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Citation for published version:
Stieglitz, S, Hofeditz, L, Brünker, F, Ehnis, C, Mirbabaie, M & Ross, B 2022, 'Design principles for conversational agents to support Emergency Management Agencies', *International Journal of Information Management*, vol. 63, 102469. https://doi.org/10.1016/j.ijinfomgt.2021.102469

Digital Object Identifier (DOI):
10.1016/j.ijinfomgt.2021.102469

Link:
Link to publication record in Edinburgh Research Explorer

Document Version:
Publisher's PDF, also known as Version of record

Published In:
International Journal of Information Management

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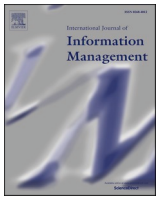
Download date: 25. Apr. 2022

International Journal of Information Management 63 (2022) 102469

Contents lists available at ScienceDirect

International Journal of Information Management

journal homepage: www.elsevier.com/locate/ijinfomgt



Research Article

Design principles for conversational agents to support Emergency Management Agencies

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ARTICLE INFO

Keywords:
Conversational agents
Chatbots
Design principles
Crisis communication

ABSTRACT

Widespread mis- and disinformation during the COVID-19 social media "infodemic" challenge the effective response of Emergency Management Agencies (EMAs). Conversational Agents (CAs) have the potential to amplify and distribute trustworthy information from EMAs to the general public in times of uncertainty. However, the structure and responsibilities of such EMAs are different in comparison to traditional commercial organizations. Consequently, Information Systems (IS) design approaches for CAs are not directly transferable to this different type of organization. Based on semi-structured interviews with practitioners from EMAs in Germany and Australia, twelve meta-requirements and five design principles for CAs for EMAs were developed. In contrast to the traditional view of CA design, social cues should be minimized. The study provides a basis to design robust CAs for EMAs.

1. Introduction

In crisis situations, people use social media alongside traditional news sources to search for information about the event or to share their experiences with friends or the public (Nabity-Grover, Cheung, & Thatcher, 2020; Stieglitz, Mirbabaie, Ross, & Neuberger, 2018). This is due to a high amount of uncertainty and ambiguity particularly in the early stages of a crisis (Mirbabaie, Bunker, Stieglitz, Marx, & Ehnis, 2020). Problems of information overload, rumors, conflicting information, and mis- or disinformation (Mirbabaie et al., 2020) can result from this behavior. Whereas misinformation means propositional content that is false but unintentional, disinformation is propositional content that is false on purpose (Mingers & Standing, 2018). Previous research showed that the virality of misinformation increases during crisis events (King & Wang, 2021).

Past crises such as massive bushfires in Australia or California (Beydoun, Dascalu, Dominey-Howes, & Sheehan, 2018), floods (Tim, Pan, Ractham, & Kaewkitipong, 2017), storms (Mirbabaie et al., 2020), terrorist events (Mirbabaie, Stieglitz, & Brünker, 2021), or the Covid-19 pandemic sparked broad discussions on various social media channels. The avalanche of information mixed with misinformation on social media was in the early phase of the COVID-19 pandemic referred to as an "Infodemic" (Zarocostas, 2020), which illustrates the issues which need to be dealt with in crisis social media communication. The uncontrolled diffusion of mis- and disinformation leads to an increased demand for reliable and up-to-date information by the general public (Elbanna, Bunker, Levine, & Sleigh, 2019). Emergency Management Agencies (EMAs) are struggling to cover the demand (Ehnis & Bunker, 2020), and thus, sophisticated solutions for filling the information gap are needed. This is also due to challenges in information exchange and management such as inaccessibility of information, inconsistent formats, inadequate information streams, a low priority of information diffusion, a difficult source identification, a media storage misalignment, unreliability or unwillingness of stakeholders (Altay & Labonte, 2014). As governmental actors (Aladwani & Dwivedi, 2018), EMAs need resources or approaches to interact with a large quantity of concerned citizens (Zhang, Fan, Yao, Hu, & Mostafavi, 2019). The social media communication pattern is a one-to-many (EMA-to-public) and

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https://doi.org/10.1016/j.ijinfomgt.2021.102469
Received 3 November 2020; Received in revised form 18 December 2021; Accepted 29 December 2021
Available online 13 January 2022
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many-to-one (public-to-EMA) communication for which robust practices and solutions still need to be developed.

One important solution space to improve crisis response and emergency management is the use of information and communication technologies and artificial intelligence (AI) (Fan, Zhang, Yahja, & Mostafavi, 2021). AI can be used not only for direct crisis response during natural disasters, but also to support long-term aims such as sustainability (Nishant, Kennedy, & Corbett, 2020). During hard to predict crisis situations such as during the Covid-19 pandemic, AI-based systems can assist managers and leaders in making effective and efficient decisions (Dwivedi et al., 2020). Thus, AI-based systems can be used to analyze crisis-relevant images and assign them to a region using semantic content classification or to assess damage to specific objects, such as bridges or roads. Furthermore, Natural Language Processing (NLP) and data mining techniques can be applied to detect and predict critical events and identify patterns based on social media data (Fan et al., 2021). Another approach of applying NLP is the use of Conversational agents (CAs) (Balakrishnan & Dwivedi, 2021a, 2021b). They can not only interact with users in natural language (McTear, Callejas, & Griol, 2016) but also provide an enjoyable user experience (Diederich, Brendel, & Lichtenberg, 2019). CAs are capable of assisting users in a variety of tasks such as answering frequently asked questions or providing ideas and inspiration at the workplace (Lembcke, Diederich, & Brendel, 2020).

In crisis communication they could solve problems such as providing real-time translation for outgoing and incoming messages via social media channels, provide location-specific information, answering frequently asked questions of citizens regarding ongoing disasters fast and accurately, or autonomously collecting and analyzing disaster relevant data (Hofeditz, Ehnis, Bunker, Brachten, & Stieglitz, 2019). CAs have already been tested to autonomously answer questions from members of the public (Ahmady & Uchida, 2020) or to coordinate spontaneous volunteers (Gerstmann, Betke, & Sackmann, 2019). First studies indicate that they can be applied to disseminate and collect information in crisis situations such as water-related crises (Tsai, Chen, & Kang, 2019) or the Covid-19 pandemic (Maniou & Veglis, 2020).

However, past systematic and comprehensive information systems (IS) research on the design of CAs mainly focused on the deployment in commercial organizations for customer support (Gnewuch, Morana, Adam, & Maedche, 2017), virtual collaborative work (Brachten, Brünker, Frick, Ross, & Stieglitz, 2020), or learning environments (Graesser, Li, & Forsyth, 2014). In contrast, EMAs facing crisis situations have unique requirements such as speed, effectiveness and efficiency (Fan et al., 2021) that directly or indirectly affect the safety of human lives. This makes it problematic to rely on knowledge about CA design that was solely developed in the context of commercial organizations and businesses. We think that existing knowledge cannot simply be adopted in an emergency management environment but needs to be carefully transferred and developed. The requirements of EMAs for structure, responsibilities and operations' management significantly differ from those of commercial organizations (Ehnis & Bunker, 2020; Hofeditz et al., 2019). Thus, it is crucial to derive specific design principles of CAs in crisis communication so that they can suit the needs of EMAs in crisis situations. We therefore aim to answer the following research question from a lens of interpretivism and a constructivism ontology (Goldkuhl, 2012):

RQ: How should conversational agents be designed to improve social media crisis communication of EMAs?

We adopted an interpretivist philosophy in order to gather empirical evidence from employees of several organizations from two countries (Australia and Germany) (Kwayu, Abubakre, & Lal, 2021). Our aim was to understand how CAs need to be designed to support EMAs in their crisis communication. For this, we needed to conduct data for further interpretation. We conducted 16 semi-structured interviews with crisis management experts in Australia and Germany. Through this research, this study will enrich knowledge about CAs in crisis situations and about fighting disasters by revealing the special requirements that EMAs have for CAs, and by comparing these against current CA design principles in IS research. Furthermore, by introducing specific design principles for CAs in crisis situations, this study provides a foundation which practitioners may use to develop more sophisticated CAs, and thereby help the fight against "Infodemics" by reducing information overload and reducing false information during large scale crisis events.

2. Literature review

2.1. Specificities of Emergency Management Agencies

EMAs are typically government organizations with the focus of minimizing the effects of crisis events. Their main premise is to save lives and to minimize damage. Such organizations do not have a profit-driven focus, but their operations are limited by the funding they are receiving. The members of EMAs can be paid professionals, such as in most city fire departments, predominantly volunteers, such as in the NSW State Emergency Service in Australia, or a mixture of both, such as the Country Fire Authority Victoria in Australia.

EMAs are hierarchically structured with clear command and control systems and practices in place (Bunker, Levine, & Woody, 2015; Gupta, Starr, Farahani, & Matinrad, 2016). EMAs are operating in two distinct modes, an operational mode, when they are responding to a crisis event, and a non-operational mode in between crisis events (Ehnis and Bunker 2020). Although cooperation between different EMAs is highly important during crisis events, prior research showed that EMAs often lack interoperability due to vastly different goals among organizations (Shareef et al., 2019). Altay & Pal (2014) therefore examined, how information diffusion can be increased by establishing trust and a high level of information quality. Following an agent-based modeling approach, they concluded that cluster leads should act as hubs and establish long-term relationships in order to facilitate and filter information between agencies. For this, humanitarian operations also need to lead complex interaction between deployed technology and humanitarian groups. Considering the complex character of humanitarian operations that arises, among crisis-related issues, from rapidly formed teams, intergroup leadership might reduce complexity and increase performance among the various subgroups (Dubey et al., 2020; Salem, Van Quaquebeke, Besiou, & Meyer, 2019).

It is well known that social media is an influential communication channel during crisis events (Tim et al., 2017). EMAs realized the value social media can provide and adopted various social media platforms to their communication portfolio to provide timely trustworthy information, counter rumors and misinformation, and provide recommendations for individual actions (Elbanna et al., 2019; Hofeditz et al., 2019). Previous research highlighted that demographic characters and ethnical groups differ in responses and behaviors during crisis events, resulting in different communication strategies for EMAs (Yuan, Li, Liu, Zhai, & Qi, 2021). While EMAs have adopted social media platforms for communication with the public, they often lack the ability to systematically track and analyze social media data (Ehnis and Bunker, 2020). However, activities such as identifying and analyzing potential emergency and crisis situations, developing coping strategies, and initiating and tracking countermeasures are crucial for successful crisis management (Mirbabaie et al., 2021). While some of these strategies overlap to some extent with the approaches used by commercial organizations to engage with their audiences, a distinction must be made between the motives of commercial and EMA organizations. In contrast to traditional commercial organizations whose actions are mainly based on their own economic needs, EMA's overriding goal is to protect people and the common good. To this end, various strategies are applied by EMAs such as (local) community management, volunteer management and research (Fischer-Preßler, Schwemmer, & Fischbach, 2019). These emergency management strategies are aligned to the prevention, preparedness, response, and recovery phases of a crisis (Wenger, 2017). Emergency

management activities include the provision of reliable real-time information during and between crises. EMAs use social media to provide information to the public and only to a much lesser extent to protect their own reputation. Commercial organizations, on the other hand, focus in their crisis communication predominantly on the protection of their own reputation.

Compared to the need of providing rapid and reliable information in a public crisis event by EMAs, research has shown that for traditional commercial organizations the absence of communication is a strategy that could fulfill the organization's needs (Stieglitz, Mirbabaie, Kroll, & Marx, 2019).

2.2. Crisis communication and technology use of Emergency Management Agencies

During crises, the public's need for information is closely related to the crisis itself as well as the degree of individual involvement. At the same time, EMAs need information from the public, for example, to maintain supply chains during crisis events (Shareef, Dwivedi, Kumar, Hughes, & Raman (2020). Furthermore, EMAs need to adapt to the ongoing development of the situation and may change communication strategies over time. Therefore, EMAs can distribute information towards non-institutional actors (Abedin & Babar, 2018), such as members of the general public, and institutional actors, such as media organizations (Mirbabaie et al., 2020). In this context, it is important that policy makers of the involved (non-) governmental organizations do not only consider crisis response and preparedness but also pursue the prevention of potential crises as well as the reconstruction of the damaged economy (Shodhi, 2016). The planned operations still need to be communicated and coordinated between the participating parties. For example, Shodhi & Knuckles (2021) highlight the various flows of information, money, and materials among several stakeholders of a development-aid supply chain. The number of different stakeholders including different requirements emphasizes that proper information technology is pressingly needed for successful coordination and collaboration. EMAs are often information starters within the emerging communication networks during a crisis (Nabity-Grover et al., 2020), whereas individuals are often information amplifiers and information transmitters (Mirbabaie et al., 2020). While social media technologies are beneficial to support emergency management-relevant tasks (Oh, Eom, & Rao, 2015), EMAs still seem to struggle with adopting these technologies into their crisis-related operations (Ehnis & Bunker, 2020). Resources, particularly in the early stages of an event, are limited (Power & Kibell, 2017), and many tasks rely on manual processes (Ehnis & Bunker, 2020).

Social media CAs, in particular chatbots, have the potential to support EMAs with their social media activities (Hofeditz et al., 2019). However, EMAs are a subset of traditional command and control organizations, and therefore, bring together their proven organizational structures, processes, technologies, and IS (Ehnis & Bunker, 2020). Consequently, EMAs cannot just unreflectively implement chatbots which were designed for commercial organizations; there is a need to rethink and critically assess the design requirements which are necessary to successfully utilize social media chatbots in an emergency management environment. As CAs are part of the multidisciplinary perspectives of artificial intelligence, challenges and opportunities need to be addressed (Dwivedi et al., 2019).

2.3. Conversational agents for crisis communication in Emergency Management Agencies

For conversational technologies such as CAs, some inconsistencies exist in prior research regarding terminology being used and the corresponding meaning (Brachten, Kissmer, & Stieglitz, 2021). The term CA, in the current body of knowledge, is often seen as an umbrella which includes different types of human-computer interaction systems such as chatbots (Duan, Edwards, & Dwivedi, 2019), digital assistants, virtual assistants (Mirbabaie et al., 2021) or voice assistants (Laumer, Gubler, Racheva, & Maier, 2019). CAs are ISs which can communicate with human users by using and processing natural language (Laumer et al., 2019). They have been examined in areas such as healthcare (Denecke, Vaaheesan, & Arulnathan, 2020), education (Demetis & Lee, 2018) or customer service (Gnewuch et al., 2017). In research, the terms CA, chatbots and digital assistants are sometimes used synonymously (Gnewuch et al., 2017). Nowadays CAs can act more sophisticatedly and they are applied to several tasks and processes using machine learning (Mirbabaie et al., 2020). CAs can be embodied which means that they have an animated visual representation that engages face-to-face with users (Norman & Kirakowski, 2018). CAs are actively used to assist companies in communicating with customers and have been tested in many different cases such as medicine and education (Griol, Carbó, & Molina, 2012; Laumer et al., 2019). In a commercial context, CAs are an established technology and they have been found to be very helpful in automating tasks and communication.

However, crisis communication and EMAs have different requirements which need to be addressed separately. Thus, during most crisis events such as natural disasters (Hofeditz et al., 2019) or terrorist attacks (Gupta, Starr, Zanjirani Farahani, & Ghodsi, 2020), it is very important to receive assistance in resource allocation. In the context of crisis communication and emergency management, the literature indicates that CAs are used on various social media channels in the form of chatbots.

There are examples of prototype chatbots which provide crisis-relevant information to individuals in affected areas. To reduce the problems of rumor spreading and increase reliable information on social media, Ahmady & Uchida (2020) examined the utilization of chatbots providing earthquake-related information in Japan to foreigners. This application showed that chatbots could be used to reduce language barriers and provide reliable real-time information to a specific audience. Furthermore, Tsai et al. (2019) evaluated a CA that is connected to a crisis-related data base. They showed that the CA can help crisis-affected people by providing personnel access to crisis-related data in a flood context. This allowed individuals to follow corresponding response strategies. By this, people mitigate potential harmful information related to the individual decision-making process. Beside the problems of conflicting information, rumors, or information overload, spontaneous volunteers are often a crucial factor for saving lives during a crisis. Gerstmann et al. (2019) investigated the role of CAs for coordinating the behavior of spontaneous volunteers. The scholars emphasized the potential of CAs being applicable for individual assignment and scheduling of volunteers during a crisis. This automated coordination may reduce the work-load of EMAs in crisis situations. Regarding research about CAs and task-support showed that CAs are able to reduce the cognitive load of an individual (Brachten et al., 2020) that may lead to an improved crisis management. CAs such as social media chatbots are already applied and evaluated (Maniou & Veglis, 2020). The authors investigated a working CA that disseminate accurate, timely as well as customized information. They argue that the CA's ability of providing customized information to the public is helpful to fit the individual preferences of information selection.

However, the research on the application of bots in crisis communication by EMAs is still very young. Evaluated frameworks or established design approaches in this field do not exist at this time.

2.4. Design principles for conversational agents in IS research

In their essence, design principles are statements that contain information and practices that need to be embedded in the design and development of IS (Chandra, Seidel, & Gregor, 2015). They consist of relevant knowledge and decisions that need to be manifested in artefacts, methods, processes, or whole systems (Mirbabaie et al., 2020). As already described in the previous sections, CAs are particularly suitable to counter challenges related to the dissemination and collection of

Table 1
Design principles for CAs in the existing IS literature.

Design Principle	Description	Source
(1) Sociability	Provide the CA with the ability to adapt its conversation style in order to communicate in the user's preferred way.	Feine et al. (2019), Tavanapour et al. (2019), Meier et al. (2019), Radziwill & Benton (2017), Misiura & Verity (2019)
	Design the agent with appealing social cues in order to contribute to the perception of humanness, social presence and enjoyment in the interaction without fostering feelings of uncanniness.	Diederich et al. (2020), Tavanapour et al. (2019), Meier et al. (2020), Strohmann et al. (2019), Radziwill & Benton (2017)
(2) Proactive Communication	Provide the CA with the ability to use proactive messages in order to automatically notify users about changes.	Feine et al. (2020), Misiura & Verity (2019)
	Equip the agent with conversational capabilities for intent detection in order to increase its usefulness, given that the input of the user can be anticipated by the designer.	Diederich et al. (2020); Tavanapour et al. (2019), Radziwill & Benton (2017)
(3) Transparency	Provide the CA with functional transparency so that users can understand its functions and decisions.	Feine et al. (2020)
	Self-identify the agent as a machine, present exemplary capabilities and offer the possibility to get in touch with a human representative in order to manage user expectations and decrease potential feelings of uncanniness.	Diederich et al. (2020), Strohmann et al. (2019), Radziwill & Benton (2017)
(4) Flexibility	Provide the CA with conversational flexibility in order to react to changing contexts, tasks, and data requests.	Feine et al. (2020), Radziwill & Benton (2017)
(5) Usability	Provide the CA with user-friendly interactive capabilities in order to create an effective, efficient, and satisfying communication experience.	Feine et al. (2020), Meier et al. (2020)
	Guide the user in a conversation where required, foster context-specific handling of fallbacks, and iteratively extend the agent's conversational abilities from dialogue data in order to increase the agent's responsiveness.	Diederich et al. (2020); Tavanapour et al. (2019), Radziwill & Benton (2017)
(6) Error Handling	Provide the CA with the ability to handle errors of any kind and to save them for future improvements.	Feine et al. (2020), Strohmann et al. (2019), Misiura & Verity (2019), Radziwill & Benton (2017),

reliable information (Ahmady & Uchida, 2020; Tsai et al., 2019) or support EMAs in real-time crisis management (Gerstmann et al., 2019; Maniou & Veglis, 2020). In these application fields, CAs are subject to crisis-specific requirements. Thus, we need to develop design principles aiming at alleviating crisis-related issues.

Radziwill & Benton (2017) developed a high-level list of quality attributes which should be embedded in the design of a chatbot. (1) Performance, which involves the timely and robust interaction with a user. The CA should be particularly able to handle unexpected input. (2) Functionality, which includes the functions of the CA as well as the linguistic capabilities. (3) Humanity refers to the realism of the conversation and potential ability to pass the Turing Test. (4) Affect, which encompasses the emotional capabilities of the CA. (5) Ethics, which refers to security and privacy as well as cultural knowledge and practices towards the user audience. (6) Accessibility, which refers to the ability to be operated by a diverse set of users.

At their core, CAs in the crisis management sector need to provide a comprehensive and clear human-computer interaction. Subsequently, they need to apply to interaction principles (Misiura & Verity, 2019) as outlined by Molich & Nielsen (1990): The interaction should consist of simple and natural dialogue, use language which is familiar to the intended user, use simple instructions, minimize the user's memory load, be consistent, provide feedback, provide shortcuts, and have a design that prevents errors. Further research in the context of citizen participation derived distinct design principles describing that CA should provide social cues and conversational capabilities to ensure goal-oriented facilitation as well as display messages in simple and understandable language (Tavanapour, Poser, & Bittner, 2019). Likewise, Meier, Beinke, Fitte, Behne, & Teuteberg (2020) suggest that CA should meet the user's expectation to enable goal-oriented conversation. To this end, distinct input and output devices should be supported by the CA that is based on an information-focused interface. Regardless of the place of application, Strohmann, Höper, & Robra-Bissantz (2019) postulate that a VA should provide a robustness to errors and should not pretend to be human.

However, as CAs interact with their audience through natural language, which is a quasi-social interaction where information and meaning are transferred between a human actor and a technological actor, the interaction should be able to support social triggers. Feine, Gnewuch, Morana, & Maedche (2019) identified a taxonomy of verbal, visual, auditory, and invisible social cues from the literature. Cues as a form of social signals (Feine et al., 2019) show that the meaning of the communication in CA-to-user interaction is not just transferred through the text which is provided but on multiple levels of social communication. Applying the concept of social cues towards CAs in enterprise communication, Table 1 outlines design principles for CA in IS literature.

3. Material and methods

Research that matches the unquestionable need of EMAs for more automated communication and the IS literature stream of CAs is very limited. Therefore, we followed an exploratory approach to identify design principles for CAs that can be applied by EMAs to improve their crisis communication. As this qualitative research takes the perspective of an "interpretivist" ontology, we argue that individuals "*do not passively react to an external reality but, rather, impose their internal perceptions and ideals on the external world and, in so doing, actively create their realities*" (Suddaby, 2006, p.636). Thus, to obtain and understand the individual perspectives and relationships (Morgan & Smircich, 1980), we conducted 16 semi-structured interviews (Myers & Newman, 2007) with representatives of EMAs from Australia and Germany. Two trained researchers coded the transcripts of the interviews. Based on a random interview sample including 62 code segments, a reliability score for coding data of $\kappa = 0.95$ could be reached (Cohen, 1960). Based on the strength of agreement classification by Landis & Koch (1977), this score can be understood as *almost perfect* agreement.

Furthermore, information the interviews provide may be biased, and thus, the principle of triangulation is essential in terms of validity of the study. Triangulation is "used to refer to the observation of the research issue from (at least) two different points (Flick, 2004, p.193). In order to address multiple perspectives in our research issue's observations, we adopted a *multiple triangulation* approach (Denzin, 2009).

We chose Australia and Germany as two countries because of their federal structure and contrasting risk profile of different crisis events building the prerequisite for the *triangulation of data* in qualitative research. Furthermore, we conducted interviews from two different countries, at different times, in different places and from different

people to further ensure proper triangulation of data that allows the transferability of our findings by not focusing on a single source (Patton, 1999). To balance out subjective influences of individuals, we also aimed for *investigator triangulation* using two different interviewers (Flick, 2004). The perspective of a researcher can have a significant influence on the entire research design (Clarke & Davison, 2020). We therefore discussed findings and coding among the individual authors' perspectives to further balance subjective influences. Regarding the *triangulation of theories,* we aggregated design principles based on various IS research perspectives as referred in Table 1. This juxtaposition ensures considering multiple perspectives on the design of CAs.

Furthermore, the researchers could get access to experts from several emergency management organizations through existing collaborations in these countries. We consulted experts that work in the area of crisis communications, social media crisis communication, intelligence, and operational response on a state level as their agencies are in charge during large scale crisis situations. The organizations we considered included EMAs that are in charge or at least involved during major crisis situations such as natural disasters (pandemics, forest fires, floods, etc.) or man-made disasters (terror attacks, oil spills, financial crises, ect.). A complete list of all interviewees can be found in the Appendix in Table 4.

For conducting the interviews, we used two interview guides (one in German and one in English) divided into six main sections. For the interview guides we considered different categorizations of crisis situations (Imran, Mitra, & Castillo, 2016; Wenger, 2017) and provided a definition of CAs (Gnewuch et al., 2017). After the introduction part, the use of social media by EMAs was queried. We asked concrete questions related to social media goals, guidelines, strategies, and types of messages that they publish during disasters. To determine the interviewees' role in crisis communication, the third section of the interview dealt with questions about concrete disaster cases. This included aspects like subjects' involvement and participation (Kamboj, Sarmah, Gupta, & Dwivedi, 2018). We focused on their practical work as EMAs, but also on their crisis communication during these events.

As a transition to the next part of the interview, the participants were asked if they knew of any chatbot activities during disasters. If not, they were asked what they generally imagined when they thought of bots and if they had ever recognized any automated accounts on social media platforms. We then asked if the subjects used CAs in their organization and if so, how they used them. To examine suitable application fields of chatbots in respective disaster phases, the fifth part of the interview emphasized the occurring problems and needs of organizations who use online communication for disaster management. Afterwards, we asked about challenges of social media emergency management. Interviewees were asked to highlight areas in which CAs could be applied, based on their knowledge of missing aspects and problems with the crisis communication. In the last interview section interview partners were asked to name the most important tasks in online communication during a disaster. Based on this, they were then asked which specific tasks CAs could take over to support the EMAs. Finally, we asked the interviewees whether they saw problems in the use of chatbots or if there were areas that should not be adopted. Overall, the approximately one-hour interviews contained 18 main questions with several subquestions.

The interviewees were recruited by email and through existing contacts via phone. They received an information sheet in advance and they were informed about the general conditions of the interview on the interview consent form, which ensured that they agreed that the interviews were recorded and notes taken. All interviews were conducted by two researchers each. We interviewed all experts at their usual workplaces and conducted the interviews when there was no acute crisis situation, so that the emotional, cognitive and motivational condition of the subjects could be described as stable. The interviews were transcribed manually.

We started analyzing our data with open coding (Glaser & Strauss, 2017). We then carried out a qualitative content analysis according to Mayring (2015) to code the data and to derive a category system. The goal of the content analysis was to identify specific requirements for chatbots that can improve the crisis communication of EMAs. Therefore, the analysis form of reduction was selected, to summarize the interview materials to the essential components and to provide appropriate categories suitable for the research questions. We created a codebook with eight coding categories including:

1. Contextual requirements of chatbots in crisis communication
2. Technical requirements of chatbots in crisis communication
3. Organizational requirements of chatbots in crisis communication
4. Legal requirements of chatbots in crisis communication
5. Reasons for EMAs to apply a chatbot for their crisis communication
6. Existing implementation approaches for chatbots in EMAs
7. Possible challenges and problems of using chatbots in an EMA
8. Reasons not to use chatbots in an EMA

After categorizing the interview data according to our codebook, we extracted meta requirements for CAs in crisis communication and management. For this, we followed Gnewuch et al. (2017).

4. Results

We found that all interviewees were very receptive to CAs and other forms of automated crisis communication and some were already using or testing the application of chatbots for their crisis communication. Our interviewees mentioned common requirements for CAs as a support in their organizations such as the ability to answer frequently asked questions in the context of disasters such as bushfires or floods (RMM). However, we found that in crisis communication there are also specific requirements for CAs to support both organizations and the public. For example, three interviewees (CL, EMI, REC) stated that CAs supporting crisis communication should actively ask users for further information about the crisis in their environment: "Then you might have a bot that might go, "Hey, your photo looks really interesting to us. We'd like to use it to help respond better. Could you please tell us when you took the photo, where you took it?" (EMI). This led us to MR1, the CA should actively ask for further information on the crisis (e.g., a fire, flood or storm) in the user's environment.

Another important requirement we identified was the reduction of social cues to a minimum. It was important to the interviewees that communication with a CA was purely functional and focused on content: "But making sure that what you're putting out is, like I said, [.] it's not confusing, and it's concise and clear" (PCB). This was mentioned especially in the context of short-term crisis events such as bushfires in Australia (PCB). This led us to MR2, social cues should be reduced to a minimum (see Table 1).

Another specific requirement for a CA in crisis communication that we identified is to label the source and how up-to-date the information is. As interviewee CL said: "This [information] is from [fire department], the official site. This [information] is the update". The information source could be linked to allow users to be directed to the source (CL, REC). This requirement was mentioned in the context of many different disaster types and led us to MR3, the CA should indicate the source and timestamp of each piece of information it provides.

It should also be clearly indicated whose opinion the CA represents: "[if] it's not labeled as a social media thing but it's an official advice from [fire department] or police or whatever then people will trust it". For this purpose, the CA must also be clearly marked as non-human. With one exception, the interviewees agreed on this point: "make sure that people do know that they're talking to a bot" (CL). This requirement was mainly mentioned in the context of fires and led us to MR4.

Another requirement (MR5) that we identified was that the CA should also clearly communicate how the user data is processed: "It's about privacy" (EMI). Since user inputs are partly used by organizations to improve their response to a crisis, the user must be informed about how they are used. These three requirements MR3, MR4 and MR5 thus

Table 2
Meta requirements derived from interviews.

Meta requirement	Interviewees
MR1: The CA should actively ask for further information on the crisis in the user's environment.	CL, EMI, REC, VSM, MAN, FFC, DRN
MR2: Social cues should be reduced to a minimum.	REC
MR3: The CA should indicate the source and timestamp of each piece of information it provides.	ASE
MR4: It should be clearly visible to users whose opinion the CA represents and that they are communicating with a CA.	CL, REC, EMS, VSM, JJN
MR5: The CA needs to clearly communicate how the user's input/data is processed.	EMI
MR6: The user should be able to input not only text, but also pictures, videos and location data.	EMS, EMI, VSM, FFS
MR7: The CA should be able to provide location-based information.	PCB, CMM, REC, FFS
MR8: The CA should be able to process multiple languages such as local languages and languages of minorities.	RMM, FFS
MR9: It should be ensured that the CA is connected to the systems and databases of the EMAs in order to retrieve information and store user inputs.	CL, VSM, FFS
MR10: It should be ensured that the CA can be accessed not only at one, but at multiple contact points.	PCB, CL, EMS, VSM, JJN, FFS
MR11: It should always be possible that the user is forwarded to a human.	CL, VSM, MAN, DRN, FFS
MR12: The CA should also be able to answer questions not directly related to the crisis.	REC, JJN, FFC, DRN

Table 3
Derivation of the design principles based on identified meta-requirements.

Design principle	Corresponding meta requirements	Description
DP1: Targeted communication in Crisis Situations	*MR1, MR2*	Provide the CA with a minimum of social cues and actively ask people for further information regarding the crisis event in order to focus on providing and distributing specific knowledge.
DP2: Special transparency during the Crisis Situation	*MR3, MR4, MR5*	For every piece of information, provide a suitable source (provided with a URL to further information) and a time stamp, explain how the user's input is processed. Furthermore, label the CA as a bot of a specific organization in order to achieve a high level of trust.
DP3: Appropriate implementation of the CAs in EMAs	*MR6, MR7, MR8*	Provide the CA with location-based information and the functionality to allow media content (text in multiple relevant languages, pictures, videos), in a possible combination with location data in order to collect more information about the crisis.
DP4: Interoperable integration of CAs among different digital platforms	*MR9, MR10*	Connect the CA to the intelligence systems of the EMAs and provide the CA platforms (such as social media platforms and an official website) in order to make sure to deliver reliable and current data and to reach as many people as possible.
DP5: Take the user seriously, also if it is not crisis related	*MR11, MR12*	Provide the CA with the functionality to forward specific requests of a user which may not be crisis related to a human encounter in order to leave no question unanswered and minimize uncertainty.

aim to create trust among users through transparency.

It was also very important to the interviewees that users could not only enter text as input, but also pictures, videos and spatial information. One interviewee, as an example, stated that it would be very helpful if "[.] there is somebody there with a phone or whatever posting a video [.]" (REC) he or she could send it through a CA. Location-based information was also considered necessary as an input during fires and floods, because EMAs need it to be able to send targeted messages regarding a crisis. This led us to MR6.

The EMAs we considered have the option of disseminating information in a local area in crisis situations via technology such as an app or SMS: "Yes, an emergency alert originally came out and it would go to hardlines and mobile phones with– Where people have an address in an area. Then it progressed to where people are in the area" (PCB). According to our interviewees, a CA should also have the ability to send this location-based information to users, because some warnings and recommendations for action only apply in certain areas while in other areas they could lead to uncertainty: "A chatbot automates that. What is my fire district? It knows that based on your location. [.] this is what you need to know based on your district, because of your district and because of your fire danger rating today this is what you can do, this is what you cannot do, all of those" (EMS). Based on these requirements in the context of fires, we derived MR7 described as the CA should be able to provide location-based information.

Not only the ability to provide location-based information was mentioned frequently, but also the capability to process and respond to multiple languages. Our interviewees stated that during a bushfire in Australia a wide range of different groups of people can be affected such as tourists, immigrants or even indigenous communities which all speak different languages. According to our interviewees (RMM, EMS), an essential requirement for a CA is to understand the most common languages in the local area, because a manual answer would be too slow and too time consuming for the EMAs. That led us to MR8: the CA should be able to process multiple languages such as local languages and languages of minorities.

It was especially important to our interviewees and their organizations that the systems and databases already in use have to be connected to the CA. One interviewee said that it would be important "to provide chatbots that we would then plug in to our own systems. [.] if things are connected into each other that adds a greater value to it" (RMM). This led us to MR9.

In crisis situations, it is often difficult to reach people, because not everyone uses the same information channels. Therefore, EMAs rely on different contact points, such as different social media channels, websites or apps, to reach the largest possible percentage of the affected population. Therefore, a requirement for CAs to improve crisis communication was to place the same CA on different channels simultaneously: "It could be something that is trusted by the user who has a file or a presence on the internet, but it is actually visible in a number of different ways on different platforms but it's the same bot" (EMI). This led us to MR10 that emphasizes it should ensure that the CA can be accessed not only at one, but at multiple contact points. Both MR9 and MR10 point out a need for interoperability and integration into different systems.

Even though CAs can relieve EMAs of their work in crisis situations, there was a consensus for the context of different disaster types that there should always be the option of a user being referred to a real person (MR11).

The CA should also be able to answer questions that are not directly related to the current crisis situation (CL, REC) in order to prevent users who may need help from running into a dead end (MR12). However, in such cases, according to our interviewees, the contact to a human should

always be offered directly: "They had to put in some pretty clear triggers for when something like that would activate a real person for them to then get onboard and to assist them and give them help" (EMS).

The summary of our meta requirements can be found in Table 2.

5. Discussion

This paper is at the interchange of emergency management and IS where practical strategies will contribute to mitigate the impact of a crisis. The study aims to answer the question of how CAs can be designed to improve crisis communication of EMAs and thus to fight pandemics. To this end, five major design principles revealing specific characteristics of CAs in the context of crisis communication during disasters were identified.

5.1. Design principles for CA in crisis management

Table 3 shows the derived design principles aligned with the identified meta requirements. For the derivation of the design principles, we followed the approach outlined by Lechler, Stoeckli, Rietsche, & Uebernickel (2019).

The first design principle, Targeted Communication (DP1), highlights the importance of providing the CA with a minimum of social cues. This may allow affected people to focus on reliable information. This DP contradicts the findings of Feine et al. (2019) who emphasize the importance of CA's social cues for several CAs In the context of disasters, excluding social cues of a CA might lead to a lower application of stereotypes, e.g., gender stereotypes (Nass, Moon, & Green, 1997). Following, people focus on the information itself and are less biased by entrenched stereotypes. This may allow those affected by the crisis to save cognitive resources and directly convert helpful information into action. This may help EMAs to receive valuable information in order to obtain their supply chains during crisis events (Shareef et al., 2020). CAs can thus also provide important information as a basis for decision making, which according to Dwivedi et al. (2020) is one of the great potentials of AI-based systems. However, this could differ between types and phases of crises as these differ in terms of crisis communication strategies (Gupta et al., 2016). Furthermore, the CA needs to consider the EMA's function during the crisis as those might be responsible for specified activities such as forecasting, the distribution of supplies, or the coordination with other (non) government organizations (Gupta et al., 2016).

DP2 aligns with previous IS research (Kim, Park, & Suh, 2020). Particularly in the context of transparency and AI, it is important to explain how the users' input is processed and which source is subject to the CA's message. This becomes evident, especially during crisis situations which are characterized by ambiguity and uncertainty (Mirbabaie et al., 2020), therefore, the CA as a transparent and trustworthy information provider is crucial for resolving these issues. Balakrishnan & Dwivedi (2021a) argue that is important to design the CA transparent in order to help the users perceive the CA intelligent and competence. Transparency by indicating sources and timeliness of a CA's information can also help stakeholders to distinguish real news from fake news, which is often spread during crisis events (King & Wang, 2021). A next possible step could be an integrated Fake News Detector, which enables people to ask the CA whether information is factual or fake news. This could be realized via a database linked to a fact checking tool. Not only affected citizens could benefit from the implementation of a CA that follows DP2. A CA with this functionality could also be very useful for the communication and exchange of information among EMAs, as the arising trust can lead to a better diffusion of information (Altay & Pal, 2014). It is therefore highly recommended to consider CAs when developing new and appropriate strategies to deal with crises.

Furthermore, DP3 highlights the importance of location-based information in crisis situations. Providing the CA with the functionality of processing multiple input types and languages allows EMA to collect comprehensive information about the crisis. While users in commercial applications of CAs are usually not able to send information such as videos or location data, these rich information sources become essential in crisis situations (Konicek, Netek, Burian, Novakova, & Kaplan, 2020). Although our interviews mentioned this in the context of floods in Germany and bushfires in Australia, previous studies also highlighted the usefulness of location data in other countries ((Holderness & Turpin, 2015)Holderness and Turpin 2015). DP3 is not only relevant for crisis communication during natural disasters, but also for man-made disasters such as terrorist attacks, where information symmetry, completeness of information, private information about terrorist secrecy and deception are important (Gupta et al., 2020). Here, CAs could use different media types to gather and match information for EMAs. It should also be emphasized that the combination of location data and other data such as images or videos is also of great value for emergency management, since image data of destroyed roads, bridges or other buildings, for example, can be assigned to specific regions (e.g., by means of an AI-based system) (Fan et al., 2021). The complex and dynamic nature of disaster situations raises the need for supply chain agility (Dubey et al., 2020) and enhanced cooperation between subgroups (Salem et al., 2019) that can be managed by intergroup leadership. In this way, disaster relief material movements can be coordinated and organized. Taking knowledge from operations research, EMAs may use AI-based CAs for (inventory) management of relief materials or the alignment of relief workers (Balakrishnan & Dwivedi, 2021a). However, collaborative relationships between the various EMAs and relief workers are crucial as no single organization may manage the crisis by its own. This becomes apparent regarding the coordination between different types of organizations such as governmental and non-governmental organization among the supply chain (Shaheen & Azadegan, 2020).

In this context, DP4 highlights that the CA should be connected to the intelligence system of the EMA. This allows the organization to better process and analyze the heterogeneous data, and therefore, quickly provide reliable information. As demographic characters and ethnical groups differ in terms of their responses and general behavior during crisis events (Yuan et al., 2021), people need to access the CA through multiple contact points such as social media platforms or official websites to reach various target groups as well as the majority of the public. For example, geographical IS and social media are already used to organize local response efforts. However, this is often based on a non-organized open-source approach (Shodhi & Tang, 2014). Deploying a CA that is connected to EMAs' systems can address challenges raised by Altay & Labonte (2014) such as inaccessibility of information, inconsistent formats, inadequate information streams, a low priority of information diffusion, a difficult source identification or a media storage misalignment by providing a natural communication channel for citizens. Furthermore, it is crucial that gathered information and resources are stored, verified, and distributed to coordinated collaboration partners. To realize this, the collaboration between different departments and EMAs needs to be improved initially, since in some cases they do not function well due to different objectives (Shareef et al., 2019). However, receiving location-based information raises further challenges on a governmental level (Aladwani & Dwivedi, 2018) as well as for EMA (Zhang et al., 2019). This highly sensitive information has to be stored, processed and provided to align to the legal requirements of the state. At the same time, the data needs to be protected against abuse.

Furthermore, DP5 emphasizes the robustness to unexpected uses of the CA. In contrast to (Cassell & Thorisson, 1999), the CA should not try to hide a lack of knowledge and force to provide no or an unsatisfying answer. The findings show that in crisis situations the CA's replies need to be accurate, reliable and transparent. This leads to the CA having to refer to a human if he cannot give a reliable answer to the user. Relying on the system gains in importance regarding the findings of Balakrishnan & Dwivedi (2021b) conceptualizing the role of trust as a system-based belief in the context of CA interaction.

In summary, we found major similarities between the requirements

of these EMAs from different countries yielding into the five design principles. This might be due to a regular exchange with EMAs from other countries (e.g., from the U.S.).

5.2. Theoretical contribution

The new design principles should be followed when developing CAs for the use of emergency management agencies during crisis situations. Previous research had already identified general design guidelines for CAs in organizations. Our paper contributes to the ongoing discussion around the use of technology in crisis situations and to the preparation of EMAs for future crisis situations is that these design principles put the specific requirements of EMAs in concrete terms. It is necessary to rethink some of the previously known principles and add important aspects.

There are certainly similarities. The ability to answer queries unrelated to the crisis instead of blindly following a script, and the ability to speak to a human when the bot fails (DP5), are not entirely new. They follow from flexibility and transparency principles identified in previous research. However, when transparency was described as an important goal of CAs (Diederich, Brendel, & Kolbe, 2020; Feine, Adam, Benke, Maedche, & Benlian, 2020), the authors meant that the agent needs to be clearly labelled as artificial, and users need to be able to understand what functionalities it offers (functional transparency). Through our interviews, it additionally became clear how crucial it is that the information offered by the agent is transparent, for example that its source is mentioned and that it is accurately dated (informational transparency, DP2).

A similarly superficial parallel that, under closer scrutiny, reveals important distinctions can be found in the descriptions of the desired communication style. Previous research identified the requirements that the CA is proactive in its communication, for example that it notifies users about information that is relevant for them instead of only taking input from them (Feine et al., 2020). The requirements identified by our interviewees go one step further. The CA should actively prompt the user to provide additional information that it might need (DP1). In combination with DP3 it further becomes clear that in the crisis context, this extends to pictures, videos and location information as well as support for multiple languages.

A key difference lies also in the alleged requirement of sociability that previous research identified. Social cues were deemed an important aspect that contributes to the perception of a CA as human-like, to social presence and to the overall enjoyment of the interaction. In contrast, our interviewees were much less enthusiastic about cues that they perceived as superfluous. The CA, it was felt, should focus on asking and providing essential information, and keep the chit-chat to a minimum (DP1).

It is already known that flexibility is an important characteristic of CAs, but previous research used this term to mean flexibility within the conversation: a good CA should not merely follow a script but it should be able to react to various situations such as unexpected requests from the user. Our interviews made clear that in the context of crisis communication, a degree of flexibility about the communication channel in which the conversation takes place and from where the CA draws its information is also crucial (DP4). This is clearly much more effort for the developers, because it requires the integration of different systems that might work with different data formats and software architectures and might not have well-defined communication interfaces.

5.3. Practical contribution

Chatbots are widely used in various areas, for example in sales and customer service, to provide a customized experience, handle complaints and answer commonly asked questions. Mobile phone users are familiar with CAs that answer questions and perform tasks such as setting reminders. Given the burden that crisis situations place on the emergency services, it does not come as a surprise that police services, fire departments and others are looking to use similar technologies in the near future.

However, our research has made it clear that there is still a fundamental gap between what current technology can offer and the vision that decision-makers in emergency service agencies have in mind for successful CAs in this area. Together, our design requirements show a vision of the CA of the future that is far more ambitious than anything that is currently on offer, and this vision has little in common with the virtual agents and chatbots of today. In this context the CA may improve the management of relief materials as well as the coordination and collaboration among the disaster relief workers that could lead to a reduced complexity of disaster situations.

The emergency CA of the future does not only respond to user-initiated conversations in the way Siri, Google Assistant and Cortana focus on answering questions and carrying out tasks after the user has initiated the conversation. Instead, it purposefully initiates conversations on its own. For example, it may approach social media users who have posted relevant content and ask them for more background information before passing this information to its owners, or it may approach social media users in a specific geographic area with relevant information or requests for information. Thus, managers in EMAs are well advised not to simply deploy traditional chatbot applications, but to adopt more intelligent systems for their crisis communications. That information could be distributed to field teams and allow a dynamic adaption of the specific leadership styles to the current hazardous situation.

It does not attempt to form an emotional connection, at least not when an acute emergency is ongoing and an efficient exchange of information is of the utmost importance. Such attempts may be better suited to longer running crises, such as the ongoing COVID-19 pandemic. Managers of EMAs need to take this into account.

In addition, the emergency CA of the future is always fully aware of the current situation by frequent updates of information sources such as databases or systems. One challenge the CA needs to face is the assimilation of emerging technologies and online communication channels. The user may be following several media channels (TV, radio, news apps) alongside social media. The CA needs to understand this context. Depending on the nature of the situation, a chatbot that is giving advice which is outdated, even if only by half an hour, may be more harmful than one that is not giving advice at all.

EMAs can therefore learn much from the interviews we examined about the opportunities that CAs offer to improve their crisis communications, but also about their challenges. CAs such as chatbots cannot simply be implemented in the same way in the context of EMAs as in other contexts. This implies that when EMAs recruit experts in assistance systems and CAs or entrust other organizations with their implementation, the developers cannot simply transfer their existing knowledge and solutions to the crisis context. Therefore, a rigorous knowledge transfer is mandatory between managers, disaster relief workers and developers to further improve collaboration resting upon shared experiences.

However, our design principles can serve as guidance to peculiarities of the crisis context that have to be addressed before CAs can be used by EMAs. We further recommend to start step by step and not by trying to take into account all of our design principles at once. Crisis communication is a sensible field where errors can make the difference between life and death. It is advisable to start with a social media chatbot first and then gradually connect the systems of the EMAs. Also, the implementation within an EMA app might be a good starting point. Subsequently, other smart-home applications such as dissemination via smart speakers (e.g., Amazon Alexa) are also conceivable in order to reach as many people as possible in crisis situations.

Of course, when doing so, the EMAs should also compare their requirements with the requirements we identified for the Australian and German EMAs that we focused on in this study, and then determine whether the identified design principles may need to be modified.

5.4. Limitations and future research directions

Our qualitative research design imposes specific limitations on our findings. We collected enough data to have a diverse sample according to our interpretative judgement and expertise in qualitative research and to be able to answer our research question (Braun & Clarke, 2021). However, the transferability to other contexts in crisis communication is constricted through the organizations and the cultural context they are situated in; transferability to a broader context needs to be carefully evaluated and further investigation (Lee & Baskerville, 2012). Also, some requirements for CAs were mentioned noticeably more often than others. Even if the quantity of statements is less relevant in qualitative research, future research should examine more closely if there is a relationship between frequently mentioned requirements and importance of these requirements.

We conducted interviews from two different countries (Australia and Germany) to ensure a broader relevance of our findings, by not focusing on a single country. However, our findings might differ in other countries and cultures. Future research could consider our findings in the context of other countries and disaster management cultures in a cross-case analysis.

When our interviewees referred to crisis events, they were usually talking about natural disasters such as fires, floods or storms. Although we interviewed experts from a variety of countries and a wide range of organizations, our findings cannot be generalized to all crisis types since our study applied an interpretationist lens to the experiences of the experts we interviewed. The requirements and applicability of our design principles might differ between disaster types. Future research should therefore examine our design principles in the context of other crises, such as the Covid-19 pandemic.

Our research highlights differences in the design of CAs for commercial organizations and EMAs. Future research needs to apply these peculiarities in other contexts and in practice building on our findings.

6. Conclusions

Current IS literature provides various perspectives for designing CA in general (e.g., Feine et al., 2019, Diederich et al., 2020). However, the crisis related requirements for CA reveal the specific need for design principles considering the perspective of a crisis (Ahmady & Uchida, 2020, Maniou & Veglis, 2020). This study reveals aggregated insights from two countries suggesting of EMAs across the globe have similar requirements regarding crisis management. This specific need is conceptualized by the derived design principles.

In summary, this study uncovered five actionable design principles representing concrete but demanding requirements for EMAs. These go far beyond the previously known requirements for general-purpose CAs used in organizations (Feine et al., 2020), but they are necessary to ensure a satisfactory crisis response (Mirbabaie et al., 2021). Arguably, these requirements also go far beyond what current technology can offer. The derived design principles form a bridge between research and practice, with clear implications for what future research can focus on to ensure that it contributes to future crises, including pandemics, being managed more effectively.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 823866.

CRediT authorship contribution statement

Stefan Stieglitz: Supervision, Funding acquisition, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Lennart Hofeditz**: Data curation, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Felix Brünker**: Data curation, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Christian Ehnis**: Conceptualization, Formal analysis, Writing – original draft. **Björn Ross**: Writing – review & editing. **Milad Mirbabaie**: Writing – review & editing, Project administration, Resources.

Table 4
List of interviewees.

Pseudonym	Organization	Position	State, Country
RMM	State Level Crisis Coordination	Manager, Public Information & Warnings	VIC, AU
EMS	State Level Crisis Coordination	Social Media and Content Specialist	VIC, AU
EMI	State Level Crisis Coordination	Online Intelligence Officer	VIC, AU
DA	State Police	Information & Communications Manager	SA, AU
PCB	State Police	Emergency Manager	SA, AU
CMM	State Police	(Former) Police Officer	SA, AU
REC	State Police	(Former) Police Commissioner	SA, AU
ASE	State Emergency Service	Media Expert	NSW, AU
RTC	State Fire Department	Volunteer Coordinator	NSW, AU
CL	City Fire Service	Communications Manager	NSW, AU
FFC	City Fire Service	Communications Manager	NRW, GER
JJN	NGO	State Association Manger (Quality management and organizational development)	NRW, GER
FFS	State Fire Department	Information and communications Manager	HE, GER
VSM	State Level Crisis Virtual Support	Board Member	NRW, GER
MAN	NGO	Press Officer	NRW, GER
DRN	NGO	State Commissioner for Disaster Control	NRW, GER

Declarations of interest

None.

Appendix

See Appendix Table 4.

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