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Situated crowdsourcing during disasters: Managing the tasks of spontaneous volunteers through public displays

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ABSTRACT

Although emergency services have already recognized the importance of citizen-initiated activities during disasters, still questions with regard to the coordination of spontaneous volunteers and their activities arise. Within our article, we will present a technological approach based on public displays which aims to foster situated crowdsourcing between affected citizens, spontaneous volunteers as well as official emergency services. We will address the research question: How can the situated tasks performed by spontaneous volunteers be supported by the use of public displays during disasters? First we will present the current state of the art with regard to the coordination practices of spontaneous volunteers and emergency services within disaster situations as well as related problems, potentials and specifics of situated crowdsourcing and public displays. To gain insight into actual coordination practices, we conducted an empirical study with 18 different stakeholders involved in disaster management. Based on the literature review and our empirical study, we have derived a technical concept that supports the task and activity management of spontaneous volunteers as well as the coordination both of the demands of affected people and the offers from spontaneous volunteers. We have implemented our concept as the public display application 'City-Share', which provides a robust communication infrastructure and encompasses situated crowdsourcing mechanisms for managing offers and demands of activities on-the-ground. Based on its evaluation with several users, we will discuss our findings with regard to the assignment of tasks on-the-ground and situated crowdsourcing during emergencies. We outline that City-Share can improve a community's disaster resilience, especially when focusing on the kind of collaborative resilience emerging between official stakeholders and spontaneous volunteers or affected citizens at a local level.

1. Introduction

People all over the world are affected regularly by emergencies and disasters. Briefly, examples include typhoon Haiyan in November 2013 that killed approximately 10,000 people, the European floods in June 2013 that created overall losses of € 12 billion or hurricane Sandy that turned New York into a disaster area one year earlier in October 2012. All emergencies have in common that they constitute a "hazard impact causing adverse physical, social, psychological, economic or political effects that challenges the ability to rapidly and effectively respond" (Institute for Crisis Disaster and Risk Management, 2009). Depending on their impact, emergencies can develop into disasters, unpredictable in nature, and which can affect individuals, groups, communities, or whole societies. Recent disasters, such as the ones mentioned above, have confirmed that, in addition to formal crisis management provided by the professional emergency services (i.e. firefighters and aid agencies), citizen-based crisis management – characterized by situated altruism (Dynes, 1994) – is prevalent. Individual citizens organize to form emergent and temporary groups to deal with improvised relief and rescue activities (Stallings and Quarantelli, 1985; Wachtendorf and Kendra, 2006).

Although citizen-initiated self-help activities and voluntary relief tasks have always existed whenever disasters have occurred (Tierney et al., 2006), the sheer pervasiveness of modern technology has extended not only the types of communication possible but also the coordination activities and tasks available to all individuals prior to, during and following a disaster. Via mobile devices and social media, affected citizens and spontaneous volunteers can organize to perform physical activities that require the volunteers to be in a specific location, like filling sandbags or clearing up locations (Ludwig , et al., 2015). They can now quickly ask for support or assign tasks (on the go) for dealing with

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response and recovery activities when facing emergencies or disasters (Gao and Barbier, 2011). The uncertain character of a disaster, however, challenges the rapid provision of information for all stakeholders involved (Turoff et al., 2009). Especially at the onset of a disaster, both affected citizens and spontaneous volunteers demand both rapid help and concrete information from emergency services. It is only to be expected that in the early stages, information provided by local emergency services and organizations may only be rudimentary due to the fact that they are often being overwhelmed (Schweer et al., 2014). Emergency services have already recognized the importance of citizen-initiated activities during disasters (Kleinebrahn, 2014; Ludwig et al., 2015). However, questions still arise: How can the coordination of those situated tasks of spontaneous volunteers be supported? How can the demands of affected citizens and offers from spontaneous volunteers be managed on-the-ground? How can citizen-performed on-site activities be managed and aligned with official procedures? Not least, tackling these questions is important to prevent the disruption of both official interventions and existing volunteer work. Answering these questions requires empirically-based research on how cooperation between the various stakeholders takes place (Bhamra et al., 2011).

In this article, we will present a technological approach based on public displays which aims to foster situated crowdsourcing between affected citizens and spontaneous volunteers as well as official emergency services. We will address the research question: *How could the situated tasks performed by spontaneous volunteers be supported by the use of public displays during disasters?* We will present the current state of the art with regard to the tasks and coordination practices of spontaneous volunteers and emergency services within disaster situations as well as related problems, potentials and specifics of public displays (Section 2). To gain insight into actual communication and coordination practices, we conducted an empirical study with 18 different stakeholders involved in disaster management, including spontaneous volunteers, public administrators as well as the emergency services (Section 3). Based on the literature review and our extensive empirical study, we have derived a technical concept that supports the task and activity management of spontaneous volunteers as well as the coordination both of the demands of affected people and the offers from volunteers (Section 4). We have implemented our concept as the public display application 'City-Share', which aims to support affected citizens, spontaneous volunteers as well as public authorities and emergency services by providing a communication infrastructure that encompasses situated crowdsourcing mechanisms for managing offers and demands of activities during disasters (Section 5). Results of its evaluation with several stakeholders will be presented in Section 6. Finally, we will discuss our findings and draw relevant conclusions on and design guidelines for assigning tasks on-the-ground and situated crowdsourcing during emergencies (Section 7).

2. Related work

Establishing and supporting cooperation between all stakeholders in this context, such as emergency service workers as well as affected volunteers and other citizens has become a vibrant concern in the research fields of Computers-Supported Cooperative Work and Human Computer Interaction. It is particularly interesting for us as it stands at a juncture of several different research interests, including how spontaneous volunteers and their activities are structured, how information is used by the crowd, how their tasks are coordinated, how communication as well as cooperation between official emergency services and volunteers is managed, and what kind of interface can mediate and support effective and efficient disaster response.

2.1. Emergent citizen groups and spontaneous volunteers

In case of a disaster, usually three different groups of people are implicated. These groups encompass (1) the professional public authorities with security responsibilities, emergency services and private aid organizations with a "we care" attitude and acknowledged responsibility for most of the tasks during the response and recovery work, (2) the volunteer-based emergency services and aid organizations that are quite similar to and often perceived as fully and paid 'professionals', and (3) the citizens engaged in various ways during disasters, often with less involvement in prevention or response strategies, at least historically. More recently, the boundaries have blurred such that the sharp distinction between these three different groups is less evident.

Past disasters clearly show that the people affected by a crises also show a high amount of involvement (Palen et al., 2010; Quarantelli, 1991). Even if systematic involvement of citizens as active actors is not planned for official prevention strategies (Schweer et al., 2014), people in practice often take over "First Responder" activities (Stallings and Quarantelli, 1985). During long lasting and large-scale disasters even people that are uninvolved and not affected by the disaster itself can and do mobilize. Stallings and Quarantelli (1985) describe early and often spontaneous forms of citizen-based crisis management, with new structures as well as new tasks, which are characterized as "emergent groups (e.g. unaffiliated volunteers) undertaking activities that were previously foreign to them and developing a social structure that lacks formalization, tradition and endurance" (Stallings and Quarantelli, 1985).

Emergent citizen groups are helping in disaster situations through their autonomous searching and solving practices. They do that without significant hierarchical structures, allocating tasks between themselves in a self-organized manner (Stallings and Quarantelli, 1985). Citizen groups emerge in many disaster situations and in the past they were sometimes seen as the result of a failed preparation on the part of the professional actors. Today, however, they are more often seen as an alternative reaction by affected people towards a situation that evolves in such a way that the preparations of professionals are not adequate (Stallings and Quarantelli, 1985). The first and arguably most important requirement for emergent citizen groups is the exchange of information and concomitant networking. The second is knowledge about key positions and how to access them in the disaster environment. The third is specialized knowledge about the situation (Stallings and Quarantelli, 1985). Persons from outside often lack the information and contacts needed (Pfeil, 2000). Tourists and new members of the community as well as volunteers who do not arrive until after the occurrence of the disaster may have very little knowledge about relevant locations and therefore need information from other citizens or from crisis management teams (Pfeil, 2000).

It also seems that where disaster situations are commonplace, both long-term improvement in preparations as well as the formation of a so-called "disaster subculture" (Voorhees, 2008) can be discerned. For instance, in areas where floods occur on a regular basis, knowledge is often collected that can be applied and used by all in subsequent disasters (Voorhees, 2008). Nevertheless, not all engaged persons are integrated into those subcultures (perhaps because they are newly arrived, for instance) and therefore lack access to the knowledge available in the disaster subculture. One example of these groups arising spontaneously is the volunteers who grouped together impromptu following the attacks on the World Trade Center in 2001. This group, who became known as "Clarkson Village" or "Clarkson", was formed independently by volunteers on-site and its goal was to autonomously accept, sort and distribute donated resources (Voorhees, 2008). In the context

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of this group, it became obvious that there was and is a great potential for improving communication through technical support (Voorhees, 2008).

2.2. Ad hoc communication between officials and volunteers

Crises and disaster situations confront all involved parties with a tremendous number of challenges. The communication of risk possibilities, i.e. the kind of communication that should enable preparation for disaster situations, is not yet sufficient (Schweer et al., 2014). Thus risk communication is unlikely to be successful without actively involving people in the planning and decision-making processes. Attempts at risk communication such as flyers and information provided by websites tend to reach only a small part of the population. Poor risk awareness means that the majority of households do not practice any kind of crisis prevention in their everyday lives (Quarantelli, 1999). Since the range and extent of disaster situations cannot, or at least cannot fully, be planned in advance (Schweer et al., 2014), it is not possible for the emergency services or citizens to estimate the need for communication beforehand. In turn, this means that coordination always happens ad hoc, both for unprepared citizens as well as for the prepared emergency services.

When a disaster occurs, affected people search different channels of information for information that can help them manage the situation (Palen et al., 2010). Here, credibility of information is an important factor (Palen et al., 2010). People often lack the expertise to pass on information that is sufficiently concrete. In the same way, it becomes obvious that the information needs of individual actors are not visible enough for other participants. Due to this lack of transparency, it is possible that relevant information exists but has not yet been identified as such and is therefore not passed on to the interested parties. In disaster situations, it can often be observed that a serendipitous effect emerges concerning the knowledge available, i.e. the unplanned discovery of relevant information which can be identified as useful (Bunker, 2011). Detailed information about individual volunteers can also become relevant. Since a variety of different tasks emerge, it is especially important for the planning process to know about special qualifications (e.g. physician, cook) and know-how (Ministry of Civil Defence & Emergency Management, 2006).

2.3. The use of social media

Recent years have seen the development of remote groups of helpers, so-called "*digital volunteers*" (Starbird and Palen, 2011), consisting of affected people and first aiders on-site. Based on the significantly increased information flow (mainly) enabled by social media, coordination and communication tasks can now be dealt with by external volunteers (Cobb et al., 2014). However, as social media are not specially designed for disaster situations, handling the emerging information and the number of different and incompatible platforms (Reuter et al., 2015) during a crisis can become very complex (Bressler et al., 2012). The involvement of digital volunteers, it is argued, can address this. Handing over tasks like filtering or assigning information (e.g. administrating lists of missing people) to external digital volunteers allows helpers on-site to deal with the emerging information flood better (Starbird and Palen, 2011).

As a consequence, it becomes necessary to synchronize the two main aspects of remote communication and crisis management on-site, thereby significantly enhancing crisis communication between citizens with the help of external actors (Ludwig et al., 2015). The widespread adoption of social media indicates its use as the established channel of choice for addressing the connection between virtual and real volunteers (Reuter et al., 2013). Reuter et al.'s. (2013) study identifies the lack of a shared central meeting point for both groups as well as the lack of coordination platforms specially created for real volunteer groups. Until today, the co-operation between real and virtual volunteer communities has not been able to reach its full potential. In the context of decentralized communication through social media, it became obvious that centralized and persistent communication should also be considered as relevant.

2.4. Ubiquitous and situated crowdsourcing

One possibility for combining emergent volunteer citizen groups during emergencies with social media could be crowdsourcing. Open innovation concepts – emerging from Web 2.0 – have been geared to citizen involvement as well as community engagement in recent years. These concepts mainly comprise support for greater participation and integration of citizens into the tasks and activities of professional organizations (Brabham, 2013). Nowadays, the concept of *crowdsourcing* is common, but understanding varies. Based on several existing definitions, Estelles-Arolas and Gonzalez-Ladron-de-Guevara (2012) present an integrated definition of crowdsourcing as a "type of participative online activity in which an individual, an institution, a non-profit organization, or company proposes to a group of individuals of varying knowledge, heterogeneity, and number, via a flexible open call, the voluntary undertaking of a task.".

Usually and classically, crowdsourcing is seen as activities based on *online* platforms such as Amazon Mechanical Turk for performing paid micro tasks, Qmarkets for discovering new streams of innovative ideas, or CrowdFlower for collecting, cleaning, and labeling existing data sets. Recently, the ubiquity of mobile devices has meant that tasks can be pushed to workers independently of space and time, what Vukovic et al. (2010) have summarized under the concept of ubiquitous crowdsourcing. Hosio et al. (2014) have outlined, "an active community has grown around the topic of crowdsourcing measurements and sensing". Vukovic et al. (2013) group existing ubiquitous crowdsourcing systems based their support of the complexity of the tasks.

One specific subset of crowdsourcing, which emerged with the ubiquity of smart mobile devices is participatory sensing (Burke et al., 2006) in which individuals are asked to gather, analyze and share data and information using the integrated sensor capabilities of their mobile devices. Application areas for participatory sensing include, for example, sensing smartphone data for contextual research (Ludwig et al., 2016), gathering GPS or speed data from cyclists to infer route and traffic noisiness (Reddy et al., 2010) or to measure the air quality (Kuznetsov et al., 2014). The presence of such multimodal sensors is enabling a broad range of possibilities through the automatic collection of sensor data. In comparison with classical crowdsourcing approaches, ubiquitous crowdsourcing approaches have the advantage that "many people almost always have their mobile devices with them in order to gather real-time information" (Goncalves et al., 2015). Ludwig, et al. (2015), for example, show the possible activities of a mobile crowd during disaster situations by requesting specific information about the situation on-the-ground via open public requests. Based on the ubiquitous technologies' contextual capabilities, participation through "increasing workers' intrinsic motivation, and that the in-situ nature of ubiquitous technologies can increase both participation and engagement of workers" (Goncalves et al., 2015).

Hosio et al. (2014) argue that the use of mobile phones for crowdsourcing tasks requires workers to implicit deploy, configure and use those devices, which "makes worker recruitment challenging, as a number of steps are necessary before a worker can actually contribute using their device". To overcome this burden, *situated* crowdsourcing approaches consist of embedding input

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mechanisms, such as public displays or tablets into the physical space and as outlined by Goncalves et al. (2015) "make use of the user's serendipitous availability". By providing situated technologies for crowdsourcing, the carrying out of a task does not necessarily require much deployment effort and, due to its situated character, geofenced or allowing a "contextual controlled crowdsourcing environment thus enabling certain individuals, leveraging people's local knowledge, cognitive states, or simply reaching an untapped source of potential worker" (Goncalves et al., 2015).

2.5. Public, publicity and public displays

Embedded input mechanisms, such as public displays, enable ubiquitous and situated crowdsourcing. The term 'public' is currently used to mean anything that "concerns or affects the people or community; is maintained for or used by the people or community; is participated in or attended by the people or community; is connected with or acting on behalf of the people, community, or government; and/or is open to the knowledge of judgment of all the people" (O'Hara et al., 2003). Based on the term public, publicity can be understood as "information that concerns a person, group, event, or product that is disseminated through various media to attract public notice" (O'Hara et al., 2003).

Public displays are situated technologies that are a ubiquitous part of our environment and inform the public about places or events of interest and often help reflecting the activities of others. They offer a "rich resource around which conversations and group activities are structures, complementing verbal communications and shaping group dynamics" (O'Hara et al., 2003). Modern public displays have various advantages: Their visibility (Taylor and Cheverst, 2012) allows the possibility of creating an awareness towards current and recently happened events (Taylor and Cheverst, 2012). The visibility of the display is also interpreted as 'openness' and therefore is generally understood as inviting contribution (Brignull and Rogers, 2003). The presentation of the content can create an effect of serendipity in the form that relevant information and knowledge can be found or even contributed without being searched for specifically (Gonçalves et al., 2013). Their permanency allows published information for an event to remain accessible for later use by people who were not present during the event happened (Taylor and Cheverst, 2012). As Kostakos and Ojala (2013) argue, public displays are currently transforming our urban environments.

2.5.1. Situatedness of public displays

Alt et al. (2011b) argue that as long as displays are specifically placed, they provide a strong connection with their location (Alt et al., 2011b). Therefore, such urban technology das to be designed to fit the local, social and cultural context (Alt et al., 2011a; Davies et al., 2012). Urban computing is defined as "the amalgamation of cultural practices, everyday activities, and implicit values of specific people situated in a unique urban location that is defined both in terms of architectural qualities and cultural meanings. These are augmented by one or more technological systems that respect and support the aforementioned practices and activities in a non-intrusive way that enhances rather than redefines that given location" (Kukka et al., 2014). As Kukka et al. (2014) therefore argue, researchers from the social science as well as architecture and urban are needed to support the deployment of public technologies in the wild. Public displays have a representational function for the community at their location and provide an access point to it (Taylor and Cheverst, 2012). They are highly suitable as a place to go for social coordination and enable a common understanding of the location (José et al., 2012). Huang et al. (2008) examined how attention was to be attracted and hence the creation of motivation through displays. Accordingly, it is necessary to strive for a high visibility and conciseness of applications so that potential users can identify what a display can do and what it is for, and can decide in a few seconds for or against interaction.

The transition from attention to a display to interaction with it requires an appropriate motivation (Müller et al., 2010). Müller et al. (2010) develop a taxonomy based on what kind of interaction, the degree of explicitness of the interaction and the mental model, which means the classification of the interaction (e.g. as a poster), are compared with each other. Another factor concerning the motivation is the so called "social embarrassment" which is the potential shame of interacting with the display while there are potential spectators present (Brignull and Rogers, 2003).

2.5.2. Interaction types and use cases of public displays

There are different interaction types possible for public displays: ranging from isolated autonomous systems (Brignull and Rogers, 2003) to the provision of wireless connections around the display to a connected network of multiple displays (Alt et al., 2011b; Redhead and Brereton, 2009). One avenue of research has been the investigation of optimal ways of interacting with displays for potential users. Distributed interaction through devices like smartphones as a means of interaction has been investigated multiple times (cf. Hosio et al., 2010). Hosio et al. (2010) present the following four alternatives for distributed user interfaces: (1) Control of the display through mobile devices, where the display is only used for displaying, (2) Control of the display through the display itself e.g. via touchscreen, allowing no control through mobile devices, (3) Control through both user interfaces, display as well as device, (4) No control at all, allowing only viewing on mobile devices and the display. It became clear that none of these single options alone are optimal for the interaction required (Alt et al., 2013).

After the earthquake of Sichuan, China, in 2008 the interaction with different display systems was analyzed (Graham et al., 2008). The different types of media examined covered television, mobile phones, computers, pin boards and bulletin boards. The telephone network failed long-term and internet was only available in a few places. Bulletin boards and big advertising banners were used for emotional messages as well as for information, especially concerning key actors, rules and suggestions, lists of missing persons and maps of temporal settlements. The creation of identities and recognition of other participants, the reduction of distances between potential participants of the community physical and social (Memarovic et al., 2014) as well as the inclusion of actors outside the community (Taylor and Cheverst, 2012) are central themes. In the public space basic human needs are fulfilled by "passive engagement", "active engagement" and "discovery" (Carr et al., 1992). Olech et al. (2012) describe Digital Interactive Public Pinboard, a concept for information supply for professional and voluntary helpers during disaster situations. Placed at central locations, people register themselves at the public display upon arrival.

2.6. Summary

Our review of relevant literature demonstrates that there is a common concern with certain issues, including the structure of emergent citizen groups, the management of their activities as well as coordination and cooperation with official emergency services. Compared to emergency services, spontaneous volunteers – at least in Germany – are de facto not integrated into official emergency response practices (Schweer et al., 2014). Volunteers as well as those affected therefore form emergent citizen groups to deal with their common problems. Volunteers, it is clear, perform online activities, as well as physical activities on-the-ground (Ludwig et al., 2015). An early self-organization of volunteers

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appears therefore to be necessary because, especially in the early stages of a disaster, official authorities could be overwhelmed (Pfeil, 2000). Ubiquitous and situated crowdsourcing using public displays might, we feel, address some of the current limitations. But how in practice the cooperation within emergent citizen groups and their tasks coordination to as well as cooperation with emergency services is managed and what technologies are used, is currently not fully understood.

3. Empirical study

To get insights into the activities and technology usage of emergent citizen groups and cooperation with emergency services, we performed an empirical study in the domain of crisis management. Our objective was to examine the potential of supportive IT for coordination practices between official emergency services and spontaneous volunteers as well as between volunteers and affected citizens.

3.1. Methodology

We conducted and analyzed 18 interviews with stakeholders who have been involved in emergencies. To get a comprehensive overview about current practices, we focus on spontaneous volunteers who actually helped during disasters as well as official emergencies and public authorities. Here we focused on the Central European floods in June 2013. Within those floods, 35 federal states of seven European countries had to declare a state of disaster in multiple districts; including 55 districts in Germany. Besides the large number of professional forces and organizations, such as the German armed forces (19,000 soldiers), the fire services (75,000 firefighters) or the German Red Cross, a lot of volunteers and affected people participated in response work, such as building up flood barriers, filling up and piling sandbags or donating work material and goods for victims. We therefore searched within related Facebook groups for responsible actors and contacted seven of them via Facebook (Table 1).

Focusing on the official emergency services, we aimed for a cross section of different organizational and hierarchical units within our interviews ranging. By focusing on several actors on different management levels, our aim was a comprehensive overview of the work practices entailed in different roles (Table 2).

Each interview lasted between 1 and 2 h and followed a guideline, which was separated into three parts. The first part focused on the participants' role, qualification and work activities under normal conditions. The second part covered the participants' work tasks and the problems they have encountered during disasters. The third part covered cooperation between the different actors as well as the use of applied technology. All interviews were audio-recorded and transcribed for subsequent data analysis. The analysis was based on the inductive approach of *grounded theory* (Strauss, 1987), at least to the extent that we used open coding associated with grounded theory to derive categories from empirical data by the careful reading aggregation of categories. Transcripts were therefore open coded and the statements of the agents were divided into text modules and later into categories. The knowledge previously acquired in the literature study was used to heighten theoretical sensitivity (Strauss, 1987).

Table 1
Interviews with spontaneous volunteers.

No.	Job title	Experiences in disaster response
I07	Policewoman	Police tasks during Crisis Management
I08	Engineer of Water Conservancy	No Experience
I09	Trucker	Voluntary Member of Fire Department
I10	Electrician	Voluntary Member of Federal Agency for Technical Relief and Fire Department
I11	Writer	No Experience
I12	Building Contractor	No Experience
I13	Goldsmith	No Experience

Table 2
Interviews with emergency services and public authorities.

No.	Type	Organization
IS01	Emergency Service	Aid Agency
IK03	Emergency Service	Aid Agency
IS03	Emergency Service	Fire Department
IS04	Emergency Service	Fire Department
IK13	Emergency Service	Fire Department
IK14	Emergency Service	Fire Department
IK15	Emergency Service	Fire Department
IK02	Public Authority	City Administration – Small City
IK11	Public Authority	City Administration – Small City
IK05	Public Authority	District Administration
IS02	Public Authority	Federal Office of Civil Protection and Disaster Assistance

3.2. Results

In the following subsections empirical findings are presented, underpinned by quotations of the stakeholders listed above. At the beginning of Section 4, below results are summarized in a table in order to provide a better overview and lead over to the concept.

3.2.1. Voluntary activities during disaster situations

Volunteers coming from the general public do a great amount of work during disaster situations. A majority of them came from distant localities or other federal districts (I07, I09), but some of them were also locals who had formed some kind of neighborly help groups. The helpers coming from different distant locations always had to cooperate with the local actors in order to find reasonable roles:

> *"We always depended on the people who lived there or lived nearby and who helped […]. It was all done by the people living in those places. On site they took over the donation camp and managed it all and they also assigned tasks to volunteers."* (I07)

Some of those tasks can be done without any need for expert knowledge:

> *"I had know-how based on my previous knowledge even if it was not necessary for most of the tasks. There are specifications on how to fill a sandbag and how a dam should be built but in such a situation everybody just helps as well as he can. Expert knowledge is always an advantage but not mandatory."* (I10)

Besides those tasks that needed no expert knowledge there are still some that did needed some, for instance, the need for specific qualifications. For example, there was a need for people with a driver's license for trucks (I08) and also for those who could handle a forklift. Such people organized themselves in a shift schedule to do the needed work:

> *"I saw it myself, there were a lot of people that drove forklifts, because palettes had to be loaded and there were a lot of volunteers that helped with that too. There were a lot of volunteers. They worked round the clock, so they had to be replaced by others from time to time and that was done by volunteers as well." (I08)*

Trained electricians were also needed to prepare the houses for later cleanup efforts; some of these volunteers even had previous

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knowledge from working with relief agencies:

"I called and told them about the experiences I had gathered from my work with the Federal Office of Civil Protection and Disaster Assistance and German Red Cross. So they said it would be great, if I came to help. […] My special task was to disconnect the electrical connection of buildings that were flooded." (I10)

Some activities took place over an extended period of time and were adapted to the respective needs:

"We later carried out bulky waste voluntarily; we helped to paint a single mom's house. Now we will do a little bit of the outdoor area, because it's not quite finished. We have cut and cleaned up piles of waste in the grounds […]." (I07)

Besides cleaning up, some interpersonal skills were needed, including therapeutic activity:

"There was also the psychological help, the assistance on site for the people that were hit by the flood. […]. I wasn't prepared for that. I just wanted to do one thing: help, because I knew those people could not have done it alone." (I07)

In addition to those kinds of tasks, there were also remote coordinating and supporting activities like donation organization which complemented the help on site also over a long period of time:

"While I was at home I collected donations. For weeks we sold cake at farmer's markets and those donations were sent down there afterwards. For example, we started the campaign 'Buy 2 Donate 1' at the local supermarket […] Actually it kept going for six months or so." (I07)

I13 also told about a donation campaign he started himself. As a goldsmith he was able to design and sell a pendant and 20% of the revenue was subsequently donated to the victims of the flood (I13).

The longer a disaster lasts, the more volunteers out of the population tend to withdraw because professional help is made possible by large scale contributions from e.g. the banks:

"The help I could do was limited after the money from the investment banks was paid, and then the craftsmen had to do their jobs. At that point my help had kind of ended, because I'm not able to tile and I'm not able to lay the screed." (I07)

3.2.2. Mobilizing private resources and donations

After the flood - as the big official sandbag filling stations and the building of dikes was no longer necessary - private help activities were undertaken more and more by small groups. The coordination was done via Facebook or contacts that were made on site (I07). I11 also mentioned that the coordination of the donation camp - in which she had served - was done via Facebook as well as through word-of-mouth advertising. Many of the resources were organized privately (I12, I07). Those were donations of all kinds, like food, building materials, clothing, tools or volunteers. An efficient supply of resources mostly failed due to the lack of information from flood victims about their needs via Facebook:

"You have to consider that not every flood victim on-site had Facebook or even internet and in general his mind wasn't clear enough to say, I need help and I need 100 m² of insulation board." (I07)

Therefore, some of the volunteers tried to gather information by driving to the disaster area and posting the needs afterwards to Facebook (I07). Still the allocation of resources by relief agencies had gone wrong sometimes, so that whole truckloads of resources were transported to the disaster area, even if they were not or not yet needed:

"If the people have only been in the locality for two or three days and none of the houses have been cleaned up yet, they can't bring in uncountable truckloads of furniture." (I09)

Besides faulty allocation there were transportation shortages as well, since the coordinators could not handle all messages because of the sheer amount (I07).

3.2.3. On site cooperation between volunteers and emergency services

The activities undertaken by people should be organized to prevent uncontrolled and inefficient activities happening, i.e. by emergency services:

"So help is not provided simply by everyone showing up and wanting to help. Instead it is a step by step process in which everyone can help at a point where he is really good at." (I13)

To support the emergency services appropriately in such emergency situations, however, it is "*extremely important that we instruct the citizens*" (IS04), because otherwise they lack sufficient knowledge.

IS01 mentioned that emergencies need have a big picture of the entire situation to be able to assign resources as well as to coordinate volunteers efficiently:

"For instance, we also have to check the sandbags. What's the use of having 150 people and 50 bags or maybe nothing to do at all? I must get an overview of the entire area, of operations and the situation itself." (IS01)

Volunteers are usually not under the command of emergency services. However, from the emergency services' point of view efficient voluntary activities depend on their supervision. They have to try to convince volunteers rather than giving instructions:

"We can allow them to act under our supervision, to try to convince them through conversations and to help them adapt our operational strategy." (IS01)

The synchronization among the volunteers themselves and between the official emergency services was not always frictionless, which was also caused by the use of Social Media and insufficient communication:

"In places the situation was chaotic. The coordination on site was bombarded with information so that they did not know what to coordinate anymore. Because of Facebook, it was in part coordinated incorrectly. So many volunteers turned up for even the smallest cry for help, even if they would have been needed somewhere else more urgently." (I12)

This leads to activities from volunteers and official services acting contrarily:

"90% of the help we offered was organized by private people. The emergency services did not always communicate that well with the privately organized people and because of that they hindered each other rather than helping." (I11)

Emergency services also cooperated with a local DJ, who played music for the volunteers, to transmit announcements:

"Every time we needed support it was called out and there was a DJ who played music so that filling the sandbags was easier. He made announcement like: 'A driver could come forward to keep the access road free'." (I08)

Such announcements are especially important since there are location specific conditions to be managed during a disaster

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situation. The activities have to be adapted according to the situation:

"It is also based on the situation, depending on the kind of disasters. In City3 there was only water and mud, in City2 there was oil as well. In City3 it did not matter, if people went barefoot into the water, but in City2 they would have been skinned because it was that toxic." (I13)

3.2.4. Distribution of volunteers and task prioritization

One of the main problems during the organization of volunteers was their appropriate distribution and the prioritization of tasks:

"Whoever shouts the loudest will get the most help. I could imagine that people in City2 and City3 could also have needed help, since it is only a few kilometers away. But they were quiet and we had no chance to notice them." (I07)

When calls for help came in from the other localities, many of the volunteers were already assigned or were no longer reacting. Also managing many volunteers and persons affected overstrained the organizers:

"Later there were also calls for help for other localities, to which I simply could not react anymore, because it simply was not possible anymore. It would have just been too much and it would have become too confusing. I think many of the flood victims were left alone with their sorrows and problems." (I07)

This caused some of the areas to be undersupplied and others to have too many volunteers:

"As already said, everybody had found his place and was pretty busy there. Thus I later would have wished for more volunteers that have said let's go to the other localities." (I07)

Especially in those areas with too many volunteers, frustration was common, though they had no idea that they might be needed somewhere else:

"We drove down there and saw the unbelievable amount of Emergency Services, that there were around 2,000 students already waiting to help but were not admitted, so we thought what should we do here, we do not need to line up too." (I13)

On site needs could, then, be usefully linked with the offers from the external population:

"What do they want, what must they have? Gather donations and bring them over. Distribute them specifically. That would have been my wish." (I07)

Such activities should be structured in a way so that as little physical and personal resources are wasted as possible and an appropriate supply over time is given:

"What I can clearly say is that the chronological order of such a disaster could be better coordinated, I mean this unbelievable amount of relief goods together with clothing and equipment, and it was all too much. A lot of the volunteers were bound to organize those things which were maybe needed later on. […] What I also heard is that many emergency services from the whole country came without contacting each other. Those were sent back home and a week later we would have needed them and then they were not there anymore". (I13)

3.2.5. Central contact points as crucial coordination instruments

There was a large amount of contact points inside the disaster area where tasks and resources were coordinated:

"There were also others points where you could have helped. Sometimes there were announcements that volunteers were picked up from the sandbag-filling place I was at to be transported somewhere else where they were needed more at the moment. For me personally that was the best way of doing it. To go to that place [contact point] and offer my help." (I08)

These contact points were either run by volunteers or by Emergency Services. At the official contact points, mainly resources and information were shared either by the officials or among volunteers meeting there:

"It was more like a clubhouse with an addition hall. […] And there we always met to get our information, also from the mayor. That was the place you should have reported yourself as volunteer. So I drove there and said: 'I have rubber boots and old pants. I want to help.' And so somebody said: 'Ok, you can come with us, there is already someone else'." (I07)

Private arrangements run by volunteers were mostly more fragmentary, with a multiplicity of little contact points which often consisted only of one person, who was often overstrained by the vast number of requests. However, these contact points were known among volunteers in the respective area, sometimes given roles like 'section chief', and tried to plan and coordinate voluntary activities or simply reacted as the situation demanded:

"There was no real central contact point. There was a phone number of one person that got all the calls and that person was excessively overstrained." (I12) "On one location all people reported to a so called 'section chief' and he collected the most important data of the people. After that there was a short introduction, from where you could get the resources like shovels et cetera. In some other place there was no such coordination. There everything happens based on the situation." (I10)

Thus some kind of headquarter for networking between the volunteers and the official services would have made sense:

"I would have wished for an improvement of the networking between volunteers and official services. In some parts it worked well but in others not at all. Maybe it would be possible to create an agency or a central meeting point for such cases which controls the organization and coordination. Probably state wide coordination united under one umbrella organization that coordinates it all." (I11)

But such central positions or contact persons were often unknown at that time:

"There are some of those positions in Germany or even worldwide, one disaster management […] those are experts that take care of the coordination and such. […] And whether they are that effective, I do not know. Because there is a lack of communication skill and one or the other might not even know that somebody like that existed." (I13)

The official services informed the volunteers that they should register before arrival. This registration was problematic because of overstressed staff and so the volunteers were left alone:

"As the flood situation became obvious for City3, the city administration installed a crisis phone where you could call and register yourself as a volunteer. […]So I did it because I thought they knew the best spots to help, where you could send the people, because as a volunteer I am not experienced with things like technical equipment. But I still wanted to do something. So I called them and they said to me: ,We will call you back.' But I realized during the first day that this would not work. They simply do not call back." (I08)

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3.2.6. Use of social media for information gathering and coordination

During the flood, different social media was used by volunteers for diverse activities, mostly location specific. In addition, other online services, i.e. google maps were used to coordinate voluntary activities:

> *"There is a website 'flood news City1'. So I click on it and over this privately organized group and its channel much information came together, where people are needed to fill and stack sandbags. There was also a map on Google Maps. On this map the locations were marked and named together with a time. For example at the inn near the Elbe 20 volunteers are needed for filling and stacking sandbags. And there was also noted a certain time and so I saw it and thought: ,Good, you can get there by bike and help filling and stacking sandbags'." (I08)*

On Facebook in particular, many different groups were created (I07) which were used parallel to other social media which lead to overlapping information, this hampering coordination work:

> *"Because of the Facebook-Pages, Twitter and WhatsApp accounts, there was a lot of information that overlapped. The disaster management group of course released information regularly as well and this lead to some coordination problems because this lead to too many volunteers on one location and none on others. But it was still better to spread information through those channels than getting none." (I08)*

At the beginning there were many of those groups of which some were later merged into one single Facebook-Group:

> *"After a time volunteer groups came together. There was a group from City3, one from City4, one from City1, one Group from City2. With the group from City2 I transported some furniture. So we met each other. […] But ,Flood Lower Saxony' pulled it all together - also information from other groups - and published to their group. […] that was well distributed and when specific activities had not enough people they have called for help* via *Facebook and so we went there." (I07)*

Nearly all information from the volunteers and the affected citizens was shared via Facebook, also as a result of lack of information sharing by emergency services:

> *"Really much was done* via *Facebook like help offers, water levels and weather. The data was always up-to-date compared to newspapers and so on. Sirens were rebuilt but there was no information on TV or Radio after they sounded. […] Sometimes there was even competition between the official services and the private volunteers. That is also a reason why a lot of information was not at all or just poorly shared." (I11)*

Besides offers for help, Facebook was mainly used for the coordination of donations:

> *"As I drove there the next time I asked* via *Facebook: 'What do you currently need the most? Do you still need cleaning agents? Or is toothpaste still needed? Or are we that far that we now need tools and other things? ' And so we tried to get information on site. We stopped collecting clothing, instead we later focused more on furniture, later we gathered build material and donated it and of course money always helped. But I wished for more information. So that I would not have packed my car with baby sanitation stuff, instead I would have brought sheetrock." (I07)*

Later also the official services and agencies used Facebook groups to distribute tasks to volunteers:

> *"There was a disaster management group that released information in certain intervals and they also noted that the Facebook-Page 'Floodnews City1' is a really good way to reach the people and so they have published their bulletins not only on the site of the provincial capital City1 but also on this Facebook-Page. And I think that was pretty great that such a privately organized page would be used as information channel for the population." (I08)*

Breaks during activities were also used to get up to date over mostly Facebook groups:

> *"When I made a break to eat and drink something, […] I sat down to look up if there was something new. Is there a new disaster area or is there information that no sandbags are needed anymore or if somewhere volunteers are needed and such things were posted on this site […]." (I08)*

One problem of using Facebook was the 'Other'-folder which led to many unanswered help requests or requests that came too late to be answered (I10). Another problem was that many affected people had no access to the information in social media or even to the internet at all, thus could not express their needs:

> *"You have to consider that not every flood victim on-site had Facebook or even internet and in general his mind wasn't clear enough to say, I need help and I need 100 m² of insulation board. […] Facebook is one thing but first you have to get that information from the people and there you reach your limits in your help activities." (I07)*

3.2.7. No suitable on site communication infrastructure

Besides the missing access to social media from a personal and organizational point of view there were also technical and infrastructural problems. There was no communication infrastructure on site:

> *"It was all dead, there was no electricity; the equipment was also broken, because everything was flooded, but most importantly there was no electricity. So you have to explain how it works, if I get there and build a camp, a communication base, and next door lives an old man whose medicine has to be kept cool, I cannot say to this man that he has to forget about his medicine because the communication is more important." (I13)*

A functional communication infrastructure has a very high priority. But there was an additional problem that a large part of the volunteers, the affected people and the official services had not established a common communication base:

> *"If you have the resources it would be the best thing to do to first establish a communication base inside a crises location, in a way that the people have the opportunity to communicate. Only some of the affected people had the chance or even had the equipment to exchange something." (I13)*

Therefore, if a mobile internet connection was available, people used Facebook. However, within Facebook there was no information published specifically for voluntary help. For example, many of the volunteers came in shorts and loose footwear. At the same time, they forgot to drink enough liquid (I08).

> *"That would have been something you could have communicated* via *this Facebook-Page. Even if it sounds so obvious, it was not for many. What I thought was a good thing that the people were constantly reminded that they had to drink enough and that it was handled that they got sunscreen […] that they should wear hats and such things." (I08)*

One volunteer who was already active in 2002 during a flood had made a website back then for offers and needs. In his experience it was the better thing to build multiple regional

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distributed communication infrastructures then just one central one, since most groups of aiders are only active in a certain region (I11).

> *"Multiple small groups should be established here and they have to be well connected with each other. Places on higher grounds should be central meeting point for the places more below because these places can never be harmed by floods. The support of the agencies had to be expanded." (I11)*

4. Concept: managing voluntary tasks by situated public displays

4.1. Pre-study-based design implication

Our empirical study shows that trying to integrate spontaneous volunteers into disaster response work and especially support their situated tasks and activities is still challenging. Table 3 indicates the findings and main challenges for the management of voluntary actions as well as the design implications we derived for the conceptual architecture of our approach.

Spontaneous volunteers play an important role in crisis response work. Volunteers often arrive at the scene from the outside and must work with locals to find reasonable roles and especially tasks. The challenge here is how to find those locals and how to find local contact points (C01). We aim at the deployment of a public available information board (based on a public display) at public places of volunteers' arrival, such as railway stations or central bus stops. Here, we want to provide information about local contact persons and local arrangements. The more people are involved, the more sufferers are non-locals, the unfamiliar is the situation for those affected, the less time for preparation remains on the situation, the more likely a need for community building for crisis management will be held (Quarantelli, 1991).

Currently central contact points are hosted by emergency services or local volunteers, where people coordinate and try to align official and voluntary activities. But especially voluntary contact points are often overstrained by the vast number of requests, are often unknown during a crisis (I13), or missing at all (I12). Voluntary organizers cannot handle the large amounts of offers and demands, which leads to an undersupply or oversupply of resources. The challenge is how to support volunteers at central contact points in managing offers of help and demands of affected (C02). We therefore focus on a public platform for creating as well as mediating voluntary offers and needed demands and support matching these.

The unclear situation on-site and as a consequence thereof the overload of local voluntary coordinators leads to misallocation of resources (also on an emergency services' level). Emergency services must therefore convince volunteers to follow their instructions rather than giving commands. But currently there is no communication infrastructure – especially at the beginning of a disaster and when many volunteers come from the outside – and such lack of communication between volunteers and emergency services can lead to contrary actions. Besides using general social media, emergent citizen groups have no support to communicate or manage their tasks on-the-ground (I07, I08, I10, I11). Emergency services already try to rely on local conditions, such as cooperating with local key players (i.e. a DJ) in order to reach and coordinate volunteers. The key challenge here is to provide a common communication infrastructure that allows emergency services to cooperate with volunteers, but also to allow volunteers coordinating their activities themselves that go in line with those of emergency services (C03). We therefore aim at a sharing functionality that allow emergency services to spread instructions and coordinative information to victims and volunteers based on a public display in order to reach a wide audience.

With regard to the assigned roles and tasks and central contact points, the emergency services argue some tasks require expert knowledge, others do not. But a challenge here is how to identify experts with specialized knowledge and how to assign them to the matching tasks (C04). We therefore build upon the idea of situated crowdsourcing and let the crowd identify themselves as experts and assign themselves to announced tasks. A design implication is therefore allowing volunteers themselves to answer demands of victims or to create offers of help by their own.

When focusing on the management of the volunteers' offers as well as the victims' demands, the spontaneous volunteers currently split up into small groups that are usually coordinated via Facebook. However, as the empirical study shows, victims do not necessarily post their needs in Facebook due to distraction (I10) or a broken technical infrastructure. A challenge is therefore how to allow the consideration of online management activities as well as

Table 3
Pre-study-based design implications.

No.	Empirical findings	Existing challenges for managing voluntary tasks	Design implications
C01	Volunteers often arrive at the scene from the outside and must work with locals to find reasonable roles and tasks (I07)	Enable the finding of relevant locals and local contact points	Deployment of a public available information board at public places of volunteers' arrival
C02	Contact points are often overstrained, unknown (I13), or missing at all (I12)	Support volunteers at central contact points in managing offers of help and demands of affected	Implementing a public platform for creating and mediating voluntary offers and needed demands and support matching these
C03	There is no existing common communication infrastructure for emergency services and volunteers (I07, I08, I10, I11)	Provide a common communication infrastructure that allows emergency services to cooperate with volunteers	Implementing a sharing functionality that allows spreading instructions and coordinative information from emergency services to victims and volunteers
C04	Due to the diverse information, the assignment of tasks to experts with specialized knowledge is almost impossible (I07, I13)	Enable the identification of experts with specialized knowledge and assign them to matching tasks	Allowing volunteers themselves to answer demands of victims and to create offers of help by their own
C05	Victims do not necessarily post their needs in Facebook (distraction, technical infrastructure) (I07)	Allow the combination of online activities as well as 'offline' physical activities to provide victims' access to those resources	Presenting on-site activity information as well as online data from social media to provide an overview about current actions.
C06	Unstructured information in social media hampers the volunteers as well as the voluntary organizers to align activities effectively (I07, I08)	Enable the integration of social media information into the public information space on-site	Implementing a social media based news ticker to inform the public audience with location specific information
C07	Damaged infrastructures often lead to power outages and cripple communication (I13)	Guarantee coordination mechanisms during infrastructure breakdowns	Setting up a local Wi-Fi for letting volunteers and victims share offers and demands

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'offline' physical response activities and to provide victims access also to those online resources (C05). We therefore aim to present demands and offers from on-site and combine them with situated and located posts and tweets of Facebook and Twitter – as the two main social media services in Germany – in the public display to provide social media activities also to those who do not use social media or those who do not have access to modern media.

Volunteers use breaks to get up to date via social media. But unstructured information hampers the volunteers as well as the voluntary organizers to align activities effectively. Especially poorly categorized help requests (that appears in the Facebook folder 'other') often remain unanswered. A challenge is therefore how to integrate that information into the public information space on-site (C06). We therefore aim to present relevant social media information as a kind of social media based news ticker at the public display to inform the public audience.

As the volunteers said, location-specific conditions require on-site communication channels that are improvised supported through social media, such as Facebook. But damaged infrastructures often lead to power outages, which cripple the communication and access to social media (I13). A design challenge here is to guarantee coordination mechanisms when (internet) infrastructure or mobile networks break down (C07). We therefore want to enhance the public display with a router that enables a local Wi-Fi for letting volunteers and victims share offers and demands.

4.2. Situated crowdsourcing for managing voluntary tasks

In our empirical study we have uncovered seven challenges on which we derived design implications in order to support voluntary response work during disasters. Our concept encompasses public displays as situated crowdsourcing technologies that could be appropriate for assigning tasks, matching voluntary offers and affected citizens' demands during disasters based on its high up-to-datedness and visibility (Fig. 1)..

We want to deploy a public available information board based on a public display. Located at local hot spots such as train stations, these displays aim to provide a central point of contact to support the management of arriving spontaneous volunteers without local knowledge (Alt et al., 2011; Ludwig et al., 2015). Situated information points located close to on-site activities help distributing volunteers efficiently. Thus, we also focus on also deploying a public display within a neighborhood and within a radius of 500–1,000 m².

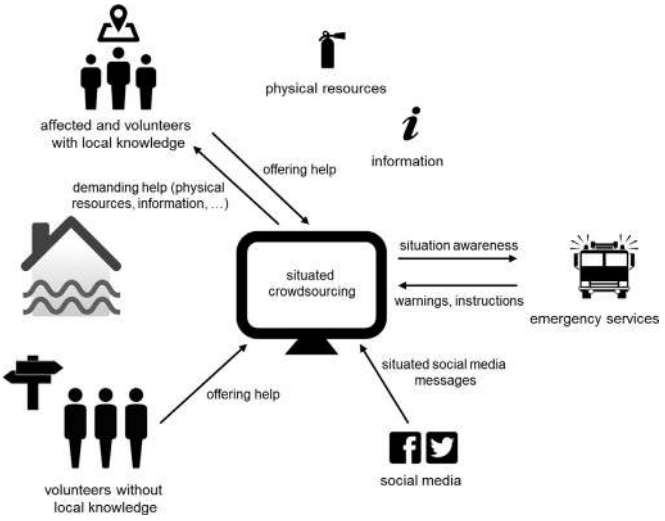

Fig. 1. Situated crowdsourcing for managing voluntary tasks.

The public display can be used to create voluntary offers as well as demands from affected citizens and also align those activities with those of the emergency services. Everybody can create a demand of a physical resource (i.e. spades, emergency generator or food), personnel, activities or information. The public display provides situated overviews (within the specified radius) about those demands and current voluntary offers. The requests will mainly be provided by the affected and volunteers themselves to rely on situated crowdsourcing concepts.

People use the same technologies in disaster situations as in everyday life (Jennex, 2012), wherefore it is important to provide a technology that is not only expected to be used during disasters. Public displays help to foster local identity for a specific location (Taylor et al., 2007) and can therefore serve as a communication and information infrastructure not only during emergencies, but also during everyday life. Public displays equipped with emergency power or solar power can serve as an information point also during infrastructure breakdowns. In comparison to classical bulletin boards, a connected public display (with internet connection) supports remote interaction and therefore building a bridge between physical on-site and digital online activities. Based on options for filtering as well as searching, the affected citizens as well as spontaneous volunteers can be supported to deal with a high amount of demands and requests as well as social media information.

A situated public display can also foster cooperation between official emergency services as well as volunteers. Emergency services could easily promote information regarding warnings or instructions, assign tasks to volunteers and perceive progress about crowd tasks. The crowd of volunteers can consume warnings or request for mobilization, also from social media without having an own account. Such presentation provides social media activities also to those who do not use social media or those who do not have access to modern media, which help raise situation awareness on-site (Hosio et al., 2010). By cooperating via this technical instrument, emergency services additionally receive situation awareness about voluntary activities, that otherwise would be hard or even impossible to get aware of (i.e. private Facebook groups).

5. Implementation of the public display application 'City-Share'

To examine the support of situated crowdsourcing based on public displays during emergencies, we have implemented our concept as the public display application 'City-Share' that aims to offer and to demand resources, activities or information, provide a current list of local contact people and local news as well as important social media messages to facilitate communication and interaction between affected people and spontaneous volunteers. With City-Share we provide a public available information and collaboration board that is most suitable at public locations. Further objectives are to offer and provide coordinative and mobilizing information from emergency services to voluntary groups, to align their activities. Each public display only presents situated content for its respective location within a radius of 500–1,000 m².

The concept of City-Share consists of two components. The public display itself as well as a mobile client that facilitates the interaction with the public display. As public displays situated at high frequent areas are prone to vandalism. we want to install the display at a safe – but accessible – place, e.g. behind a shop window. However, this way, the display cannot be interacted with by touch screen or other attached hardware input devices. We decided therefore to deploy our application on a Raspberry Pi, use non-touchable displays and place them behind shop windows to protect them against vandalism.

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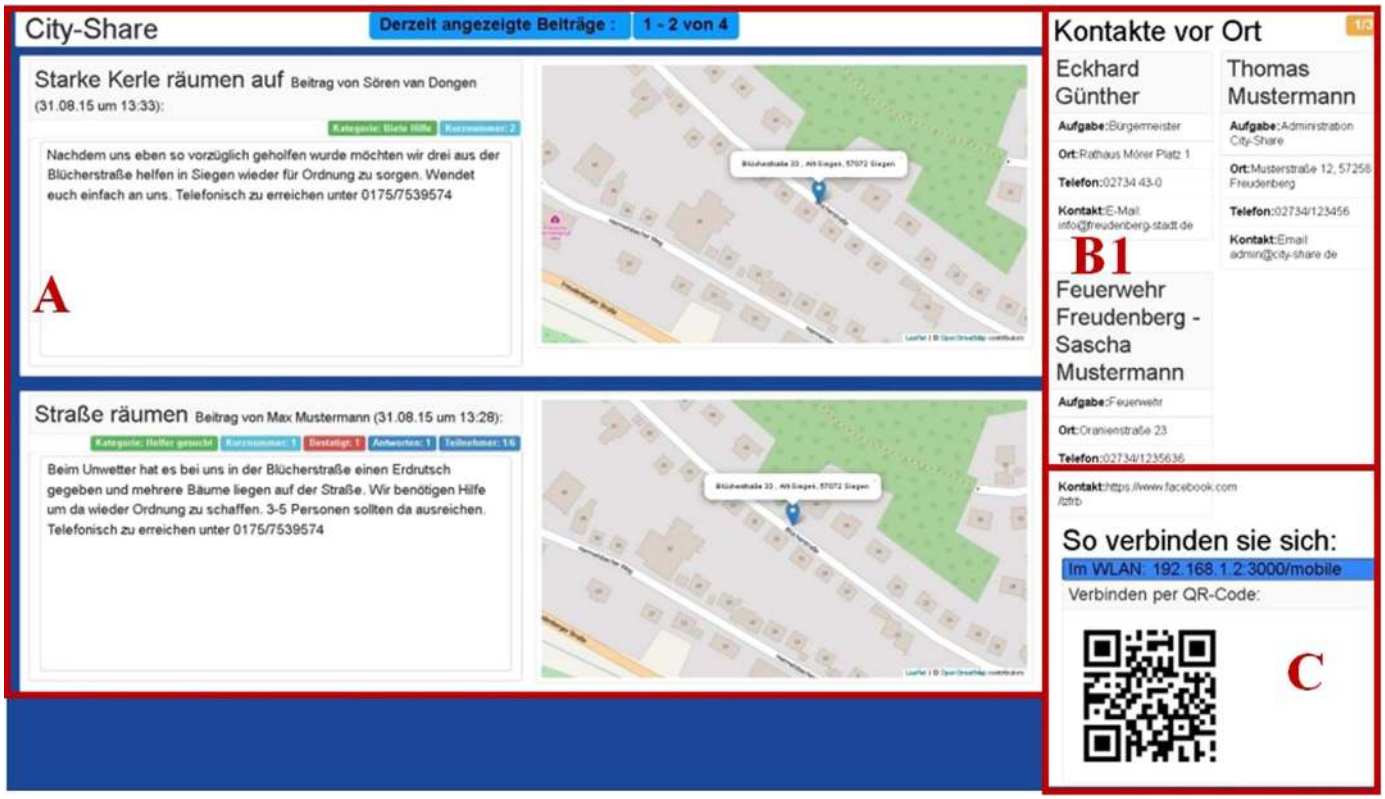

Fig. 2. City-share: display.

To interact with City-Share through the shop window and even if the internet connection breaks down, the Raspberry Pi provides a local Wi-Fi network and a mobile web app (accessible via a QR-code). That means, the public display can still be used for communication and assigning of tasks when there is no internet connection. This way, content could also be shared with people's smartphones to take along with them to the on-site activities. For the interaction, such as creating offers and demands or sharing content, people can use their smartphones, because they are already familiar with such mobile technologies and sharing multimedia data becomes possible (Alt et al., 2011).

The screen of City-Share is divided into three areas (Fig. 2): The main area on the left side (A), the upper sidebar on the right side that presents contact persons, local news feeds and situated social media messages (B) and the area that presents information about how to use City-Share (C)..

The main area (A) is used for representing offers and demands from the affected citizens, spontaneous volunteers as well as emergency services. The main area has a high visibility for the displayed content, even from a distance. For this reason, the main area by default includes at any time only two posts. Each content item represents an offer or a demand for an activity, a physical resource or information and each volunteer or victim has the option to create such a demands or offer. The headline of each content item consists of a title, author, and creation date of the contribution. Additionally, there is the meta information for the category for classifying, such as physical resources, search for activities and the item short number for a later searching and the additional information such as the number of answers, the requested amount of voluntary helpers and number of confirmations grouped and displayed differentiated by color. By using categorization, we want to avoid unstructured information classification like it happened with the Facebook folder 'other'.

A content item consists of four areas: the description of the content item, followed by a block of an appended social media post, then an attached picture and finally a map. If only little multimedia content is available, the map takes up the extra space to use all the available space and so to be more visible. The display content changes items change every 20 s for the next two contributions. Periodically, the server is requested to get current posts to put in the loop.

The right sidebar (B) contains an area with changing content. It provides information created by the emergency services about contact persons on-the-ground and their phone numbers and locations (Fig. 2B1). This should help arriving volunteers as well as affected citizens to know who is in charge for the respective location and provide direct contact options for aligning tasks. The content of the right sidebar changes every two minutes from contact information to news feeds (Fig. 2B2) from local newspapers (here: 'Siegener Zeitung', a newspaper from the city Siegen in Germany) as well as social media posts that match specific keywords of that location (Fig. 3).

The lower area (C) gives a short introduction to City-Share and shows the QR-code to connect to the local mobile web app through the local Wi-Fi provided by City-Share based on the Raspberry Pi. If a person connects to the local Wi-Fi and scans the QR-code, the mobile web app for interacting with City-Share is opened on the smartphone. By opening and connecting to City-Share with the mobile device, a user controls the entire display for five minutes by default and can navigate through the entire application. The citizens can now create new content items (Figs. 4 and 5), such as the following demand: 'I need up to ten people in the street XYZ (that is referring to a specific location) at 2 pm to help clearing my flooded garden.' Since then, the demand is presented on the public display and all available meta information such as the location's map or the requested helper amount are presented. All potential spontaneous volunteers can now see the situated demand and answer the request by committing to that request and/or commenting it. If a demand has reached the requested number of spontaneous volunteers, it

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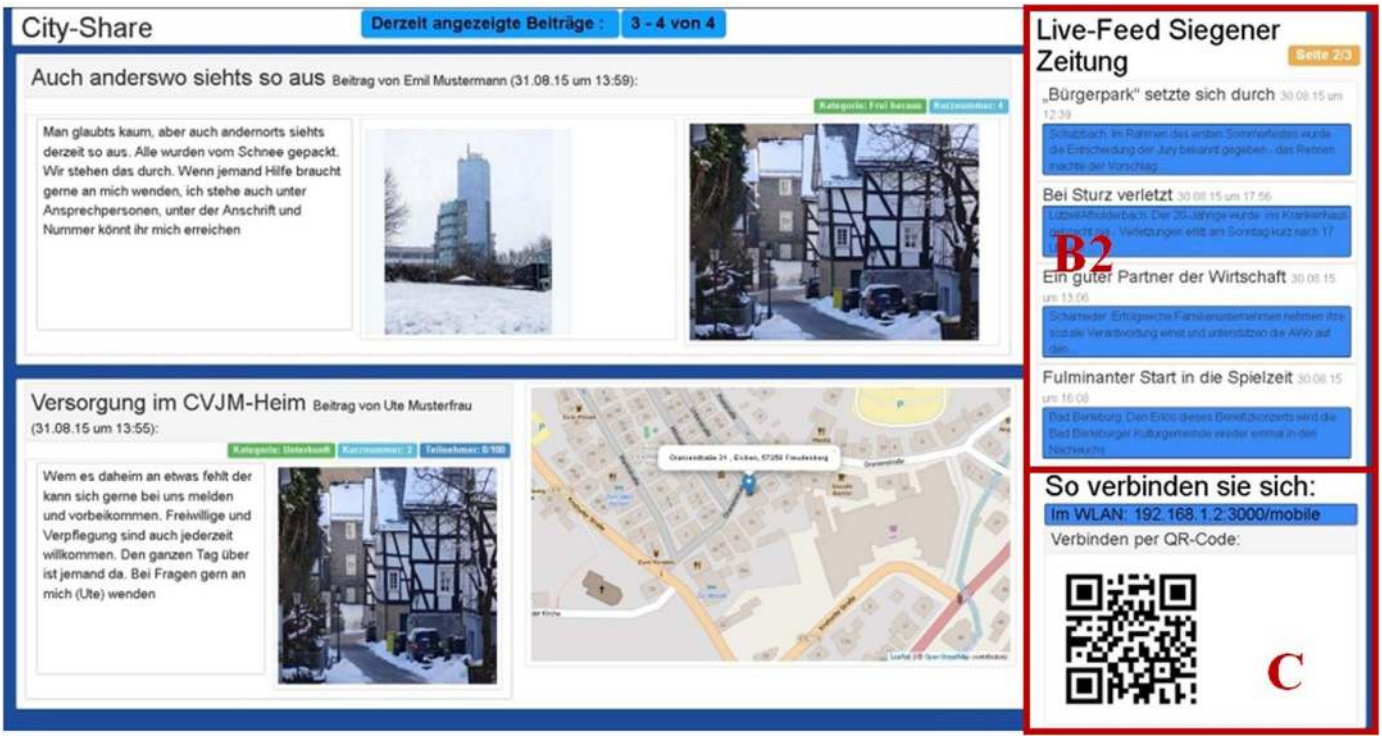

Fig. 3. City-share: multimedia data and news feed.

disappears from the display. For emergency services it is possible at any time to create or modify content of the display for sending our warnings or other kind of coordinative information. We have therefore developed a kind of 'management console' for emergency services that lists all available public displays and emergency services can access specific public displays and publish situated warnings or instructions (when internet connection is available)...

6. Evaluation

As Memarovic et al. (2013) have outlined, the deployment of public displays in the wild is challenging due to its dependence on five different layers encompassing community interaction design, system interaction, content, system architecture, and hardware. However, to be still able to evaluate City-Share, we conducted different types of evaluation. The first was a study that aimed at getting an understanding about the potential use of City-Share in general for which we enlisted 15 ordinary people as potential spontaneous volunteers. The second type of evaluation was a Brainwriting session (W1) with further 12 ordinary people. We further focus on the potential practice relevance from the emergency service's official perspective: We therefore held two workshops, each with several emergency service units (W2, W3). Within these workshops we were primarily concerned with identifying ways in which City-Share would be used, and anticipating the difficulties in use which might be encountered (Twidale et al., 1994).

6.1. Methodology

The first kind of evaluation was an exploration of the entire application City-Share and its interaction type with 15 users (E01-E15). Here, we conducted additional interviews with all of the users. We evaluated City-Share with 10 male and 5 female participants with an age range from 21 to 60 years (average: 38 years). Beside usability issues, we also aimed to evaluate the outlined relevance of the application for voluntary practices and situated crowdsourcing. We were primarily concerned with identifying whether and in what ways the app would be used, and what difficulties could conceivably be encountered during usage. The application was evaluated using a scenario-based walkthrough (Fig. 6)..

The scenario was based on a hurricane, comparable to the well-known blizzard 'Kyrill' that occurred 2007 in Germany, which caused heavy damage and deaths. Our fictive blizzard consisted of fallen trees, blocked roads and loss of rail transport, (partial) loss of electricity, telephone and internet connection. Emergency services were overloaded on-site by an additional flood. Participants were told that they should use City-Share which was deployed in a town hall. To evaluate City-Share comprehensively and to cover most of the possible concerns of users, the participants were assigned different roles. The participants should inform themselves that a group of volunteers has already implemented a number of activities on-site, but that more volunteers are needed. Additionally, the participants should search for opportunities to help on-site and create a content item for demanding an accommodation.

During the evaluation, we used a guideline for interviewing the participants. In addition, we asked them to use the 'thinking aloud' protocol (Nielsen, 1993) to gain insights into the user intentions. All interviews were audio-recorded and transcribed for subsequent data analysis. To analyze our data, we used a qualitative content analysis this time. *Content analysis* is appropriate when prior theory exists, but remains open to unexpected themes and only at a later stage relates findings to existing theory (Karapanos et al., 2009). We coded the transcripts openly and divided participants' statements into text modules and, later, into categories.

Based on the exploration of City-Share as well as its interaction types, we further conducted a workshop to gain further application fields and needed functionalities (W1). The workshop lasted two hours and consisted of one moderator and 12 participants (E16-E27), with six female and six male participants. Their age ranged from 20 to 55 years.

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Fig. 4. Create new Item (I).

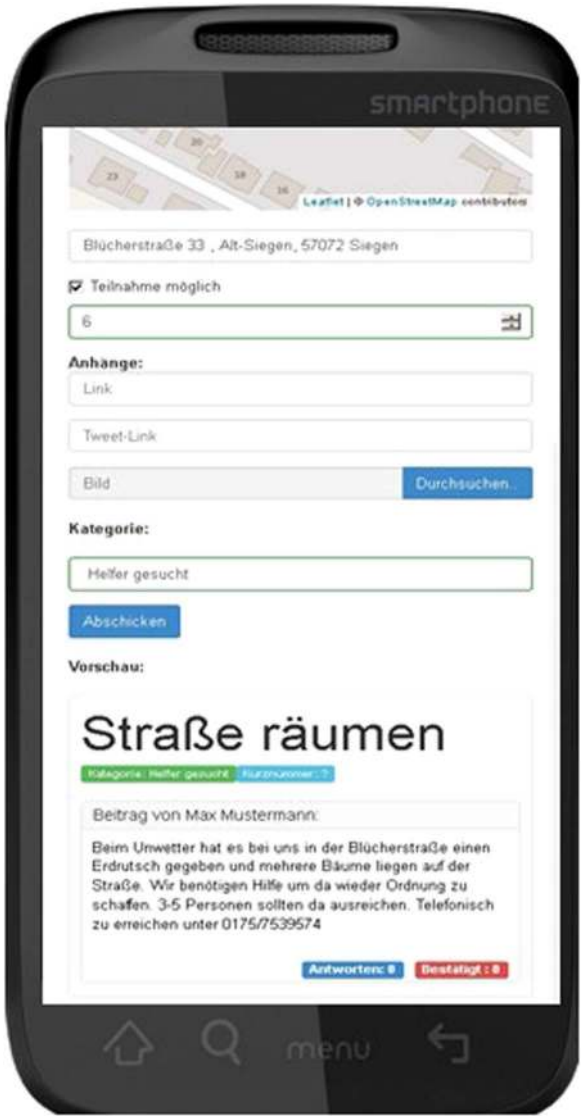

Fig. 5. Create new Item (II).

We split the workshop into two parts, the first part comprising an introduction of City-Share and a brainstorming session. This part helped the participants to get familiar with City-Share. Within the second part, we tried to gather insights, further use cases as well as design implications of City-Share. We did this by conducting a Brainwriting Pool activity, which is a sequence-structured group format whereby silently written ideas were shared (Heslin, 2009). First, we gave a short introduction into the overall method, because not all participants were familiar with creative methods and only one of the participants had already been involved in a Brainwriting Pool activity.

The second step was the pool itself. Here we split the twelve participants in three groups each with four participants. We gave out several index cards with different colors to each group. The colors were based on the following questions: Green: Which further functionality is needed? Blue: What are new application fields and potential use cases? White: What are potential technical and organizational requirements? Yellow: What are potential risks and potentials? At the end of this step, the index cards were attached to the blackboard. The last step of the Brainwriting Pool was the prioritization of the cards (Fig. 7)..

Each participant got three yellow marks and had another five minutes to review all index cards and to choose three cards. These

Fig. 6. Evaluation of City-Share.

three cards should be the most relevant cards for next steps and current shortcoming as well as potentials. After finishing the review, the participants presented their choice separately and

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Fig. 7. Brainwriting Pool: Prioritizing the Index Cards.

Fig. 9. Workshop W3 with Emergency Services.

explained why they thought that these were the most relevant ideas. The chosen cards were marked for later analysis (Fig. 8)..

To ensure practice relevance of City-Share from the officials' perspective, we conducted additional workshops with official emergency services (Fig. 9). It was held as a two-day workshop (W2) that was executed during the annual forum of the German committee of crisis prevention (German: 'Deutsches Komitee Katastrophenvorsorge e.V.', http://www.dkkv.org). We presented City-Share and got valuable feedback about the application from a variety of emergency services ranging from aid organizations to policemen. The third workshop (W3) was conducted as a two-hour workshop with a mixed audience consisting of 17 participants, whereof ten of them are researchers in the field of information and communication studies (male=8, female=2). The other seven are professional emergency services (male=2, female=5). As the evaluation with emergency services mainly focuses on further potentials of City-Share and requirements with regard to the design instead of the processes of volunteers and aspects of cooperation, this paper mainly focuses on the evaluation with ordinary people regarding the usability of City-Share and its relevance for the activities of volunteers..

Our evaluation bases on the notion of 'situated evaluation' (Twidale et al., 1994) in which qualitative methods are used to draw conclusions about the real-world use of a particular technology. The aim here is not to measure the relationship between evaluation goals and outcomes, but to derive subjective views from potential participants about how useful or relevant the framework might be.

Fig. 8. Brainwriting Pool: Clustered Index Cards.

The results of the Brainwriting Pool with ordinary people and the workshops with emergency services aim mainly to receive informed feedback about future risks and potentials as well as new application fields for City-Share. We therefore integrated the results into the future work within the conclusion. In the future work section, we further outline first steps towards an evaluation of City-Share in-the-wild.

6.2. Results

6.2.1. Situated Coordination during Internet Breakdowns

All participants agreed that public display applications like City-Share are especially important during internet or communication infrastructure breakdowns, because they can be used to coordinate volunteers and their activities on-the-ground and enable the matching of citizen needs and voluntary offers:

> *"In such a situation everybody has some resources and capacities to carry something out, and with the distribution of the competences, ordinary people could help almost all affected citizens." (E10)*

In the event of internet connections and mobile phone networks breaking down (design challenge no. C07), such technology could be the only interactive technology to communicate and therefore align activities:

> *"When I have no chance to connect* via *a mobile phone network, this is the best opportunity to communicate." (E01)*

As one participant mentioned, the power for the public display itself can easily be provided by placing it in central buildings and locations with emergency generators, such as hospitals or train stations (E11). To prevent internet breakdowns, the decision to provide local Wi-Fi and a local website instead a native mobile web app, is seen as important:

> *"A local website that could be accessed fits the concept of connecting* via *Wi-Fi if there is no internet. That is absolutely brilliant, because I cannot download a mobile app without the internet." (E15)*

By providing a local option for offline communication, City-Share addresses the needs of the affected people who – in serious disasters – are usually cut off from typical communication systems

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(E10). With City-Share, those affected are given a tool to communicate (E10). Local Wi-Fi allows higher data rates for exchanging multimedia data than mobile phone networks. Especially when there are considerable amounts of data (e.g. 'Silvester effect'), the mobile phone network may become overloaded (E14). The public display therefore relieves the pressure on the mobile phone network which could then be used for making important phone calls (E14).

During long-term power breakdowns, the mobile phone batteries will inevitably run down and go flat, so there ought to be another option for using the mobile client such as a terminal on-the-ground operated by the emergency generator (E12).

If internet connection is still in operation, using it for sharing information with other people and the remote operation of City-Share are seen to be two of its main advantages (E05, E06):

> *"In doing this, people from other cities can help people in affected regions and can offer some activities that would not be possible on-the-ground." (E05)*

It is important that the voluntary activities open to volunteers are not situated at the same place as the disaster:

> *"I could also help by sitting on my couch. I can search for help options or offer some help-" (E06)*

6.2.2. Centrality and Situatedness of Public Displays as Control Point Characteristics

The public display addresses the centrality and situatedness of a disaster, which enable emergent citizen groups (design challenge no. C01). As one participant said, City-Share is a *"combination of physical presence, comforting words and getting together, as well as a central point of help"* (E05). The situatedness makes it possible to specially tailor the content to the situation and location of the affected and volunteers on-the-ground (E07).

The centrality of the public display supports the community and the willingness to help (design challenge no. C02):

> *"Such a central point on-the-ground is better than at home, because at home the information is interpreted by one person only." (E05)*

As most of the participants agreed, a critical mass is needed to successfully establish public display applications like City-Share:

> *"If the situation drives people to use it, I think it will work." (E04)*
> *"If five, six or seven people have used City-Share, I can see their content and align my own activities based on that." (E01)*

To reach such a critical mass of users, the application has to be well-known beforehand a disaster:

> *"It is important to establish such a tool way before a disaster occurs." (E04)*

As one participant mentioned, the coolness of the public display could help to encourage the crowd to fulfil specific tasks:

> *"If I can make sense of the entire fancy application in depth, I will help the affected people." (E12)*

If the public display is well-known, it would relieve the pressure on the emergency services that have lots of other primary activities to perform and therefore often do not have the time to communicate with volunteers and align both official and voluntary tasks and activities (design challenge no. C03):

> *"I can see* the potential in it that emergency services on-the-ground are not overwhelmed by the numerous questions. Instead, they can look after *the* people who aren't just interested in coordinative information." (*E13) People on-site could thus "be instructed by the public display itself and get the information from the display." (E13)*

An additional option to reach a critical mass of citizens, as one participant suggested, would be to connect the public displays by ad hoc mobile networks (E15). Such connections would allow the offers and demands from different locations to be matched despite no Internet connection being available.

6.2.3. Structuredness and meta data as efficient coordination support

Public displays facilitate communication and the exchange of information within a crowd, especially for those people who do not have an account with a social media service (design challenge no. C05):

> *"City-Share is useful for those people who own a smartphone but don't want to create a social media account." (E02) "We would use it [City-Share, T.L.] because I don't have a Twitter account and I don't have WhatsApp. Other people who are more connected could still use those networks, if available." (E12)*

Focusing on the situated assignments of activities and matching offers to demands for resources is seen as advantage in comparison to social media services (design challenge no. C04):

> *"It has the big advantage of being more structured than Facebook. In situations like this, Facebook also shows you data that is not relevant" (E13). "Facebook contains a lot of advertisements which distract you if someone writes you a message. Platforms are needed that focus on disasters but are also useful in daily business." (E14)*

A situated public display and social media services provide a mutual benefit (E13). For example, a demand for resources could be answered via Facebook or demands expressed within social media could be fulfilled on-the-ground (E14).

The structuredness of the content items of City-Share and additional meta data such as the location and navigation options support the execution of situated tasks (design challenge no. C06). This enables non-local people in particular to find out more about where help is needed (E13):

> *"If I arrive in a big city with the idea of helping somewhere, a technology such as this and a visualization on a map make sense, because it shows me the best way to reach the location." (E11)*

The participants in our evaluation asked for more context information, such as phone numbers (E01), or general contact details for affected citizens (E04).

The participants further requested another form of creating a content item. They want to create first a category for the content item such as 'clothes' or 'food' and afterwards create the content item itself:

> *"When I add a category, it should be obvious that I want to contribute with a content item as well." (E08)*

Based on this additional meta data, the participants wanted to be guided more while creating a content item and also wanted to make use of the integrated possibilities of a smartphone:

"If I have the phone number in my smartphone, it should be linked directly to the contact." (E10).

There should also be the possibility to attach contact options to a content item in order to establish a feedback channel to the creator of a demand or a request, such as:

> *"Do you have my phone number? If so, please send me a message." (E01)*

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Such a feedback channel must also be available so that any requests from the emergency services, e.g. police or fire departments, can be answered directly (E10).

6.2.4. Address those people who would otherwise be left out

As the participants said, public display applications can be used to coordinate activities and tasks wherever needed:

> *"Such a public display can be used whenever a lot of people meet up." (E13)*

The use of information and warnings for almost all ordinary people as well as coordinative functionality for all of those who own a smartphone was appreciated (design challenge no. C05):

> *"From my point of view, the application is very important for all those people who are not very keen on smartphones. They can inform themselves at central locations, such as supermarkets." (E03)*

Elderly people in particular could use such applications to request assistance in everyday life:

> *"For elderly people, for example, who need help for situated activities - like asking for assistance for a visit to the doctor." (E03)*

Further application fields for the deployment of City-Share were mentioned:

> *"To allow people to become familiar with the application, it should be used as a daily marketplace, like a local E-Bay for physical resources." (E06)*

As already conceptualized, such deployment when there is not an emergency might help people to become familiar with the technology. Another idea was to use City-Share and public display applications during public elections:

> *"People should be allowed to vote based on the public display about current topics." (E09)*

6.2.5. Current shortcomings, suggested improvements

The participants also mentioned the shortcomings of the current version of City-Share and they suggested improvements for future developments. There should be two modes of City-Share, one for daily business and the other for the use in cases of disaster ('disaster mode'). The labeling of the input fields within a disaster should then be more tailored to the terminology used within disasters (E05):

> *"The terminology of the application is not understandable during disasters. In an emergency, there should only be terms - 'new offer' and 'searching for help'. I think that would be great." (E05)*

Further, not all participants have a QR-code reader pre-installed on their smartphones. If a user has neither a QR-code reader nor internet connection for downloading such an app, it is not possible to interact with the display (E04).

Additionally, functionality for a later editing and correcting of the content items is needed (E13), such as *"new locations, new contact persons, new names, new things to do"* (E05). But such editing or correcting needs user accounts and a previous registration which might be a stumbling block for spontaneous voluntary tasks (E12). Another participant mentioned she would add her qualifications and if a specific task required her qualifications (e.g. medical assistance), she would be notified (E05). Another suggestion mentioned is that the content can be taken along and used elsewhere, e.g. to navigate to a specific location or just to store the content item in the local cache of the smartphone (E15).

6.2.6. Potential application fields of City-Share

Our Brainwriting Pool conducted within our evaluation has outline lots of potential application fields for situated public displays. Based on the prioritization of the index cards those were mainly:

6.2.6.1. Multiple dwelling. The concept of City-Share could be used to foster 'neighborhood awareness' in a multiple dwelling. Especially in big cities there is a high anonymity and often people in the same dwelling do not know who is living in the same dwelling. In case of an emergency for example the neighbors could help each other and share resources.

6.2.6.2. Ride-sharing. The concept of City-Share could be used to facilitate offers and demands of sharing a ride. Situated displays at central locations could help building spontaneous and ad hoc ride-sharing, which could help reducing the amount of different rides.

6.2.6.3. Emergency shelter for refugees. The concept of City-Share could be used in an emergency shelter for refugees to match the demands of refugees and offers of the people. Refugees often request support for visiting authorities, shopping groceries, or performing other types of activities. Refugees often own smartphones, wherefore the placement of a public display within an emergency shelter and the interaction type outlines within this article could be of interest.

6.2.6.4. Food sharing. The concept of City-Share could be used for food-sharing with homeless people within cities. There are already some online approaches that focus on food sharing with homeless people, but usually homeless people do not own Internet connection, wherefore the situatedness of a public display could improve the cooperation between food givers and homeless people.

7. Discussion and conclusion

Although citizen-initiated self-help activities and voluntary relief tasks have always existed whenever disasters have occurred (Tierney et al., 2006), modern technology has changed the possible types of communication and coordinating activities and tasks available prior to, during and following a disaster. Situated crowdsourcing make use of the people's serendipitous availability and embeds input mechanisms into the physical space (Goncalves, Hosio, Kostakos, et al., 2015). It is based on the location-based distribution of crowdsourcing tasks, which have allowed the people to perform context specific tasks for others (Hosio et al., 2014). Public displays are situated technologies that could be used as input device for situated crowdsourcing activities, because they are a ubiquitous part of our environment and inform the public about places or events of interest and often help reflecting the activities of others (O'Hara et al., 2003).

The prototype City-Share developed in our study contributes to existing work by emphasizing the crowd-based crisis management and situated nature of voluntary activities. With City-Share we wanted to transfer crowdsourcing concepts of emergent volunteer citizen groups during emergencies within social media to physical locations and situations – also available during internet breakdowns. The low burden of volunteers for participating online attracts a wide audience and helping online became an important – although still unstructured – activity during crisis response work. In the online context, there are already voluntary organizations that focus on structuring information available within social media. The so-called Virtual Operation Support Teams (VOST) are already a part of official emergency management structures on which official agencies rely on during disasters. But when taking a

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look at physical circumstances, such as the European flood in 2013, neither do voluntary organizations for performing on-site activities exists, nor do emergency services have the resources to manage those and align their activities.

The concept of situated crowdsourcing promises that carrying out of tasks does not necessarily require much deployment effort and, due to its situated character, enables individuals reaching an "untapped source of potential worker" (Goncalves et al., 2015), wherefore the burden of participation and organization could be lowered. City-Share provides a central point of contact for those spontaneous voluntary 'workers', for the affected citizens as well as for emergency services and allows them to share offers as well as requests for resources. Tasks that are performed are activity-based, physically-based or information-based. Beside sourcing the crowd of volunteers, official 'sourcers' in form of emergency services further have options for warning and mobilizing the people.

City-Share combines the advantages of ubiquitous crowdsourcing approaches, such as making use of the sheer pervasiveness of people's mobile devices as well as situated crowdsourcing approaches, such as the contextual controlled crowdsourcing environment. When considering both concepts in combination, a "location-based distribution of crowdsourcing tasks" (Hosio et al., 2014) becomes possible, that build upon the individual's flexibility and mobility, but also "leveraging people's local knowledge" (Goncalves et al., 2015).

When considering the circumstances within disasters and the current unstructured (but needed) activities of spontaneous volunteers, situated crowdsourcing can provide a local control point for performing tasks and structuring voluntary work. We are aware that during daily use the functionality of City-Share such as creating demands or offers can easily be transferred and substituted by online services. But this is only appropriate, if internet connection is available and if the target group solely consists of internet users. However, to get people getting used to the technology as well as to secure the sharing of demands and offers without internet connection, a situated approach seems to be necessary. We outline seven lessons learnt when designing approaches that encompass situated crowdsourcing for voluntary emergency response work within disasters:

- *Considering potential infrastructure breakdowns:* During disasters information infrastructures (technically as well as socially) can collapse. When designing situated crowdsourcing tools for crisis management fallback concepts should always be implemented, such as online as well as offline usage.
- *Considering the entire context:* When designing situated crowdsourcing tools within crisis management it is necessary to design for the entire context. As a participant said, public displays provide a central point of help and combine a physical presence, comforting words and getting together. During crisis management affected people often struggle with personal hard times that need to be considered during design.
- *Considering dual use:* Most community-based crowdsourcing approaches need a critical mass to work. Within disasters it gets even harder, because usually no disaster or crisis exit, wherefore people do not focus on prevention or mitigation during their daily life. When designing situated crowdsourcing tools, it is therefore important to find ways of supporting people also during non-disaster periods.
- *Considering accessibility to everybody:* When designing situated crowdsourcing tools within crisis management, it is important that all affected are addressed and enabled to contribute and participate. For example, one of the major shortcomings of Facebook communication during crisis is its exclusion of non-Facebook users.
- *Considering online as well as offline activities:* During disasters activities of volunteers and affected people are performed online as well as 'offline' on-site. When designing situated crowdsourcing tools for crisis response work, it is necessary to consider and combine both kinds of information and activity space to get a comprehensive overview about tasks and activities.
- *Considering power structures of emergency services:* Although voluntary work is appreciated by emergency services, the official services are responsible for managing disasters and always have the power and legitimization to overrule volunteers or to exclude voluntary work. A situated crowdsourcing tool therefore needs to address these relations by different roles.
- *Considering moderator roles*: During emergencies, misleading information or too much information can decide between death and life. Therefore, it is important to integrate a kind of interlayer between volunteers and victims that mediates and proofs the content. Here, points of reference can be made to VOST.

Situated crowdsourcing applications like City-Share encompass different information sources such as social media, official emergency services and local news and can foster community's disaster resilience, especially when focusing on the situated kind of collaborative resilience emerging between official stakeholders and spontaneous volunteers as well as affected citizens at a local level. 'Disaster resilience' can be understood as the "ability of countries, communities and households to manage change, by maintaining or transforming living standards in the face of shocks or stress – such as earthquakes, drought or violent conflict – without compromising their long-term prospects" (Department for International Development, 2011). However, in practice its implementation is often understood in diverse ways (Aldunce et al., 2014). Based on the concept of disaster resilience (Department for International Development, 2011), *collaborative resilience* aims to support disaster resilience by a strong cooperation between all the involved stakeholders such as public administration (i.e. decision makers in politics and government), the emergency services (police and fire fighters), aid agencies (e.g. the Red Cross) and industrial companies, but also affected citizens as well as spontaneous volunteers (Goldstein, 2011). Accordingly collaboration between the "private and public sectors could improve the ability of a community to prepare for, respond to, and recover from disasters" (Board on Earth Sciences and Resources, 2011).

We are aware, that situated crowdsourcing concepts still have some disadvantages within disaster response. One of the major limitations of our approach is that the public display itself requires energy and could not be used when the entire energy infrastructure breaks down. It may therefore be a fallback strategy to have blackboards, pen and paper available in addition to City-Share, because those tools are more resilient due to their energy requirements. Further research will show if our public display can 'analogize' its services once it may be in danger of breaking down such as printing our maps and messages. We further do not provide any verification of the content made by the people. The content items could therefore contain any pornographic or violent material. It may therefore be necessary to authorize some – remote or digital – volunteers with editor roles to verify the content made. Further research will show if the volunteers will have the resources to fulfil such editor and verification tasks. The concept also depends on the everyday usage, so citizens can get familiar with the system and will remember it as a useful application in a crisis situation.

To tackle the current limitations of our approach, we see a necessity to extend our experiences made within a real scenario over a long period of time and examine how people use and appropriate the technology over time. As a next step we are therefore currently deploying and evaluating City-Share at the 'Kieler Woche' in Germany, which is the biggest sailing event in the

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Fig. 10. Evaluation of CityShare at Kieler Woche 2016 with Emergency Services.

World and a big festival (Fig. 10). Based on the gained insights, we aim to implement next versions of both applications in order to guarantee a high applicability and usability from a practical perspective..

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