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Fifteen years of social media in emergencies: A retrospective review and future directions for crisis Informatics

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Social media has been established in many larger emergencies and crises. This process has not started just a few years ago, but already 15 years ago in 2001 after the terrorist attacks of 9/11. In the following years, especially in the last 10, sometimes summarized under the term crisis informatics, a variety of studies focusing on the use of ICT and social media before, during or after nearly every crisis and emergency has arisen. This article aimed to recapitulate 15 years of social media in emergencies and its research with a special emphasis on use patterns, role patterns and perception patterns that can be found across different cases to point out what has been achieved so far, and what future potentials exist.

1 | INTRODUCTION AND BRIEF HISTORY

Social media is nowadays a part of everyday life. The former so-called Web 2.0 (O'Reilly, 2005) was initially defined as an architecture for participation with new possibilities for social interaction. According to O'Reilly (2006), Web 2.0 "does not only represent content that has been provided by an individual for the purpose of distribution; it also represents interaction among people." Over the years, this interaction has been summarized more and more frequently under the term social media: a "group of internet-based applications that build on the ideological and technological foundations of Web 2.0, and that allows the creation and exchange of user-generated content" (Kaplan & Haenlein, 2010). In this context, user-generated content refers to "the various forms of media content that are publicly available and created by end-users" (Kaplan & Haenlein, 2010). Allen (2004) points out that the "core ideas of social software itself enjoy a much longer history, running back to Vannevar Bush's ideas about the storage-device Memex in 1945 through terms such as augmentation, groupware, and Computer Supported Cooperative Work (CSCW) in the 1960s, 70s, 80s, and 90s." Accordingly, Koch (2008) argued that "most of what currently is advertised as a revolution on the web has been there as CSCW applications years (or even decades) ago – however, not as nice and as usable as today." However, during the last 10 years, these services were intensively used. Currently, the most common types of social media include Facebook with about 1.86 billion active users monthly, YouTube (1 billion), WhatsApp (1 billion), Instagram (500 million), LinkedIn (433 million), Twitter (320 million) and Google+ (235 million)[1] .

Social media is not only part of everyday life but also appearing in critical situations: already after the 9/11 attacks in 2001, citizens created wikis to collect information about missing people (Palen & Liu, 2007), and FEMA and the Red Cross used web-based technologies to inform the public and to provide status report internally and externally (Harrald, Egan, & Jefferson, 2002). Starting in about 2006, social media use in emergencies has become a very big research field, sometimes summarized under the term *crisis informatics*. Coined by Hagar (2007) and later elaborated by Palen, Vieweg, Liu, and Hughes (2009), it "views emergency response as an expanded social system where information is disseminated within and between official and public channels and entities." Today, crisis informatics "is a multidisciplinary field combining computing and social science knowledge of disasters; its central tenet is that people use personal information and communication technology to respond to disaster in creative ways to cope with uncertainty" (Palen & Anderson, 2016). During the last years, various studies have arisen addressing emergencies and the use of social media. Also, various international journals have published special issues (Hiltz, Diaz, & Mark, 2011; Pipek, Liu, & Kerne, 2014; Reuter, Mentler, & Geisler, 2015) as well as tracks at various conferences, such as *ISCRAM*. This trend was predicted some years ago: "the role held by members of the public in disasters [. . .] is becoming more visible, active, and in possession of greater reach than ever seen before" (Palen & Liu, 2007).

Many studies focus on the concrete use of social media during a specific emergency, such as the 2011 London riots (Denef, Bayerl, & Kaptein, 2013), the 2012 hurricane Sandy (Hughes, Denis, Palen, & Anderson, 2014) or the 2013 European floods (Reuter, Ludwig, Kaufhold, & Pipek, 2015). These studies demonstrate the specific ways in

which social media responded to various crises. Across various studies of emergencies and disaster events, numerous positive and negative aspects of social media have been identified, groups of users have been defined, and perceptions have been studied. However, after 15 years of social media in emergencies, it is time to summarize what has been achieved so far to derive what should be the next step. Based on an overview of cases on social media in emergencies (section 2), use patterns (section 3), role patterns (section 4) and perception patterns (section 5) are derived, followed by a discussion and conclusion on future directions (section 6). According to the Oxford Dictionary, with pattern we refer to "the regular way in which something happens or is done." Broken down to our case we refer to repetitive ways in which social media is used in different cases, what roles have been observed and how this use is perceived. Having said this, our article focuses less on technological patterns, which can be found in other papers (Imran, Castillo, Diaz, & Vieweg, 2015).

2 | PUBLISHED CASES OF SOCIAL MEDIA IN EMERGENCIES

According to the World Disaster Report (IFRC, 2015) during the last 10 years in average about 631 disasters happened per year with 83,934 people killed, 193,558 people affected and estimated damage of 162,203 million US dollars. While natural disasters killed 76,420 people, technological disasters caused 7,513 lives per year. According to Hiltz, Diaz, et al., (2011), Hiltz, van de Walle, and Turoff (2011), disaster, crisis, catastrophe and emergency management "are sometimes used synonymously and sometimes with slight differences, by scholars and practitioners." This is also the case while searching for articles on social media use in these contexts. However, the *internationally agreed glossary of basic terms related to disaster management* (United Nations Department of Humanitarian Affairs, 2000) defines an *emergency* as a "sudden and usually unforeseen event that calls for immediate measures to minimize its adverse consequences." A *disaster* is a "serious disruption of the functioning of a society, causing widespread human, material, or environmental losses which exceed the ability of affected society to cope using only its own resources." The term *crisis* has not been defined in that document. Yet, *crises* are situations that the normal structural and process organization cannot overcome (BSI, 2008). The Greek root word *krisis* (judgement, decision) shows the ambivalent possibilities. In the following, we will talk about emergencies, but do not want to limit ourselves in the cases to take into consideration.

For 15 years, the public has used social media in emergencies (Reuter, Marx, & Pipek, 2012). After the terrorist attacks of 11 September 2001, for example, wikis created by citizens were used to collect information on missing people (Palen & Liu, 2007), while citizens used photograph repository sites to exchange information following the 2004 Indian Ocean tsunami (Liu, Palen, & Sutton, 2008) or the 2007 Southern California wildfires (Shklovski, Palen, & Sutton, 2008). Another early study focused on hurricane Katrina in 2005 (Murphy & Jennex, 2006). Social media were quickly revealed as an emergent, significant and often accurate form of public participation and backchannel communication (Palen, 2008).

About 10 years ago, Palen and Liu (2007) anticipated a future where ICT-supported public participation would be regarded as both normal and valuable. Subsequently, analysis of social media in emergencies, mainly in the USA but also in other places, has become conventional. There are fewer studies covering the situation in Europe (Reuter et al., 2012). Most studies have focused on the use of Twitter so far, partly due to its frequency of use in the USA. However, looking at the current statistics, Facebook has 1.7 billion active users, while Twitter "just" has 320 million, this might not be the main reason. The ease of data selection (e.g., to obtain a statistically sound sample) in Twitter (Reuter & Scholl, 2014) might be most influential for this bias. While comparing larger emergencies and studies about social media in emergencies, it appeared that nearly no emergency exists without articles on the use of social media there.

Many published research papers have mainly focused on the use of Twitter. Many articles focus on social media use during various disasters in the USA (e.g., 2001 9/11, 2005 Hurricane Katrina, 2012 Hurricane Sandy, 2013 Colorado Flood). Other studies have provided a more international backdrop (e.g., 2004 Indian Ocean tsunami, 2008 Sichuan earthquake, 2011 Tunisian revolution, 2011 Norway attacks, 2013 European floods, 2015 Paris shootings). Existing studies focus on both natural hazards (tsunamis, hurricanes, earthquakes, floods) and human-induced disasters (shootings, terror attacks, uprisings).

Table 1 gives an overview about studies on social media in emergencies[2] . We are aware that this list cannot be complete. Our focus was less to identify and include all research on this topic, but more to highlight the existence of scientific cases about nearly all events during the last 10–15 years. The cases and studies have been identified following the instructions of Brocke, Simons, Riemer, Niehaves, and Plattfaut (2015) and searching in Google Scholar for the keywords "social media," "web 2.0," "Twitter," "Facebook," "emergency," "disaster," "crisis" in singular and plural without any restrictions concerning the time frame. Furthermore, backward and forward search has been applied. In addition, for recent larger emergencies, we explicitly searched for studies on the use of social media while using the search term of the case (e.g., Paris shootings 2015). The cases are presented regarding their reference, the related case or scenario and a brief overview of the scientific contribution. They are sorted by the year of occurrence. Due to the amount of studies, only a limited number per case has been selected to provide an overview.

3 | USAGE PATTERNS—TYPES OF INTERACTION IN SOCIAL MEDIA

The range of different emergency situations and responses to them have produced attempts to categorize the use of social media. The aim is to both promote systematical analysis of behaviours and

TABLE 1 Overview of selected cases and sample studies in the literature

References	Case	Contribution
Palen and Liu (2007)	2001 9/11	Use of wikis to collect information about missing people.
Harrald et al. (2002)		FEMA and the Red Cross used web-technologies to inform the public and to provide status report.
Liu et al. (2008)	2004 Indian Ocean tsunami	Citizens used photograph repository sites to exchange information.
Endsley, Wu, Eep, and Reep (2014)	2005 Hurricane Katrina, 2010 volcano Eyjafjallajökull in Iceland	Credibility of social media information is less than of printed, official online or televised news and information from family, relatives or friends.
Shklovski et al. (2008)	2007 Southern California wildfires	Citizens used photograph repository sites to exchange information.
Hughes and Palen (2009)	2008 Hurricanes Gustav and Ike	Highlights differences between the use of Twitter in crises and the general use.
Qu et al. (2009)	2008 Sichuan earthquake	Outlines that people gather and synthesize information.
Sutton (2010)	2008 Tennessee River technological failure	Outlines the phenomena of broadcasting emergency-relevant information via Twitter.
Heverin and Zach (2010)	2009 Lakewood attack on police officers	Shows the ability of Twitter to organize and disseminate crisis-related information.
Latonero and Shklovski (2011)	2009 Los Angeles fire Department	Public Information Officers highlight the importance of the information evangelist within organizations.
Starbird and Palen (2010)	2009 Oklahoma fires	Highlights the role of retweeting for information processing, especially filtering and recommendation.
Vieweg et al. (2010)	2009 Red River floods	Highlights broadcasting by people on the ground as well as activities of directing, relaying, synthesizing and redistributing.
Mendoza et al. (2010)	2010 earthquake in Chile	Shows that the propagation of tweets that correspond to rumours differs from tweets that spread news because rumours tend to be questioned more than news by the Twitter community.
Birkbak (2012)	2010 Bornholm blizzard	Two Facebook groups show that the geographical location and self-selection into groups create different views of a crisis.
Muralidharan, Dillistone, and Shin (2011)	2010 Deepwater Horizon oil spill disaster	BP's corrective action as the dominant image restoration strategy caused high presence of negative emotion.
Starbird and Palen (2011)	2010 Haiti earthquake	Analyses the earthquake with the help of translators and reveals the phenomenon of "digital volunteers."
Reuter et al. (2012)	2010 Love Parade mass panic in Germany, volcano Eyjafjallajökull in Iceland	Systematizes the communication between authorities and citizens during emergencies, outlining the need for duplex communication.
Nagy, Valley, and Stamberger (2012)	2010 San Bruno Californian gas explosion and fire disaster	Illustrates that sentiment analysis (analysis for identifying and extracting subjective information) with emotions performed 27% better than Bayesian Networks alone.
Helsloot and Groenendaal (2013)	2011 large-scale fire in Moerdijk, the Netherlands	Most tweets do not contain new relevant information for governments; tweets posted by governments got buried under an avalanche of citizen tweets.
Starbird and Palen (2012)	2011 Egyptian uprising	Shows how the crowd expresses solidarity and does the work of information processing through recommendation and filtering.
Wilensky (2014)	2011 Great East Japan earthquake	Emphasizes the use of Twitter to provide emotional support and mentions the problem of widely publishing obsolete or inaccurate information and the unequal distribution of useful information.
Perng et al. (2012)	2011 Norway attacks	The notion of peripheral response has been developed in relation to emergent forms of agile and dialogic emergency response.
Jennex (2012)	2011 San Diego/Southwest blackout	The availability of social media illustrates that "the cell phone system did not have the expected availability and users had a difficult time using social media to contact family and friends."
St. Denis and Hughes (2012)	2011 Shadow Lake fire	Shows the deployment of trusted digital volunteers as a virtual team to support an incident management team.
Reuter et al. (2013)	2011 Super Outbreak	Distinguishes groups of twitterers, such as helpers, reporters, retweeters and repeaters.

(Continues)

TABLE 1 (Continued)

References	Case	Contribution
Wulf, Misaki, Atam, Randall, and Rohde (2013)	2011 Tunisian revolution	Social media linked the young activists with actors in other cities and stimulated the participation in weekly demonstrations.
Kuttschreuter et al. (2014)	2011 Escherichia coli contamination crisis	Social media can act as a complementary information channel for a particular segment, but it is neither a substitute for traditional nor for online media.
Yang, Chung, Lin, Lee, and Chen (2013)	2012 hurricane Isaac	Leads to knowledge, which classification algorithms work best in each phase of emergency.
Hughes et al. (2014)	2012 hurricane Sandy	Shows that few departments used online channels in their response efforts and that communication differed between fire and police departments and across media types.
Medina and Diaz (2016)	2012 Madrid Arena tragedy	Opportunities according to the main principles of the theory of Crisis Communication Management provided by Twitter.
White and Palen (2015)	2013 Colorado flood	Highlights the blending of online and offline expertise to evacuate horses from an isolated ranch.
Kaufhold and Reuter (2014)	2013 European flood in Germany	Identifies challenges of the public response among emergent groups and digital volunteers highlighting the role of moderators.
de Albuquerque et al. (2015)	2013 European flood in Germany	Messages near to severely flooded areas have a much higher probability of being relevant.
Burnap et al. (2014)	2013 Woolwich (London) terrorist attack	The sentiment expressed in tweets is significantly predictive of both size and survival of information flows.
Wan and Paris (2015)	2014 Sydney siege	System to analyse posts of a special topic and visualize the emotional pulse of a geographical region.
Chaturvedi, Simha, and Wang (2015)	2015 cyclone Pam 2014 Kashmir floods, Indonesia landslide	Data collection via Twitter for exploration of the ICT infrastructure for disaster management.
Fung, Tse, Cheung, Miu, and Fu (2014)	2014 Ebola fear in the USA	Examines the amplified fear of the imported Ebola virus through social media.
Fichet, Robinson, and Starbird (2015)	2015 Amtrak derailment, Baltimore protests, hurricane Joaquin floods	Examines the use of the live-streaming application Periscope by both citizens and journalists for information sharing, crisis coverage and commentary.
Soden and Palen (2016)	2015 Nepal earthquake	Investigates the work of mapmakers working and outlines factors contributing to the emergence of infrastructure.
Zipf (2016)	2015 Nepal earthquake, 2013 Philippines typhoon, 2011 Japan tsunami	Help of "Ambient Geographic Information" via social media (Twitter and Flickr) at crisis management.
An, Kwak, Mejova, and Oger (2016)	2015 Charlie Hebdo shooting	Examines sociological theories in terms of the social factors that contribute to online individual behaviour.
Zeng, Chan, and Fu (2016)	2015 Tianjin blasts	Clustering analysis and time-series analysis of social network Weibo's rumour management strategies.
Wiegand and Middleton (2016)	2015 Paris shootings	Examines the velocity of newsworthy content and its veracity with regard to trusted source attribution.
Sagar (2016)	2016 Roanu cyclone in Sri Lanka	Twitter and Facebook were used to help flood-affected victims with disaster warnings, relief information, and weather alerts.

interactions and to facilitate the use and development of qualified technology: Reuter et al. (2012) derived a classification matrix for cooperation in crisis situations, depending on the sender (*x*-axis) and the recipient (*y*-axis) of digital content. Considering citizens (C) and authorities (A), such as emergency services, Reuter et al. (2012)'s crisis communication matrix distinguishes between four observed information flows or patterns of social media use in emergencies (Figure 1): on the interorganizational level, organizations of crisis response communicate with each other (A2A). On the public level, citizens and volunteers communicate with each other in real or virtually via social media such as Twitter or Facebook (C2C). This citizen-generated content is also being analysed by crisis response organizations (C2A). Besides the communication among the citizens, organizations responsible for recovery work inform the public (A2C).

Moreover, the "categories of organizational behavior" of Quarantelli (1988) describe five different categories for the flow of information in a crisis, which have similarities to this categorization. However, to describe different use patterns and because of the relevance of communication among citizens (C2C) in social media, we will use the crisis communication matrix.

3.1 | Citizens to citizens (C2C)—Self-coordination and help

Not all activities of citizens in social media are intended for emergency services, and we would argue that most of the activities aim to inform other citizens. People help each other and social media is a possible tool for this. However, this self-coordination and help has not been invented by social media: 40 years ago, Quarantelli and Dynes (1977) as well as Stallings and Quarantelli (1985) characterized these "emergent groups" as "private citizens who work together in pursuit of collective goals relevant to actual or potential disasters but whose organization has not yet become institutionalized." According to Quarantelli (1984), the essential conditions for the emergence of such groups are a legitimizing social environment, a perceived threat, a supporting social climate, a network of social relationships and the availability of specific (immaterial) resources. According to some studies, citizens react in a largely rational way to crisis situations, rarely in panic, are not helpless and do not loot (Helsloot & Ruitenberg, 2004). They are instead capable of taking part in a large amount of rescue and response work. Here, Reuter, Heger, and Pipek (2013) distinguish between activities in the "real"and the "virtual"world: real "emergent groups" (Stallings & Quarantelli, 1985), which usually act in the form of neighbourly help and work on-site, and virtual "digital volunteers" (Starbird & Palen, 2011), who originate from the Internet and work mainly online.

An early study on 2008 hurricanes Gustav and Ike differentiates between the use of Twitter in crises and its general use suggesting that information broadcasting and brokerage can be found more often (Hughes & Palen, 2009). 2008 Sichuan earthquake confirms that people gather and synthesize information (Qu, Wu, & Wang, 2009); also a study on the 2008 Tennessee River technological failure confirms this with the effect of exceeding the boundaries of locally limited networks and raising emergency awareness among citizen (Sutton, 2010). The 2010 Yushu earthquake shows that people use microblogging to seek information about the status of the emergency or people (Qu, Huang, Zhang, & Zhang, 2011). During the 2010 Haiti earthquake, the nowadays well-known notion of "digital volunteers" converging to strongly intertwined networks was revealed by analysing the Twitter usage with "Tweak the Tweet" translators (Starbird & Palen, 2011). Digital volunteers perform activities of relaying, amplifying, synthesizing and structuring information in the wake of disaster events (Starbird, 2013). During the 2012 hurricane Sandy, citizens handled activities that are unlikely to be done by official emergency services such as recovering lost animals (White, Palen, & Anderson, 2014). Expressing solidarity, as seen during 2011 Egyptian uprising (Starbird & Palen, 2012) and providing emotional support, during 2011 Great East Japan Earthquake (Wilensky, 2014), are further tasks. A timeline analysis of the 2011 Super Tornado Outbreak (Reuter et al., 2013) indicates that during the preparedness and response phases highly retweeted warning and crisis tracking activities occur, while virtual self-help communities started their relief activities in the recovery phase along with a relatively increasing number of external resource links. Besides Twitter, also other media are used: the use of two Facebook groups during the 2010 Bornholm blizzard shows that the self-selection into groups creates different views (Birkbak, 2012). Goolsby (2010) reports on ad hoc crisis communities using social media to generate community crisis maps. Nowadays, seven distinct crisis-mapping practices in OpenStreetMap have been identified (Kogan, Anderson, Palen, Anderson, & Soden, 2016).

To draw conclusions on a broader scope, Olteanu, Vieweg, and Castillo (2015) investigated several crises in a systematic manner. They show that the average prevalence of different information types (32% other useful information, 20% sympathy and emotional support, 10% donations and volunteering, 10% caution and advice and 7% infrastructure and utilities) and sources (42% traditional or Internet media, 38% outsiders, 9% eyewitness accounts, 5% government, 4% NGOs and 2% businesses) as well as their temporal distribution across a variety of crisis situations. Furthermore, Eismann, Posegga, and Fischbach (2016) conducted a systematic literature review identifying that "sharing and obtaining factual information is the primary function of social media usage consistently across all disaster types, but the secondary functions vary."

However, there are also risks of widely publishing obsolete or inaccurate information and the unequal distribution of useful information (Wilensky, 2014). In cases of uncertainty, caused by redundant information and mistakes due to chaotic "unorganized" online behaviour of volunteers, "there will be a larger amount of collaboration on the platform" (Valecha, Oh, & Rao, 2013). This might be addressed by cross-platform working moderators (Reuter, Ludwig, Kaufhold, et al., 2015) or attempts to install public displays for volunteer coordination (Ludwig et al., 2017). Furthermore, Purohit et al. (2014) propose a system for identifying seekers and suppliers in social media communities to support crisis coordination. However, besides all these achievements, many aspects are still open: Cobb

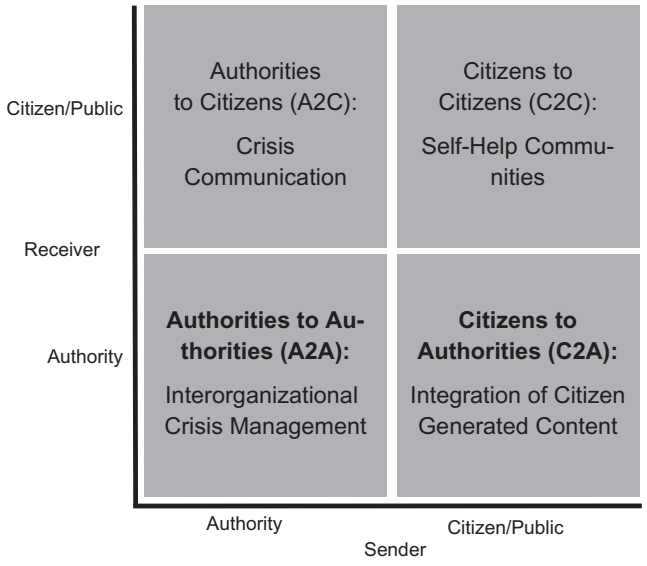

FIGURE 1 Crisis Communication Matrix (Reuter et al., 2012), adapted concerning the terminology

et al. (2014) suggest the coordination and integration of voluntary activities, the connection between different tools and tasks as well as the possibility to share own activities to generate learning effects for spontaneous and less experienced volunteers. Additionally, Kaufhold and Reuter (2014) identified challenges to support digital and real volunteers in achieving clarity and representation of relevant content, to facilitate processes of moderation and autonomous work as well as to promote feedback and updates in interaction relationships and to integrate technologies and interaction types.

3.2 | Authorities to citizens (A2C)—Crisis communication and public alerting

Besides the use of social media among citizens, authorities nowadays and increasingly in the future integrate social media into their crisis communication efforts to share information with the public on how to avoid accidents or emergencies and how to behave during emergencies (Reuter, Ludwig, Kaufhold, & Spielhofer, 2016). However, already the 2009 case study of Public Information Officers (PIO) of the Los Angeles Fire Department highlights the importance of the information evangelist, who promotes the use of new forms of media and technology within authorities to achieve an effective organizational utilization of social media (Latonero & Shklovski, 2011). Hughes and Palen (2012) argue that members of the public "have a changed relationship to the institution of emergency response" through the authorities' use of social media. A comparative study of police units in the 2011 London riots discusses the benefits and challenges of instrumental and public-including expressive communication approaches through Twitter (Denef et al., 2013), such as close relations and increased possible reach on the one hand and the requirement of high maintenance on the other hand. Another study about the 2011 Thailand flooding disaster describes the authorities' actions taken to correct the mistakes caused by the "emerging risks of the chaotic use of social media" (Kaewkitipong, Chen, & Ractham, 2012). Therefore, Starbird and Stamberger (2010) recommend the use of structured crisis-specific Twitter hashtags to increase the utility of information generated during emergencies and to facilitate machine parsing, processing and redistribution for the proposed microsyntax "Tweak the Tweet." However, a study on 2012 hurricane Sandy also shows that communication differed between fire and police departments and across media types (Hughes et al., 2014). For this, they suggest new features and tools "to better track, respond to, and document public information." Furthermore, Veil, Buehner, and Palenchar (2011) provide an overview of best practices, examples of social media tools and recommendations of practitioners. Time-series analyses reveal that relevant information became less prevalent as the crisis moved from the prodromal to acute phase and that information concerning specific remedial behaviours was absent (Spence, Lachlan, Lin, & del Greco, 2015).

Still, there are several barriers in the authorities' use of social media. The collaboration among humanitarian aid organizations and Volunteer and Technical Communities (V&TCs) was analysed in an exploratory study, categorizing the latter into software platform development communities, mapping collaborations, expert networks and data aggregators (Gorp, 2014). It further identifies six barriers of collaboration with aid organizations: limited resources, the management of volunteers, different levels of engagement, the level of commitment by V&TCs, different ways of working and the aid for organizations' limited knowledge about the V&TCs' expertise. Plotnick and Hiltz (2016) show how social media is used by county-level US emergency managers and summarize barriers to effective social media use and recommendations to improve use: The lack of sufficient staff, a lack of guidance and policy documents, trustworthiness and information overload and lack of skills.

3.3 | Citizens to authorities (C2A)—Integration of citizen-generated content

In addition to the communication from authorities to citizens, the use of citizen-generated content is important. Making use of data mining, social media can be used to calculate statistical measures to be used to, for example, estimate citizen alertness (Johansson, Brynielsson, & Quijano, 2012). In this case, the large amount of social media posts is a guarantee for the correctness of the statistical measures. Going beyond statistics, the potential of benefitting from citizen-generated content lies within illustrating problematic situations through photographs taken with mobile phones. The perceived unreliability of such information is a significant obstacle in exploring such opportunities (Mendoza, Poblete, & Castillo, 2010). This could be alleviated by crowdsourcing strategies to confirm the trustworthiness of information visible in a picture (Reuter et al., 2012). In a comprehensive literature review regarding the integration of social media content, Hughes and Palen (2014) complement the challenges of verification, liability, credibility, information overload and allocation of resources. Furthermore, a study on the 2010 Haiti earthquake showcases opportunities of social media for disaster relief in terms of donations towards the Red Cross (Gao, Barbier, & Goolsby, 2011). Akhgar, Fortune, Hayes, Guerra, and Manso (2013) describe how public safety and security organizations are increasingly aware of social media's added value proposition in times of crisis. Another study suggests that volunteer groups in emergencies will in the future be challenged to mature and improve according to these enhanced possibilities so that "professional responders will begin to rely on data and products produced by digital volunteers" (Hughes & Tapia, 2015).

During social media research, several applications and methods were examined to integrate citizen-generated content and support authorities in processing social media content. Ludwig et al. (2016) implemented a public display application with a robust communication infrastructure to encompass situated *crowdsourcing* mechanisms. Moreover, Castillo (2016) brings together computational methods (e.g., natural language processing, semantic technologies, data mining) to process social media messages under *time-critical constraints*. Several contributions aim on extracting *situational awareness* from social media: for instance, Vieweg, Hughes, Starbird, and Palen

(2010) applied information extraction techniques to enhance situational awareness on Twitter. Based on the case of Japanese earthquakes in 2009, Sakaki, Okazaki, and Matsuo (2010) propose an algorithm that incorporates Twitter users as social sensors for real-time *event detection*, and Pohl, Bouchachia, and Hellwagner (2015) present clustering approaches for *subevent detection* on Flickr and YouTube to automate the processing of data in social media. Furthermore, de Albuquerque, Herfort, Brenning, and Zipf (2015) show that geographical approaches for quantitatively assessing social media messages can be useful to improve relevant content. Moi et al. (2015) propose a system to process and analyse social media data, transforming the high volume of noisy data into a low volume of rich content that is useful to emergency personnel. To achieve this goal, they identify the steps of information gathering and data preparation, data enrichment, information mining, semantic data modelling with ontologies, information quality assessment, alert detection and information visualization.

Also, in this area, there are still unaddressed aspects: Imran et al. (2015) contribute with a comprehensive overview on processing social media messages to discuss challenges and future research directions including techniques for data characterization, acquisition, and preparation, event detection and tracking, clustering, classification, extraction, and summarization, and semantic technologies. Additionally, a study by Pohl (2013) summarizes existing frameworks and tools developed in the context of crisis-related (e.g., Twitcident or "Tweak the Tweet") and noncrisis-related (e.g., Twitinfo) research work to analyse social media or to include new functionalities into the social media usage for crisis management. The comparison reveals that there are systems for different applications, considering one or several social media platforms for monitoring, especially developed for crisis management, and performing different kinds of analysis: monitoring, event detection and sentiment analysis. However, at the same time, other studies have shown that not all emergency responders make use of such data during disasters, due to the difficulties of receiving and filtering particularly large amounts of data in emergencies (Hughes & Palen, 2012; Reuter, Amelunxen, & Moi, 2016).

3.4 | Authorities to authorities (A2A)—Inter- and intra-organizational crisis management

The inter- and intra-organizational collaboration (A2A) of authorities, as a last pattern, is often not supported by social media such as Facebook or Twitter. However, social media can help to improve interorganizational awareness and informal processes. White, Plotnick, Kushma, Hiltz, and Turoff (2009) examined the potentials of online social networks with emergency management students: sharing information, communication and networking were the most popular features. They also show that possible concerns against those systems may be information integrity, user identification, privacy and technology reliability. Experiences show that interorganizational social networks for authorities might generate potentials (Pipek, Reuter, Ley, Ludwig, & Wiedenhoefer, 2013; Reuter, 2014). Furthermore, authorities may use social media for internal communication. However, in this review, this pattern will not be explored in detail, as it does not directly involve citizens.

4 | ROLE PATTERNS—TYPES OF USERS IN SOCIAL MEDIA

Within all those published cases (section 2) and detected usage patterns (section 3), different role patterns have been identified. Research regarding types of users active on social media began by identifying individual roles and proceeded with the development of role typologies. In their literature review, Eismann et al. (2016) state that different actor types make use of social media in similar ways, but perceive different conditions and restrictions for social media usage in disaster situations. These roles and role typologies take either a citizens' (public) or authorities' (organizational) perspective and are related to either the real or virtual realm. Based on the analysis of existing roles, this section proposes a role typology matrix for individual and collective roles.

4.1 | Citizens, or public perspective

Citizens might be classified in various roles. Hughes and Palen (2009) initially identified *information brokers* who collect information from different sources to help affected citizens. For Starbird and Palen (2011), the second step was to recognize the actions of *remote operators* as *digital volunteers* who progress from simple Internet-based activities like retweeting or translating tweets to more complex ones, for example, verifying or routing information. To further differentiate potential user roles, Reuter et al. (2013) distinguish between activities in the "real"world as opposed to the "virtual"world: real *emergent groups* (Stallings & Quarantelli, 1985), whose involvement usually takes the form of neighbourly help and work on-site and virtual *digital volunteers* (Starbird & Palen, 2011), who originate from the Internet and work mainly online. Ludwig, Reuter, Siebigteroth, and Pipek (2015) build on it and address these groups by enabling the detection of physical and digital activities and the assignment of specific tasks to citizens. Based on a timeline and qualitative analysis of information and help activities during the 2011 Super Outbreak, Reuter et al. (2013) suggest a more specific classification of Twitter users in different roles: *helper*, *reporter*, *retweeter*, *repeater* and *reader*. Kaufhold and Reuter (2014) additionally suggested the role of the *moderator*.

Furthermore, according to Blum et al. (2014), three roles contribute to collective sensemaking in social media: The *inspectors* who define the boundaries of events; the *contributors* who provide media and witness statements and construct rich but agnostic grounded evidence; and *investigators* who conduct sensemaking activities to arrive a broad consensus of event understanding and promote situation awareness. Table 2 presents terms that authors have used to describe different (overlapping) social media users in crisis from the public perspective.

4.2 | Authorities, or organizational perspective

While the previous role descriptions and models address the public use of social media, Bergstrand, Landgren, and Green (2013) examined the utilization of Twitter by authorities and suggest an account typology containing *high-level formal organizational accounts*, *accounts for formal functions and roles*, *formal personal accounts* and *affiliated personal accounts*. Furthermore, Reuter, Marx, and Pipek (2011) proposed community scouts as amateur "first informers" to the perceived unreliability of social media information for authorities and St. Denis & Hughes (2012) describe the use of trusted digital volunteers during the 2011 Shadow Lake fire in virtual teams to inform a type I incident management team about social media activities. On a higher level, Ehnis, Mirbabaie, Bunker, and Stieglitz (2014) distinguish *media organizations*, *emergency management agencies (EMAs)*, *commercial organizations*, *political groups*, *unions* and *individuals*.

From an emergency services' perspective, the German Red Cross contributed with the definition of *unbound helpers* which are nonaffected citizens that mobilize and coordinate their relief activities autonomously and event-related, especially via social media (DRK, 2013). Accordingly, Kircher (2014) summarizes the helper groups by their organization form as well as their spatial and social affection to the catastrophic event into the four categories *self-helpers and neighbourhood helpers* (I), *unbound helpers*, ad hoc *helpers and spontaneous helpers* (II), *preregistered helpers and first responders* (III), and *honorary office and full-time helpers in disaster management* (IV). Detjen, Volkert, and Geisler (2016) further specify the characteristics of these helper groups. Hence, unbound helpers (I, II) conduct reactive and (partially-)bound helpers (III, IV) proactive activities. From I to IV, the prosocial behaviour evolves from spontaneous to sustainable characteristics; the helping process grows in terms of long-term, continuous, plannable, involved, professional and formal engagement; and the helper properties increase in awareness, commitment, experience and professionalism. Table 3 presents terms that authors have used to describe different (overlapping) social media users in crisis from the organizational perspective.

4.3 | Towards a classification of roles related to social media use

The literature review on roles and role typologies reveals two constant dimensions upon which a classification of roles seems suitable. Identified roles either (a) affiliate to the citizens' (public) or authorities' domain (Reuter et al., 2012) or (b) perform their activities in the real (Stallings & Quarantelli, 1985) or virtual realm (Reuter et al., 2013). Adopting the matrix style, four different role patterns may be distinguished considering the realm of the role's action (*x*-axis) and the affiliation of the role (*y*-axis). The idea of the role typology matrix (Figure 2) is to provide an overview, to encourage systematic analysis and development of role patterns and to promote the successful implementation of roles in public and organizational domains. However, there are further criteria to be considered in the classification of role patterns, for instance: in literature, roles are often defined according to the research interest or unit of analysis, for example, collective sensemaking (Blum et al., 2014) or self-help activities (Reuter et al., 2013). Further criteria are types of activities (e.g., information processing, the status of the user (elite or ordinary), administrative autonomy (unbound or (partially-)bound), coordination (instructed or self-coordinated) or personal skills (none, personal or disaster-specific skills).

Emergent groups who include people "whose organization has not yet become institutionalized" (Stallings & Quarantelli, 1985) represent the public-real response. Typical roles of this pattern are affected citizens, self-helpers and neighbourhood helpers. Beyond, the public-virtual response is best characterized with *Virtual and Technical Communities (V&TCs)* who "provide disaster support with expertise in geographic information systems, database management, social media, and online campaigns" (Gorp, 2014). Roles like celebrities, digital volunteers, readers, repeaters and retweeters fit in this pattern. However, because emergent groups and V&TC's potentially (horizontally) collaborate in the course of an emergency (Kaufhold & Reuter, 2016), there are roles performing activities in both realms, for example, different types of helpers, media or reporters. Additionally, moderators even seek a direct collaboration with authorities.

Regarding the real-authority response, *Incident Management Teams* perform on-the-ground operations aiming "to save human lives, mitigate the effect of accidents, prevent damages, and restore the situation to the normal order" (Chrpa & Thórisson, 2013). To integrate the virtual-authority response, emergency services deploy *Virtual Operations Support Teams (VOST)* adapting "to the need for emergency management participation in social media channels during a crisis, while also having that activity support but not interfere with on-the-ground operations" (St. Denis & Hughes, 2012). For this activity, official personnel or roles like *community scouts* or *trusted digital volunteers* are considered. Furthermore, to cover both the real and virtual realms in authorities, horizontal collaboration is required. For instance, incident managers are required to synthesize real and virtual information in the decision-making process. Besides that, different kinds of vertical collaboration take place during emergencies. During the 2013 European floods, for instance, emergent groups and incident teams worked together to overcome the emergency (Kaufhold & Reuter, 2016). However, because virtual communities on Facebook and Twitter influenced the work of emergent groups, a collaboration between authorities and citizens became necessary to coordinate relief efforts. Therefore, *moderators* closely collaborated with authorities to eventually fulfil the role of trusted digital volunteers.

5 | PERCEPTION PATTERNS—VIEWS ON SOCIAL MEDIA

Social media is used in emergency management. Different usage patterns (section 3) and role patterns (section 4) showed this. However, the question arises how these activities are perceived—both by the pubic (e.g., citizens) and by authorities. In the following, the results

TABLE 2 Public perspective on social media roles

References	Role	Description
Stallings and Quarantelli (1985)	Emergent groups	"Private citizens who work together in pursuit of collective goals relevant to actual or potential disasters [. . .]" – actually not a social media role but still important.
Gorp (2014)	V&TC	Virtual & Technical Communities with expertise in data processing and technologies development, have potential to inform aid organizations.
Starbird and Palen (2011)	Digital volunteers	Element of the phenomena popularly known as crowdsourcing during crises. In the twitter sphere, they are called Voluntweeters.
Wu, Hofman, Mason, and Watts (2011)	Celebrities	Celebrities are among the most followed elite users.
Reuter et al. (2013)	Helper	Provide emotional assistance and recommendations for action, offer and encourage help, are involved in virtual and real activities.
	Reporter	Integrate external sources of information, thus providing generative and synthetic information as a news channel or eyewitness.
	Retweeter	Distribute important derivative information to followers or users, correspond with the information broker (Hughes & Palen, 2009).
	Repeater	Generate, synthesize, repeat and distribute a certain message to concrete recipients.
	Reader	Passive information-catching participants who are interested in or affected by the situation.
Kaufhold and Reuter (2014)	Moderator	Establishes supportive platforms, mediates offers and requests, mobilizes resources and integrates information.

of larger surveys on authorities' and citizens' perception on social media are summarized.

5.1 | Authorities' perception of social media

There are a few (quantitative) studies on authorities' perception of social media (Reuter & Spielhofer, 2016), although most are from North America. First, San, Wardell, and Thorkildsen (2013) analysed the results of a survey of a comparative study conducted in 2012 by the American National Emergency Management Association (NEMA) among members of emergency services from all 50 Federal States of the US about social media use in emergency management. Second, Plotnick, Hiltz, Kushma, and Tapia (2015) conducted a survey of 241 US emergency managers at county level in 2014 about use patterns, barriers and improvement recommendations for the use of social media during emergencies. Third, the annual study of the International Association of Chiefs of Police (IACP) reports about law enforcement's use of social media on "the current state of practice and the issues agencies are facing in regard to social media" (International Association of Chiefs of Police, 2015). Last but not least, Reuter, Ludwig, et al., (2016) published their findings of the survey conducted with 761 emergency service staff across Europe in 2014 about current attitudes and influencing factors towards the use of social media in emergencies.

On the one hand, there is a positive attitude towards the use of social media in general (San et al., 2013), including private and organizational use (Reuter, Ludwig, et al., 2016). The majority of US authorities already use social media as they value its suitability for information dissemination (San et al., 2013). This includes warnings, advice and guidance on how to cope with or prevent emergencies or disasters, hints and advice on how to behave during an emergency, coordination of the help of volunteers, summary information after an emergency and coordination of clean-up activities (Reuter, Ludwig, et al., 2016). Currently, agencies' use of social media has already increased from 81% (77% Facebook, 37% Twitter, 16% YouTube) to 96% (94% Facebook, 71% Twitter, 40% YouTube) during the last 5 years (International Association of Chiefs of Police, 2010, 2015). Additionally, the number of social media policies has also increased from 35% to 78% (International Association of Chiefs of Police, 2010, 2015). Further increase of social media use is expected (74%), even more for organizations already using it (Reuter, Ludwig, et al., 2016).

On the other hand, there are several restrictions within the use of social media: first, there is a huge gap between rhetoric and reality (Reuter, Ludwig, et al., 2016). Despite the overall positive attitude towards social media for obtaining an overview of the situation and for raising situational awareness, in fact only a few agencies have often or sometimes used social media sites for this purpose (Reuter, Ludwig, et al., 2016). As the predominant use of social media is more to share information (Reuter, Ludwig, et al., 2016; San et al., 2013) than to receive messages (Reuter, Ludwig, et al., 2016) so that only a modest use of social media can be observed, groundbreaking crowdsourcing and crisis-mapping activities are neglected (San et al., 2013). In addition, about 20% of the local and about 30% of the county agencies surveyed "had not identified a goal for social media operations" at all (San et al., 2013). Also, only about half of the observed emergency agencies at county level in the study of Plotnick et al. (2015) use social media at all.

Identified barriers for the use were despite a lack of dedicated personnel (San et al., 2013), doubts about its credibility and reliability (Reuter, Ludwig, et al., 2016; San et al., 2013), concerns about privacy issues (Reuter, Ludwig, et al., 2016) and still a lack of formal policies to guide the use of social media (Plotnick et al., 2015). But even for those emergency agencies who do have formal policies,

TABLE 3 Organizational perspective on social media roles

References	Role	Description
Olteanu et al. (2015)	Media organizations	Traditional or Internet media have a large presence on Twitter, in many cases more than 30% of the tweets.
Ehnis et al. (2014)	Commercial organizations	Publish rather small number of messages, for example, containing humorous marketing messages.
Olteanu et al. (2015)	Government	A relatively small fraction of tweets source from government officials and agencies, because they must verify information.
Reuter et al. (2011)	Community scouts	Proposed as amateur "first informers" to overcome the perceived unreliability of social media information for authorities.
St. Denis and Hughes (2012)	Trusted digital volunteers	Used during the 2011 Shadow Lake fire in virtual teams to inform a Type I incident management team about social media activities.
Bergstrand et al. (2013)	High-level formal organizational accounts	Used to formally inform the public about ongoing events in a unidirectional way of communication.
	Accounts for formal functions and roles	Distribute information about certain entities, retweet other civil security actors, and maintain a bidirectional communication.
	Formal personal accounts	Disseminate role-specific information and references of official work or actual topics.
	Affiliated personal accounts	Used for an expressive dissemination of information, personal opinions, reflections, and social conversation.
Kircher (2014)	Self-helpers and neighbourhood helpers	Directly affected by the event and work on overcoming it with or without organizational forces.
	Unbound, ad hoc, and spontaneous helpers	Come from areas, which are not directly affected, are motivated by news and media, and work self-organized or in an organization.
	Preregistered helpers and first responders	Have registered themselves before the event and contribute with personal but no special disaster control qualifications.
	Honorary office and full-time helpers	Trained in specific tasks for disaster control.

prohibitions for the use of social media still exist (Plotnick et al., 2015). Reasons for limited success in the use of social media could be stated for limited reach and insufficient resources as data collection and analysis capabilities (San et al., 2013). For this, enabling conditions for the use of social media could be identified within the organizational culture and skills (Reuter, Ludwig, et al., 2016) and the verification of citizen-generated content (San et al., 2013).

5.2 | Citizens' perception on social media

Very few quantitative studies have been conducted where citizens have been asked about their perception of using social media in emergencies. In particular, four are worth mentioning. These include a comparative study with over 1,000 participants conducted by the Canadian Red Cross (2012), which aimed to identify to what extent Canadian citizens use social media and mobile devices in crisis communication and what they expect from the emergency services both currently and in future. Secondly, the American Red Cross (2012) studied citizens' use of social media during emergencies, with 1,017 online and 1,018 telephone survey respondents. In the third study worth mentioning, Flizikowski, Hołubowicz, Stachowicz, Hokkanen, and Delavallade (2014) present a survey within Europe, conducted among citizens (317 respondents) and emergency services (130 respondents), which identified the possibilities and challenges of social media integration into crisis response management. Finally, Reuter and Spielhofer (2016) analysed the findings of a survey of

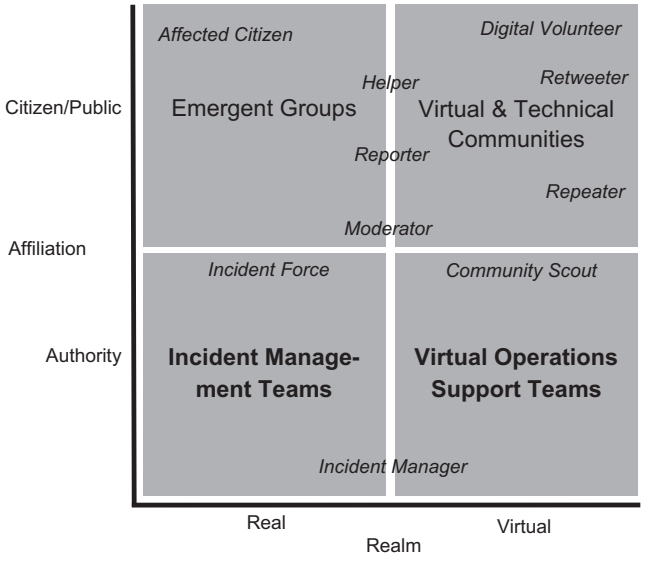

FIGURE 2 Role typology matrix

1,034 citizens across Europe conducted in 2015 to explore citizens' attitudes towards the use of social media for private purposes and in emergency situations.

In principal, the participants' attitude towards the use of social media was largely positive (Flizikowski et al., 2014). Benefits in using social media during emergencies can be seen in the reassurance for citizens, in providing situational information and monitoring

(Canadian Red Cross, 2012). Due to these benefits, social media is seen as a support for existing channels; however, it cannot replace them (Canadian Red Cross, 2012). In particular, friends, family, news media (or reporters) and local emergency officials are seen as the most trusted sources (American Red Cross, 2012). Therefore, the Canadian Red Cross employs "trusted volunteers" to support official response via social media (Canadian Red Cross, 2012). In contrast to authorities' use, citizens use social media rather to search (43%) than to share information (27%) (Reuter & Spielhofer, 2016). Most likely, users seek information about weather, traffic, damage caused and information on how other people were coping (American Red Cross, 2012). If they do provide information, users not only share weather information, safety reassurances and their feelings about the emergency but also their location and eyewitness information (American Red Cross, 2012).

5.3 | Towards comprehensive perception patterns

Even if the attitude towards social media is positive, only 12% of the general public, but still 22% of high school graduates, conducted in the study of the American Red Cross (2012), have used social media to share or obtain information during emergencies and disasters or in severe weather conditions. Because of this, challenges in the use of social media during emergencies were identified within all studies. Both, citizens and emergency services identify the same challenges (Flizikowski et al., 2014). Possible barriers for the use of social media are especially credibility doubts of citizen-generated content (Canadian Red Cross, 2012; Flizikowski et al., 2014; Reuter & Spielhofer, 2016), a lack of knowledge and personnel issues (Canadian Red Cross, 2012; Flizikowski et al., 2014), lacking uniform terms of use (Flizikowski et al., 2014) and difficult accessibility for older generations (Flizikowski et al., 2014). Regarding the trustworthiness, unknown people in the general vicinity of the emergency are the least trusted (American Red Cross, 2012) so that emergency services are expected to monitor social media (Reuter & Spielhofer, 2016). Beyond, unfortunately, there is only very little awareness of social media Safety Services and Emergency Apps (Reuter & Spielhofer, 2016).

6 | THE PAST AND THE FUTURE: DISCUSSION AND CONCLUSION

6.1 | Achievements of 15 years of research

Social media become more and more mature, however, not only social media in general—but also the use of social media in emergencies. Fifteen years ago, the first documented case of disaster support with social media was found, and for about 10 years, social media has been used in a more and more intensive way. Research has tried to examine different cases, different users, different methods, practices and tools; trying to support all actors involved in crises, disasters and emergencies of different type and size. Summarized under the term crisis informatics (Hagar, 2007; Palen et al., 2009), much has been achieved so far—and much is still to do. This article contributed to the development in providing a compilation about existing cases of social media use in emergencies—knowing that this list cannot be complete (section 2). Furthermore, the article analyses the state of the art regarding different use patterns (section 3). Based on this, different role patterns that have been identified across various studies are elaborated and synthesized (section 4). Additionally, perception patterns of both authorities and citizens are elaborated (section 5). Finally, in this section, we discuss the past and especially the future (section 6).

During nearly every larger emergency of the last 10 years and during many of the last 15 years, we found studies highlighting the use of social media. While many had a focus on the USA initially, studies from other continents are catching up allowing more comparative and systematic analysis across different circumstances and types of emergencies. Still, most of the studies focus on Twitter; we suggest this is based on the ease of data selection there (section 2). The analysis focused on different *usage patterns*, including the communication among citizen (C2C), with concepts of self-coordination and help, emergent groups and (digital) volunteers; the communication from authorities to citizens (A2C), including concepts of crisis communication; from citizens to authorities (C2A), including concepts like big data- or social media analysis, crowdsourcing and crowd tasking; and among authorities (A2A), including interorganizational social networks (section 3). Within the two basic affiliations of authorities and citizen as well as the real and virtual realms, various *role patterns* become apparent. Affected citizens and helpers form emergent groups to overcome the emergency on-site; digital volunteers self-organize in virtual and technical communities (V&TC) to remotely support amateur and professional response; emergency services deploy incident management teams (IMT) for professional on-site emergency response; and trusted digital volunteers are organized in Virtual Operations Support Teams (VOST) to assist professional response in the virtual realm (section 4). Also, social media is perceived in different ways by authorities and citizens, while the challenge is to match different expectations and to address current barriers. Both groups see the same challenges, like a lack of trust, lack of knowledge—however, citizens expect authorities to monitor social media (section 5).

6.2 | Future practice and research potentials

For future practice and research, many issues are still open: *Self-coordination and help (C2C)* have been proven to be of high importance; however, chaos is a characteristic pattern detected. Here, the question arises how this can be addressed. The automatic cross-media suggesting of relevant posts according to crises dynamics (Kaufhold & Reuter, 2016) of interest or the matching of needs and offers (Purohit et al., 2014) might help to structure communication, while flexibility is required as well. The granularity of citizen activities—are single citizens supporting or rather groups of citizens, like clubs—is also important to determine appropriate organization and work practices. Furthermore, currently many different tools are used

in an opportunistic way. The visibility of different practices that have shown to work seems important to facilitate appropriation among citizens and, in the long term, to improve disaster preparedness and overcoming. In *crisis communication (A2C)*, it is still a challenge to apply "perfect" crisis communication. According to some studies, many citizens expect responses to messages in social media from authorities within 1 hr (Reuter & Spielhofer, 2016). However, not all emergency services might be able to act in that speed, sometimes caused by a lack of personal, or a lack of skills, as some studies suggest (section 5). Press officers must adapt to a new role including more dynamics compared to presocial media times. The verification and careful creation of own posts are necessary which conflicts with the need of quick response. Therefore, types of communication, like instrumental or public-including expressive communication approaches (Denef et al., 2013), should be further elaborated, to also suggest smaller authorities ways of crisis communication.

For analysing and *integrating citizen-generated content (C2A)* from social media, research applied various algorithmic approaches (Imran et al., 2015). They, on the one hand, intend to detect or predict critical events and to transform the high volume of big and noisy data, which cannot be processed by emergency mangers in a limited amount of time before or during large-scale emergencies, into a low volume of rich and thick content (Moi et al., 2015). On the other hand, algorithms aim to detect underlying patterns (e.g., mood or geospatial correlations) using statistical approaches or visual analytics (Brynielsson, Johansson, Jonsson, & Westling, 2014; Fuchs, Andrienko, Andrienko, Bothe, & Stange, 2013). Social bots and fake news challenge these attempts. However, not only large-scale emergencies but also small incidents with suitable algorithms and different granularities and thresholds must be considered. While emergency managers are sometimes sceptical about the quality of citizen-generated content and social media (Hughes & Tapia, 2015; Reuter, Ludwig, et al., 2016), it must be ensured equally that they trust in the quality of algorithms as an additional filtering layer, for example, by providing a certain degree of customizability and transparency (white-box approach). Furthermore, research examined crowd sensing approaches to sharpen the authorities' awareness about citizens' activities (Ludwig et al., 2015; Sakaki et al., 2010). Concerning *inter- and intra-organizational crisis management (A2A)*, social media can be used for the coordination of crisis communication and more informal networking among authorities and employees. Here, structures of social media could support the development of collaborative ICT or inform encapsulated social networks. The latter have the benefit of trust, because the usage group is limited and controlled.

The systematization of *role patterns* and role properties potentially supports the interaction among authorities and citizens. For instance, a semiautomatic identification of role patterns (Reuter et al., 2013) and their display in social media may improve role awareness, the self-finding process and guidance for citizens to take a role. Due to the chaotic organization in such emergencies (Valecha et al., 2013), well-defined role properties could furthermore improve capacity planning for authorities and among citizens, for instance, to crowdsource tasks to the situationally correct audience. Considering these opportunities, the role typology matrix may be used to systematically optimize collaboration and communication structures among different crisis actors in the real and virtual realm, for example, to improve the communication between first responders and digital volunteers, or the incident manager's awareness of the activities and scope of VOST. Then, from an IT perspective, role patterns should inform the tailoring of ICT to support role-specific activities. This, however, is problematic because users tend to use general software they are familiar with, like Facebook, during emergencies and not always specific and maybe better tools. Here, applications that are embedded into the social media ecosystems, for example, Facebook apps, may allow a smooth appropriation of emergency-specific tools (Reuter, Ludwig, Kaufhold, et al., 2015).

The *perception* of social media is both a result and a starting point of the aforementioned aspects. It depends on own experiences and media coverage. Online rubbernecking is widely reported during crises (Bruns, 2014). However, while looking at the published studies (section 5), it seems that there is a gap between reported cases in academia, looking more at potentials, but also at risks, and the coverage by mass media, where negative aspects are more present. They include rumour propagation, dissemination of false or misleading information, ethical dilemmas (Alexander, 2013), and propaganda or social bots (Reuter, Pätsch, & Runft, 2017). Also, studies found that crisis-related social media traffic revealed a self-correcting mechanism (Jong & Dückers, 2016). Risks and bad sides of media usage cannot be controlled comprehensively, but research may try both to foster good sides and to guide bad aspects to the right direction. In addition to that, some studies about the perception of social media exist; however, they are not representative. This is also important as long as social media is used in different ways among countries. Trust is the main issue, so future work might focus on the key enablers, like positive examples of social media use. The feeling to be part of a movement that productively works together to overcome crises and emergencies is the intended result of this.

In sum, *crisis informatics* has achieved a lot. It is only sometimes named alike, but the use of social media in crisis management has been established as an important research area. This article could—as a limitation—just look at a part of it. The article tried to summarize some selected aspects to give a current overview and to suggest at least some aspects for the upcoming years.

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ENDNOTES

[1] http://socialmedia-institute.com/uebersicht-aktueller-social-media-nutzerzahlen/

[2] This table extends and earlier version (Reuter, Ludwig, Friberg, Pratzler-Wanczura, & Gizikis, 2015).

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