging	-	-	-	-	n/a	-	-	-	-	-	-
Email	-	-	-	-	n/a	-	-	-	-	-	X
Webform	-	X	-	-	n/a	-	-	-	-	X	X
Radio Traffic	X	-	-	-	n/a	X	X	X	-	-	-
Social Media	-	-	-	-	n/a	-	-	-	-	X	X

Table 6: Communication Channels for inbound messages (Source: own elaboration)

4.3 OUTBOUND COMMUNICATION (QUESTION B5)

The purpose of sending messages to citizens follows the same patterns as with receiving messages and finds the telephone as the most commonly used channel. All other channels are similarly used as for inbound messages (see Table 7).

[17] See for example: https://www.providenceri.com/PEMA/about/emergency-management; often is “mitigation” used instead of prevention (we define mitigation as part of the prevention stage).

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10	Case 11
Telephone calls	X	X	X	X	n/a	X	X	X	X	X	X
SMS	-	X	-	-	n/a	X	-	X	X	-	-
Paging	-	X	-	-	n/a	X	-	X	-	-	-
Email	-	-	-	-	n/a	X	-	X	-	-	-
Webfor	-	-	-	-	n/a	-	-	X	-	-	-
Radio Traffic	-	X	-	-	n/a	X	X	X	-	-	-
Social Media	-	-	-	-	n/a	X	-	-	-	X	X

Table 7: Communication Channels for outbound messages (Source: own elaboration)

4.4 BROADCASTING (QUESTION B6)

Authorities appear less reluctant in using social media for broadcasting messages. Most participants use the radio for broadcasts, although it was commented there has been a shift from the press and the radio to the online channels. The use of their websites, other online media websites and social media provide the opportunity to inform the public very fast and allow the message to spread rapidly. In some cases, social media, such as Twitter, were previously used for communicating with the media, and have proved to present an excellent opportunity for providing public information. The results are summarized in Table 8.

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10	Case 11
Radio	X	X	X	X	-	-	X	-	X	X	X
Local TV	-	-	-	X	-	-	X	-	X	X	-
SMS-Broadcast	-	-	-	-	-	-	-	-	-	-	-
Social Media	-	-	-	-	-	X	-	-	X	X	X
Sirens	-	-	-	-	-	-	X	-	-	X	X
Special warning 1)	-	-	-	-	-	-	-	-	-	-	-
Offline media & press	-	X	-	X	-	-	-	-	X	X	X
Online media	-	X	-	X	-	-	-	-	X	X	X

[1)] systems like KatWarn or AmberAlerts

Table 8: Communication Channels for broadcasting warning messages (Source: own elaboration)

5 SOCIAL MEDIA IN EMERGENCIES

5.1 CURRENT USE (QUESTIONS D1-D14)

Most of the analyzed case studies use social media (except case 4 and 5) for different purposes that will be described below. Twitter is often used, sometimes Facebook and YouTube. Other services are rather seldom used. The following table (see Table 9) gives an

overview about what kind of social media is present at the institutions/authorities that were part of the survey. The different tools were not predefined, but collected during the interviews.

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10	Case 11
None	-	-	-	X	X	-	X	X	-	-	-
Twitter	X	X	X	-	-	X	-	-	X	X	X
Facebook	X	X	-	-	-	X	-	-	X	-	-
YouTube	-	X	-	-	-	-	-	-	X	-	-
Flickr	-	-	-	-	-	-	-	-	X	-	-
LinkedIn	-	-	-	-	-	-	-	-	X	-	-
Tweedeck	-	-	X*	-	-	-	-	-	X	-	-
Hootsuite	-	-	X*	-	-	-	-	-	-	-	-

*individual key players

Table 9: Current use of social media (Source: own elaboration)

5.2 POTENTIAL USE (QUESTION D15-D23)

The analysis of the first stage interviews highlighted that, in general, social media is seen as an important tool for the future, among others for gathering of information, interpretation of incidents and communication to/with the public. It is seen as one of the fastest ways to disseminate information about prevention or to inform the public with warnings or notifications before, during and after a major incident. Further, social media supports a bi-directional communication and can support all stages of an emergency management cycle: starting with identification of potential hot spots and informing or warning the public about certain facts regarding an incident (prevention or mitigation), informing the public about certain warnings or directions regarding an incident like spread of hazardous substances (preparedness), informing the people about forthcoming evacuation out of exposed areas, and reduce or avoid the possibility of emergency escalations (response), inform the people about medical aid and further behavior (recovery).

The intensity and degree of “information exchange” concerning relevant phases of the emergency management cycle making use of social media is diverse. Case 1 for example distinguishes between the foci “operation” and “general”. Concerning the operation, the focus is set up on the receipt of relevant information for operation. This information is used for e.g. necessary intervention concerning the process of communication (e.g. information provided by e.g. media) and thereby control and regulation of information (e.g. instructions concerning behavior, revision and correction of wrong information). In general it concerns public relations, information about training positions and advertisements.

Even if the use of social media is seen as important, there are some special restrictions concerning the “exchange” (gathering and mining) of data, not only due to the limited resources, but also limited tools and authorization. Case 10 differentiates the responsibility according to the dimension: in special cases and big emergencies the responsibility lies with the police communications department. In other “simpler” or pure information cases everyone in the dispatching center is responsible for social media use. Due to missing technical possibilities and tools (“Internet lock out”) for example in case 1 only the staff of the press office (fire department) are allowed to gather data (here data filtering/gathering is done only – if at all – when this is connected to a clear operation). A similar situation is seen in case 2,

where the communication service local (government) and communication service (fire service) is only allowed to spread data (responsibility belongs to the experts in the service) or case 6 the dispatching center (responsible there: dispatch officer, IT staff) or as in case 11 the officer in command.

Nevertheless, some of the analyzed cases already use (more or less) social media tools. Case 2 uses the Twitter platform, Hootsuite, Storify, Social Mention and aims to use Coosto in future. Here, the observation of current communication processes is used. Some other examples are crowd sourced maps including OpenStreetMap, Google Crisis Map or crowd sourced information management, crowd sourced pictures, information about smoke spread is used by e.g. case 2. Case 10 was said to use several tools (Hootsuite, Tweetdesk and Coosto) when preparing for a big event but not in urgent emergencies. During an emergency one or two people are gathering the data. Case 11 did not use any specific tools or applications.

In one case, the use of a specialized Twitter service, Twitter Alert was reported. Twitter Alert was launched in late 2013 and aims to enable authorities to keep people well informed by providing accurate and important information during an emergency. It is open to be used by authorities, government services and NGOs worldwide.

Beside the limited human and technical resources, the financing of using new social media is quite problematic and constrains its use. In some cases (case 1, 4, 5) there is no financing for social media. Nevertheless, in other cases (2, 3, 6, 10, 11) a budget is available or could be provided (local, regional, own budget) to guarantee this task, even if it is not part of the regular budgets and not marked as a use for social media.

The strategy for implementation into the organization differs through the case studies. Some case studies have no clear plans (like case 1); other organizations (case 3) are experimenting with the use of social media in case of an emergency. There have been experiments developed throughout the use of Coosto but these experiments were sporadic and without reciprocal reconciliation. Others (case 2) have clear expectations and define the first steps how to use and implement social media. Case 2 is running experiments with the active role of citizens during emergencies: they use social media on a daily basis to monitor and to gather information about incidents. Up to now this is performed manually, but in the near future it is aimed to implement software to automate this process and to implement social media in the dispatching rooms of the fire service and police (in the police, social media monitoring through specific software is already used to improve intelligence).

In case 6, fire officers and dispatchers are using social media without a clear and determined goal. This way, it is present in their daily routines. However none of the staff have received any training on how to use it so far. They plan to provide warning messages via Twitter and Facebook in incidents, where more than two fire brigade units are present at the spot or during incidents with hazardous materials. Nevertheless and as mentioned before, there might be some problems with integrating it with the existing software. As any new software has to be checked and verified by the PSAP director, this might take a while (in future, there might be a chance to integrate it into the existing software). While there are no formal or documented implementation strategy or guidelines in case 10, search for information and monitoring of social media is done continuously and in parallel with all normal activities. This is similar to the situation in case 11, where the information is used (one person in the PSAP is responsible for posting messages, all people are responsible for reading messages), but no formal workflow, method, or guidelines exist and no special tools are used.

Case 2 aims at a distinction between expert social media users and basic users: Basic users are, for example, PSAP operators who just have to get information from social media when

it's relevant. For these users, case 2 is focusing on buying software that will allow it to build a dashboard to show the right information when it is available. Expert users are the ones who control the dashboard and choose the search protocol. They are also the users that provide crisis communication on social media, as there is a requirement to be very familiar with social media "language" to be able to communicate in the most appropriate way. At this moment, implementation is still a problem as a lot of the necessary knowledge is only held by experts in the organization.

5.3 RESEARCH (QUESTIONS D24-D27, F5)

The importance and position of new social media will increase in future. This is stated in the cases analyzed, although most interviewees are not active in the field of research (e.g. cases 6, 7, 8 and 11). Therefore, a further use is in principle welcome and recommended. Nevertheless due to missing technical and time resources, an implementation in case 1 is currently not possible. Case 2 plans to use social media for e.g. gathering information, communication to the public, cooperation between services (for example Google Hangouts to communicate between the gold and silver command). There are concerns to follow research and development on social media as stated by case 2 in the field of monitoring tools (e.g. implementation of Coosto), continuous evaluation of social media use (what works and what doesn't), strengthen the cooperation with universities and the "team D5", a newly formed team of public communication specialists who help each other during crisis ("team D5" have a specific section on social media monitoring).

Case 11 states that possibilities of social media are currently being considered, even there are no formal plans for using it. Here, the verification of information is important as well as the possibility of an account being hacked is considered a serious risk, especially if at the same time there is a serious emergency.

5.4 BENEFITS (QUESTION E1)

Basically all possible benefits (warning, reachability, situation awareness for authorities and citizens) have been mentioned by all interviews. The following table (see Table 10) shows an overview about the benefits of social media use not only for the public but also for authorities.

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10	Case 11
Better public warning	X	X	n/a	X	n/a	X	X	X	X	X	X
Better reachability of citizens	X	X	n/a	X	n/a	X	X	X	X	X	X
Improvement of the situation awareness for authorities	X	X	n/a	X	n/a	X	X	X	n/a	n/a	X
Improvement of the situation awareness for citizens	X	X	n/a	X	n/a	X	X	X	n/a	n/a	X

Table 10: Benefits of Social Media use (Source: own elaboration)

In times of an incident, inhabitants want to be informed by the authorities in the same way as they daily gather news. That is dependent of the involvement and curiosity of the inhabitants.

Case 11 states social media has taken away some of the distance between the public and the Police, resulting in the police coming closer to citizens. Case 10 highlighted that people know they get valid information from emergency services and that they can trust this information. Here, trust is seen as a prerequisite for an appropriate relationship between local / regional authorities and the society. Trust has a key role in dealing with given risks and communication and should be regarded as fundamental for risk interpretation and awareness of the public between "real" and "perceived" risks (interpretations of "risk" differ according to individual and social contexts).

It has to be kept in mind that public decision-making, which is based only on the factual "scientific" dimension of risk leads to distrust, not taking into account the "socio-cultural" dimension, which includes how a particular risk is viewed when values and emotions are concerned (e.g. whether a risk is judged acceptable, tolerable or intolerable by society is partly influenced by the way it is perceived to intrude upon the value system of society). In addition, it contributes to the vulnerability of institutional settings as well as affected individuals. Case 3 stated that when the government takes a position in the social media networks, they will be able to deliver an interpretative perspective and handling perspective to the inhabitants in the area of the incident. This causes effects on the resilience of a community, because only those who are well informed and integrated in the process will accept the decisions made by different authorities and undertake the right choices/decisions in cases of risks. Furthermore it "proves" the image of the organization. Case 3 highlighted the fire service has a fine (positive) image towards the inhabitants compared to different other services and the government, where their image is significantly perceived worse.

The government must be a reliable partner concerning information exchange in the daily life, before they will be considered reliable at times of an incident. By quickly providing the "correct" information (concerns quality and quantity), the inhabitants will be provided only this kind of information they really want and especially need. By this way, the government can prevent panic situations during a big incident or a critical event.

5.5 CHALLENGES (QUESTION E2)

In parallel to the benefits, the interview study highlights additional challenges (even if some of the case studies have no experience with it, the difficulties could be estimated, as seen in the table below (Table 11). The biggest challenge is reliability of the sources, followed by the liability, believability and objectivity. Less important challenges are timeliness, reproducibility, understandability and legal uncertainty.

Additionally to this, case 3 stressed that some identified difficulties are the speed information is released with, it is never possible to quickly discover in which communities the most critical information is shared; you do not know who needs the information at most and messages cannot be quickly or sufficiently checked concerning their truth. In fighting a crisis, there is a crucial process of validation of the facts to prevent the ex-post evaluation and the wrong conclusions.

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10	Case 11	average
Reliability of the different sources	high	medium	n/a	high	n/a	high	high	high	n/a	high	high	High (2,9)
Liability of the different sources	medium	medium	n/a	high	n/a	high	high	high	n/a	high	high	High (2,8)
Believability / Verifiability	medium	medium	n/a	high	n/a	high	high	high	n/a	high	high	High (2,8)
Objectivity	high	medium	n/a	medium	n/a	medium	high	high	n/a	high	high	High (2,6)
Timeliness	low	low	n/a	no	n/a	medium	high	high	n/a	high	medium	Medium (2,0)
Reproducibility	low	low	n/a	medium	n/a	medium	high	high	n/a	high	n/a	Medium (2,1)
Understand-ability	low	low	n/a	medium	n/a	low	high	high	n/a	high	n/a	Medium (2,0)
Legal uncertainty	low	low	n/a	high	n/a	high	high	high	n/a	low	n/a	Medium (2,1)

high=3; medium=2; low=1; no=0

Table 11: Difficulties of using social media (Source: own elaboration)

5.6 FUTURE PLANS (QUESTIONS F1-F4)

Our interview study reveals that concerning future plans for using social media in emergencies the impact is estimated increasing (cases 1, 2, 4, 5, 6, 7, 8). Furthermore, case 2 stated that in 5-10 years crowdsourcing and big data will be standard technologies in crisis management. Therefore, it is necessary to focus on such items. In a crowd sourced and big data world (cf. Ludwig et al., 2015), verification becomes the main skill of the PSAP operator and the information manager. Nevertheless case 1 voiced the concern that as long as the technical and personnel circumstances will stay as they are, there will be no significant change. In cases 4 and 5 there are no examples of using social media in emergences by public administration. Probably some will be observed as important issue only when this gap will be filled by citizens. For sure social media will be used mostly in the field of situation monitoring and public warning.

Case 6 dispatching center will promote the implementation of notifications such as warnings or alerts. The attention should be moved also to gathering information from the public. Case 8 has no clear concept, but will place the social media growth and usage on the own agenda shortly. Case 11 will consider the use of Instagram and Facebook, but there are no precise plans at the moment (“we know what social media is only for a few years”).

Concerning new technologies, case 2 is focused on Coosto and case 6 aims at providing information to the general public using one app. This app should post a warning message to everybody on that area, regardless of the follower status. Case 6 and case 1 highlighted social media will be present in the daily routines in dispatch centers, PSAPS, etc. and it is possible that the reporting of the fire departments will focus more toward social media and the “older” solutions (such as a website) will lose importance.

The units (as in case 3) are aware about the development around social media and know that they will have to work with it. Nevertheless, for government agencies this is a new

phenomenon. At this moment, there are only experiments, for example Coosto, put together to look how and what you are able to do with social media during a crisis. However, all interviewed institutions / units agree in opinion that research projects like EMERGENT are helpful to gain new insights.

6 CONCLUSION

Social media is and has already been widely used during a variety of emergencies. After presenting a definition for social media, various related studies are presented. Our performed study includes a variety of respondents who helped collecting the reported results. Participants were from different European countries and their profile varied in terms of their role in emergency management, operational size, methods and tasks. The main results are given in Table 12.

Question	Answer
Current Use	Twitter often, sometimes Facebook and YouTube. Other services rather seldom.
Potential Use	Gathering of information, interpretation of incidents and communication to/with the public
Research	Most interviewees are not active in the field of research
Benefits	Basically all possible benefits (warning, reachability, situation awareness for authorities and citizens) have been mentioned by all interviews.
Challenges	Reliability of the sources, followed by the liability, believability and objectivity. Less important challenges are timeliness, reproducibility, understandability and legal uncertainty
Future Plans	Impact is estimated increasing

Table 12: What is the use of social media by emergency services in Europe?

Social media provides a direct and fast channel for communicating with the public and spreading accurate and trusted information, especially during emergencies, when it is even more important for people to have access to trusted information. Social media provides the possibility for bi-directional communication and it is currently used in the majority of the cases. However, the current practice shows higher use of broadcasting information to citizens, rather than responding to individual cases.

The use of social media during the different stages of an emergency management cycle highlighted the importance of information gathering and validation. This is considered as one of the great challenges in the use of social media and in some cases it may prohibit or restrict further use. To overcome this barrier, an alternative model of operation is explored by some authorities, where the purpose of using social media is distinguished between use for operational purpose versus informational purpose, or use during an emergency versus use during normal operation. The emerging difficulty in handling the data streams from social media, trigger the opportunity for supporting these processes with applicable tools. Authorities already experiment with the use of different tools, although the current study reports a lack of a clear understanding of what tool to use or which tool is better in different situations.

While implementation strategies or models for integration with current workflows are clearly interesting topics and some authorities currently explore or discuss different options, no clear or documented plans or goals were identified. Interviewees were not active in the research field of social media and emergency management. However, all shared an interest to follow

the advances of this theme and expect the importance of social media in emergencies to rise in the future.

To achieve a broader view across Europe, larger studies are necessary. The project EmerGent conducted an additional European survey in 2014 and 2015 (a) among 700 people (working within emergency services) across 27 countries and (b) among 1000 citizens to investigate their experiences and visions on how to use social media nowadays and in the future. These qualitative and quantitative results will give the project directions on how to use social media more effectively in the future and how to support both emergency services and citizens in a better way during emergencies.

ACKNOWLEDGEMENTS

The research project EmerGent' was funded by a grant of the European Union (FP7 No. 608352). We would like to thank all members of our project for their remarks and for supporting in the work. This work has been conducted as part of EmerGent's work package 3: "Analysis of Social Media in Emergencies Today and Tomorrow".

REFERENCES

American Red Cross. (2012a). More Americans Using Mobile Apps in Emergencies. Retrieved May 26, 2014, from http://www.redcross.org/news/press-release/More-Americans-Using-Mobile-Apps-in-Emergencies

American Red Cross. (2012b). Social Media in Disasters and Emergencies. Retrieved from http://a1881.g.akamai.net/7/1881/26640/v0001/redcross.download.akamai.com/26640/PollData/Social

Baxter, K., & Courage, C. (2005). *Understanding Your Users: A Practical Guide to User Requirements Methods, Tools, and Techniques*. Morgan Kaufmann.

Bergstrand, F., Landgren, J., & Green, V. (2013). Authorities don't tweet, employees do! In *Proceedings of the MobileHCI 2013*.

Birkbak, A. (2012). Crystallizations in the Blizzard : Contrasting Informal Emergency Collaboration In Facebook Groups. In *Proceedings of the Nordic Conference on Human-Computer Interaction (NordiCHI)* (pp. 428–437).

Canadian Red Cross. (2012). *Social Media during Emergencies*. Retrieved from http://www.redcross.ca/cmslib/general/pub_social_media_in_emergencies_survey_oct2012_en.pdf

Cobb, C., McCarthy, T., Perkins, A., & Bharadwaj, A. (2014). Designing for the Deluge: Understanding & Supporting the Distributed, Collaborative Work of Crisis Volunteers. In *Proceedings of the Conference on Computer Supported Cooperative Work (CSCW)*. Baltimore.

Endsley, T., Wu, Y., & Eep, J. (2014). The Source of the Story: Evaluating the Credibility of Crisis Information Sources. In *Proceedings of the Information Systems for Crisis Response and Management (ISCRAM)* (Vol. 1, pp. 158–162).

Flizikowski, A., Hołubowicz, W., Stachowicz, A., Hokkanen, L., & Delavallade, T. (2014). Social Media in Crisis Management – the iSAR + Project Survey. In *Proceedings of the Information Systems for Crisis Response and Management (ISCRAM)* (pp. 707–711).

Fuchs, G., Andrienko, N., Andrienko, G., Bothe, S., & Stange, H. (2013). Tracing the German Centennial Flood in the Stream of Tweets: First Lessons Learned. In *SIGSPATIAL International Workshop on Crowdsourced and Volunteered Geographic Information* (pp. 2–10). Orlando, USA.

Gorp, A. F. Van. (2014). Integration of Volunteer and Technical Communities into the Humanitarian Aid Sector: Barriers to Collaboration. In *Proceedings of the Information Systems for Crisis Response and Management (ISCRAM)* (pp. 620–629).

Heverin, T., & Zach, L. (2010). Microblogging for Crisis Communication: Examination of Twitter Use in Response to a 2009 Violent Crisis in the Seattle-Tacoma, Washington Area. In *Proceedings of the Information Systems for Crisis Response and Management (ISCRAM)*. Seattle, USA.

Hughes, A. L., Denis, L. A. S., Palen, L., & Anderson, K. M. (2014). Online Public Communications by Police & Fire Services during the 2012 Hurricane Sandy. In *Proceedings of the Conference on Human Factors in Computing Systems (CHI)*.

Hughes, A. L., & Palen, L. (2009). Twitter Adoption and Use in Mass Convergence and Emergency Events. In J. Landgren & S. Jul (Eds.), *Proceedings of the Information Systems for Crisis Response and Management (ISCRAM)*. Gothenburg, Sweden.

Jennex, M. E. (2012). Social Media – Truly Viable For Crisis Response ? In L. Rothkrantz, J. Ristvej, & Z. Franco (Eds.), *Proceedings of the Information Systems for Crisis Response and Management (ISCRAM)* (pp. 1–5). Vancouver, Canada.

Kaplan, A. M., & Haenlein, M. (2010). Users of the world, unite! The challenges and opportunities of Social Media. *Business Horizons*, *53*(1), 59–68. doi:10.1016/j.bushor.2009.09.003

Latonero, M., & Shklovski, I. (2011). Emergency Management, Twitter, and Social Media Evangelism. *International Journal of Information Systems for Crisis Response and Management (IJISCRAM)*, *3*(4), 1–16.

Liu, S., Palen, L., & Sutton, J. (2008). In search of the bigger picture: The emergent role of on-line photo sharing in times of disaster. In *Proceedings of the Information Systems for Crisis Response and Management (ISCRAM)*. Washington D.C., USA.

Ludwig, T., Reuter, C., Siebigteroth, T., & Pipek, V. (2015). CrowdMonitor: Mobile Crowd Sensing for Assessing Physical and Digital Activities of Citizens during Emergencies. In *Proceedings of the Conference on Human Factors in Computing Systems (CHI)*. Seoul, Korea: ACM Press.

Machado, G. (2014). PSAPs Organisation in Europe. Retrieved from http://www.eena.org/ressource/static/files/2013_04_16_psaporgeurope.pdf

Murphy, T., & Jennex, M. E. (2006). Knowledge Management , Emergency Response , and Hurricane Katrina. *International Journal of Intelligent Control Systems*, *11*(4), 199–208.

Nagy, A., Valley, C., & Stamberger, J. (2012). Crowd Sentiment Detection during Disasters and Crises. In *Proceedings of the Information Systems for Crisis Response and Management (ISCRAM)* (pp. 1–9). Vancouver, Canada.

Perng, S.-Y., Büscher, M., Wood, L., Halvorsrud, R., Stiso, M., Ramirez, L., & Al-Akkad, A. (2012). Peripheral response: Microblogging during the 22/7/2011 Norway attacks. In *Proceedings of the Information Systems for Crisis Response and Management (ISCRAM)* (pp. 1–11).

Plotnick, L., Hiltz, S. R., Kushma, J. a, & Tapia, A. (2015). Red Tape : Attitudes and Issues Related to Use of Social Media by U . S . County- Level Emergency Managers. In *Proceedings of the Information Systems for Crisis Response and Management (ISCRAM)*. Kristiansand, Norway.

Qu, Y., Wu, P. F., & Wang, X. (2009). Online Community Response to Major Disaster : A Study of Tianya Forum in the 2008 Sichuan Earthquake. In *Proceedings of the Hawaii International Conference on System Sciences (HICSS)*. Waikoloa, USA.

Reuter, C., Heger, O., & Pipek, V. (2013). Combining Real and Virtual Volunteers through Social Media. In *Proceedings of the Information Systems for Crisis Response and Management (ISCRAM)* (pp. 1–10).

Reuter, C., Ludwig, T., Kaufhold, M.-A., & Pipek, V. (2015). XHELP: Design of a Cross-Platform Social-Media Application to Support Volunteer Moderators in Disasters. In *Proceedings of the Conference on Human Factors in Computing Systems (CHI)*. Seoul, Korea: ACM Press.

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.

San, Y. S., Wardell III, C., & Thorkildsen, Z. (2013). Social Media in the Emergency Management Field: 2012 Survey Results, (June).

Shklovski, I., Palen, L., & Sutton, J. (2008). Finding Community Through Information and Communication Technology During Disaster Events. In *Proceedings of the Conference on Computer Supported Cooperative Work (CSCW)*. San Diego, USA: ACM-Press.

St. Denis, L. A., Hughes, A. L., & Palen, L. (2012). Trial by Fire: The Deployment of Trusted Digital Volunteers in the 2011 Shadow Lake Fire. In *Proceedings of the Information Systems for Crisis Response and Management (ISCRAM)* (pp. 1–10).

Starbird, K. (2013). Delivering Patients to Sacré Coeur : Collective Intelligence in Digital Volunteer Communities. In *Proceedings of the Conference on Human Factors in Computing Systems (CHI)* (pp. 801–810).

Starbird, K., & Palen, L. (2010). Pass It On?: Retweeting in Mass Emergency. In *Proceedings of the Information Systems for Crisis Response and Management (ISCRAM)* (pp. 1–10). Seattle, USA.

Starbird, K., & Palen, L. (2011). Voluntweeters: Self-Organizing by Digital Volunteers in Times of Crisis. In *Proceedings of the Conference on Human Factors in Computing Systems (CHI)* (pp. 1071–1080). Vancouver: ACM-Press.

Starbird, K., & Palen, L. (2012). (How) Will the Revolution be Retweeted ? Information Diffusion and the 2011 Egyptian Uprising. In *Proceedings of the Conference on Computer Supported Cooperative Work (CSCW)* (pp. 7–16).

Sutton, J. (2010). Twittering Tennessee: Distributed networks and Collaboration Following a Technological Disaster. In S. French, B. Tomaszewski, & C. Zobel (Eds.), *Proceedings of the Information Systems for Crisis Response and Management (ISCRAM)*. Seattle, USA.

Vieweg, S., Hughes, A. L., Starbird, K., & Palen, L. (2010). Microblogging During Two Natural Hazards Events : What Twitter May Contribute to Situational Awareness. In *Proceedings of the Conference on Human Factors in Computing Systems (CHI)* (pp. 1079–1088).

Wilensky, H. (2014). Twitter as a Navigator for Stranded Commuters during the Great East Japan Earthquake. In *Proceedings of the Information Systems for Crisis Response and Management (ISCRAM)* (pp. 695–704).

Wulf, V., Misaki, K., Atam, M., Randall, D., & Rohde, M. (2013). "On the Ground" in Sidi Bouzid: Investigating Social Media Use during the Tunisian Revolution. In *Proceedings of the Conference on Computer Supported Cooperative Work (CSCW)* (pp. 1409–1418). New York: ACM.

Yang, S., Chung, H., Lin, X., Lee, S., & Chen, L. (2013). PhaseVis: What, When, Where, and Who in Visualizing the Four Phases of Emergency Management Through the Lens of Social Media. In *Proceedings of the Information Systems for Crisis Response and Management (ISCRAM)* (pp. 912–917). Baden-Baden, Germany.

ANNEX A: INTERVIEW QUESTIONS

SECTION A: INTRODUCTION TO THE ORGANIZATION

- A1. Specify the type of your organization.
- A2. Specify your PSAP model.
- A3. General Information about you
- A4. Geographical and regional information
- A5. What are the main risks in your region?
- A6. Specify the vulnerability of your region:
- A7. Estimate the average number of calls / emergency calls per anum for the following categories.
- A8. Estimate the average number of emergency operations per anum for the following categories.
- A9. Specify the number of your workforce (ft/pt)
- A10. On which administrative division is your organization operating in your state?

SECTION B: INFORMATION ABOUT THE PSAP AND/OR DISPATCHING CENTER YOU ARE PART OF, OR RESPONSIBLE FOR.

- B1. Select the main tasks within your PSAP (Multiple choices are welcome)
- B2. Are there any further tasks your PSAP is responsible for?
- B3. Specify in which phases of the emergency management cycle your organization operates and describe the main tasks.
- B4. Select the communication channels that your PSAP supports to handle input messages (i.e. messages from citizens).
- B5. Select the communication channels that your PSAP supports to send out messages (i.e. messages to inform or support citizens)
- B6. Select which communication channels your PSAP uses to broadcast warning messages. A warning message should inhabitants make aware of a danger.
- B7. Please describe the special warning systems that your PSAP uses to send out warning messages.
- B8. Select the responsible roles for output messages.

SECTION C: TECHNICAL INFORMATION ABOUT THE PSAP AND/OR DISPATCHING CENTER YOU ARE PART OF, OR RESPONSIBLE FOR.

- Contributed to D3.2 Guidelines for Social Media integration into existing authorities systems.

SECTION D: THE USE OF SOCIAL MEDIA IN EMERGENCIES

- D1. Does your organization already use Social Media, e.g. to gather or spread information?
- D2. Select the Social Networks that are used by your organization.
- D3. Who is allowed to post/send out data?
- D4. Is information from Social Media provided by citizens used in authorities?
- D5. Which tools do you use to analyze/collect data from Social Media (e.g. Twitcident)?
- D6. Who is allowed to use gathered data from Social Media in your organization?
- D7. Does your organization use other web 2.0 technologies?
- D8. In which phases of an emergency do you use Social Media? Please select and describe the usage.
- D9. Please try to categorize the main purposes in using Social Media.
- D10. What is the main purpose in using Social Media? Please describe in detail.
- D11. How does your organization finance Social Media usage?
- D12. Please try to categorize the implementation strategy that would fit at most to your current implementation.
- D13. Describe your organizations' implementation strategy on Social Media in detail.
- D14. Please describe how you or your organization has implemented Social Media into workflows or processes within your organization. Try to describe the main workflows and how the implementation is done.
- D15. Is Social Media an interesting topic for your organization?
- D16. Select the Social Networks which are most interesting for your organization in order to inform, encourage or engage citizens.

- D17. Please try to categorize the main purposes that you would like to focus in Social Media.
- D18. Describe the main purposes in the use of Social Media.
- D19. How would you finance the usage of Social Media?
- D20. Please try to categorize the implementation strategy that would fit at most.
- D21. Please try to describe a suitable implementation strategy on Social Media for your organization.
- D22. Please describe how you or your organization would implement Social Media into workflows or processes within your organization. Try to identify the main workflows and describe how the implementation is done.
- D23. Please describe why Social Media isn't an interesting topic for you.
- D24. Does your organization make research and development on Social Media?
- D25. Please describe the research and/or development that your organization does on Social Media.
- D26. Is your organization following or would like to follow research and development on Social Media?
- D27. Please describe the research topics you're interested in.

SECTION E: CHALLENGES AND BENEFITS ON SOCIAL MEDIA IN EMERGENCIES

- E1. What are the main benefits of Social Media use?
- E2. What are the main difficulties or challenges experienced with working with Social Media?
- E3. If you have some interesting references to cases studies, SWOT- or risk-analysis regarding Social Media, especially Social Media in emergencies, please paste them below.

SECTION F: FUTURE PLANS

- F1. How do you think the impact of Social Media in emergencies will change in the next years?
- F2. How will your organization deal with Social Media in the next years?
- F3. How will workflows and tools evolve?
- F4. What are the new technologies you are looking at?
- F5. Do you think research projects like EMERGENT are helpful to gain new insights?

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.

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.

Therese Friberg, Dipl.-Inf., research assistant at the University of Paderborn, is engaged in the field of information quality since 2008. Her diploma thesis was distinguished by the German Association of Information Quality (DGIQ) wherein she is part of an expert group about the standardization of definitions and measurements of information quality. She has published several national and international publications in the field of information quality and human influences; her paper was awarded as best paper at the international conference of information quality (ICIQ' 09). Ms. Friberg was involved in six successfully finished national research projects and the EU-Projects PRONTO and Secur-ED, all in the field of public safety and security. Currently she is the project manager of EmerGent, a FP7 security project focusing on social media in emergencies. Furthermore she has built up a broad network in the domain of Public Safety and Security (f.i. GESA, EENA, ISCRAM) and also organises workshops on an international level (ISCRAM 2011-2015).

Dr.-Ing. Sylvia Pratzler-Wanczura - is the principal engineer of the Institute of Fire Service and Rescue Technology of the City of Dortmund - Fire Department. After her academic studies of spatial planning at the TU Dortmund University (Germany) she worked several years as research assistant and received there her Dr.-Ing. In her PhD-Thesis she dealt with methods for measurement of an effective and efficient coordination in the risk governance process (communication, management, assessment and analysis of risk) for flood risk. She has over 10 years of experience in the organisation and management of several European as well as national safety & security related research projects.

Alexis Gizikis holds a Master of Engineering (MEng) from the University of Aberdeen in Scotland and has worked for companies and research institutions in the UK and Greece. Alexis has been involved in the ICT sector since 1999 and has acquired experience in business analysis, requirements engineering, HCI and software engineering. He currently works for the European Emergency Number Association (EENA) and he is responsible for planning and monitoring EENA's participation in research projects.

Gaze Guiding as Support for the Control of Technical Systems

Benjamin Weyers, Visual Computing Institute, JARA HPC, RWTH Aachen University
Barbara Frank, Dept. of Work and Organizational Psychology, Ruhr University Bochum
Kathrin Bischof, Dept. of Computer Science and Applied Cognitive Science, University of Duisburg-Essen
Annette Kluge, Dept. of Work and Organizational Psychology, Ruhr University Bochum

7 ABSTRACT

The control of technical systems is often defined by standard operating procedures, e.g. provided by paper-based manuals or decision trees. These procedures specify how a human operator should handle a specific situation occurring in the system control, which might also be safety-critical. This work presents a concept of guiding users' gaze in such control scenarios of technical systems, which aims at preventing the user from having to leave the control context in order to consult such a paper-based standard operating procedure. Instead, the presented approach fades in information into the control interface based on the current situation of the system and the intended procedure. The work further argues for the use of this technique in the context of refresher-based training to enhance retrieval of once-learned knowledge. This concept, called gaze guiding, has been implemented in a framework in which it can be applied to existing control interfaces. The feasibility of gaze guiding in such control scenarios is demonstrated in a user study with 21 participants.

1. INTRODUCTION

According to the New Theory of Disuse introduced by Bjork and Bjork (1992; Bjork 2011), the retrieval strength of once-learned knowledge or abilities is reduced after a period of non-use, while the information is stored permanently in the cognitive memory (storage strength). This leads to a reduction in retrieval, which is generally known as "forgetting". This is especially true in the context of monitoring and control of (semi-)automated technical systems, in which the human operator is no longer closely embedded in the control loop. As a consequence, the probability of a reduction in retrieval (Kluge et al., 2009) increases, and might lead to error-prone control operations, which can be especially problematic in safety-critical situations of the system. In the worst-case scenario, this can culminate in accidents, with an impact on the environment (Onnasch et al., 2014; Parasuraman et al., 2000; Hamesk et al., 2009).

To reduce the probability of errors occurring in the monitoring and control of technical systems, refresher training is conducted with the human operators of a system. Refresher

training has been shown to be suitable for maintaining the performance level and improving retrieval after a specific time of non-use of the once-learned skill (Kluge et al., 2014). One option for conducting refresher training lies in a simulation of the technical system, such as a process control situation (Kluge & Frank, 2014). This type of process control situation comprises various tasks that have to be performed by the operator. For each task, the operator has to know the standard operating procedures (SOP; Kluge, 2014; Wickens & Hollands, 2000) that are relevant for the handling of normal control or safety-critical situations (Kluge et al., 2009). SOPs describe how the operator has to act in a specific situation and how a situation is specified. For each situation, there are predefined SOPs that have to be known and followed by the operator. Such SOPs can be embodied by decision trees or fixed sequences that have to be followed, e.g. by using a manual (Kluge, 2014). Most SOPs are known well by the operator, but rarely used SOPs may be forgotten (Bjork & Bjork, 2006).

Simulation-driven refresher training can be based on the practical operation of the simulation in specific situations, and offering SOPs as an additional manual which contains the relevant operation sequences for the given situation. Thus, operators have to analyze the situation and then apply the correct operation with the help of the SOP according to their observation. If the operator is unable to apply the correct operation, he/she has to leave the context of the simulation and refresh the missing information by reading the text documentation or by asking the training supervisor. However, this change in context during the refresher training interrupts the learning process and may lead to an increased mental workload (Young et al., 2015). To avoid unnecessary mental workload, we developed a framework that implements a visual mechanism for cueing the operator's attention to parts of the control interface that are relevant in the context of the simulation situation in order to support the recall of an important SOP.

We call this mechanism of cueing the operator`s attention *gaze guiding*. This is distinguishable from the term "Gaze Guided", which implies an interaction process or a system that is controlled by the user's gaze (Sibert & Jacob, 2000). Gaze guiding is based on the person's pre-attentive visual perception, which refers to a part of human visual perception that affects the person's attention before the visual stimulus is intentionally processed by human cognition (Ware, 2004). Examples of pre-attentively perceived visual cues include changes in the shape or color of an object and changes in its direction or speed of movement.

The main contribution of this work is the presentation of the concept and the implementation of a framework for gaze guiding, which was evaluated in a user study with 21 participants conducted in winter 2014. Four different gaze-guiding versions were evaluated by the participants in terms of their design, content and support for retrieval. The study reveals a high feasibility of the concept for guiding the attention of human operators in the control of technical systems, and thereby demonstrates that it is suitable to be used instead of classic refresher training. The effectiveness of the approach in the context of refresher training compared to other approaches is currently being investigated in a more broadly applied experiment. Both studies are based on a simulation of a wastewater treatment facility called WaTrSim (Kluge et al., 2014).

This paper is structured as follows: Section 2 presents related work, addressing in particular previous approaches for cueing users' attention. This is followed by an introduction to the gaze-guiding framework, which encompasses the description of a formal specification of system states corresponding to the concept of SOPs, the description concept for the gaze-guiding models, and the implementation of the framework (Section 3). Section 4 introduces the conducted user study, including the presentation of the WaTrSim system as well as the results of the study. The final Section 5 provides a conclusion and an outlook on future work.

2. RELATED WORK

Visual Cueing in Learning Systems and Animations – The use of visual cues for guiding the user's attention has been investigated in various research fields, both in the past and up to the present day. Especially in the context of learning systems, visual cueing has been used extensively for guiding the learner's attention regarding relevant content to be learned. Lin and Atkinson present the use of visual cues in the context of animation in learning systems (Lin and Atkinson, 2011; Lin et al., 2014). They define "visual cueing [as] […] the addition of non-content information (e.g. arrows, circles, and coloring) to visual representations" (Lin and Atkinson, 2011, p. 651). This definition fits particularly well with the type of visual cueing presented in the current work. Lin and Atkinson further investigated visual cueing with regard to the use in animations, meaning a visual representation that "generates a series of frames, so that each frame appears as an alternation of the previous one" (Bétrancourt & Tversky, 2000, p. 313). In the context of the present work, the nature of animations can be transferred to standard graphical user interfaces used in the control of a technical system: These user interfaces consist of non-changing parts, but also of meters which represent, for instance, technical values relevant for the control task. A promising finding was that when using visual cues with animation, no significant increase in workload was apparent: "From the cognitive load perspective, a substantial number of studies have found that visual cueing is an effective method to reduce extraneous load in multimedia learning environments (for reviews, see Mayer & Moreno, 2003; Wouters, Paas, & van Merriënboer, 2008)" (Lin and Atkinson 2011, p. 651). Moon and Ryu (2013) confirmed these findings in their study, and also investigated the use of audio-based narration as a further cue, identifying a significant increase in the cognitive load for narrations with higher speed compared to narrations with lower speed. In terms of the present work, these findings support the use of visual cues, but raise the question of what influence the use of audio might have for future studies. Further investigations of visual cues in learning with multimedia documents showed a decrease in the amount of time spent fixating on irrelevant content (Jamet, 2014). This is of special interest for the work presented in this paper, as neglecting irrelevant information in safety-critical situations might enhance the overall performance in terms of solving the situation and applying the SOP correctly. Support for the use of visual cueing in learning systems was also found using methods such as attention guidance techniques and emphasis changes (de Koning, Tabbers, Rikers, & Paas, 2009; de Koning, Tabbers, Rikers, & Paas, 2010; Gopher, 2007; McGuirl et al., 2009). Nevertheless, past studies concentrated on the use of visual cueing in learning systems, but not in terms of supporting the retrieval of learned skills in the control of technical processes, and especially not for safety-critical situations.

Visual Cueing in a Process Control Task – Gaze guiding as a concept for visual cueing in a process control task was investigated in a previous study using the process control task WaTrSim (described in Section 3.4; (Kluge et al. 2014)). The results suggested that gaze guiding can improve the operator's performance dependently of the amount of information provided. It was shown that operators in a simulated process control task benefit from gaze guiding if it includes information about the interface operation in addition to information about the procedure operation steps (textual and graphical). This enables the possibility to refresh the procedure steps and the interface operation knowledge.

Previous research on gaze guiding for the simulated process control task WaTrSim indicated a high potential of gaze guiding when participants interact with the simulated process control task after three weeks or six months of non-use. The study showed that gaze guiding can support performance after a period of non-use and that it should be accompanied by specific information about how to interact with the interface (Kluge et al. 2014).

Subliminal Visual Cueing – Subliminal visual cueing techniques tend to guide users' attention by applying visual stimuli which are only subliminally perceived by the user. Discussions regarding the benefits of subliminal visual cueing in graphical user interfaces have been controversial: A study by Pfleging et al. (2013) showed that non-blinking subliminal cues in particular were not usable in a task in which the participants had to follow a red ellipse as fast as they could. On the other hand, a study by Wallace et al. (1991) demonstrated a positive impact of subliminal visual cueing.

Bailey et al. (2009) introduced "Subtle Gaze Direction" (SGD) as a technique to attract visual attention by presenting different ways of modulating the presentation to the peripheral field of view. This differs from the work by Pfleging et al. (2013), who did not use any modulation. SGD combines a real-time analysis of the user's gaze data, such as eye movement, with a subtle image space modulation to direct the user's gaze toward a selected target of known location. The modulation is controlled by the user's view direction and the saccades of his/her eye movement. Further work based on this technique has included the use of SGD to decrease the demand of visual search tasks as described by McNamara et al. (McNamara et al., 2008; McNamara et al., 2009). Although the work at hand does not explicitly apply subliminal visual cueing concepts, these techniques represent a broad variety of possible future extensions of the currently presented technique, particularly as it is known that these techniques do not increase mental workload during the execution of tasks (Negri et al., 2014).

3. GAZE-GUIDING FRAMEWORK

The embedding of visual cues such as gaze guiding (see Introduction) demands a framework that provides the functionality to identify system states in order to be able to react to relevant situations the system is in (defined by SOPs), to define and apply gaze-guiding methods to the system's user interface, and to offer suitable modeling strategies to create and adapt these gaze-guiding models. This enables the framework to address different systems or upcoming changes in the specification of SOPs, the system's technical implementation, or the user interface design. It should further be possible to add the implementation to an existing simulation or technical system implementation, such that it can be used in a flexible fashion by adding or removing the gaze guiding to or from the given system and user interface. With regard to these pre-conditions, for the following introduction to the gaze-guiding framework, it is assumed that the technical system is given as a black box, but offers a set of system values which are visible during runtime. A more detailed description is provided in the following sections. Furthermore, the user interface should be programmatically accessible, such that an overlay can be added to the implementation of the given user interface of the technical system.

In the following sections, the gaze-guiding framework will be introduced in detail, beginning with an overview of the architecture, which outlines the different components necessary for the system state identification, the gaze-guiding tool mapping, and the implementations required for introducing the gaze-guiding tools into the user interface of the system to be controlled (Section 3.1). Along with the technical components of the system, the modeling concepts for the system state and the gaze-guiding model will be introduced and defined (Section 3.2 and 3.3). The applicability of the framework will be shown by means of a use case (Section 3.4) that was applied in the user study presented in Section 4.

3.1 ARCHITECTURE

The whole concept of the guidance of visual attention in this work is based on the workflow shown in Figure 1. It is separated into two phases: the modeling phase, for the creation of a system and a gaze-guiding model, and the execution phase, in which these models are used during runtime to apply visual cues to an interactive control process of a technical system.

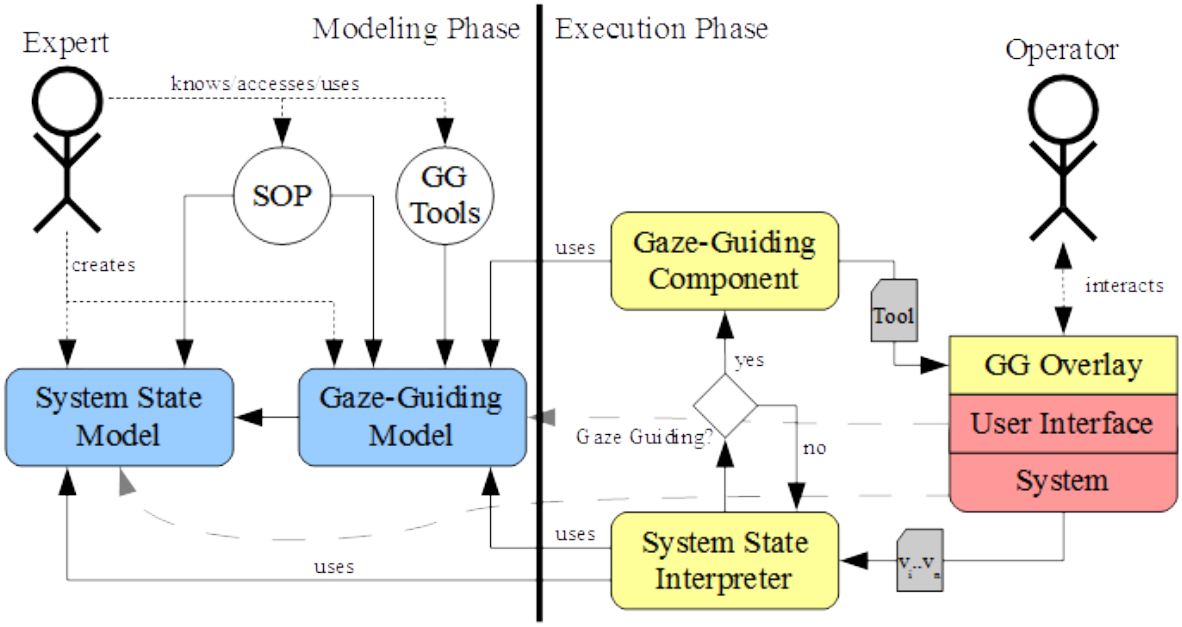


Figure 2: Workflow for the guidance of visual attention in the control of technical systems as a concept for refresher training. It is separated into a modeling phase, in which the relevant descriptions are created by an expert, and an execution phase, in which the modeled gaze-guiding strategy is applied to the control process of a technical system applied by the operator.

In the modeling phase, which is devoted to an expert with an understanding of the control of the technical system and the use of gaze guiding, two models are created: the *system state model* and the *gaze-guiding model*. The system state model is composed of a set of system states which are mapped onto observable system values during runtime. This mapping extracts the current system state from the model. As SOPs are mandatory guidelines on how the user must react to a certain state of the system, this state-based model of the system represents the basis for the representation of an SOP in the framework. A detailed description of this formalization will be introduced in Section 3.2. The concrete action a user has to perform due to a particular state (as specified in an SOP) is described in the gaze-guiding model, which is created in a second step. Besides its relation to the system state model, which is specified by unique identifiers attached to each modeled system state, the gaze-guiding model further parameterizes a predefined set of gaze-guiding tools. The gaze-guiding tools offer a programmatic implementation and certain visual characteristics. The parameterization is based on the given user interface (its size, the position of interaction elements) and on the respective system state into which this tool should be faded in. The relation of the system and gaze-guiding model to the system which is to be controlled, and the user interface in which the gaze-guiding tools will be faded in, are indicated by gray-dashed arrows in Figure 1. A detailed description of the gaze-guiding definition and the gaze-guiding tools implemented in the framework will be provided in Section 3.3.

As can be seen in Figure 1, in the execution phase, there are three components which are relevant for the application of the gaze-guiding during runtime of the system/the control process: the *system state interpreter*, the *gaze-guiding component*, and the *gaze-guiding overlay*. The latter extends the graphical user interface that implements the control interface for the technical system to be controlled. The system state interpreter periodically reads a set of visible system variables and matches these to the formally modeled system states. The system states are given by the previously defined system state model. After this matching has occurred, the state interpreter checks whether or not a visual cue should be faded in using a parameterized gaze-guiding tool. This takes place on the basis of the resolved system state. The mapping of an identified system state to a gaze-guiding tool is accomplished by sending the unique identifier of the state to the gaze-guiding component. This component first matches the unique identifier to the gaze-guiding model, which is resolved into a description of a gaze-guiding tool, if any is defined. If this is the case, it is then presented to the user in the gaze-guiding overlay. As briefly mentioned above, this component is an extension of the system's graphical user interface and is simply placed as an overlay over the existing implementation. During the ongoing system state mapping, the state interpreter informs the gaze-guiding component whether or not the user has applied the guided operation to the user interface, which is also based on the recognition of a system state. Finally, this determines whether the gaze guiding is faded out or whether it remains visible. This process will be examined more closely in Section 3.4.

3.2 SYSTEM STATE MODEL

Assuming that the system to be controlled is given as a black box, in the context of this work, it is modeled as seen from the "outside". This is accomplished by describing the system as a set of system states (as discussed above), which are composed of a number of system values visible to the outside world. Thus, the modeler does not have to know the detailed internal workings of the system, as would be the case if description concepts, such as state change diagrams or other modeling approaches, were used for modeling the system (cf. Gogolla & Presicce, 1998).

To map such a state description to a concrete system, each of the values indicated in the system state are mapped to the current instance of these values of the running system. If these instances of the values lie within an interval defined for every system value, the system is interpreted as being in this state. This process is implemented in the system state interpreter (Figure 1, right). In the following, a formal definition for describing a system state model will be provided, taking into consideration the discussed type of system state mapping. Therefore, first, an observable system will be defined in such a way that it can be used for the previously described mapping process. Subsequently, the formal modeling concept will be defined, accompanied by a formal specification of the mapping process.

Definition 1 (Observable System): An observable system $S = (V, M)$ is a system which offers a finite set of system values V, in which every element v of V is mapped by a function $m_v \in M$ for a specific point in time t to a real number, such that

$$m_v(t) = r \in \mathbb{R}.$$

■

The set of functions M implicitly defines the functionality of the system. Nevertheless, M will be assumed as given and not specifically known. Based on this definition of an observable system, a system state can be defined as follows:

Definition 2 (System State Model): Given an observable system *S*, a system state *s=(V', min, max, id)* is defined as a tuple composed of a subset $V' \subseteq V$ of system values, a unique identifier *id*, and two functions $min: v \in V' \longrightarrow min_v \in \mathbb{R}$ and $max: v \in V' \longrightarrow max_v \in \mathbb{R}$, such that

$$\forall\, v \in V': min(v) \leq max(v).$$

The observable system *S* is in system state *s=(V', min, max, id)* for a given point in time *t* if

$$\forall v \in V': min(v) \leq m_v(t) \leq max(v).$$

A system state model of an observable system *S* is a finite set of system states $St = \{s_0,\ldots,s_n\}$.

■

The given definition of a system state model is both simple and highly flexible. It does not need to be complete or unique, in the sense that a system is always only in exactly one system state for every time *t*. Moreover, it does not require a representation of the internal workings of the modeled system, in accordance with the assumption that the given system is a black box. Nevertheless, for this work, it is preferable to generate models without intersecting states, which are states s_i and s_j ,where for all $v \in V_i' \cap V_j'$, with

$$min_i(v) \leq max_j(v) \;\vee\; min_j(v) \leq max_i(v),$$

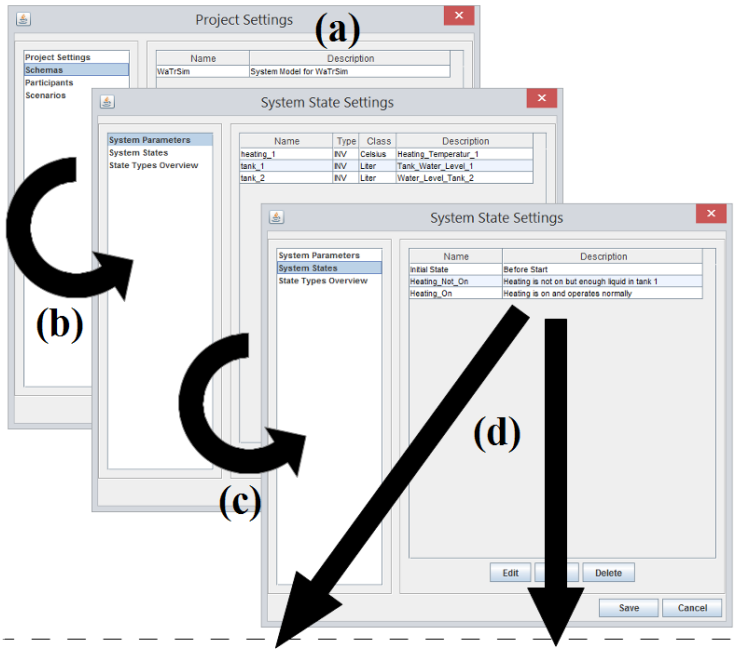
as this could end up in a situation in which a system is in two (or more) states at the same time. In this case, the uniqueness would be violated.

To simplify the modeling process of such a state model and to support the modeler in describing non-intersecting states, we developed a modeling tool, as shown in Figure 2. Besides a set of input masks for defining system values and system states (as seen in Figure 2), the modeling tool offers functionality to serialize a generated model as an XML-based serialization, thereby making it available to the aforementioned system state interpreter during runtime. Based on this serialization, it is further possible to tag the modeled system states with their criticality: from normal, through critical, to failure states, if necessary. Figure 2 further shows the representation of an exemplary system state model based on the formal definition introduced above.

The modeling tool's set of windows offer masks to enter general information for a specific project. This addresses the description of a system state model for a given system, as shown in Figure 2 (a). This basic information enables, in a first step, the visible system values to be specified (b), and based on this set of visible system values, system states can be specified (c). At the top right of Figure 2, the corresponding formal definition of this system model can be seen. The mapping functions for the different system values (`heating_1`, `tank_1`, and `tank_2`) are indicated as function plots along parameter `t` representing the time. The input masks for the definition of the system states are shown at the bottom of Figure 2 (d). Here, three states can be seen: `Initial_State`, `Heating_On`, and `Heating_Not_On`. The latter is an example of a non-normal or critical state. Assume that the relevant SOP for the implicated control situation specifies that the heating of a system has to have a temperature higher than 50 degrees Celsius in the case that tank 1 has more fluid stored than 150 liters (which has been modeled as state `Heating_On`). If the heating is not working correctly (if more than 150 liters are stored in tank 1), thus having a temperature under 50 degrees Celsius, the critical state `Heating_Not_On` matches. In this case, the gaze-guiding component will be notified, which then tries to map a gaze-guiding tool to the matched critical state. The

corresponding formal definition of these three states can be seen in the bottom right corner of Figure 2. The whole scenario will be discussed in more detail in Section 3.4.

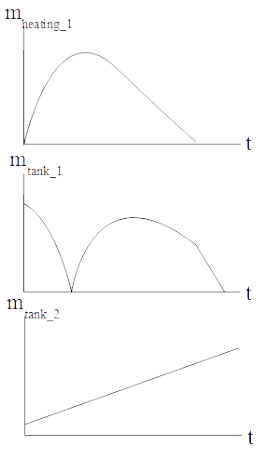
The modeling tool further offers functionality to support the modeler (expert in Figure 1) during the creation of the system description, as can be seen in Figure 2, in the bottom-right corner (e). Here, the modeling tool tests created state descriptions according to intersections with other states. In the case shown (cf. Figure 2), the modeling tool notifies that the `Heating_Not_On` state intersects with another state, here the `Heating_On` state. This is due to the similar interval definitions of variables `tank_1` and `tank_2` and the overlap of variable `heating_1` at the extreme value `50.0` in both states. Thus, in the current model, the system can be in two states at the same time. In the context of gaze guiding, the modeler can ignore this interaction if the gaze-guiding model offers a tool definition only for the critical state and not for the intersecting normal state.

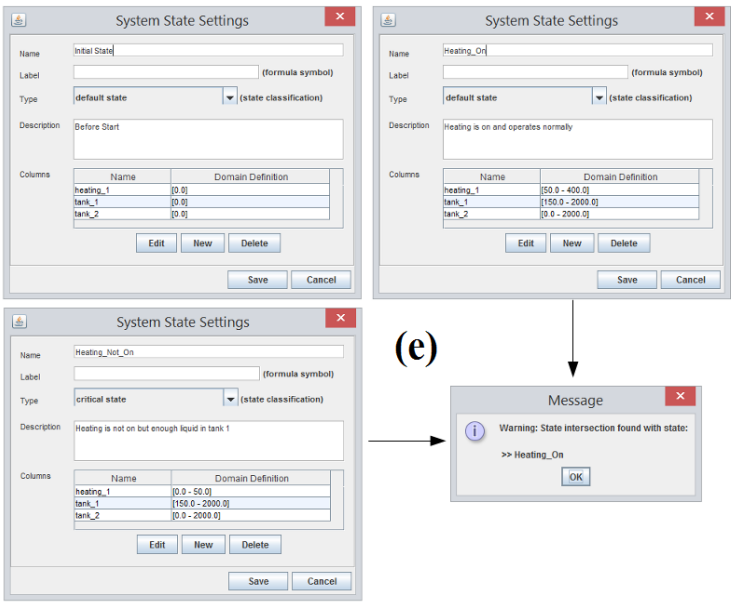


System Model:

$S = (V, M)$, with

$V = \{heating\_1, tank\_1, tank\_2\}$, and
$M = \{m_{heating\_1}, m_{tank\_1}, m_{tank\_2}\}$





System States:

$s_1 = (V, min_1, max_1, id_1)$, with
$min_1(heating\_1) = 0.0$, $max_1(heating\_1) = 0.0$
$min_1(tank\_1) = 0.0$, $max_1(tank\_1) = 0.0$
$min_1(tank\_2) = 0.0$, $max_1(tank\_2) = 0.0$
$id_1 = Initial\_State$

$s_2 = (V, min_2, max_2, id_2)$, with
$min_2(heating\_1) = 50.0$, $max_2(heating\_1) = 400.0$
$min_2(tank\_1) = 150.0$, $max_2(tank\_1) = 2000.0$
$min_2(tank\_2) = 0.0$, $max_2(tank\_2) = 2000.0$
$id_2 = Heating\_On$

$s_3 = (V, min_3, max_3, id_3)$, with
$min_3(heating\_1) = 0.0$, $max_3(heating\_1) = 50.0$
$min_3(tank\_1) = 150.0$, $max_3(tank\_1) = 2000.0$
$min_3(tank\_2) = 0.0$, $max_3(tank\_2) = 2000.0$
$id_3 = Heating\_Not\_On$

Figure 2: Modeling a system (state) model based on the developed interactive editor. The process is based on various windows offering input fields for defining the project (a), the system values to be covered from a system (b) and the system states (c). Every system state is defined separately (d) by specifying the different value intervals for each system value. If intersecting states are defined, the tool informs the modeler (e).

Finally, the modeling tool implements the *system state interpreter*. This component enables the mapping of observable system values during runtime to a given system state model and serialization capabilities for the system state model based on XML. For the interpretation of the system values, the component offers various options. First, system values can be directly sent from the system to the system state interpreter via a software interface, which is only possible if the system implementation offers such an interface. Second, the system state interpreter offers the capability to load constantly updated logging information as log files produced by the system. Therefore, the modeling tool offers an editor for the specification of the log data format, as shown in Figure 3. This keeps the whole implementation sufficiently flexible to be connected to various types of systems and ultimately also enables the analysis of logging data, which is implemented in the modeling tool but is not relevant in the context of this work.

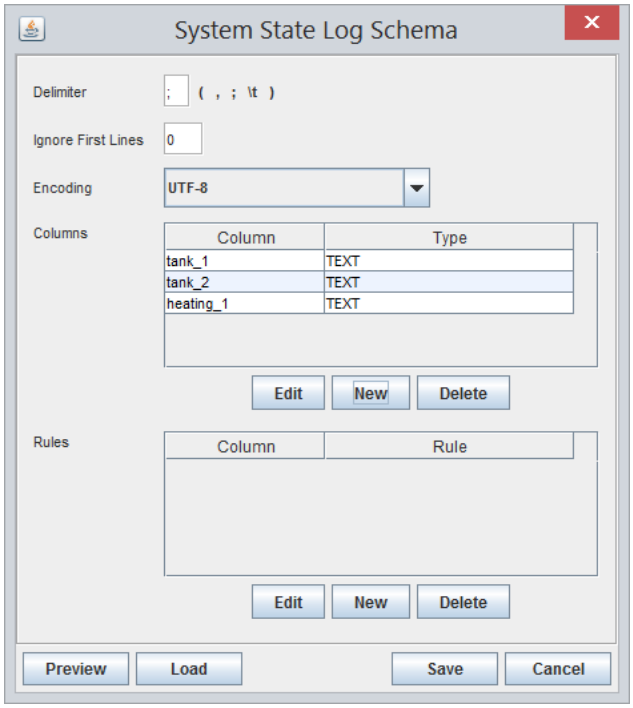


Figure 3: Definition window for specifying the log data format as the basis for online parsing from a file.

The next section describes the modeling of the gaze-guiding tools, which are related to the system state model by the unique identifier associated with every modeled system state.

3.3 GAZE-GUIDING MODEL

The *gaze-guiding model*, as it is used by the *gaze-guiding component* in the gaze-guiding framework (Figure 1), is composed of various sets of instances of *gaze-guiding tools*, so-called *tool sets*. Gaze-guiding tools are meant to highlight a specific element or area of the user interface so that the user's visual attention is drawn to it. A tool set can integrate one or more instances of different or identical tools, and thus multiple tools of the same type. Almost

every tool can be parameterized with regard to its color, size, or position. To steer the user's attention, the tools utilize different attention cues (Ware, 2004). As has been shown in the area of cognitive psychology, a human's visual attention can be attracted by movements or changes in movement, and changes in the color and intensity of elements, and this still works in the peripheral field of view. It is well known that a line leads a person's gaze between its endpoints, and this has been further used to semantically link different tools to each other using a line drawn between them.

In the current version of the framework, the following gaze-guiding tools can be used. Parameters and example images are shown in Table 1.

(1) A transparent and colored overlay that covers the whole user interface, with one or more areas that are not covered, in order to highlight the objects in these areas (cutouts).

(2) An arrow can be used to point at a specific area of the user interface. It can also be specified as a blinking or flashing arrow. Therefore, the blink interval can be specified, as well as its initial state (on or off).

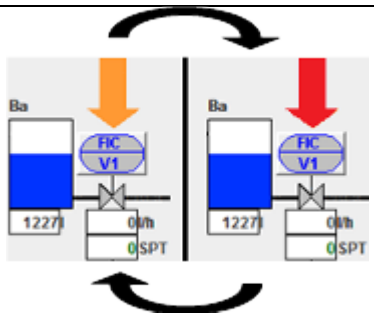
(3) Another possibility for an arrow is to define it as being animated. This mainly periodically draws the arrow being translated to the element of the highlighted user interface element.

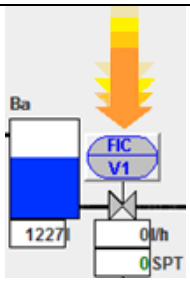
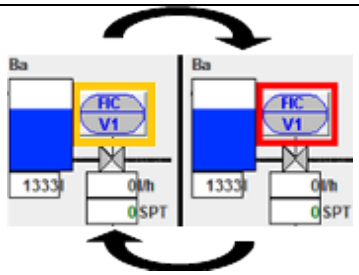
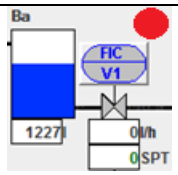
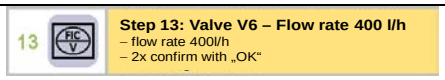
(4) A frame can surround a specific area. The shape of the frame can be rectangular or oval and the line size can be varied. Such a frame can also be defined as a blinking frame.

(5) Another blinking tool is a blinking lamp in the form of a colored oval or rectangle. This is meant to be used as an attention marker.

(6) A help text can be used to show the user a particular message such as instructions on what the next steps are or how to react to a certain situation. This help text can include one or more pictograms to give the user additional hints. The width and height of this tool can either be parameterized or adapted to the text length.

Table 1: Currently implemented gaze-guiding tools, which can be combined into tool sets and related to specific states as specified in the state model.

Name	Example Picture	Parameters
(1) Transparent Overlay	see Figure 4	1) size and position 2) alpha value for transparency 3) color 4) optionally with help text 5) position of cutout(s)
(2) Fixed Arrow		1) position of arrowhead 2) arrow direction 3) color 4) auxiliary variables for shape of arrow, 5) optional blink interval, initial state and second color

(3) Animated Arrow		1) position of arrowhead 2) arrow direction 3) color 4) auxiliary variables for shape of arrow 5) number of steps 6) step size
(4) Frame		1) size and position 2) shape 3) color 4) border thickness 5) optional blink interval, initial state and second color
(5) Attention Marker		1) size and position 2) shape 3) color 4) optional blink interval, initial state and second color
(6) Help Text		1) size (or adapted to text length) and position 2) background color of text box and/or of pictogram box 3) color of the frames 4) font, font color, font size, font style, 5) line spacing 6) optionally with one or more pictograms

An exemplary tool set ((1), (4), (6)) is shown in Figure 4. Additionally, Figure 4 shows a further feature of the gaze-guiding tool sets: Two tools can be connected to each other by an associating line. This is suitable, for instance, for relating a help text and frame to each other, as is the case in Figure 4. The line can be further parameterized by specifying its color and whether it is dashed or solid, and it can be equipped with one or two arrowheads.

The aforementioned tools are only shown in the gaze-guiding overlay (Figure 4) for a period of time until the system state changes (triggered by the system state interpreter) or the user interacts with the system by, e.g., applying certain operations to the system through the user interface. If the interaction does not change the current state of the system, the tool set will be shown again after a certain period of time, which can be specified as a global parameter of the gaze-guiding model. If the system state changes during the gaze guiding are visible and no interaction has been recognized, a new tool set will become visible if there is one which matches the new state. If the gaze-guiding component is unable to match the new state to a tool set, the gaze guiding will simply be faded out. To enhance usability, the toolset can be also faded out, if the user clicks somewhere on the screen. This enables an unrestricted view to the user interface and thereby the user is able to observe the complete situation. After a time out and without a reaction from the user, the toolset will be faded in again, such that the user can then use this extra information to handle the situation. This can be also repeated if necessary. The central question to be investigated in this context is whether the attention of the user is still guided by the warning character of the elements or by the fading mechanism

instead. This could be a further aspect of the planned investigation in context of future user studies.

Some tools can be specified to not disappear when the user interacts with the system, and only to be faded out if a certain system state is reached. For example, the gray overlay (1) can be configured as such. It can be further embedded permanently into the user interface; this also applies for an image, which can be permanently added to the overlay. The image can consist of an illustrated manual or important hints which the user should always be able to read. In conceptual terms, the latter is based on the help text tool implementation (6). Finally, the frame (4) can be further specified as being constantly visible in the gaze-guiding overlay.

The whole description concept and implementation framework has been implemented in such a manner that it can be extended with new gaze-guiding tools and is exchangeable regarding existing implementations. This has been achieved by the use of XML for the serialization of gaze-guiding models as well as technologies such as JAXB to keep the underlying implementation as flexible as possible.

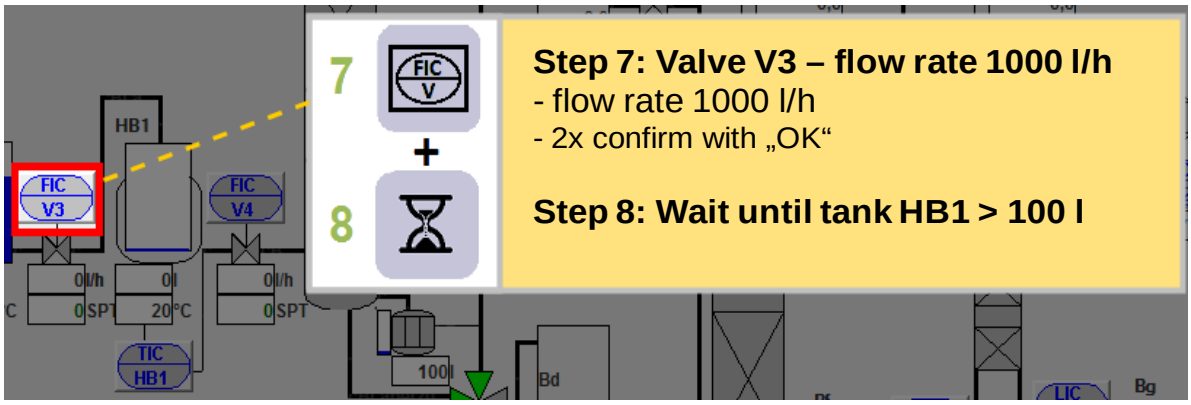


Figure 4: Example of a tool set, which combines a frame (red, left), a help text including pictograms, a gray overlay as seen in the background, and an associating line that represents the relation of the indicated interaction element (FIC / V3) and the help text.

3.4 GAZE-GUIDING FRAMEWORK – A USE CASE

WaTrSim is a simulation of a processing plant for industrial wastewater (Kluge & Frank, 2014). Wastewater is delivered while the plant is running, and is split into solvent and water using the technical process in the plant. The goal of the operator controlling the splitting process is to maximize the amount of purified water and minimize the amount of accruing wastewater, which cannot be cleaned again and has to be deposited. The participant, acting as operator, starts the process by applying a specific SOP, which is a fixed 13-step start-up procedure that has to be followed by the participant to produce purified waste water (Kluge & Frank 2014). This procedure includes the handling of various technical installations in the plant as part of the whole process: One of these installations is a heating system, which has to be switched on to heat the tank to a specific temperature, enabling the subsequent aperture to split the wastewater. To switch the heating on, the operator has to ensure that the preceding tank is filled higher than 150 liters. Otherwise, damage to the heating can occur. If the heating is not switched on, the water is not hot enough for the subsequent splitting procedure and the wastewater has to be deposited. The system state model of this SOP was presented in Section 3.2.

To prevent these errors from occurring and to support the operator in following this SOP correctly, the gaze guiding as shown in Figure 5 can be faded into the user interface. Here, the

situation is shown that the tank has enough content (163 liter) but the heating HB1 is not switched on. After the user has switched on the heating as described in the text box, the gaze guiding vanishes and the operator can continue to control the system. If the critical state is still valid, the gaze-guiding tool will become visible again after a certain period of time, until the required operations have been applied to the system control

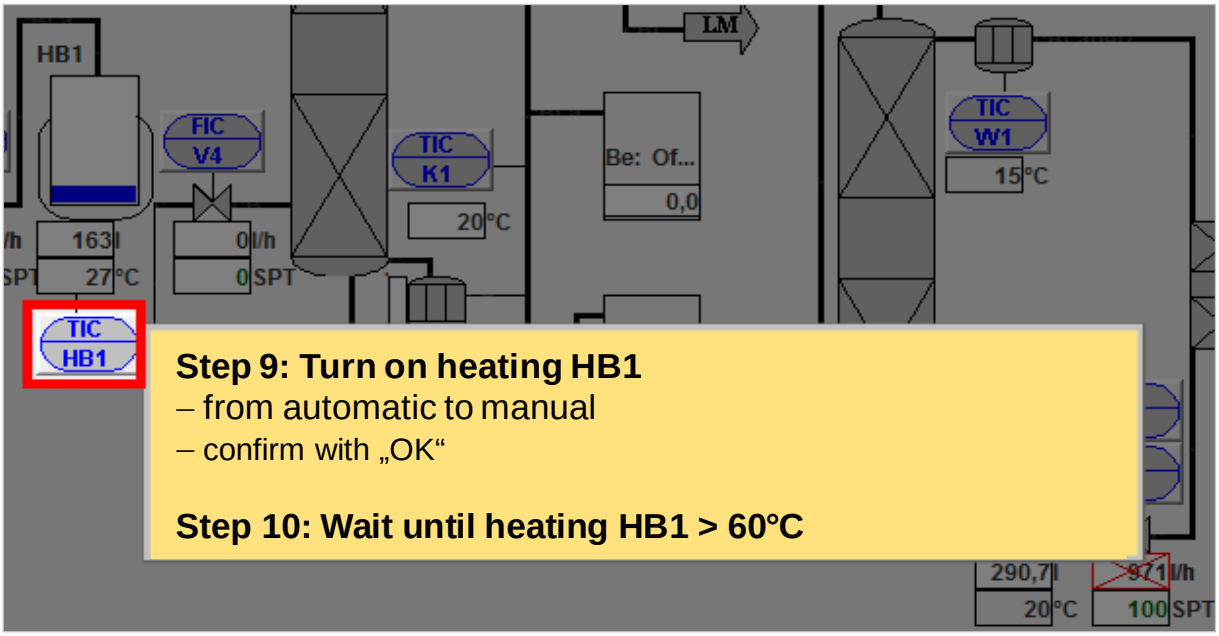


Figure 5: Gaze-guiding instructions for the heating HB1 in the case that the preceding tank has enough fluid stored for starting the process but the heating has not yet been initialized.

4. USER STUDY

The objective of the study was to investigate how the participants subjectively rate the gaze-guiding variants introduced in Section 3. Therefore we trained 21 participants in how to operate WaTrSim and afterwards the participants evaluated the four gaze guiding versions.

The study revealed the feasibility of the concept for guiding the attention of human operators in the control of technical systems, thereby demonstrating its applicability for use as refresher training. We evaluated the gaze guiding with regard to the following questions:

1. Evaluation of gaze-guiding version: Which gaze-guiding version was chosen by the participants?
2. Evaluation of design: Is the gaze guiding perceived as well designed?
3. Evaluation of helpfulness: Is the gaze guiding perceived as helpful/disruptive?
4. Evaluation of potential for recall support: Is the gaze guiding able to support the user in recalling the operation?
5. Evaluation of text: Is the text length perceived as reasonable?
6. Evaluation of pictograms: Are the pictograms perceived as well designed?

4.1 SAMPLE

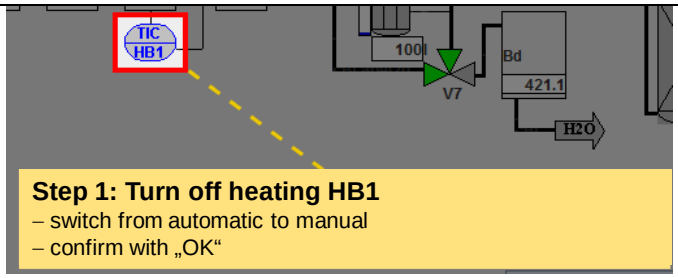
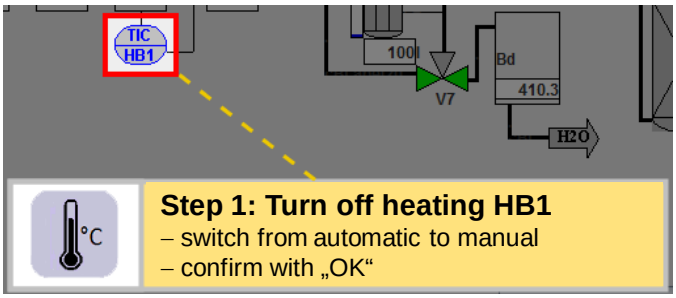
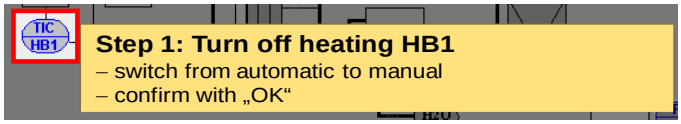
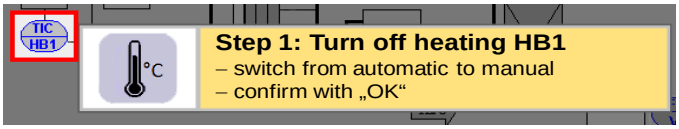
In October 2014, 21 participants (5 male) from the Ruhr-University Bochum took part in the study. The experiment lasted for 50 minutes. The participants were students who were

attending a university course on Human Factors. They were informed about the purpose of the study and were told that they could discontinue participation at any time (in terms of informed consent). Participation was voluntary, and no compensation was provided.

4.2 WATRSIM & GAZE GUIDING

The participants received training on how to control and operate the start-up procedure of the micro world WaTrSim. Subsequently, they operated WaTrSim with the four different gaze-guiding versions (Table 2) to support the start-up procedure of the plant (see 4.4. procedure). Finally, different blink patterns for the applied frame were presented: version 1. red/orange, version 2. blue/yellow, version 3. gray/light gray, and version 4. black/white.

Table 2. Four gaze-guiding versions

Gaze-guiding version	Example
Version 1) With associating line, without pictograms	
Version 2) With associating line, with pictograms	
Version 3) Without associating line, without pictograms	
Version 4) Without associating line, with pictograms	

4.3 PROCEDURE

The participants were introduced to WaTrSim and given training on the start-up procedure. During the training, the participants used a manual containing the 13-step procedure. After the training phase, the participants demonstrated that they were able to operate the start-up procedure in WaTrSim without the support of the manual. In order to test the perceived usefulness of the four gaze-guiding versions, the participants were then asked to control WaTrSim for four more trials, using a different gaze-guiding version each time (e.g. trial 1: version 1, trial 2: version 2, trial 3: version 3, trial 4: version 4; randomized for each participant). Subsequently, the four blink patterns were presented to the participants for 15 seconds each (randomized). At the end, the participants were asked to indicate which gaze-guiding and blink pattern version they preferred the most. The study lasted for 50 minutes for

each participant. The whole procedure is shown in Figure 6. It was important for the evaluation of the gaze guiding that the participants were able to rate the gaze guiding version with the knowledge of how to operate in WaTrSim and what are important aspects for the operation.

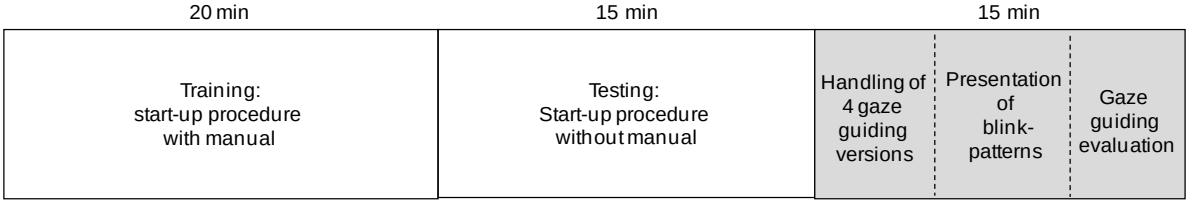


Figure 6. Procedure of user study: Training, testing, handling of 4 gaze-guiding version, presentation of blink-patterns, and the final questionnaire-based evaluation.

4.4 QUESTIONNAIRE

After operating WaTrSim with the four gaze-guiding versions, the participants filled in an evaluation questionnaire (approx. 5 min). First, participants had to declare their preferred gaze guiding version ("Which of the gaze guiding versions do you prefer?") and they declared one of the blink patterns as their favorite ("Which of the four blink patterns do you prefer?"). After this, they filled in the general gaze-guiding evaluation questionnaire. This questionnaire consisted of eleven items grouped into six categories. The items were rated on a Likert scale ranging from "1 - Completely disagree" to "6 - Completely agree" (Table 3). One open question additionally asked for free comments ("Please provide any further comments if you wish").

Table 3. List of items of the general gaze-guiding evaluation questionnaire and the categories

Number	Item	Category
GG1	The gaze guiding is designed in an attractive manner	Design
GG2	The gaze guiding was helpful for interacting with the systems	Helpful
GG3	With the help of the gaze guiding I was able to remember the next steps of the start-up procedure	Support
GG4	The gaze guiding helped me to remember how to operate the heating/the valves	Support
GG5 (-)	The gaze guiding was disruptive (-)	Helpful
GG6	I read the content of the gaze-guiding information completely	Read
GG7 (-)	I did not read the content of the gaze-guiding information completely (-)	Read
GG8	The gaze-guiding information contains too much text	Text
GG9	The gaze-guiding information contains too little text	Text
GG10	The pictograms were designed in an attractive manner	Pictogram
GG11	The pictograms were helpful	Pictogram

Note: GG1 = gaze guiding 1; "-" = reverse-coded items

4.5 RESULTS

For the analysis of the questionnaire data, the total sample of N=21 was used. Additionally, the results of those participants (n=10) who had chosen the gaze guiding without a line and without pictograms (version 3) as the most favorable are presented separately. The questionnaire was analyzed descriptively.

4.5.1 GAZE-GUIDING VERSION & BLINK PATTERNS

Question 1: Which gaze-guiding version was chosen by the participants?

The gaze-guiding version which was not equipped with an associating line and pictograms (Mode=version 3, Range=1-4. $\chi^2(3)=9.29$, $p=.026$; Figure 7) and the red/orange blink pattern (Mode=version 1, Range=1-3, $\chi^2(2)=8.00$, $p=.018$) were chosen by the participants as the most favorable.

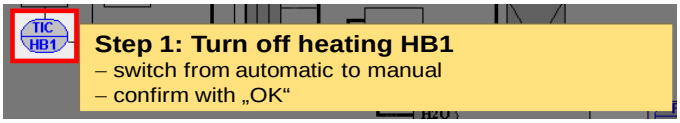


Figure 7. Selected gaze-guiding version 3 - without an associating line and without pictograms

4.5.2 GAZE-GUIDING EVALUATION

Question 2: Is the gaze-guiding perceived as well designed?

The results (Table 4) show that both groups, the complete sample (N=21) and the participants who opted for gaze-guiding version 3 (without line and without pictograms; n=10), rated the gaze guiding as well designed (overall group: M=4.86, SD=0.91, sub-group: M=4.80, SD=1.03).

Question 3: Is the gaze-guiding perceived as helpful/disruptive?

Overall, the gaze guiding was perceived as helpful (overall: M=4.60, SD=1.10, sub-group: M=4.65, SD=1.38; Table 4).

Question 4: Is the gaze-guiding able to support the user in recalling the operation?

The participants believed that the start-up procedure of WaTrSim and the interaction with WaTrSim can be supported by gaze guiding (overall: M=4.36, SD=1.46; sub-group: M=4.40, SD=1.22; Table 4).

Question 5: Is the text length perceived as reasonable?

The participants stated that they had read the content (overall: M=4.07, SD=1.63; sub-group: M=3.95, SD=1.52) and evaluated the text length as appropriate (not too much and not too little; overall: GG8: M=2.10, SD=1.14; GG9: M=1.62, SD=0.80; Table 4).

Question 6: Are the pictograms perceived as well designed?

The pictograms were rated as well designed (overall: M=3.57, SD=1.96, sub-group: M=3.80, SD=1.99) but were also deemed to be less helpful (overall: M=2.86, SD=1.74, sub-group: M=2.50, SD=1.43).

In general, the results show that the gaze guiding was appreciated and perceived as well designed and helpful, with the appropriate amount of information.

Table 4. Descriptive statistics of gaze-guiding evaluation questionnaire

	N=21 (all versions)	N=10 (version 3)
Item	*M (SD)*	*M (SD)*
Design	4.86 (0.91)	4.80 (1.03)
The gaze guiding is designed in an attractive manner (GG1)	4.86 (0.91)	4.80 (1.03)
Support	4.36 (1.46)	4.40 (1.22)
With the help of the gaze guiding, I was able to remember the next steps of the start-up procedure (GG3)	4.24 (1.51)	4.30 (1.34)
The gaze guiding helped me to remember how to operate the heating/the valves	4.48 (1.57)	4.50 (1.43)

(GG4)		
Helpful	4.60 (1.10)	4.65 (1.38)
The gaze guiding was helpful for interacting with the systems (GG2)	4.57 (1.60)	4.90 (1.52)
The gaze guiding was disruptive (-) (GG5)	4.62 (1.12)	4.40 (1.35)
Read	4.07 (1.63)	3.95 (1.52)
I read the content of the gaze-guiding information completely (GG6)	3.62 (1.69)	3.50 (1.35)
I did not read the content of the gaze-guiding information completely (-) (GG7)	4.52 (1.69)	4.40 (1.78)
Text	1.86 (0.85)	1.95 (0.83)
The gaze-guiding information contains too much text (GG8)	2.10 (1.14)	2.20 (1.14)
The gaze-guiding information contains too little text (GG9)	1.62 (0.80)	1.70 (0.82)
Pictogram	3.21 (1.71)	3.15 (1.55)
The pictograms were designed in an attractive manner (GG10)	3.57 (1.96)	3.80 (1.99)
The pictograms were helpful (GG11)	2.86 (1.74)	2.50 (1.43)

Note: Rating scale ranging from 1 = Completely disagree, 6 = Completely agree; "-" = inverted items

4.5.3 COMMENTS ON THE OPEN QUESTION

In the questionnaire, participants were able to comment on an open question ("Do you have further comments?"). Answers revealed that the pictograms were not perceived as being very helpful (M=2.50-2.86, SD=1.43-1.74). Five participants mentioned that the pictograms might distract their attention. One participant described the pictograms as too dominant, and three participants suggested introducing the pictograms in the preceding training session or in the manual. One participant emphasized the closeness of the blink pattern to the information box as very important.

4.6 DISCUSSION OF USE CASE

The user study showed that the gaze-guiding version 3, with red-orange blink patterns, was evaluated most positively. Responses to the questionnaire showed that the gaze guiding was evaluated as well designed, helpful, and supportive for the operation recall and with a reasonable text length. Although the gaze-guiding version with pictograms was not evaluated as the most positive one, the pictograms were perceived as well designed. Nevertheless, the participants comment in the free-text section of the questionnaire that for future studies the gaze-guiding pictograms should be modified (e.g. made smaller) or designed as intuitively as possible. Moreover, the participants suggest that the pictograms should be briefly introduced to the participants in advance. This contradictory results lead us to the conclusion that the use of pictograms is not useless but has to be applied in a very usable and simple to understandable way.

Overall, this indicates that the developed gaze-guiding version 3 is applicable to other similar experiments, and it is currently being implemented in an experiment to analyze its potential for skill retention. The adaptability of the gaze guiding tool to other systems will be investigated in future studies. As a limitation of the study, it should be considered that a student sample evaluated the gaze guiding. However, the participants were trained in WaTrSim to ensure the knowledge and understanding of WaTrSim as close as possible to professionals.

5. CONCLUSION AND FUTURE WORK

This paper introduced a framework for guiding users' gaze in the control of technical systems. The framework comprises a modeling approach for the description of state-based representations of black-box systems derived from SOPs as well as a modeling approach for the description of gaze-guiding tool sets. The latter describes the added content, such as

frames, text boxes or arrows in an overlay, which extends the given user interface of the controlled system. The framework further contains modeling tools and software components for mapping these system state models to a running system as well as for applying the gaze guiding during runtime. The present work also introduced a user study, which demonstrated the feasibility of the gaze-guiding framework, mainly highlighting its usefulness and the support that it can provide to an operator controlling a given system. Nevertheless, the four variants differ in their perceived usefulness. Together with the findings from related work on visual cues, which show no increase in cognitive load through the use of such concepts, the framework presented here is suitable for use in the control of such systems, as well as for use within refresher interventions.

Future work will comprise an applied user study with different procedures and different simulated operational settings. Central to our research will be the question whether gaze guiding can replace refresher interventions such as recurrent training. Several occupations contain so many procedures that it would be impossible to refresh them all regularly, meaning that gaze guiding could be an efficient and effective alternative. Further contributions will include analysis of the potential retrieval support of gaze guiding and of which areas of the gaze guiding are perceived by using objective measures such as actual performance and eye tracking. Another relevant aspect to investigate is the influence of gaze guiding on the usability of the user interface and in this regard also the evaluation of different usability measures and questionnaires.

Finally, we plan to implement various other gaze-guiding tools. The current implementation of the gaze-guiding overlay is based on JAVA Swing components, which makes this implementation easy to extend. It is planned to also provide implementations for other user interface frameworks, such as Qt. Therefore, the gaze-guiding component and the system state component will be encapsulated and coupled with non-JAVA implementations using messaging libraries, such as ZeroMQ, which offers Java as well as C++ bindings. This is possible due to the current structure of components and the existing decoupling of system state and gaze-guiding component, as has been presented above (cf. Figure 1).

6. ACKNOWLEDGEMENT

This research was founded by the DFG (Deutsche Forschungsgemeinschaft/German Research Foundation), project number KL2207/3-3. The present work is an enhanced and improved version of the article by Bischof et al. (2015) presented at the 2015 Workshop “KritischeHCI”, which took place in Stuttgart in 2015 and has been published in the workshop’s proceedings (Reuter et al., 2015).

8 REFERENCES

Bailey, R., McNamara, A., Sudarsanam, N., and Grimm, C. Subtle Gaze Direction. ACM Trans. Graph. 28, 4 (Sept. 2009), 100:1-100:14.

Bétrancourt, M., & Tversky, B. (2000). Effect of computer animation on users’ performance: a review. *Le Travail Humain, 63*(4), 311–329.

Bischof, K., Weyers, B., Frank, B., & Kluge, A. (2015). Gaze guiding zur Unterstützung der Bedienung technischer Systeme. In *Proceedings of the Workshop on Mensch-Computer-Interaktion und Social Computing in sicherheitskritischen Systemen* (pp. 58-63). DeGruyter.

Bjork, R. A. (2011). On the symbiosis of learning, remembering, and forgetting. In A. S. Benjamin, (Eds.), *Successful remembering and successful forgetting: A Festschrift in honor of Robert A. Bjork* (pp. 1-22). London, UK: Psychology Press.

Bjork, R. A. & Bjork, E. L. (1992). A new theory of disuse and an old theory of stimulus fluctuation. In Healy, A., Kosslyn, S. & Shiffrin, R. (Eds.), *From learning processes to cognitive processes: Essays in honor of William K. Estes* (Vol. 2; pp. 35-67). Hillsdale, NJ, USA: Erlbaum.

Bjork, R. A., & Bjork, E. L. (2006). Optimizing treatment and instruction: Implications of a new theory of disuse. In L. G. Nilsson & N. Ohta (Eds.), *Memory and Society. Psychological Perspectives* (pp. 109-134). Hove: Psychology Press.

Cooper, G., Tindall-Ford, S., Chandler, P., & Sweller, J. (2001). Learning by imagining. *Journal of Experimental Psychology: Applied, 7*(1), 68-82.

de Koning, B. B., Tabbers, H., Rikers, R. M., & Paas, F. (2009). Towards a framework for attention cueing in instructional animations: Guidelines for research and design. *Educational Psychology Review, 21*(2), 113–140.

de Koning, B. B., Tabbers, H., Rikers, R. M., & Paas, F. (2010). Attention guidance in learning from a complex animation: Seeing is understanding? *Learning and Instruction, 20*(2), 111–122.

Farmer, E., Van Rooij, J., Riemersma, J., Jorna, P., & Moraal, J. (1999). *Handbook of simulator-based training*. Aldershot: Ashgate.

Farr, M. J. (1987). *The long-term retention of knowledge and skills*. New York: Springer.

Gogolla, M., & Presicce, F. P. (1998). State diagrams in UML: A formal semantics using graph transformations - or diagrams are nice, but graphs are worth their price. In University of Munich, pp. 55-72.

http://citeseerx.ist.psu.edu/viewdoc/download;jsessionid=FE0E891CD72746575DAF7FD3CAEAA420?doi=10.1.1.51.6069&rep=rep1&type=pdf

Gopher, D. (2007). Emphasis change as a training protocol for high-demand tasks. In A. F. Kramer, D. A. Wiegmann, & A. Kirlik (Eds.), *Attention: From theory to practice* (Vol. 4, pp. 209-224). New York: Oxford University Press.

Harnesk, D., Lindström, J., & Samuelsson, S. (2009). Socio-Technical Design Approach for Crisis Management Information Systems. *International Journal of Information Systems for Crisis Response and Management, 1*(3), 1-18.

Jamet, E. (2014). An eye-tracking study of cueing effects in multimedia learning. *Computers in Human Behavior, 32*, 47-53.

Kluge, A. (2014). *The Acquisition of Knowledge and Skills for Taskwork and Teamwork to Control Complex Technical Systems*. Heidelberg: Springer.

Kluge, A. & Frank, B. (2014). Counteracting skill decay: Four refresher interventions and their effect on skill and knowledge retention in a simulated process control task. *Ergonomics, 57*(2), 175-190.

Kluge, A., Greve, J., Borisov, N., & Weyers, B. (2014). Exploring the usefulness of two variants of gaze-guiding-based dynamic job aids for performing a fixed-sequence start-up procedure after longer periods of non-use. *International Journal of Human Factors and Ergonomics, 3*(2), 148-169.

Kluge, A., Sauer, J., Schüler, K. & Burkolter, D. (2009). Designing Training for process control simulators: a review of empirical findings and current practices. *Theoretical Issues in Ergonomics Science, 10*, 489–509.

Lin, L., Atkinson, R. K., Savenye, W. C. & Nelson, B. C. (2014). Effects of visual cues and self-explanation prompts: empirical evidence in a multimedia environment. *Interactive Learning Environments,* in press, 1-15.

Lin, L., & Atkinson R. K. (2011). Using animations and visual cueing to support learning of scientific concepts and processes. *Computers & Education, 56*,3 , 650-658.

Mayer, R. E., & Moreno, R. (2003). Nine ways to reduce cognitive load in multimedia learning. *Educational psychologist, 38*(1), 43-52.

McGuirl, J., Sarter, N., & Woods, D. (2009). Effects of Real-time Imaging on Decision-Making in a Simulated Incident Command Task. *International Journal of Information Systems for Crisis Response and Management*, *1*(1), 54-69.

McNamara, A., Bailey, R., & Grimm, C. (2008). Improving search task performance using subtle gaze direction. In *Proc. APGV 2008*, 5156.

McNamara, A., Bailey, R., & Grimm, C. (2009). Search task performance using subtle gaze direction with the presence of distractions. *ACM Transactions on Applied Perception*, *6*(3), 1-19.

Moon, J., & Ryu, J. The Effect of Visual Cueing and Narration Speed on the Comprehension Scores with Types of Task and Overall Cognitive Load. Online document: http://icome2013.iwd.jp/program/pdf/1p_PDF/B39.pdf, Last accessed on Nov. 11, 2015.

Negri, P., Gamberini, L. & Cutini, S. (2014). A Review of the Research on Subliminal Techniques for Implicit Interaction in Symbiotic Systems. In *Symbiotic Interaction* (pp. 47-58). Springer International Publishing.

Onnasch, L., Wickens, C. D., Li H., & Manzey, D. (2014). Human Performance Consequences of Stages and Levels of Automation: An Integrated Meta-Analysis. *Human Factors*, *56*(3), 476-488.

Parasuraman, R., Sheridan, T. B. & Wickens, C. D. (2000). A Model for Types and Levels of Human Interaction with Automation. *IEEE Transactions on Systems, Man, and Cybernetics- Part A: Systems and Humans*, *30*(3), 286-297.

Pfleging, B., Henze, N., Schmidt, A., Rau, D., & Reitschuster, B. (2013, April). Influence of subliminal cueing on visual search tasks. In CHI'13 Extended Abstracts on Human Factors in Computing Systems (pp. 1269-1274). ACM.

Reuter, C., Mentler, T., Geisler, S., Herczeg, M., Ludwig, T., Pipek, V., Nestler, S., Sautter, J. (Des.). (2015). *Proceedings des Workshops „MenschComputer-Interaktion und Social Computing in sicherheitskritischen Systemen“ (KritischeMCI)*, DeGruyter.

Roediger, H. L., & Karpicke, J. D. (2006). The power of testing memory: Basic research and implications for educational practice. *Perspectives on Psychological Science*, *1*(3), 181-210.

Sibert, L. E., & Jacob, R. J. (2000, April). Evaluation of eye gaze interaction. In Proceedings of the SIGCHI conference on Human Factors in Computing Systems (pp. 281-288). ACM.

Wallace, F. L., Flanery, J. M., & Knezek, G. A. (1991). The effect of subliminal help presentations on learning a text editor. *Information processing & management*, *27*(2), 211-218.

Ware, C. (2004). *Information Visualization: Perception for Design* (2. Aufl.). Morgan Kaufmann.

Wickens, C. D., & Hollands, J. G. (2000). *Engineering psychology and human performance* (Vol. 3). Upper Saddle River: Prentice Hall.

Wouters, P., Paas, F., & van Merriënboer, J. J. (2008). How to optimize learning from animated models: A review of guidelines based on cognitive load. *Review of Educational Research*, *78*(3), 645-675.

Young, M. S., Brookhuis, K. A., Wickens, C. D., & Hancock, P. A. (2015). State of science: mental workload in ergonomics. *Ergonomics*, *58*(1), 1-17.

Benjamin Weyers *is currently working in the EU flagship project 'The human brain project' at the Virtual Reality Group, RWTH Aachen University. Benjamin studied computer science at the University of Duisburg-Essen (2003–2008, Dipl.Inform.) and went on to obtain his doctoral degree with the Computer Graphics and Scientific Computing group at the University of Duisburg-Essen (2011, Dr.Ing). His research interests include human-computer interaction, formal modelling and information visualisation. During his studies he has closely worked with scientists from various scientific areas, such as collaborative systems, ambient intelligence and scientific visualisation.*

Barbara Frank *is a research assistant of the department of business psychology at the Ruhr-University Bochum, Germany. She studied applied cognitive and media science at the University of Duisburg-Essen, Germany and retrieved her Master degree in September 2013. She is currently doing her Ph.D. at the Ruhr-University Bochum on the topic of "Effects of Cognitive Abilities, Refresher Interventions and Gaze Guiding on Complex Cognitive Skill Retention". Her research interests include human factors and methods for complex cognitive skill retention.*

Kathrin Bischof *is research assistant in the Interactive Systems group at the University of Duisburg-Essen, Germany since October 2015. After an education as pharmaceutical-technical assistant, she studied Applied Computer Science and Applied Cognitive and Media Science at the University of Duisburg-Essen. After receiving her bachelor's degrees in 2013, she started to study Applied Cognitive and Media Science to reach the master's degree. In 2014 she worked as a scientific assistant at the Department of Work and Organizational Psychology at the University of Duisburg-Essen and at Ruhr University Bochum until July 2015.*

Annette Kluge *is a Full Professor for Business Psychology at the Ruhr University Bochum, Germany since 2014. She obtained her Doctorate in Ergonomics and Vocational Training at the University of Kassel, Germany in 1994 and achieved her habilitation (post-doctoral degree 2004 at the Technical University of Aachen). She worked in the field of human factors, ergonomics and industrial- and organisational psychology as an Assistant Professor at the University of St. Gallen, Switzerland and as a Full Professor at University of Duisburg-Essen, Germany. Her research interests are knowledge and skill acquisition, retention and forgetting in process control, as well as training science.*