112.SOCIAL: DESIGN AND EVALUATION OF A MOBILE CRISIS APP FOR BIDIRECTIONAL COMMUNICATION BETWEEN EMERGENCY SERVICES AND CITIZENS

Research paper

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Abstract

Emergencies threaten human lives and overall societal continuity, whether or not the crises and disasters are induced by nature, such as earthquakes, floods and hurricanes, or by human beings, such as accidents, terror attacks and uprisings. In such situations, not only do citizens demand information about the damage and safe behaviour, but emergency services also require high quality information to improve situational awareness. For this purpose, there are currently two kinds of apps available: General-purpose apps, such as Facebook Safety Check or Twitter Alerts, already integrate safety features. Specific crisis apps, such as KATWARN in Germany or FEMA in the US, provide information on how to behave before, during and after emergencies, and capabilities for reporting incidents or receiving disaster warnings. In this paper, we analyse authorities' and citizens' information demands and features of crisis apps. Moreover, we present the concept, implementation and evaluation of a crisis app for incident reporting and bidirectional communication between authorities and citizens. Using the app, citizens may (1) report incidents by providing a category, description, location and multimedia files and (2) receive broadcasts and responses from authorities. Finally, we outline features, requirements and contextual factors for incident reporting and bidirectional communication via mobile app.

Keywords: Crisis Management, Mobile Crisis Apps, Social Media, Bidirectional Communication

1 Introduction

Emergencies, crises and disasters threaten human lives, interfere with societal continuity and induce monetary damages all over the world. Some disaster databases and studies indicate that the frequency and intensity of natural disasters, such as the Tōhoku earthquake and tsunami in 2011, the European floods in 2013, or the hurricanes Harvey and Irma in 2017, have increased over the last decades (Eshghi and Larson, 2008; Munich Re, 2017, p. 53). Moreover, the number of man-made disasters and casualties by terrorism is increasing worldwide (Coleman, 2006; Giuliani, 2016), such as the November 2015 Paris attacks, the 2016 Munich shopping mall shooting or the 2017 London Bridge attack. However, also small occasions, such as car accidents or fires, are emergencies that have to be considered in this context.

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Besides social media, which meanwhile play an important role in informing the population (Reuter and Spielhofer, 2017) and acquiring situational awareness (Reuter et al., 2016), mobile crisis apps can support the information needs of both emergency services and citizens. While emergency services are interested in situational updates, multimedia files and public mood (Reuter et al., 2016), citizens demand instructing and orientation information (Coombs, 2009; Nilges, Balduin and Dierich, 2009). With *crisis apps*, we refer to mobile apps providing specific functionality needed during crises, emergencies or disasters, such as KATWARN (Meissen, Hardt and Voisard, 2014) or FEMA (Bachmann et al., 2015). These provide information on how to behave before, during and after emergencies, as well as capabilities for reporting incidents or receiving disaster warnings (Reuter et al., 2017a). However, although some crisis apps support the reporting of incidents (Groneberg et al., 2017), none allows the establishment of bidirectional communication threads, enabling a dynamic and timely request and exchange of multimedia files and situation updates between authorities and citizens across different phases of the emergency management cycle. Thus, we strive for three contributions: First is the development of a novel mobile crisis app for bidirectional communication among authorities and citizens (C1). Furthermore, we seek insights into two research questions: What are features and requirements for the successful reporting of incidents using a mobile app concept (C2)? What are contextual factors for the successful establishment of bidirectional communication between authorities and citizens (C3)?

The paper is structured as follows: Firstly, we present related work on authorities' and citizens' information demands during emergencies, crises and disasters as well as existing crisis apps supporting crisis response (Section 2). Secondly, based on the design science research paradigm, we outline the requirements analysis, development, features and implementation of the mobile app 112.social (Section 3). Thirdly, we present the evaluation of 112.social during multiple practices and field trials (Section 4). Finally, the paper concludes with a summary, discussion and outlook (Section 5).

2 Related Work and Comparison of Crisis Apps

About 2.32 billion people were using smartphones worldwide in 2017, a number which is estimated to increase to 2.87 billion by 2020 (Statista, 2017). Citizens use smartphone apps to read and share information in different social media, such as social networks (Facebook), microblogging services (Twitter), multimedia sharing platforms (YouTube) or instant messengers (WhatsApp). These social media are not only used in everyday life, but also to stay informed during emergencies, crises or disasters (Eismann, Posegga and Fischbach, 2016). By using different kinds of social media during crises, people often publish information of some value to the emergency services, such as eyewitness reports in real-time (Reuter, Hughes and Kaufhold, 2018). For the conceptual framing of this paper, we refer to the crisis communication matrix (Reuter and Kaufhold, 2018) which distinguishes authorities and citizens, both as sender and receiver, to derive four communication flows: crisis communication (A2C), self-help communities (C2C), interorganizational crisis management (A2A), and integration of citizen-generated content (C2A). Since this paper examines bidirectional communication between authorities and citizens using crisis apps, we focus on the communication flows of C2A and A2C.

2.1 Authorities' Demand for Citizen-Generated Content (C2A)

The multidisciplinary research field of crisis informatics has revealed interesting and important real-world uses for information and communication technology (ICT) during crises (Hagar, 2007; Palen and Anderson, 2016). Fischer, Posegga and Fischbach (2016) indicate that the communication between authorities, such as emergency services, and citizens faces technological, organisational and social barriers across the mitigation, preparedness, response, and recovery phases of a crisis. In the beginning of and during an emergency, it is vital for authorities to get as much emergency-relevant information as possible to obtain and maintain a situational overview, support decision making and carry out effective crisis communication (Coombs, 2014; Vieweg et al., 2010). Besides "getting the right information to the right person at the right time" (Hagar, 2010, p. 10), emergency services have to deal with information production by diverse actors and agencies using informal and formal channels, conflicting information and the credibility of different sources.

The rise of social media and distribution of smartphones empowered the role of citizens as active participants before, during and after emergencies, which is also of use for emergency services (Reuter, Hughes and Kaufhold, 2018). The potential of benefitting from citizen-generated content lies within illustrating problematic situations through eyewitness reports, photos or videos taken with mobile phones (Alam, Ofli and Imran, 2018; Olteanu, Vieweg and Castillo, 2015). A survey with 761 emergency services workers from 32 European countries revealed situational updates (73%), photos (67%), public mood (62%), videos (59%) and specific information (56%) to be important types of information derived from social media (Reuter et al., 2016). To make use of such content, the field of social media analytics aims to combine, extend, and adapt methods for the analysis of social media data across the steps of discovery, collection, preparation, and analysis (Stieglitz et al., 2018). Accordingly, several contributions aim at extracting situational awareness from citizen-generated content, highlighting the importance of geographic coordinates and timely information (Imran et al., 2015; Moi et al., 2015).

2.2 Citizens' Demand for Crisis Communication (A2C)

The citizens' needs for information differ in the phases of the emergency management cycle (Fischer, Posegga and Fischbach, 2016). In the preparation phase, information for sensitisation and crisis preparation are necessary. For the implementation of preventive measures, a sense of danger is required and warnings have to be delivered urgently (Geenen, 2009; Volgger et al., 2006). This comprises information about existing and potential hazards, their probabilities, possible consequences, as well as *instructing information*, i.e. plans and instructions with best practices for emergencies (Coombs, 2009). Predictable crises have to be communicated on every available channel as early as possible, making sure that as many people as possible get the information (Volgger et al., 2006). Although social media and crisis apps offer rich opportunities (Reuter et al., 2017a), warnings of disasters are mainly distributed through mass media (TV, radio), sirens or multichannel warning systems, where, for example, SMS, email, and RSS feeds can be combined (Klafft, 2013).

In the response phase, consistent and transparent information supply is necessary, i.e. *orientation information* for affected people to assess the situation as best as possible is required, such as weather warnings (Nilges, Balduin and Dierich, 2009) or other people's safety (Wade, 2012). Information disseminated to the public should contain basic information, e.g. recommendations for action, site-specific information, e.g. the expected duration of a local power breakdown, and configuration-specific information, e.g. for individuals with special needs (Reuter, 2014). In the course of communication between citizens, information is also distributed, discussed, and interpreted, showing that the contact with our fellows significantly co-determines our behaviour during a crisis situation (Kaufhold and Reuter, 2016). This process of *sensemaking* can be understood as a "steady process of gaining knowledge through the transformation and integration of new information into cognitive schemata" (Mirbabaie and Zapatka, 2017), which is supported by different roles, such as information starters, amplifiers and transmitters.

2.3 Crisis Apps and Contextual Factors for Bidirectional Communication

Mobile crisis apps are not uncommon nowadays: Reuter & Ludwig (2013) compared 25 apps which support *different functionalities* such as the interactive display of crises on maps, sharing of information, collection of eyewitness reports, or live broadcasts by authorities or infrastructure providers. Some apps are specialized for *different types of disasters* such as earthquakes, epidemics, floods, storms and wildfires, or they provide instructing information on how to act during emergencies. Karl, Rother and Nestler (2015) compared characteristics and purposes of crisis apps, including alerts for situation awareness, sending alarms and asking for help, behavioural instructions and support, and the use by volunteers and trained first aiders. Another study compared warning apps in terms of location-based warnings, warning maps, general disaster information, information sharing, and disaster reporting (Reuter et al., 2017a). Furthermore, Kotthaus, Ludwig and Pipek (2016) compared user comments from app stores on KATWARN and NINA, concluding that warning messages "lack in quality and timing", "malfunctions lead to high amount of user complaints" and "both apps [do not] aim at addressing users [individually]".

Finally, a research report from the German project SMARTER analysed 59 international crisis apps from 14 countries, categorising their functions into information (i.e. push notifications, maps, news, organisational information), communication (i.e. social media integration, direct 112 emergency calls, contact directory, "I'm safe" notification), preparation (i.e. emergency planning, behavioural tips, descriptions of dangers, trainings) and other (i.e. language change, app rating, feedback) (Groneberg et al., 2017). These include mobile apps that support either bidirectional communication or the reporting of incidents: The MoRep app allows relief forces to report incidents to the headquarters by providing a title, description, photo and geocoordinates of the incident (Reuter, Ludwig and Pipek, 2016). In addition to these metadata, the Ushahidi app allows the selection of a category, date and time, as well as a news URL (Ludwig et al., 2014). Similarly, the FEMA app allows citizens to report disaster photos, enriched with geocoordinates, to authorities (Bachmann et al., 2015). While MoRep focuses inter-organisational reporting, all three apps do not allow the establishment of bidirectional communication threads. Contrarily, the Hands2Help mobile app supports the bidirectional communication between authorities and citizens; however, its focus does not lie on reporting of incidents and the dynamic exchange of situation-related information, but on coordination of demands from authorities and offers by citizen volunteers (Sackmann, Hofmann and Betke, 2014).

Groneberg et al. (2017) conclude that no documented experiences or scientific surveys about the actual use of smartphones or crisis apps are currently available, and that existing scientific publications focus on the development of smartphone apps on a conceptual level or the integration of social media into crisis and disaster response (Al-Akkad and Raffelsberger, 2014). Furthermore, literature indicates a variety of contextual factors that are worth examining for the successful establishment of bidirectional communication via crisis apps. Based on two quantitative studies, a snowball-based survey in Europe and representative study in Germany, Reuter et al. (2017a) found a low interest in installing a crisis app (16%), whereby 11% use weather apps and 6% warning apps, and suggest further research on the promotion and motivation of using crisis apps. According to an extended representative study in Germany on citizens' perception about social media and crisis apps (Reuter et al., 2017b), 57% expect to receive emergency warnings, 51% to get advice on how to stay safe, and 42% to share information with emergency services via crisis apps in the future. However, research indicates that the adoption of new technology by emergency services faces barriers such as lack of sufficient staff, skills, guidance and policy documents and, in terms of integrating citizen-generated content, the issues of trustworthiness and information overload (Hughes and Palen, 2014; Plotnick and Hiltz, 2016).

2.4 Research Gap

The presented studies indicate a growing body of mobile apps designed for crises (Groneberg et al., 2017; Reuter and Ludwig, 2013). Although crisis apps support multiple scenarios and provide a vast amount of useful functionality, only a small portion allows the reporting of incidents and none supports a bidirectional communication between authorities and citizens facilitating the dynamic and timely request and exchange of situation-related information for mutual situation awareness (Hagar, 2010; Karl, Rother and Nestler, 2015). Although not explicitly focused on the technology of crisis apps, previous research indicates a variety of requirements (i.e. reporting of situational updates, geolocation, multimedia files and text for emergency services, and the dissemination of instructing and orientation information for citizens), but also contextual factors (i.e. the promotion of crisis apps, citizens' use motivation, authorities' organisational barriers and quality issues of citizen-generated content) that have to be considered in the design of a respective crisis app. Hence, the 112.social concept intends to assist in the structured reporting of and bidirectional communication during incidents (C1). Furthermore, there is a lack of scientific studies on requirements elicitation, documentation and evaluation of the actual use of crisis apps (Groneberg et al., 2017). While there is a large-scale study on the distribution and intended use cases of crisis apps within the population (Reuter et al., 2017a) which backs up the importance of researching the impact and potentials of crisis apps, our study aims to contribute insights from the evaluation of 112.social. Thus, we investigate features and requirements for the successful reporting of incidents using a mobile app concept (C2) as well as contextual factors for the successful establishment of bidirectional communication between authorities and citizens (C3).

3 Development and Architecture of the Emergency Mobile App

This section outlines the overall design approach and the process of requirements engineering, subsequently presenting the development of the mobile app 112.social. The system is connected to an Emergency Service Interface (ESI) and a Processing and Analysis Subsystem (PAS), which are not within the scope of this paper but are mentioned to clarify existing interfaces.

3.1 Overall Methodology

One goal of the project was to show the positive impact of gathering, qualifying, mining and routing citizen-generated content on the management of emergencies (EmerGent, 2017), which is realised through requirements analysis, as well as development and evaluation of artefacts for emergency services and citizens. Thus, design science research (DSR) plays a significant role, which is a problem-solving paradigm that "seeks to create innovations that define the ideas, practices, technical capabilities, and products through which the analysis, design, implementation, management and use of information systems can be effectively and efficiently accomplished" (Hevner et al., 2004). According to Hevner (2007), the central process is the building and evaluation of design artefacts and processes to improve an application domain, which comprises people as well as organisational and technical systems (*design cycle*). This design process should be grounded in and contribute to the knowledge base (*rigor cycle*). Since insisting "that all design research must be grounded on descriptive theories is unrealistic and even harmful to the field", as Hevner (2007, p. 90) suggests, we integrated "several different sources of ideas for the grounding of design science research", such as requirements based on literature findings, existing artefacts and the inquiry of domain experts. Our intended contributions to the knowledge base are reflected by C1-C3 (cf. Section 2.4). Furthermore, field testing is needed to raise requirements for the development or refinement of technology that supports emergency services in their emergency management practice (*relevance cycle*), and to decide whether additional iterations of this cycle are needed.

Title and Focus	Year	Participants
Interviews I: Social media in emergencies (Reuter et al., 2015)	2014	11
Workshops I-III: End-user advisory board (ES) (Gizikis et al., 2017; O'Brien et al., 2016)	2014/15/17	16/18/15
Surveys I-III: Perception of emergency services and citizens (Reuter et al., 2016; Reuter et al., 2017b; Reuter and Spielhofer, 2017)	2015/16/17	761/1,034/473
Evaluation I: First round of system evaluation (Reuter, Amelunxen and Moi, 2016)	2016	12

Table 1. Empirical pre-studies and workshops

To identify requirements, we employed a requirements analysis process: (1) Scenarios and use cases from real-life operations were chosen to be illustrated and analysed; (2) these were presented to end users, development teams and experts (workshops) to understand different approaches, establish a common understanding and allow interaction with each other; (3) and to involve a broader community, we conducted online survey to collect data. All interventions (Table 1) were supported by prior literature reviews, including a review of mobile app concepts (Ludwig et al., 2014), to consider the state of the art and to inform the application of appropriate methodologies. The complete requirements analysis process and its results are documented in a project deliverable (Akerkar, Friberg and Amelunxen, 2016). Since a fine-grained specification of requirements would exceed the scope of this paper, all elicited requirements were aggregated to high-level abstractions in Table 2.

Category	Description
Architecture	Easy-to-use, high available, maintainable, privacy-respecting, secure, stable and scalable standalone solution.
Communication	Reception, publication, response and broadcast of messages with multimedia (audio, photo, video) between authorities and citizens.
Processing	Cross-platform gathering, enrichment, relevance and quality assessment of citizen activities and alert generation.
Tailorability	Filtering of results in terms of geolocation, keywords, relevancy (mining) and information quality.
Visualization	Display of generated alerts on a list and map view, and classification of alerts according to the interoperable Common Alerting Protocol (OASIS, 2010).

Table 2. Abstraction of requirements comprising 112.social, ESI and underlying architecture

3.2 Functionalities of the Emergency Mobile App

The architecture supports multiple information flows between authorities (A) and citizens (C). Firstly, citizens may use 112.social to forward so-called "app alerts" to the ESI (C2A). Secondly, authorities may use the ESI to disseminate messages to 112.social users via broadcast or direct reply (A2C). In this way, chat-based communication threads are established across all phases of the emergency management cycle: For instance, if a citizen reports an early warning for an emergency or a witnessed incident (preparation), authorities may disseminate behavioural tips, such as instructing or orientation information, or request additional information or updates on demand to improve their situational awareness (response), allowing citizens to reply accordingly. Finally, citizens may report damages after the incident (recovery). Figure 1 shows the first (I-III) and second version (IV-VI) of 112.social, which was developed after the first trial at the OSCE (Section 4.1.1).

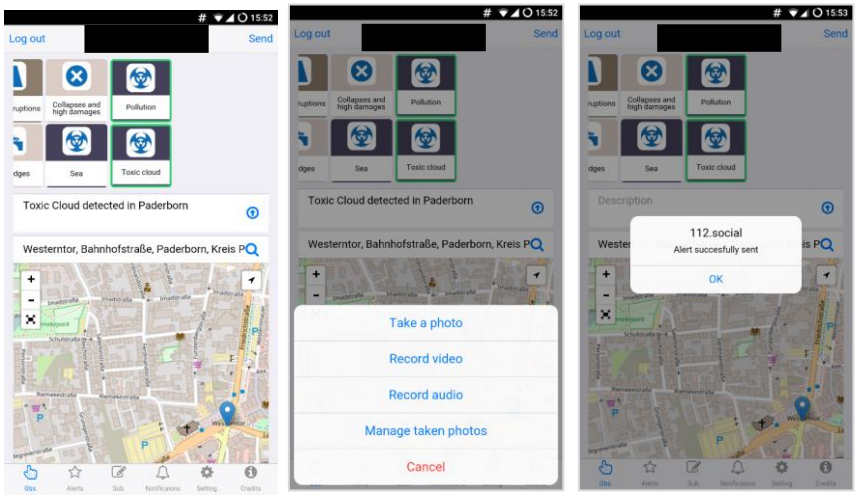

Figure 1. 112.social-1: (I) start screen, (II) multimedia dialogue, (III) alert sent confirmation

In the upper area of the start screen (I, IV), the user first chooses the main category of the incident, such as ambulance service, police, fire, accident or severe weather, and a subcategory (i.e. nature, vehicle or building for the fire category). In this way, for instance, the public-safety answering point (PSAP) would know right away what kind of help is needed. After category selection, the user may use a text field to provide additional information. On the right side of the text field, a blue-arrow icon opens the dialogue for adding multimedia files, such as photo, video or audio files (II). It is important to stress that any kind of multimedia file have to be taken in the moment the user wants to send an app alert, which is why multimedia files cannot be loaded from the phone's memory.

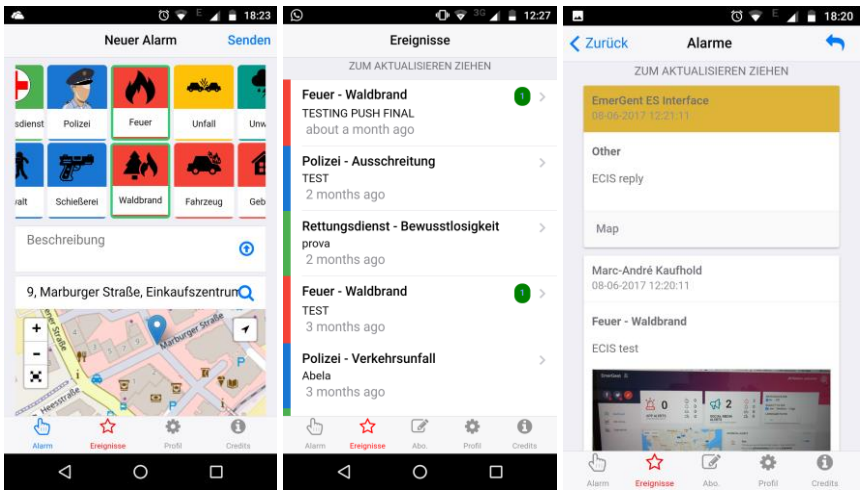

Figure 2. 112.social-2: (IV) start screen, (V) communication threads and (VI) details

At the bottom, the user may use the map and search box to determine the location of the incident (I, IV). By default, the user's GPS location is attached, and the user cannot select locations that are more than one kilometre away from their own GPS location. These restrictions were implemented to reduce the potential of abuse and allow the precise reporting of incidents in terms of location and time. After everything is set and a multimedia file is added, the so-called "app alert" is sent to the authorities (III). Since the focus was to enable bidirectional communication, a new communication thread is opened with the dissemination of an app alert (C2A) or, alternatively, if the user receives a message from authorities (A2C). A specific tab displays communication threads (V), where unread messages are indicated, and allows the user to view specific threads (VI). In this way, after the app alert has reached the ESI, the operator can choose to send a direct reply or broadcast to every app user in a certain area around the incident scene, for instance, to ask for more or specific details. Upon a reply, the app user receives a push message on his phone and can answer it by using the app again (VI).

4 Evaluation of the Emergency Mobile App

The evaluation of the app followed an iterative approach, whose methodology and results will be described in this section.

4.1 Methodology

We conducted semi-structured interviews (E2) and surveys (E1, E3) with 35 evaluation participants. While E1 had an exploratory character to get feedback from practitioners using the first version of 112.social, E2 aimed at achieving practical feedback from domain experts during exercises and field trials. E3 was conducted to evaluate the design, handling and stability of the second version.

4.1.1 VOST trial during the 23rd OSCE Ministerial Council (E1, Dec 2016, N=6)

In Hamburg, Germany, on the 8th and 9th of December 2016, the 23rd ministerial council meeting of the Organisation for Security and Co-operation in Europe (OSCE) took place. The participants were members of VOST112, a so-called Virtual Operations Support Team (VOST): "VOST as applied to emergency management and disaster recovery is an effort to make use of new communication technologies and social media tools, so that a team of trusted agents can lend support via the internet to those on-site who may otherwise be overwhelmed by the volume of data generated during a disaster" (VOSG, 2017).

Category	Data
Occupation	Fire Brigade (2), Paramedic (1), student (1), none (2)
Experience	Voluntary Fire Brigade (5), Accident Ambulance (3), Emergency Service (1), none (1)
Devices	Samsung Galaxy S7 (2), Apple iPhone 6S (1), Moto G1 (1) OnePlus One (1), Samsung Galaxy S5 (1)

Table 3. OSCE survey participants by occupation, experience (multiple selection) and device

During the council, 13 members of VOST112 used 112.social to send pictures and information to the ESI, which was watched by a silver level member of the fire department (FD) Hamburg. Additionally, the members used a dedicated channel in the Telegram messenger to report bugs and errors. After the two days of use, a survey was conducted with six VOST112 members. Besides personal details, organisation, experience and device, the survey asked whether the participant would (1) use or even (2) recommend 112.social to other citizens, (3) how they would classify the importance of A2C and C2A communication, sending multimedia content and simultaneous sharing of information on own social media channels, and (4) if the participant would like to provide additional feedback.

4.1.2 Emergency Service Demonstrations and Field Trials (E2, Jan – Jun 2017, N=21)

Firstly, during a live system demonstration, the participants interacted with the system, while in a paper-based demonstration, the interviewer introduced prepared screenshots of the system and explained its functionality. One survey was conducted in 2017 by the Scientific and Research Centre for Fire Protection – National Research Institute (CNBOP) in Poland, as well as further two interviews with members of volunteer fire departments (FD) in Germany. Secondly, the integrated system was tested at a convention in Salzburg, Austria. During the live simulation, a video of an incident (a fire) was shown, and the

audience of citizens was asked to participate by using 112.social. They used the video for taking pictures of the incident scene, sending them along other valuable information to a simulated command and control (C&C) room which, among others, was manned with an incident commander (gold level firefighter, FD Dortmund) and a social media manager (bronze level firefighter, FD Ljubljana) who used the ESI to get incident information from 112.social. Finally, for longer-lasting testing periods in real-world scenarios, three field trials were conducted. The field trial of FD Dortmund was in March/April 2017, and the one of FD Hamburg took place in April/May 2017, both lasting four weeks. Another one was conducted in July 2017 with FD Hamburg during the G20 event. During these trials, the system was used by the departments of public relations and strategic planning as well as by the head of dispatchers.

Category	Data
Roles	crew (10), head (1), incident commander (8), other (6), press (5), PSAP operator (1), PSAP supervisor (5), section leader (3)
Level	gold (3), silver (9), bronze (8), none (1)
Age	20-29 (2), 30-39 (10), 40-49 (6), 50-59 (3)
Gender	male (18), female (3)
Country	Germany (13), Poland (7), Slovenia (1)
Evaluation type	Field trial (10), live and paper-based demonstration (9), workshop exercise (2)

Table 4. Demonstration, field trials and workshop participants (I1-I22)

Overall, we conducted 21 semi-structured interviews with emergency services (Table 4). In terms of personal details, the interview guideline asked for the type of organisation, main role, command level, working years, age, gender, and country. Additionally, organisational details such as the role of social media and organisational barriers were asked. The core guidelines consisted of seven questions on the (1) first impression, (2) importance of functionality for their job, (3) evaluation of "app alerts", (4) "social media alerts" and (5) "information quality", as well as the (6) most useful functionality or (7) desired functionality in the future. Interviews were audio-recorded and transcribed for further analysis. In our subsequent analysis, we employed open coding (Strauss and Corbin, 1998), i.e., gathering data into approximate categories to reflect the issues raised by respondents based on repeated readings of the data and its organisation into similar statements.

4.1.3 Citizen Treasure Hunt for Functionality and Usability Evaluation (E3, Jul 2017, N=8)

During the field trials, the app users were mostly firefighters. However, the basic idea of 112.social was to have citizens as users. Therefore, a mixed group of students and researchers from different fields tried the app during a treasure hunt on the campus of the University of Paderborn. None of these participants had a background in the field of security, qualifying them as target users, and only two of them had used the app before. The others did get a very short introduction to the general idea and approach of the app, as it could be composed in a description in the app store. As the primary focus was the functionality and usability for untrained citizens, most of them used the same device with Android (Table 5).

Category	Data
Occupation	Research assistant (4), mechanical engineer (1), student (2), none mentioned (1)
Devices	Moto G1 (2), Moto G4 (4), OnePlus 3T (1), Samsung Galaxy S8 (1)

Table 5. Treasure hunt survey participants with occupation and device information

The treasure hunt consisted of eight "treasures" that contained answers to previously asked questions. These treasures were located on different spots of the campus and, after finding one, the participants had to report them via 112.social using every possible media file (audio, pictures and videos) at least once (C2A communication). One researcher posed as the PSAP using the ESI. After reporting a found treasure, the PSAP sent requests for further information and gave new instructions for finding the next treasure (A2C communication). In this way, the interplay of C2A and A2C communication were tested. After the treasure hunt, the citizens were asked to answer a survey. Besides personal details, organisation, experience and device, the survey asked about the (1) first impression, (2) design, (3) handling, (4) quality of features' implementation, (5) problems during the treasure hunt, (6) importance of the func-

tionalities and (7) communication channels, whether the participant would (8) use or even (9) recommend the app to friends and, finally, (10) provide additional comments, suggestions and wishes concerning the app.

4.2 Results

In the following section, we present the results of the individual evaluation events which will then be discussed in an integrated manner in the discussion and conclusion section.

4.2.1 VOST Trial during the 23rd OSCE Ministerial Council

Issues regarding the requirements of a GPS signal and internet connection. The use of 112.social during the 23rd OSCE ministerial council was the first field trial of the app within the scope of the project. In the first version, it was necessary to sign in anew for every post (e.g. via Facebook, Google+ or Twitter), which was criticised as time consuming by the users and, consequently, fixed for the second version. One of the main errors related to the fact that the app only works with GPS, since the idea is to send the exact location of the user. This was an issue if the users were inside a building weakening the GPS signal. If the signal was not received properly, the app sometimes crashed, which made a restart with a repeated sign-in necessary. Another main issue was the fact that the app cannot work without an internet connection, thus not allowing to create an app alert and look for an internet connection afterwards. The users made clear that this is necessary for a future version as it is still common to lose the internet connection every now and then. The users would also have liked to be able to use saved pictures from their phones gallery to create an app alert. One user stated that getting the phone's camera ready was fast, but getting the app ready took more time and thus, relevant information could get lost. However, the use of old pictures was prohibited by design to keep the risk of false information to a minimum and ensure the currency and authenticity of the information. In summary, all participants said that they would use the app as a citizen and recommend it to other citizens.

Rescue	Police	Fire	Crash	Weather
Unconsciousness	Crash	Forrest	Car / Bike	Blocked road
Not breathing	Riot	Car	Ship / Boat	Flooded cellar
Polytrauma	Demonstration	Building	Train	Fallen tree
Severe pain	Burglary		Plane	
Heart attack / Stoke	Violence			
Birth	Shooting			
Other	Other			

Table 6. Refined categorisation of emergencies as implemented in version two of 112.social

Features and refinement of the categorisation of emergencies. Essentially, the users liked the basic idea of having a map, a field for typing in information, and the possibility to send multimedia files, such as audio, pictures and videos. Moreover, they were satisfied with the basic design and usability, but disliked the predefined categories. Due to the developers' location in Italy, categories like "earthquake" and "eruptions" were prevalent. In close relation with the end-user advisory board, we developed new categories which were more fitting to the targeted areas for the field trials in Germany. Our end-users decided that eight categories with subcategories were necessary, whereof the first five are depicted above (Table 6). According to our end-users, these five categories and sub-categories were the most common. Three more seldom categories are: explosion, collapse and CBRN (hazardous material: chemical, biological, radiological and nuclear). These were perceived as important as well, but no subcategories were created. Since it was important to use icons for an intuitive understanding of categories, we worked in close cooperation with our end-users and came up with one icon for each category and subcategory (Figure 2, IV).

4.2.2 Fire Departments' Live Demonstration and Field Trial Evaluation

Importance and usefulness of app functionality. Five participants valued the C2A flow, representing "app alerts", due to photos and better situational assessment (I6, I7, I20, I21): "It will help to determine an exact place of an event. Sometimes it is difficult to get to a place, even if the location has been given.

Citizens using the app could help with that by giving some clues. Moreover, the photos from the scene would help a lot to estimate the current situation" (I3). Three participants valued the C2A flow on a more general level: "It's an additional way of contacting emergency services and in situations when lives are endangered all ways are welcome and increase the possibility of helping a victim" (I5). It has the potential of an information advantage: "Information before the control room receives them or before the personnel is on the ground. Information can be received which otherwise would have to be manually searched for" (I14). Thus, in everyday life, "the information acquisition is most useful" (I17). On the other hand, two participants highlighted the relevance of A2C communication (e.g., sending a message or broadcast from ESI to 112.social): "Being in the 'hot zone' I am receiving a proper message directly on my smartphone, at least I will consider that it is serious, and I will follow the instructions" (I1). Thus, "it may be helpful to tell people what to do in emergency" and "they may feel comforted as they know that they are not alone" (I6).

Importance	**max (4)**	**high (3)**	**low (2)**	**min (1)**	**Ø**
C2A	4 (19%)	11 (52%)	4 (19%)	2 (10%)	2.81
A2C	8 (38%)	6 (29%)	4 (19%)	3 (14%)	2.90
Benefit	**huge (3)**	**moderate (2)**	**small (1)**	**none (0)**	**Ø**
App alerts	11 (52%)	6 (29%)	3 (14%)	1 (5%)	2.29

Table 7. Indicated importance of information flows and benefit of functionality

In an overall feedback session after the workshop, it was stated that by using the system, it was possible to raise the alert level quicker than usual. A second dispatch was possible only one and a half minutes after the first dispatch, seven minutes before the firefighters would have arrived at the scene. Especially the information coming in via 112.social was perceived as important, since it was considered to be coming from a safe source comparable to a 112 call. The social media manager also used the ESI to get in touch with 112.social users, asking for more details or giving advice how to behave best.

Relevance of multimedia files. In total, 11 participants indicated huge, six moderate, three a small, and just one no benefits at all regarding the "app alerts" functionality. The good access to smartphones (I1) allows such a reporting app to be a fundamental alternative to 112 calls (I8, I19) and thus to reduce the number of 112 calls (I9). It was perceived to be useful (I4, I5, I18, I20) since it encourages users to upload multimedia files such as photos (I3, I11-13), allows a quick classification of information due to the CAP categories (I8), a direct contact to citizens (I3) and quick response if direct exchange is required (I6, I11): "Direct contact between a citizen and authorities may be crucial in estimating the type and scope of an emergency, e.g., fire. Especially if a person sends a photo. Having several photos may help with deciding how many people and which equipment to send" (I3). According to I13, the deployment of drones would require ~60 minutes, emphasizing the importance of a quick citizens' response.

Limitations of individual processing and quantification of app alerts. However, despite the positive attitude, many reservations about the app were discussed. First, given a broad distribution of the app, the processing of individual app alerts binds personal resources (I2, I16). Thus, it would not be possible to process them individually and always react directly (I9), but multiple alerts at a certain location could be a useful indicator of an exceptional event (I15). However, quantification is not trivial (I16): "On Saturdays in the city, you can expect more than one message. In case of a big fire, you always have several calls. Of course, this is different in rural or uninhabited places [since the] distribution of the app is different" (I15). Considering that apps already exist, one user questioned the distribution and motivation of use: "And there are a lot of apps. How could we make people install and use this particular one?" (I4).

Credibility check mechanisms and selective user groups. Although doubts about the users' credibility and quality of information were expressed (I4, I15, I17), a high quality of information could be received from credible or trusted users (I15, I16). Thus, several options were discussed: To check the identity, for instance, via registration process (I15), to sanction or block users on misuse (I16, I19, I21) or to distribute the app to dedicated user groups only (I12, I17), e.g., to qualified personnel such as authorities (I11), VOST (I8), or volunteer fire brigades (I15, I18): "Expert groups, trusted people, THW relatives, potential [112.social] app users, etc. – would be a high-quality group of users" (I10).

Improving the communication between emergency services and citizens. In the interplay of ESI and 112.social, participants emphasised the need to confirm the reception of messages, e.g., if the 112.social user sends an app alert to an ESI operator (I1) or if an ESI operator sends a broadcast or direct message to 112.social users (I9). Moreover, using ESI, each incoming app alert was displayed as an individual entity, regardless whether it was a completely new alert or a reply to an already ongoing communication thread: "Provide a history of the operators own messages, and show the different communication threads with individual users" (I9). It furthermore should be easily visible whether someone "already replied to the message" (I9). Also, one participant emphasised that the system should support more categories since "the reporting of injuries and deaths should have top priority" (I9) and suggests implementing this information into the CAP protocol and highlighting it appropriately in the interface.

4.2.3 Citizen Treasure Hunt for Functionality and Usability Evaluation

Issues in terms of design, handling and usability. More than 90% of the users rated the first impression as "neutral" and, concerning app design, the answers ranged from bad to very good, with most participants classifying it as "good". Addressing the overall handling of the app, more than 60% voted "bad". The analysis of detailed feedback provided indications for the negative feedback on the overall handling: Firstly, the users criticised that the button for adding multimedia files was too small, which was especially a problem when the app was used for the first time. Secondly, they desired the possibility to send text only, since it is currently required to add a multimedia file. Considering a case where emergency services request specific information that cannot be documented by multimedia files, this design decision would impair the citizens' response time. Furthermore, the push notifications were partly seen as confusing and the users found it difficult to respond to those notifications. Finally, a common problem was that the keyword overlapped with the text field, so that some users were not able to see what they were typing at all.

Evaluation of functionality	Very good	Good	Bad	Very bad	I don't know
Receiving messages from the headquarter	5 (62.5%)	1 (12.5%)	2 (25%)	0	0
Sending messages to the headquarter	3 (37.5%)	2 (25%)	2 (25%)	0	1 (12.5%)
Allocation of categories and subcategories	2 (25%)	5 (62.5%)	0	1 (12.5%)	0
Adding a description	2 (25%)	3 (37.5%)	3 (37.5%)	0	0
Recording and sending multimedia files	1 (12.5%)	4 (50%)	3 (37.5%)	0	0
GPS tracking by the app	1 (12.5%)	1 (12.5%)	2 (37.5%)	0	4 (50%)

Table 8. Indicated quality of functionalities

Technical problems in terms of connection, functionality, performance and stability. Unfortunately, the connectivity on the campus was erratic. This made the app crash or slowed down the sharing of multimedia files a lot. The users were missing some resilience of the app, being able to pick up the point in the process where they had lost the connection. Instead of this they had to sign in again after every loss of connection. Another problem was the GPS, since the signal was not available inside a building and also sometimes lost even outside. The response time between 5 and 20 seconds after clicking the button for adding a multimedia file was unsatisfying for the users. In summary, as depicted in Table 9, the citizens stated that the general approach of the app was between "important" and "very important". Concerning the kind of multimedia files, the opinions differed. Especially for the audio files, citizens could not see a real use case. Most value was ascribed to the attachment of pictures and GPS tracking.

Importance of functionality	Very high	High	Low	Very low	I don't know
GPS tracking through the app	6 (75%)	2 (25%)	0	0	0
Attaching pictures	5 (62.5%)	2 (25%)	1 (12.5%)	0	0
Adding a description	3 (37.5%)	5 (62.5%)	0	0	0
Attaching videos	3 (37.5%)	3 (37.5%)	1 (12.5%)	1 (12.5%)	0
Classification of the event into categories	2 (25%)	5 (62.5%)	1 (12.5%)	0	0
Attaching audio files	2 (25%)	0	4 (50%)	2 (25%)	0
Setting keywords and areas	1 (12.5%)	2 (25%)	1 (12.5%)	0	4

Table 9. Indicated importance of functionalities

5 Discussion and Conclusion

Summary. Given the widespread use of smartphones in western societies (Reuter et al., 2017a), mobile applications provide novel opportunities for bidirectional communication between authorities and citizens. In this paper, we reviewed related work on authorities' and citizens' information demands during emergencies and performed an analysis and comparison of existing mobile crisis apps (Section 2). Based on a requirements analysis, we presented the development of the mobile app 112.social, which intends to support the bidirectional communication between authorities and citizens during emergencies (Section 3). Finally, we evaluated 112.social during a council in 2016 (E1), several field trials, demonstrations and a workshop with emergency managers and citizens in 2017 (E2), and a technical evaluation of design, handling and stability in 2017 (E3), using semi-structured interviews and surveys (Section 4).

Development of a novel mobile crisis app for bidirectional communication among authorities and citizens (C1). Based on the conceptual framing of the crisis communication matrix (Reuter and Kaufhold, 2018), our first contribution represents the artefact 112.social for facilitating the bidirectional communication between authorities and citizens. It enables citizens to send original app alerts (i.e. to report an incident or send situational updates), which are defined by a category, subcategory, description, geolocation, multimedia files and, indirectly, time of an incident (C2A). Furthermore, authorities can broadcast messages to a larger audience of citizens or reply to citizens' app alerts (A2C), establishing chat-based communication threads across different phases of the emergency management cycle. Although existing literature documents a large variety of different functionality that is not implemented within this concept (Groneberg et al., 2017; Reuter and Ludwig, 2013), to our best knowledge, none of the existing app concepts realised or was evaluated in terms of a bidirectional communication feature between authorities and citizens alongside a reporting mechanism.

Features and requirements (C2)	Contextual factors (C3)
• A quick **categorisation** of incidents improves reaction time but the categories have to be adjusted to the needs of authorities. • Structured **textual descriptions** and **multimedia files**, such as photos, may supplement authorities' situational assessment. • Precise **location** information is required for situational awareness, but also tolerance in contexts where the determination of the users' geolocation is impaired. • **Timely** (multimedia) information is required to assess the relevance of the alert, but also tolerance for adding (older) files that were created outside the app.	• The incident's **scale** and **time** affect the interpretation of app alerts. • The **connectivity** on-site determines the operationality of the app. • **Promotion** is required to ensure the app's distribution for cases of emergencies. • The users' **motivation** and **technological access** are required to increase the potential use. • The **credibility** of information determines the usefulness of app alerts. • Authorities' **barriers** regarding law, personnel and time have to be considered.

Table 10. Summary of features, requirements (C2) and contextual factors (C3)

What are features and requirements for the successful reporting of incidents using a mobile app concept (C2)? The presented app was developed to research the feasibility of establishing a bidirectional communication between authorities and citizens using app alerts. Our evaluation participants identified a variety of beneficial use cases. From the authorities' perspective, these app alerts were designed to capture metadata relevant for enhancing situational awareness (Table 10, left) and assist decision-making (Vieweg et al., 2010). The proposed *categorisation*, based on the CAP specification, was perceived as a useful feature for quick information assessment, although additional information was requested, for instance, to indicate deaths or injuries. Thus, further discussion of the categorisation with emergency services seems sensible to encourage the refinement of specifications such as CAP. In line with previous literature (Reuter et al., 2016), participants highlighted the relevance of adding *multimedia* files such as photos and videos.

However, during the council (E1) and paperchase (E3) evaluations, feedback from the perspective of citizens regarding the usability of 112.social revealed interesting design trade-offs where too strong regulations for information quality assurance led to user resistance: Firstly, participants were sceptical about the mandatory attachment of at least one media file and desired the option to add multimedia files that were not created with the app. Hence, further studies could investigate authorities' willingness to

compromise on the handling of multimedia files. Secondly, the importance of *location* information for situational awareness (Imran et al., 2015) was confirmed in this study. However, the requirement of operating 112.social with GPS signal and internet access, although intended to ensure the accuracy of geolocation information, led to regular crashes among the users. This suggests that the preparation of app alerts should be possible without internet connection. Furthermore, infrastructure-less technologies such as off-grid ad-hoc networks could be explored as an opportunity to move information to devices or into zones with established connectivity (Al-Akkad et al., 2014; Alvarez, Hollick and Gardner-Stephen, 2016). Furthermore, general issues of the design and handling of 112.social might be addressed with a first use tutorial and the redesign of concerned interface elements.

What are contextual factors for the successful establishment of bidirectional communication between authorities and citizens (C3)? In favour of app alerts, most emergency services' participants highlighted the good smartphone access nowadays as an enabler for bidirectional communication among authorities and citizens. However, contextual factors have to be considered (Table 10, right). While app alerts were perceived as an alternative to 112 calls in the future, participants emphasised that the processing of individual app alerts may be too time-consuming in large-*scale* emergencies, which is in line with prior research reporting on the limited resources of emergency services in terms of personnel and time (Hiltz, Kushma and Plotnick, 2014). Furthermore, studies indicate that only 16% of citizens in Europe have downloaded smartphone apps for emergencies, suggesting that there is a need to examine the *promotion* of emergency apps and the users' *motivations* for installing such apps (Reuter et al., 2017a). Despite varying *technological access* in the population, such a concept may be developed into a worthwhile complement to existing mass media or multichannel warning systems (Klafft, 2013).

Besides findings that comply with observations from previous research, the interviews with emergency services revealed novel insights: multiple app alerts at a certain location were estimated to be a useful indicator of an exceptional event, although it has to be contextualised into different factors such as *population* density of a certain spot, the *time* of the current day or week, available *connectivity*, or specific ongoing events. Furthermore, participants emphasised that the *credibility* of information depends on the credibility of the users distributing them, although by tendency, information provided via such a communication app was perceived more credible than arbitrary social media content. Thus, the idea was preferred to implement credibility check mechanisms and to hand out the app to emergency services, volunteers, VOST or qualified citizens only for mobile reporting (Ludwig, Reuter and Pipek, 2013). For instance, fire departments could distribute 112.social in voluntary fire brigades or to trusted relatives (Kaufhold and Reuter, 2017).

Limitations and Outlook. Our results suggest the conduction of an additional design cycle (Hevner, 2007) followed by field testing to evaluate the practical relevance and value of 112.social. Although the evaluations were conducted with emergency service staff, VOSTs and a small sample of citizens, large-scale evaluations with citizens based on a more representative sample in exercises, serious games (Link et al., 2014) or real-world settings would allow a more rigorous research contributions in terms of (1) citizens' perceived usability and utility, (2) emergency services' handling of large numbers of app alerts during large-scale emergencies and (3) the technological maturity and scalability of 112.social. Furthermore, the evaluation was mainly conducted with fire services, limiting the applicability of results to other types of organisations. After implementing the gathered user feedback, further evaluations could examine requirements and specifics of danger prediction and prevention by the police interacting with 112.social users. In future, concepts for keyword-based subscriptions or location-based broadcastings will be implemented and tested. Since structured textual information potentially improves situational awareness (Starbird and Stamberger, 2010), concepts supporting the structuring of information could be examined. Furthermore, future research could consider more enhanced concepts for integrating volunteered geographic information (VGI) into emergency response (De Albuquerque et al., 2016).

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