Opinion Dynamics in Social (Media) Networks

Theorizing Procedural Influences on Technologically Enabled Opinion Formation and Diffusion in Social Networks

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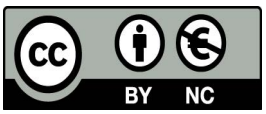

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To Thorsten. Thank you.

So, here we go…

A. Introduction to the Dissertation: Explanatory Framework, Research Approach, and Paper Overview

1. Introduction

Social media have opened fundamentally novel and enhanced opportunities for communication: they enable people to connect with family members, friends, and coworkers, as well as with strangers beyond their existing social relations; create and share digital, user-generated content; and engage in large-scale social interactions (Agarwal et al., 2008). Using social media hence allows information sharing and collaboration across established organizational boundaries, and facilitates the emergence of novel forms of organizing (Leonardi & Vaast, 2017).

The field of crisis response and management illustrates the potential of social media – most prominently, that of social media networks such as Facebook and Twitter – to facilitate information sharing and collaboration. These platforms make it possible for users among affected citizens, communities, and organizations to take action in response to crises, as can result, for instance, from natural disasters, pandemics, infrastructure breakdowns, and violent protests; recover from their impacts; and prevent or diminish future occurrences. Furthermore, using social media can facilitate collaborative approaches to crisis response and management that integrate the efforts of users across organizational boundaries, such as community members, volunteer and professional responders, businesspersons, and journalists (Tim et al., 2017).

Amongst others, people affected by crises can use social media to seek and share information and make sense of events (e.g., Fischer-Preßler et al., 2019; Heverin & Zach, 2012), disseminate crisis-related information, such as situation reports and warnings (e.g., Abedin & Babar, 2018; Rao et al., 2020), and identify and challenge rumors and misinformation (e.g., Jong & Dückers, 2016; Zhao et al., 2016). Similarly, organizations – for instance, high-reliability organizations, emergency response and humanitarian relief organizations, and state and local governments – can use social media to gather first-hand information from the affected citizens and other users on the ground (e.g., Ludwig et al., 2015; Tapia & Moore, 2014), share information with members of other organizations and local communities (e.g., Liu & Xu, 2018; Yates & Paquette, 2011), engage in community building and promote citizen engagement (e.g., Chen et al., 2020; Olson et al., 2019), and acquire resources needed for organizational response activities, for instance, through crowdsourcing (e.g., Brengarth & Mujkic, 2016; Kaewkitipong et al., 2016).

Key to these uses of social media are these platforms' *affordances*: potentials for action that arise from the interplay between technological artifacts and their goal-directed users (Volkoff & Strong, 2013). Affordances determine how people can use social media to

pursue their goals in a particular situation, contingent upon these goals and possibly further social and psychological processes (Bygstad et al., 2016). Thus, the affordances of social media determine available behaviors in a given situation, and, in consequence, can promote the emergence specific outcomes (e.g., opening organizational resources and processes to non-organizational users in response to a crisis [Eismann et al., 2021]).

Social media hence can *enable* people to act in certain ways. From that point of view, the platforms primarily serve as means of communication that allow their users to achieve their goals (e.g., in the context of crises, documenting and learning about events, identifying ways to volunteer or otherwise assist in crisis response, memorializing victims, or discussing the causes and implications of events [Houston et al., 2015]). However, that does not account for *how* the affordances of social media might furthermore influence users' behaviors: they can determine how users can pursue their goals in a given situation, in particular, through imposing explicit or implicit rules– so-called *procedures* – that affect people's behaviors and interactions.

In my work, I focus specifically on the potential impact of social media affordances on *opinion dynamics* among users. Broadly, opinion dynamics encompass all kinds of interactive processes through which agents connected through a set of relational connections develop and exchange opinions, which is, collections of statements that express these agents' beliefs about the world (Genest & Zidek, 1986). More specifically, opinion dynamics refer to activities through which agents embedded in a social network interact to communicate their beliefs (*opinion diffusion*), as well as to activities through which they adapt and revise these beliefs based on what they have learned about other agents' beliefs and possibly further information available to them (*opinion formation*).

In social media, users are typically assumed to express their opinions by creating and sharing digital content, such as text messages, photos, and videos, which is then transmitted along their relational connections that are based, for instance, on online social relations (e.g., being friends with or following other users), shared membership (e.g., in group or community spaces), or instances of dyadic interaction, such as direct messaging among the users of a platform (Kane et al., 2014; Sundararajan et al., 2013). As a consequence of *social influence* that flows along with the user-generated digital content, users may then be motivated to adapt and revise their beliefs (e.g., Goggins & Petakovic, 2014). Opinion dynamics hence capture a variety of social phenomena based on the diffusion of digital content that conveys users' beliefs, and the resulting opinion changes.

Against this background, the research question that connects the papers submitted as part of this thesis is:

How can social media, through their affordances, influence opinion dynamics among their users, specifically in the context of crisis response and management?

My goal is to *theorize* how social media affordances might affect social processes among their users especially through imposing rules for interaction (e.g., by formalizing communications through a standardized and commonly agreed upon "techno-linguistic grammar" [Oh et al., 2015]). My argument integrates social network theory and the procedural influence concept adapted from social science research, assuming that by interacting with social processes to determine relevant entities (i.e., the agents, opinions, and relations that constitute a socio-technical system), and by regulating opinion formation and diffusion processes operating within such a system, the affordances provided by a platform can effectively influence opinion dynamics among its users.

More specifically, I am concerned with developing *explanatory theory*, which is, theory directed at explaining how and why phenomena occur (Grover et al., 2008). I follow Hassan et al. (2019) in understanding theorizing as a set of discursive practices that aim at initiating the theoretical discourse on a phenomenon of interest (*foundational theorizing practices*), and at promoting and shaping that discourse once established (*generative theorizing practices*).

I am particularly interested in the *causal mechanisms* through which social media can influence opinion dynamics among their users. Mechanisms, briefly defined, are processes that establish causal connections between actions or events considered as causes and those held to be effects, through positing a series of intermediate actions or events (Gross, 2009). Mechanisms hence define and describe the entities of a causal process that leads to the emergence of a social phenomenon (Hedström & Ylikoski, 2010). The particular focus of my work is on identifying mechanisms that, in the context of crisis response and management, might account for the influence of social media affordances on users' behaviors and interactions (Williams & Wynn, 2018). Following Bygstad et al. (2016), I model these affordances as mechanisms that complement social, psychological, and technological processes at work in a given situation.

The strength of mechanism-based explanation is generally seen in its ability to uncover the causal processes behind empirical associations and tell us "what would have happened if the cause had been different" (Hedström & Ylikoski, 2010, p. 54), and it can be useful to develop theoretical propositions with some of degree of generalizability

(Avgerou, 2013; Gross, 2009). It is however incompatible with a probabilistic understanding of cause and effect that invokes statistical regularities, as mechanisms may not always be activated, and multiple mechanisms may be considered as causes of the same outcome (Hedström & Ylikoski, 2010).

The question how social media could make a difference is therefore one of *counterfactual causality*: it posits one or more antecedent events – in particular, goal-directed adoption and use of social media in a given context – such that, through a regular chain of intermediary events, the antecedent event or events result in some subsequent event which, absent the antecedent, would not have occurred; and such that, in consequence, the antecedent can be considered as sufficient cause of the empirically observed outcome (Lewis, 1973). Counterfactual reasoning can help develop explanations for how and why empirically observed events occur (Mandel, 2005); furthermore, it can help capture dependencies between events considered as causes and effects, respectively, based on abstract language and analytical frames of explanation (Reutlinger, 2017).

The question is also about the *causal influence of technological artifacts* on social processes. Information systems (IS) researchers within the socio-material research tradition have long pointed out that we cannot understand social processes enabled by technological artifacts devoid of these artifacts' technological features and properties; at the same time, the opportunities for action provided by an artifact are embedded into various social contexts that determine whether and how they are perceived and actualized (e.g., Cecez-Kecmanovic et al., 2014). In my work, I conceptualize social media as causal agents by interpreting them as sources of procedural influence that operate in addition to existing formal and informal rules of interaction. I hence assume that causal influence can arise from the interplay between social agents and technological artifacts (Williams & Wynn, 2018), and therefore, that platforms can not only enable, but furthermore interact with and influence social dynamics.

The affordances of technological artifacts such as social media are necessarily context-sensitive, given that they describe the relationship between what is offered by a platform in the technological sense on the one hand, and people's goal-directed behaviors using these platforms on the other hand, contingent on situational and other constraints (Evans et al., 2017). I focus specifically on the role of social media in response to *crises*, defined as all kinds of "process[es] of perceived disruption" (Boin, 2005, p. 163) that impair the functioning of a social system (e.g., of one or more interrelated communities), and which the social system's members perceive as collectively threatening or harmful (Boin, 2005).

Crises can result, among others, from natural hazards (e.g., earthquakes, landslides, or wildfires), socio-technical risks (e.g., traffic and transportation accidents, building collapses, or infrastructure failures), or intentional or negligent human error (e.g., acts of sabotage, extortion, or terrorist attacks [Richardson, 1994]).

In 2022 alone, the estimated economic losses resulting from crises added up to 284 billion USD worldwide (after 280 billion USD in 2021, and 217 billion USD in 2020), with more than 35,000 people left dead or missing in their wake (after approximately 11,800 fatalities in 2021, and about 8,000 in 2020 [Swiss Re Institute, 2021; 2022; 2023]). In addition to this number, more than 50 million people are currently considered internally displaced due to crisis impacts, and more than 25 million are classified as refugees (United Nations Office for the Coordination of Humanitarian Affairs [OCHA], 2022). The number of crises caused by natural hazards is continually increasing, including events that remain below the threshold of global catastrophes, nurtured by long-term systemic risks such as climate change (e.g., Swiss Re Institute, 2021; 2022). Also, continually high levels of global connectivity and interdependencies between formerly separate political, economic, social, and ecological systems can further facilitate the propagation of local crises and hamper effective crisis response and management (Biggs et al., 2011). Crises can also exacerbate existing vulnerabilities (OCHA, 2022); for instance, their impact on agriculture and food production is directly related to the achievement of human development goals such as poverty reduction and hunger alleviation (e.g., Food and Agriculture Organization of the United Nations, 2020).

As a context of research, crises have been popular with the IS community for several years. Premier IS conferences (e.g., the *European Conference on Information Systems* and the *Hawaii International Conference on System Sciences*) and journals (e.g., *Information Systems Research*, the *European Journal of Information Systems*, and *Information Systems Frontiers*) have dedicated tracks and special issues, respectively, to the study of information systems in crisis response and management, and communities such as ISCRAM (*Information Systems for Crisis Response and Management*) have further promoted IS research on crisis informatics.

Crisis informatics research hence illustrates the *bright side* of social media adoption and use: social media can empower affected people and communities, enhance the transparency of crisis response and management, and facilitate participation of internal and external stakeholders (e.g., Eismann et al., 2021; Leong et al., 2015; Tim et al., 2017). Beyond that, it demonstrates how information technology use can contribute to blurring

the boundaries between "organizational containers" (Winter et al., 2014) to connect actors within and across established organizational boundaries and interact with other elements of the potentially overlapping socio-technical systems in which they are embedded. Thus, the focus of crisis informatics research in the field of IS is on the emergent socio-technical phenomena that result from the adoption and use of these artifacts – core areas of IS research interest, according to Baskerville and Myers (2002).

Below, in Section 2, I review opinion dynamics entities and processes discussed in three reference disciplines, and on that basis develop a conceptual framework of opinion dynamics. In Section 3, I present a theoretical rationale to account for how the affordances of social media can be interpreted as sources of procedural influence that can interact with and shape social processes enabled by the platforms, integrating critical realist ontology and social network theory. In Section 4, I outline a retroductive research approach for identifying relevant mechanisms, specifically in the context of crisis response and management. In Section 5, I explain how the five papers submitted as part of my thesis contribute to each step of that research approach, as well as to my overall research question. In Section 6, I discuss the theoretical, methodological, and practical implications of my work. In Section 7, I present a concluding summary.

2. Review and Conceptual Framework of Opinion Dynamics

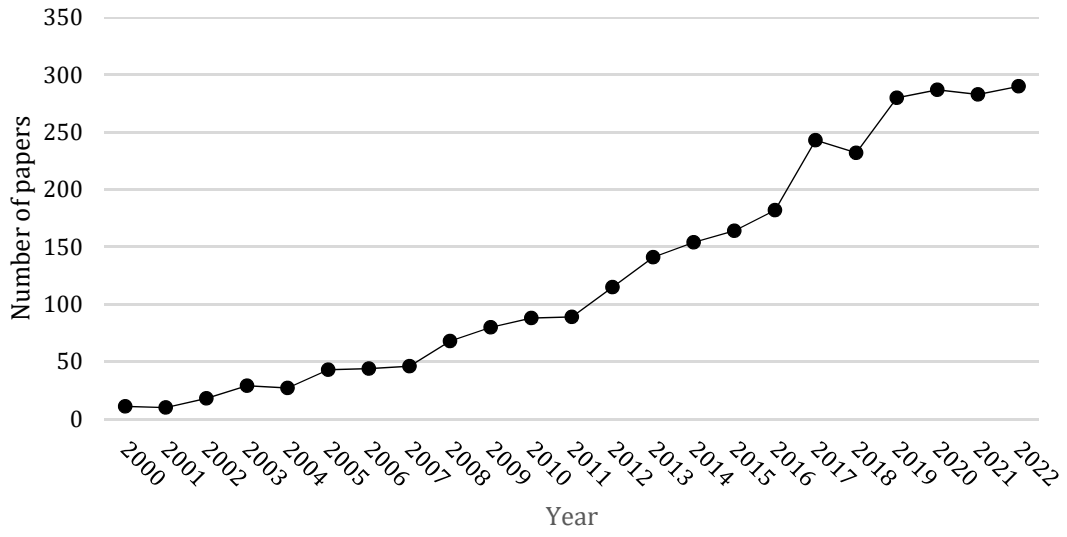
The purpose of this introductory paper is to establish the conceptual basis for theorizing the causal impact of social media affordances on *opinion dynamics*, which have previously been defined, among others, as "the dynamics of agreement or disagreement among individuals" (Castellano, Fortunato, et al., 2009, p. 598) or "the dynamical processes of the diffusion and evolution of opinions in [a] human population" (Xia et al., 2011, p. 72). Based on my work, I argue that opinion dynamics can best be described as *the entirety of processes through which individuals within a social collective (e.g., a group, an organization, or a crowd) acquire information to develop and revise their beliefs (*opinion formation*) and communicate their beliefs to other members of that collective (*opinion diffusion*)*.

Since 2000, 2,924 papers listed in the Web of Science Core Collection reference opinion dynamics, formation, or diffusion – trend increasing, as Figure 1 on the following page shows.[1] Many of these papers can be traced back to the conceptual foundations laid by a

[1]Results of a keyword-based search through Web of Science Core Collection (http://webofknowledge.com); search term: "opinion dynamics" OR "opinion formation" OR "opinion diffusion" (exact matches only); full texts searched; including all papers published between 2000-01-01 and 2022-12-31; date of search: 2023-02-15.

small number of seminal works in small-group research. In other words, the theoretical frames employed by the majority of current works date back to only few influential papers that provide the conceptual basis for opinion dynamics research across disciplines, including physics, mathematics, computer sciences, communication studies, and social research. Much of this research is be analytical in nature, employing mathematical and computational models to analyze the underlying social processes.

Figure 1
Number of papers per year referencing "opinion dynamics", "opinion formation", or "opinion diffusion", identified through a keyword-based search in the Web of Science Core Collection



Reviewing these papers furthermore reveals that recent works contribute primarily to three fields of study, namely: *sociophysics*, *behavioral economics*, and *belief merging*. Among IS researchers, the opinion dynamics concept has not gained similar prominence; only nine papers published in the AIS Senior Scholar's Basket of Journals[2] since 2000 explicitly refer to "opinion dynamics", "opinion diffusion", or "opinion formation".[3] I therefore draw upon prominent and well-cited research in the three aforementioned reference fields of study to develop a conceptual framework as basis for theorizing.

[2] Including, in alphabetical order: European Journal of Information Systems, Information Systems Journal, Information Systems Research, Journal of the Association for Information Systems, Journal of Information Technology, Journal of Management Information Systems, Journal of Strategic Information Systems, Management Information Systems Quarterly (Association for Information Systems, 2011); search procedure and criteria as above.
[3] These papers are, in alphabetical order: Bergvall-Kåreborn and Howcroft (2014); Gross (2009); Hauser et al. (2017); Ho et al. (2017); Y. Hong et al (2016); Sarker et al. (2005); Spagnoletti et al. (2015); Susarla et al. (2012); Wang et al. (2018).

Below, in Sections 2.1 through 2.4, I review these foundations of opinion dynamics research and summarize the key entities and processes that contribute to opinion formation and diffusion according to prominent models of opinion dynamics in sociophysics, behavioral economics, and belief merging research. On that basis, I develop a conceptual framework of opinion dynamics, which I present in Section 2.5.

2.1. Historical Roots: Consensus Formation in Interacting Groups

Many now popular ideas in opinion dynamics research can be traced back to a few seminal works in social psychology and mathematical sociology that address the emergence of consensus in interacting groups based on the flow of social influence among their members. These include, in particular: French's (1956) formal theory of social power, DeGroot's (1974) mathematical theory of group consensus formation, and social influence network theory as specified by Friedkin and Johnsen (1990, 1999), which combines these earlier models with ideas from the then-emerging field of social network theory.

Opinion dynamics, according to these foundational works, are based on the activities of individual *agents* who form some kind of social group. Each agent is characterized by their *opinions* regarding one or more issues, which can best be understood as numerical representations of some underlying beliefs that are ascribed to agents through a mathematical mapping formula. French theorizes opinion dynamics based on the individual agents' attributes. He assumes that group members exert *power* over others in the sense that they can interact with them to make them assimilate their opinions. Furthermore, he suggests that actors have the power to resist that influence, which he refers to as their *certainty* of opinion. DeGroot, in contrast, emphasizes the flow of social influence among agents through which opinions are transmitted. In his model, agents assign interpersonal weights to each other's opinions, which describe the extent to which their own opinions are subject to changes in response to that of each other agent within the group. Friedkin and Johnsen extend DeGroot's approach: they allow agents to assign an additional weight to their initial beliefs, which they refer to as agents' baseline *susceptibility* to social influence, as it reduces the extent to which their opinions can be influenced by that of others.

All three referenced models assume agents to engage in an iterative process of adaptation, where in each iteration, agents learn about others' opinions and revise their beliefs

accordingly. In the works of DeGroot and Friedkin and Johnsen, agents apply the weights they have assigned to their own and others' opinions to revise their beliefs through weighted averaging. French, in contrast, models belief revision through force minimization based on the trade-off between the competing influencing powers.

These early formalizations of opinion dynamics have their roots in small-group research, where usually all agents interact directly with each other or make their opinions known to all others simultaneously through some kind of plenary discussion or public announcements. The works of DeGroot and Friedkin and Johnsen adhere to that principle: while they provide individual weights to allow agents to control the overall amount of social influence, these weights represent the relative importance assigned to other agents' opinions, rather than indicating the presence or absence of social relations between them. French, in contrast, distinguishes between the interactions through which information about agents' opinions is transmitted, and the *social relations* that enable these interactions, based on social forces such as attraction, expertise, and legitimacy.

Today, early linear models of opinion dynamics are widely perceived as theoretically simplistic; in addition, they are mostly limited to explaining the emergence of consensus, but not alternative outcomes such as opinion polarization or the persistence of disagreement among interacting agents. Contemporary contributions that build upon and extend these works primarily come from three fields of research: *sociophysics*, *behavioral economics*, and *belief merging*.

2.2. Opinion Dynamics in Sociophysics: The Voter Model and Beyond

Contributions made in sociophysics and in related fields of study, such as complexity sciences and social epistemology, are based on the idea that social dynamics can be explained in terms of the interactions between the individual agents that constitute a social system (Castellano, Fortunato, et al., 2009). Sociophysics, in particular, have contributed the idea that the interplay between a limited number of micro-level parameters, as can be borrowed from statistical physics (e.g., space and distance), can account for the emergence of the macroscopic properties of a social system (Galam, 2012). This line of research comprises, among others, studies on the voter model (Holley & Liggett, 1975; Liggett, 1997) and its extensions – most prominently, the Sznajd (Sznajd-Weron & Sznajd, 2000), majority rule (Galam, 2002), and q-voter models (Castellano, Muñoz, et al., 2009) –, social impact (e.g., Kacperski & Hołyst, 1996; Nowak et al., 1990;

Schweitzer & Hołyst, 2000) and bounded confidence models (e.g., Deffuant et al., 2000; Hegselmann & Krause, 2002), the Continuous Opinions and Discrete Actions (CODA) model (Martins, 2008), and alternative formulations such as the cultural dissemination model (Axelrod, 1997) and the naming game (Baronchelli et al., 2006).

Opinion dynamics models in the broader domain of sociophysics typically rely on a set of individual agents, also referred to as *spins*. These start out with *opinions* assigned to them according to some exogenously specified distribution (e.g., normal or uniform random distributions). Opinion spaces can run the gamut from binary or discrete (e.g., in the voter model and its extensions) to real-valued (e.g., in bounded confidence models) to hybrid representations based on probability thresholds for opinion change (e.g., in the CODA model). While discrete opinions can be interpreted as choices agents face (e.g., between competing products or candidates), continuous opinions can represent beliefs, attitudes, or preferences regarding for instance some social, political, or economic issue (Lorenz, 2007). Agents' opinions are mostly represented through scalars, though some models apply explicitly also to multidimensional opinion spaces (e.g., vector opinions in Deffuant et al. [2000], cultural features and traits in Axelrod [1997], and multi-element dictionaries in Baronchelli et al. [2006]).

Both bounded confidence and social impact models have inherited further agent attributes from earlier approaches. In bounded confidence models, agents' *openness* towards social influence describes the extent to which their opinions are subject to changes due to their interactions with others, following from the concept of susceptibility in the Friedkin-Johnsen model. Social impact models, in contrast, typically include parameters that describe the extent to which agents can persuade others of their opinions (e.g., their *persuasiveness* and *supportiveness* in Nowak et al. [1990], or *influence strength* in Kacperski and Hołyst [1996]), which roughly correspond to group members' relative power in French (1956). Agents who are not at all susceptible to social influence are referred to as stubborn agents or *zealots* (e.g., Mobilia et al., 2007; Yildiz et al., 2013).

Other than in the earlier works, the structure of social relations and the individual agents' positions within that structure are key elements of sociophysics approaches: agents are assumed to occupy positions (or *sites*) in a pre-defined social space that takes the form of a regular lattice or ideal-type network topologies (e.g., scale-free networks, small worlds, or random graphs). Whether agents can interact with each other usually depends on their position within that social space, as they can exchange opinions only with their direct

neighbors or agents with whom they are otherwise related (e.g., through encounters in social meeting spaces, as in the majority rule model).

Like earlier works, sociophysics approaches describe opinion dynamics as an iterative process of adaptation, in the course of which agents gradually revise their opinions in response to internal and external events. As regards discrete opinion spaces, agents typically adapt their beliefs by imitating others' opinions. In the voter model, for instance, agents adopt the opinion of one of their neighbors. Other models attribute persuasive power to cohesive groups of agents: in the Sznajd model, pairs of agents who share an opinion can impose that opinion on their respective nearest neighbors. In the *q*-voter model, agents adapt their opinions if a sufficient percentage of *q* randomly selected neighbors support it, and in the majority rule model, agents adopt the opinion held by the majority of other agents in randomly assigned subgroups.

In the case of continuous opinion spaces, each interaction between agents leads to incremental changes in the respective agents' opinions. In the CODA model, for instance, social encounters can cause marginal changes in the likelihood with which agents support one opinion over another. Social impact and bounded confidence models, in contrast, assume that agents apply simple updating rules – most prominently, weighted averaging – to integrate their own and their neighbors' opinions. Opinion formation can furthermore be subject to *social temperature* or *noise*, which is, random errors in agents' updating behaviors (Castellano, Fortunato, et al., 2009). Following the tenets of earlier works, the resulting opinion changes are usually motivated by theories of social influence, or, similarly, those of social impact, such as formulated by Latané (1981).

Typically, opinion dynamics research in sociophysics assumes that agents revise their opinions sequentially (i.e., that they engage in opinion updating one after another), following randomly scheduled interactions with other agents that trigger belief revisions. However, a few models especially in the domains of social impact and bounded confidence rely on simultaneous updating, which means that all agents in parallel revise their opinions in each iteration (e.g., Hegselmann & Krause, 2002; Kacperski & Hołyst, 1996, 1999). In both cases, the characteristic pattern of social relations enables agents to exchange opinions, based on distinct acts of communication. However, a number of more recent works has extended this assumption by distinguishing explicitly between agents' opinions and the act of expressing them (e.g., Banisch & Olbrich, 2019; Ye et al., 2019). Interactions may be subject to further restrictions; in particular, following from the principles of *homophily*, agents may interact with others only if their opinions are

sufficiently similar in the first place. Bounded confidence models, for instance, include confidence bounds that restrict interactions to similar-minded agents, and in the naming game and the cultural dynamics model, interactions take place only if there is a sufficient overlap between the interacting agents' opinion states.

2.3. Opinion Dynamics in Behavioral Economics: The Social Learning Approach

In the field of behavioral economics, opinion dynamics have been discussed under the label of *social learning*, which captures the idea that agents' choices are determined at least in part by information they receive from others (Acemoglu & Ozdaglar, 2011). In contrast to sociophysics, the focus is not on the social processes that drive opinion dynamics, but on the individual agents' decisions to adopt and distribute information upon which opinions could be based. Apart from works that focus on the implications of Bayesian learning, such as informational cascades and herding behavior (e.g., Banerjee, 1992; Bikhchandani et al., 1992; L. Smith & Sørensen, 2000), the field of social learning comprises multifaceted research on different versions of non-Bayesian and rule-of-thumb learning (e.g., Ellison & Fudenberg, 1993, 1995; Jadbabaie et al., 2012; Molavi et al., 2018), and learning in social networks (e.g., Acemoglu & Ozdaglar, 2011; Bala & Goyal, 1998; DeMarzo et al., 2003).

In the research tradition of social learning, a group of boundedly rational agents must each choose from a finite set of decision alternatives. Information is limited, which means that the costs and benefits associated with the decision alternatives – the so-called *true state of the world* – are uncertain. Agents hold beliefs about expected pay-offs, from which they derive preferences regarding the decision alternatives. Agents' preferences can be heterogeneous (e.g., Lobel & Sadler, 2016; L. Smith & Sørensen, 2000), and also the pay-offs themselves can also be subject to idiosyncratic or common errors (e.g., Banerjee & Fudenberg, 2004; Ellison & Fudenberg, 1995; Gale & Kariv, 2003).

In social learning models, agents can access two types of information. First, they can observe the choices made before, by both themselves and other agents, though, as Bikhchandani et al. (1998) point out, they can usually only observe others' behaviors, but do not receive information about their pay-offs or the information on which decisions were based. This information regarding agents' previous choices is publicly available to all agents. Second, upon entering the model, agents receive private signals, which usually follow some probability distribution around the true value or expected pay-offs.

Social learning is then basically about the rules agents apply to integrate public and private information to make a decision. Most prominent is agents' applying Bayes' rule to update their prior beliefs using information about others' behaviors. In contrast, non-Bayesian learning, in its simplest form, refers to naïve updating rules such as weighted averaging of other agents' beliefs (e.g., Jadbabaie et al., 2012). Several works have furthermore analyzed the implications of cognitive constraints, such as memory limitations (e.g., DeMarzo et al., 2003; Molavi et al., 2018), and insights into cognitive limitations and biases have also inspired the formulation of decision heuristics for rule-of-thumb learning (e.g., Ellison & Fudenberg, 1993, 1995). Just as in sociophysics, *noise* can be an issue for social learning models, as agents may randomly deviate from what would constitute an optimal choice (e.g., L. Smith & Sørensen, 2000). We also find again the idea that certain agent attributes, such as their *stubbornness* (e.g., Acemoğlu et al., 2013) or individual thresholds of opinion change (e.g., González-Avella et al., 2011), can influence learning outcomes.

Furthermore, a class of social learning models imposes constraints in the form of *social networks* that restrict interactions to agents who share a relational connection, that is, a subset of other agents with whom they can directly communicate and exchange beliefs. In a social network setting, agents may also weigh the information they receive from others according to some quality of their relationship, such as trust or social influence strength as seen prominently, for instance, in the works of Bala and Goyal (1998) and DeMarzo et al. (2003). However, in contrast to sociophysics approaches, social learning models typically assume that relational connections between agents are initialized according to random parameter distributions that govern network connectivity and the distribution of ties, rather than following pre-established network topologies. The extent to which agents can influence others' choices can then depend, among others, on their position within the overall social network structure, in particular, the number of other agents to whom they are connected, and how well those are connected in turn (e.g., Bala & Goyal, 1998; DeMarzo et al., 2003; Golub & Jackson, 2010).

Seminal works on Bayesian learning assume that agents make decisions sequentially, that is, one after another; these decisions usually cannot be revised in later iterations. As agents observe all decisions made by preceding agents, the order in which they make their decisions are made is critical (Bikhchandani et al., 1998). In contrast, works especially on learning in social networks assume that agents update their opinions simultaneously. This implies that agents either make repeated decisions, with each decision yielding additional information about expected pay-offs (e.g., Bala & Goyal, 1998), or that rather

than committing to a final choice, agents repeatedly revise their beliefs regarding one or more alternatives on which a decision – that is not usually explicitly modeled – could be based (e.g., DeMarzo et al., 2003).

2.4. Opinion Dynamics in Belief Merging Research: Logics of Aggregation

The most recent contributions to the opinion dynamics literature come from the field of belief merging in computer science, which refers to the process through which agents combine several pieces of information from potentially conflicting sources into coherent opinions (Konieczny & Pino Pérez, 2011). Belief merging is a subfield of information fusion research that focusses on the process of information integration (I. Bloch et al., 2001), often through the use of logical language (Konieczny & Pino Pérez, 2011). Key to this line of research is the design of belief merging operators that allow agents to resolve conflicts between different information sources to fulfil certain logical properties inspired by rationality postulates (Konieczny & Pino Pérez, 2011). It primarily comprises works that address the logics of opinion change and diffusion (e.g., Cholvy, 2018; Christoff & Hansen, 2015; Hansen, 2019; Liu et al., 2014). Beyond that, it can be related to the theory of judgment aggregation, where merging operators can assist in consistently aggregating individuals' votes on logically connected propositions (e.g., Pigozzi, 2006), which has also inspired research into the consequences of applying merging operators, in particular, regarding truth-tracking and robustness against strategic manipulation (e.g., Konieczny & Pino Pérez, 2011).

Opinion dynamics models in the field of belief merging rely again on a set of individual agents, who are connected through binary or weighted links that represent their social relationships, such as, trust, friendship, or family relations (e.g., Christoff & Hansen, 2015; Grandi et al., 2021; Liu et al., 2014). Each agent is characterized by their opinions, which can consist of several interdependent beliefs regarding one or more issues. This initial state of the population is then transformed through an iterative updating process, where in each iteration, agents receive information about their neighbors' opinions. Following from information fusion research, the individual pieces of information to be merged can have different *representations* (e.g., numerical vs. symbolic), and could furthermore be characterized by a number of *information quality* attributes, such as ambiguity, uncertainty, imprecision, incompleteness, vagueness, and inconsistency of information (I. Bloch et al., 2001).

Key to the updating process are *merging operators*, which prescribe how agents revise their beliefs, contingent upon their prior beliefs, their neighbors' opinions, and additional integrity constraints that represent exogenous restrictions on belief integration (e.g., Cholvy, 2018; Konieczny, 2002). These include, for instance, *logical interdependencies* that determine to what extent agents' beliefs regarding one issue can influence those regarding another (e.g., Botan et al., 2019). Belief merging operators often rely on the similarity between agents' opinions to determine permissible updating operations, based for instance on pseudo-distance measures (e.g., *model-based operators*) or the number of beliefs on which agents disagree (e.g., *conflict-based operators* [Konieczny & Pino Pérez, 2011]). In that, they are similar to similarity-based interaction thresholds postulated by sociophysics approaches (e.g., by bounded confidence and social impact models).

Logics of opinion change in belief merging research are generally based on theories of social influence that explicitly account for influence strength. They consider, for instance, the extent to which agents adhere to their initial beliefs, their neighbors' *authority*, or the relative similarity between their own and their neighbors' beliefs (e.g., Cholvy, 2018; Liu et al., 2014). These parameters can be linked to threshold models of social influence, where a sufficient share of neighbors must adopt an opinion to trigger opinion change (e.g., Baltag et al., 2019; Liu et al., 2014), as well as to agent-specific thresholds of interaction and opinion change in sociophysics; Christoff et al. (2016) and Grandi et al. (2021), for instance, distinguish between agents' opinion states and what information about these opinions is made available to others.

2.5. Conceptual Framework of Opinion Dynamics

Summarizing the insights of the different strands of opinion dynamics research, it becomes clear that opinion dynamics comprise two types of social processes: first, *opinion diffusion*, which refers to activities through which agents make information about their beliefs available to others, typically through interactions along their relational connections. And, second, *opinion formation*, which refers to activities through which agents adapt and revise their opinions in response to what they have learned about other agents' beliefs and possibly further information from other sources.

The reviewed models developed in various fields of research are strikingly similar when it comes to conceptualizing these processes, as well as the entities that constitute them. Below, in Sections 2.5.1 and 2.5.2, I summarize these shared assumptions and integrate them into a conceptual framework of opinion dynamics, which I present in Section 2.5.3.

2.5.1. Opinion Dynamics Entities

Opinion dynamics research typically assumes that three types of entities contribute to opinion formation and diffusion processes: first, the individual *agents* who interact along their relational connections to exchange belief-related information and revise their opinions accordingly; second, these agents' *opinions*, which may influence how agents process and transmit that information; and, third, the structural characteristics of the *social networks* in which agents are embedded, which determine what information is available to them when making up their minds. Table 1 summarizes these entities, along with their relevant attributes, as modeled by prior research.

Table 1
Opinion dynamics entities summarized

Entities	Attributes	Examples of corresponding concepts
Agents	Influence over other agents	Influence strength, persuasive power, authority
	Resistance to other agents' influence	Certainty, susceptibility, confidence bounds, adaptation thresholds, stubbornness
	Information-processing and decision-making capabilities	Memory limitations, cognitive biases
Opinions	Representation	Numeric (e.g., binary, discrete, continuous), logical, symbolic
	Prior distribution	Normal, discrete or continuous uniform, empirically informed
	Dimensionality	Vector opinions, cultural features and traits, nested vocabularies
	Logical structure	Multi-issue dependence structures, logical integrity constraints
Social networks	Relationship type	Social relations, social forces, joint group membership, information flow
	Tie type	(Un)directed, weighted, signed
	Structures	*n*-dimensional regular lattice, complex network topologies (e.g., small worlds, Erdős-Rényi random graphs, scale-free networks)

The first entity is the individual *agents*. These are characterized by attributes pertaining to the extent to which they can influence others, in the sense that they can cause opinion changes in other agents (*influence over other agents*), as well as the extent to which others can influence them (*resistance to other agents' influence*). I hence interpret social influence as agents' inherent ability, as opposed to some kind of flow that emerges from their communications or other behaviors. Furthermore, agents can be described in terms of individual-level parameters that determine how they develop opinions based the information available to them (*information-processing and decision-making capabilities*).

The second entity is the agents' *opinions*, which can refer to anything from beliefs about the true state of the world to decision preferences to attitudes. Opinions can take different forms, ranging from binary or discrete choices to continuous scales to qualitative or symbolic values (*representation*). Agents' initial or prior beliefs are a key element of all models, as these determine initially permissible operations and can have lasting effects as baseline values even in later iterations of the model (*prior distribution*). In addition, agents can hold one or more opinions on issues that may be interrelated, and hence impose restrictions on how agents' opinions on one issue can influence those on others (*dimensionality* and *logical structure* of the opinion space).

The third entity is the *social networks* that connect agents, which are described primarily in terms of the characteristic patterns of social relations along which interactions can take place. Agents can be connected through one or more qualitatively distinct relations that represent, for instance, dynamic or stable social relations (e.g., friendship, kinship), the presence of social forces (e.g., attraction, expertise), shared membership in social groups, or the latent flow of information among them (*relationship type*). These relations constitute the ties of the social network, which may vary in their respective strength and directionality (*tie type*). The structure of ties may follow random parameter distributions, as in social learning models, or specified patterns such as grids, small-world, or scale-free networks, as in sociophysics approaches (*structures*). This relational pattern defines the composition of agents' neighborhood and their position within the overall network topology (e.g., their degree, eigenvector, and closeness centralities), and thus determines with whom they can interact to exchange opinions.

Agent, opinion, social network entities and their traits are not necessarily independent. For instance, agents holding more extreme opinions have been modeled as being more resistant to social influence (e.g., Deffuant et al., 2002), and agents' willingness to interact with and adapt to others has been assumed to depend on how similar their opinions are in the first place, their relational distance, or the strength or quality of their relationship (Flache et al., 2017; Mason et al., 2007). Also, social network structure and other attributes can also be treated as dynamic, as Jia et al. (2015), for instance, model changes in network structure in response to opinion dynamics processes.

2.5.2. Opinion Dynamics Processes

Research generally treats opinion dynamics as a set of iterative and interdependent processes operating upon a specified configuration of agent, opinion, and social network

attributes, where at each iteration or time step, this configuration – the *state* of the underlying social system – is transformed, contingent upon the entities that constitute it, following possibly theoretically motivated logics. Table 2 summarizes the rules of the opinion formation and diffusion processes, as well as further parameters that might influence these processes, based on prior research.

Table 2
Opinion dynamics processes summarized

Processes	Attributes	Examples of related concepts
Opinion diffusion	Transmission mode	Observation, communication, social contagion, common knowledge
	Process parameters	Sequentiality and sequence of interactions, information quality
Opinion formation	Belief revision rules	Merging operators, Bayesian updating, weighted averaging, majority rule, rules of thumb, imitation
	Process parameters	Integrity constraints, presence and extent of noise

Processes that constitute *opinion diffusion* describe activities through which agents make information about their opinions accessible to others, including both specific other agents (e.g., their neighbors or fellow group members) and the public information space (*transmission mode*). Across the three surveyed fields of research, we find different transmission modes that determine how agents exchange opinion-related information. Early works have basically treated agents' beliefs as common knowledge. Similarly, some of the more recent approaches, especially in the domains of sociophysics and belief merging, implicitly or explicitly model opinion diffusion as a process of social contagion, where opinions are transmitted as a result of mere contact between agents. In contrast, the social learning literature suggests that agents can observe others' behavior to infer their underlying beliefs, which also allows distinguishing between different (e.g., public and private) sources of information that may not be accessible to all agents likewise. Other works across the various fields treat agents' opinions separate from the act of expressing them (e.g., Banisch & Olbrich, 2019; Christoff et al., 2016; Grandi et al., 2021). In that view, communication enables agents to actively share their opinions with others – though distortion due to agents' strategic communications may be an issue (e.g., DeMarzo et al., 2003; Endriss et al., 2012; Grandi et al., 2021).

In addition, the *sequentiality* – that is, whether agents take action at the same time or one after another – and the *sequence* in which they interact – which can be random or based on agents' opinions, the similarity of these opinions, or other attributes, such as their

position within the social network – can determine what information is available to them. Moving beyond the mere act of transmission, the *quality* of information that is transmitted – for instance, whether information about others' cognitions or behavior is accurate, complete, and consistent – and the extent to which sources of uncertainty can distort agents' perception of others' opinions or a hypothetical true state of the world can affect diffusion.

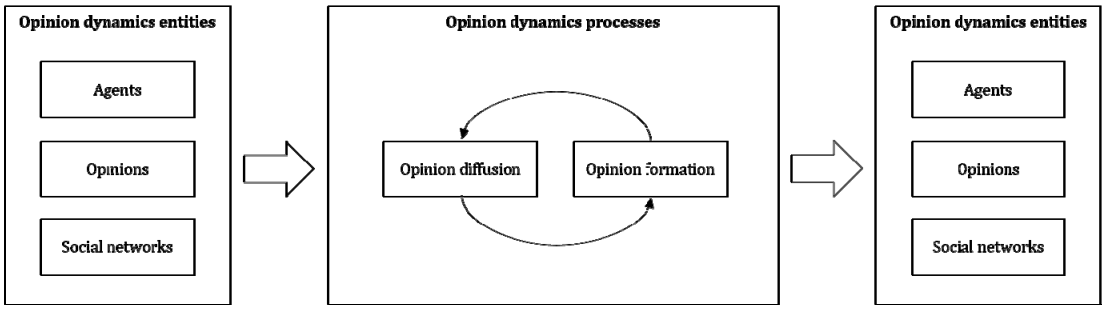
Processes that contribute to *opinion formation*, in contrast, refer to activities through which agents acquire information to develop and adapt their beliefs. The principles to which agents adhere to that end – updating procedures in sociophysics, learning rules in behavioral economics, and merging operators in belief merging research – will generally determine opinion formation outcomes (*belief revision rules*). Beyond that, *integrity constraints* – that is, restrictions to how agents are to revise their opinions – relate these operators to the agent, opinion, and social network attributes. In particular, revision is necessarily contingent on agents' opinions, parameters that describe the extent to which they can influence others or be influenced by others in turn, and the configuration of their relational connections to other agents, which determine the possibilities and conditions of information access. In addition, characteristics of the opinion space itself (e.g., the number and representation of, and logical interdependencies between opinions) may limit permissible operations. Beyond that, cognitive limitations and biases can influence how agents implement revision rules, and the *presence and extent of noise* – that is, the degree to which agents randomly deviate from the prescribed updating rules – can affect how agents make use of available information to revise their opinions.

Opinion formation and diffusion have been motivated with regard to both individualistic and social theories of agent behavior. These reflect the foci of research taken within different fields. Social learning approaches, for instance, are rooted in economic theory. They concentrate on changes in individual agents' opinions motivated by bounded (e.g., Bayesian) rationality while treating the relational connections between agents as exogenous constraints on information access. Sociophysics and related approaches, as well much research in the domain of belief merging, in contrast, are interested primarily in how agents' social environment might influence their behaviors. While they pay less attention to the individual agents' motivations, that line of research has produced insights into how characteristic patterns of social relations can affect opinion flow, based on theories of social influence and social impact.

2.5.3. Integrated Framework of Opinion Dynamics

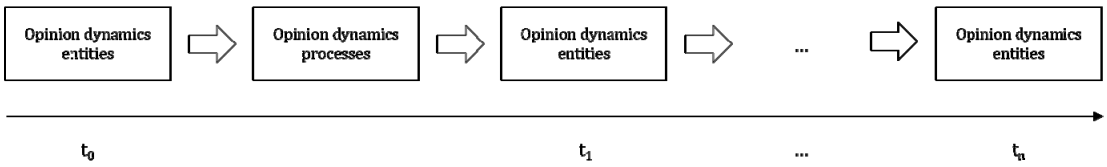
Integrating the opinion dynamics entities and processes that are evident from prior research in major reference disciplines results in the framework displayed in Figure 2.

Figure 2
Integrated framework of opinion dynamics



This dynamic framework accounts for how opinion formation and diffusion can lead to changes in the underlying configuration of agent, opinion, and social network attributes in a social system. The outcomes of each iteration of the process serves as input for further iterations, such that over time, repeated interactions between the constituent entities can lead to emergence of specific social outcomes, such as the formation of consensus, persistence of disagreement, or polarization. Figure 3 illustrates this transition of states.

Figure 3
Dynamical view on opinion dynamics



Against this conceptual background, we can begin to understand how the use of technological artifacts might influence opinion dynamics, either through altering the rules of opinion formation and diffusion processes, or through affecting the entities based on which these processes operate. In the following section, I argue how social media, through their affordances, can enable opinion dynamics among their users and furthermore influence the constituent social processes, based on a critical realist ontology enriched by social network theory and a procedural view on social interactions.

3. Theorizing Social Media Influences

Key to my work is the question how social media might influence their users' interactions, and hence can affect the social dynamics that arise from those, specifically within the context of crisis response and management. In brief, I argue that social media enable their users to engage in opinion formation and diffusion processes; but beyond that, the platforms themselves can make a difference to how users develop and exchange opinions, based on affordances that arise from the interplay between their technological features and properties and users' goal-directed activities.

In this section, I provide further background on what I refer to as an *enabling view* of social media and outline my argument on how platforms might furthermore influence opinion dynamics. Key to my argument are the affordances provided by social media, which I assume introduce (mostly informal) rules of interaction that can affect the configuration of social networks that underlie opinion dynamics, as well as the logics of the opinion formation and diffusion processes among the actors embedded within them. In Sections 3.1 and 3.2, I outline the enabling view of social media, which is currently the dominant perspective on social media in IS research, and present an alternative that ascribes causal influence to platforms beyond providing opportunities for action. In Section 3.3, I introduce the meta-theoretical background of explanation, which describes how the affordances of social media can be understood in terms of causal mechanisms through which platforms can influence opinion dynamics.

3.1. Opinion Dynamics and Social Media

My work is about opinion dynamics in *social media*, which, according to Kapoor et al. (2018), comprise "various user-driven platforms that facilitate diffusion of compelling content, dialogue creation, and communication to a broader audience." Following this definition, social media are "a digital space created by the people and for the people, [which] provides an environment that is conducive for interactions and networking to occur at different levels (for instance, personal, professional, business, marketing, political, and societal)" (p. 536).

To analyze social dynamics in social media, many IS researchers adopt what I refer to as an *enabling view*. In brief, they posit that using social media provides opportunities for people to pursue their goals; actualizing the possibilities for action provided by a platform, they can engage in activities that contribute to both established and emergent social and organizational processes. Research typically focusses on the individual *users*

(i.e., agents represented by a digital profile on social media); it often equates *digital content* (e.g., text, photos, or videos) created and shared by these users with their express opinions, and the *diffusion of digital content* with the flow of social influence among them. That view is particularly evident from papers that focus on information diffusion in social media, such as the works of Shi et al. (2014), Shore et al. (2018), and Susarla et al. (2012).

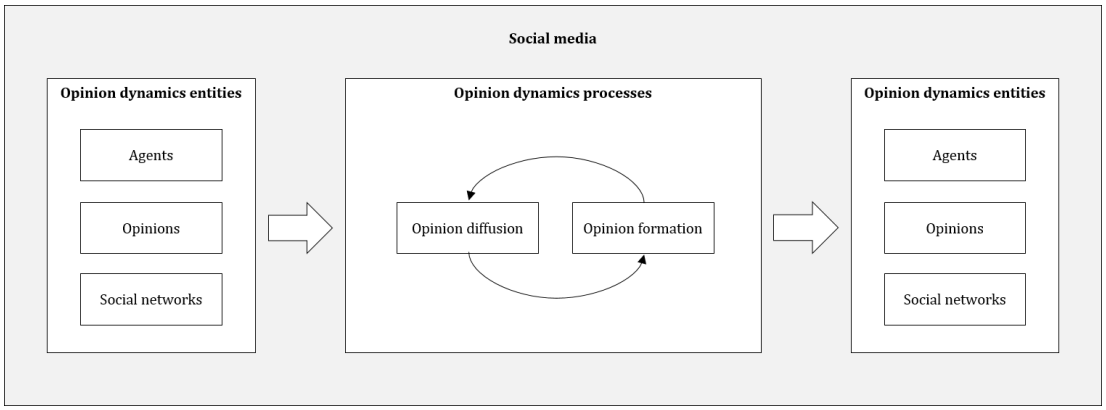
The enabling argument posits that social media facilitate connections between users, through features that allow, for instance, direct messaging, following, or friending other users, joining groups or community spaces, re-sharing digital content contributed by others, recommending, commenting on, or otherwise relating to digital content, or participating in shared projects or activities (Karahanna et al., 2018). Through these relational connections, opinions can flow, based on digital content through which users express their beliefs, even if there are no direct exchanges involved between the users producing digital content and those consuming or further processing it (Sundararajan et al., 2013). Users might then adapt their opinions in response to digital content that is available to them through social media, and thus, platforms can facilitate the emergence of interdependent opinion formation and diffusion processes (Xiong et al., 2014). Users' ability to thus influence others' opinions would hence be associated with how social media allow them to communicate with others (Goggins & Petakovic, 2014).

This argument applies most intuitively to social media networks, given that establishing relational connections to other users, and inspecting and navigating these connections, are at the heart of these platforms' uses. According to Kane et al. (2014), social media networks, such as Facebook, LinkedIn, and Twitter, can thus induce homogeneity in users' behaviors through the structural and relational features of the connections they enable and the digital content that is available to users through these connections: users may assimilate because they share a common environment in terms of how they are embedded into the overall structure of relational connections (*environmental shaping*) or because they are exposed to similar content on a platform (*contagion*).

It could hence be argued that the enabling view mostly focusses on how agents can utilize social media to achieve their goals, following from intrinsic and extrinsic motivations and possibly further situational constraints. Assumptions regarding the causal influence of social media on the opinion dynamics processes they enable are often implicit; in many cases, platforms are treated primarily as communication environments that determine the boundaries of observation. While they may affect what entities are considered relevant, and determine the processes accessible to observation, their main influence on

opinion dynamics is often seen in amplifying communications and connecting otherwise unrelated users. Figure 4 illustrates these assumptions.

Figure 4
Enabling view on opinion dynamics in social media



In contrast to that, I argue that the distinct opportunities for action (i.e., *affordances*) provided by social media determine what behaviors are available to users in a given situation, and hence provide technologically induced rules for interaction that can restructure and transform opinion dynamics processes.

3.2. Beyond the Enabling View of Social Media Affordances

From an enabling point of view, the key role of social media in opinion dynamics is to provide the technical means for interactions among their users based on features that facilitate the exchange of digital content and, in consequence, the flow of social influence. These assumptions are clearly useful to analyze information behaviors and patterns of information dissemination in response to external events such as crises, as they put a focus on people's behaviors and motivations, and on the potentials of social media to help them achieve their goals in a given situation. Furthermore, the enabling view acknowledges that platform characteristics and features might be neither necessary nor sufficient to account for emergent social dynamics: agents' behavioral goals may precede social media use, and how they develop and communicate opinions may depend at least to some extent on social and psychological processes independent of social media.

However, by treating social media primarily as vehicles that allow people to pursue their goals, we lose sight of how they might influence the processes enabled beyond increasing the reach and speed of communications. This is in contrast to evidence produced by various streams of media research, according to which the specific characteristics of

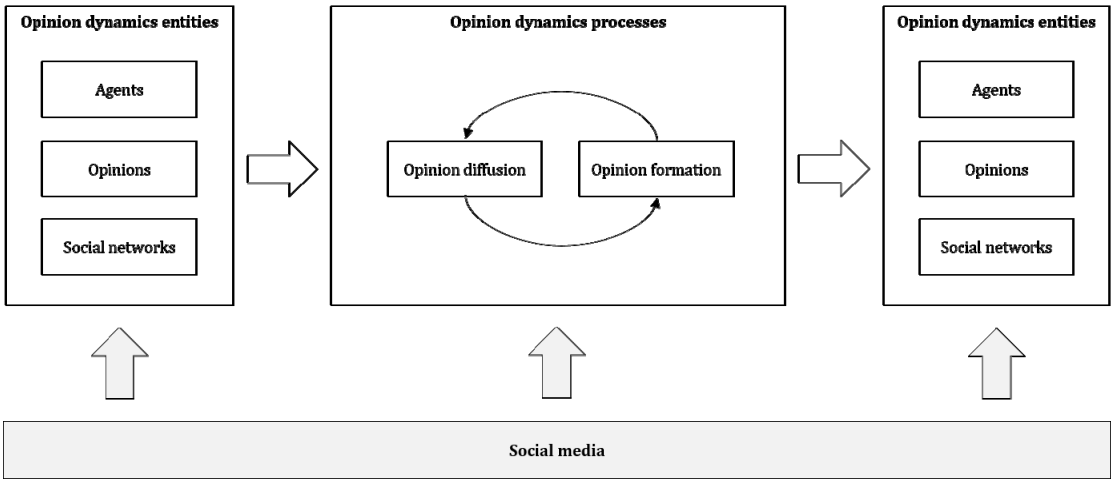
communication environments can systematically influence opinion dynamics. For instance, the medium through which information is transmitted can influence how users perceive that information (Neuman & Guggenheim, 2011), and how well using that medium is perceived by users as suited to fulfil some task (e.g., Daft & Lengel, 1986; Dennis et al., 2008). Not least, models such as the *Technology Acceptance Model* (F. D. Davis 1989) and the *Unified Theory of Acceptance and Use of Technology* (Venkatesh et al., 2003) have established a causal connection between platforms' features and how they are used.

Moreover, the enabling view cannot account for a number of findings that illustrate that specific features and attributes of social media were previously found to influence opinion formation and diffusion. For instance, researchers have discussed how non-human users present in social media – so-called *social bots* – that could express more extreme opinions while remaining unaffected by others' arguments might influence opinion dynamics (e.g., Ross et al., 2019). Social media also provide various ways in which users can gain status and reputation, which in turn can impact diffusion and the extent to which users can influence others based on the information they share (e.g., Havakhor et al., 2018; Levina & Arriaga, 2014). Likewise, exchanges between users may imply complex processes of negotiation through which they organize and make sense of information, as opposed to mere diffusion (e.g., Arazy et al., 2011; Fadel et al., 2015; Majchrzak, Wagner, et al., 2013). Users may hence not simply adopt opinions to which they are exposed through digital content, but social media may allow content creators to provide cues that influence how others process and eventually develop opinions based on that content (e.g., Meservy et al., 2019; Moravec et al., 2020; Watts & Zhang, 2008).

These works illustrate that social media cannot only enable communications, but, through the interplay between their technological features and properties and users' behaviors in a given situation, might influence how we can understand and conceptualize relevant entities and processes, as well as the rules of these processes. Figure 5 on the following page illustrates these assumptions.

I therefore argue that, other things being equal, using social media could systematically affect agents' behaviors and interactions. Key to my reasoning are the opportunities for action provided by a platform, which is, its *affordances*: "the potential for behaviors associated with achieving an immediate concrete outcome and arising from the relation between an object (e.g., an IT artifact) and a goal-oriented actor or actors" (Volkoff & Strong, 2013, p. 823).

Figure 5
Social media influences on opinion dynamics entities and processes



Affordances result from the relation between social media and their users: on the one hand, it is the platforms' features and attributes that enable specific behaviors. On the other hand, users' goals in a particular situation, as well as the specific characteristics of the situation, determine what opportunities for action are perceived and actualized by users (Bygstad et al., 2016). Affordances are distinct from information technology or feature use, but through defining the range of feasible actions in a given situation, they can effectively influence how agents can use social media to develop and exchange opinions (Evans et al., 2017; Leidner et al., 2018).

3.3. Meta-Theoretical Structure of Explanation

Ascribing causal influence to the affordances of social media platforms requires an explanation for how they can alter or otherwise affect opinion dynamics entities or processes. In my view, affordances can be interpreted as *causal mechanisms* through which social media can influence opinion dynamics among their users. Thus, my focus is on how such affordances might affect the entities (i.e., the agents, opinions, and social networks) based on which opinion dynamics operate, as well as the logics of opinion formation and diffusion processes enabled by social media.

Delving further into the causal structure of mechanism-based theorizing, Markus and Rowe (2018) distinguish between three dimensions of causality: *causal ontology*, which refers to the connection between hypothesized causes and effects on the one hand and real-world entities on the other; *causal trajectory*, which is about the nature of the macro-social entities explained and the causal relationship between micro- and macro-level

events; and *causal autonomy*, which covers the flow of causal influence between human and social agents on the one hand, and technological artifacts on the other.

As to the causal ontology dimension, my work is rooted in a critical realist worldview. Regarding causal trajectories, I assume that social networks constitute the link between micro-social behavior and interactions and the emergence of macro-social phenomena. Finally, as regards causal autonomy, I extend the notion of procedural influences to account for the causal agency of technological artifacts. Below, in Sections 3.3.1 through 3.3.3, I outline my assumptions regarding these three causality dimensions.

3.3.1. A Critical Realist View

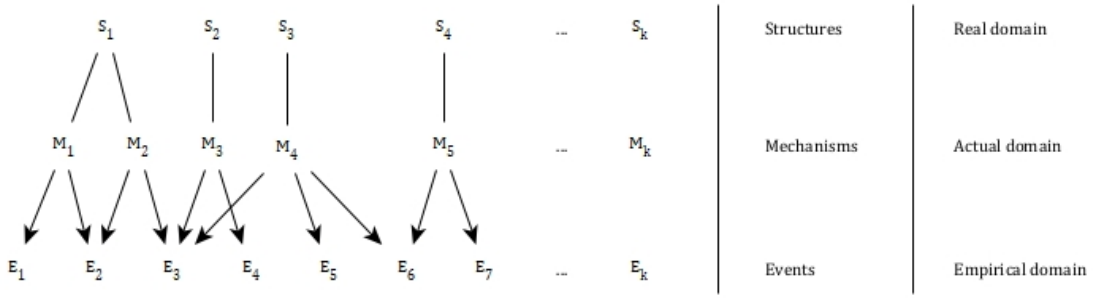
Research into causal mechanisms is frequently based on a critical realist ontology, even though this connection is not strictly necessary (Hedström & Ylikoski, 2010). Within the context of my work, the epistemology and the retroductive research logic implied by critical realism is particularly appealing: *manifest knowledge* (i.e., knowledge gained through empirical observation or abstraction thereof) and *antecedent knowledge* (i.e., existing theories, conceptualizations, and other types of cognitive frames) are integrated to develop explanations for a given phenomenon that neither alone could produce (Williams & Wynn, 2018).

Critical realism hence presumes three ontological strata: *the real*, which refers to the realm of being itself and contains entities (or *structures*) that exist, even though they might be inaccessible to observation (e.g., physical objects, social structures, and cognitive concepts); *the actual*, which refers to events that might occur and that are, in principle, observable; and *the empirical*, which refers to events that are actually observed, and hence constitute the basis of human knowledge and experience (Mingers et al., 2013). It hence relies on three fundamental assumptions: first, that what we can know is distinct from what is, and hence, the domain of the empirical is a subset of the domain of the real (*intransitivity*); second, that causal laws that produce empirically observed events are independent of the real-world systems in which they operate, and hence, the domain of the actual that comprises these laws is both a subset of the domain of real and a superset of the domain of the empirical (*transfactuality*); and third, that thus locating causal mechanism inbetween the domains of the real and the empirical allows for establishing chains of cause and effect between the two (*stratification* [Bhaskar, 1998]).

In a critical realist view, mechanisms "exist as the causal power of things" (Bhaskar, 2008, p. 50), which is, tendencies of physical, social, or other real entities to act in particular

ways and which, if triggered by some event or context, may generate observable outcomes. Thus, critical realism advocates a focus on mechanisms as attributes of real entities that establish causal links between those and empirically observed events through sequences of intermediate events and activities (Mingers et al., 2013). Figure 6 illustrates the ontological assumptions of critical realism.

Figure 6
Mechanisms in critical realist ontology (adapted from Sayer [1992])

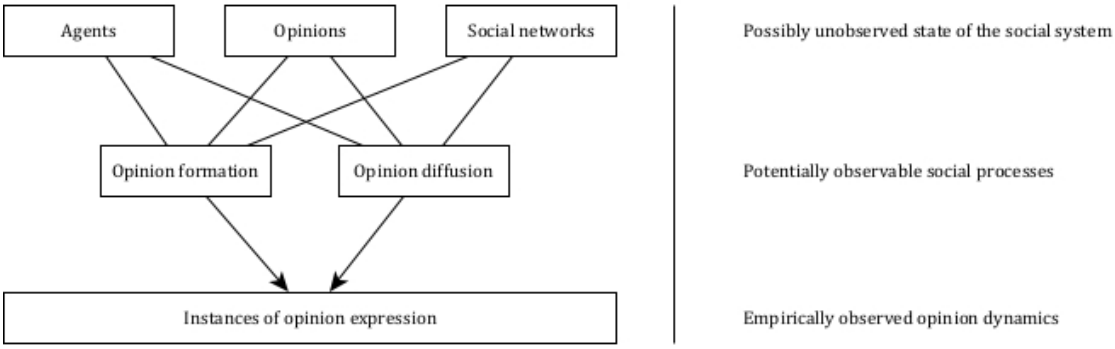


What we *can* observe, therefore, is the empirical events that constitute the explanandum, and possibly some of the processes that cause them. Knowledge of these events can be gained through empirical observation. Mechanisms, in contrast, are the opinion formation and diffusion processes that precede them. While mechanisms are, in principle, accessible to observation, our knowledge about them may be incomplete. It is thus necessary to integrate different sources of knowledge available – in particular, existing theories and conceptualizations, as well as empirical evidence – to arrive at adequate representations of the underlying causal mechanisms. This can be achieved through a retroductive research approach, which I explain in more detail in Section 4.

In a critical realist view, mechanisms hence constitute the causal link between real-world structures and empirically observed events. In doing so, they integrate the behaviors and interactions of agents, both social and technological, as shown in Figure 7 on the following page. The agents, opinions, and social networks that are at the heart of opinion dynamics are conceptualized as entities within the domain of the real: while we may have knowledge over some of them, others may remain unobserved. For instance, we may not know about agents remaining silent about their beliefs, latent social relations not activated in a particular situation, or agents' inherent beliefs and other cognitions. This implies that agents are interpreted as abstract entities capable of acting in particular ways

in the first place, meaning that they are conceptually distinct from the manifest actors (e.g., natural persons) whose activities we can observe.

Figure 7
Opinion dynamics processes in critical realist ontology



Following that logic, opinion formation and diffusion can be conceptualized as the mechanisms that drive opinion dynamics. While they are at least in principle observable, our knowledge of them may be incomplete, as relevant activities may lie beyond the boundaries of observation (e.g., instances of offline communication not registered via social media), while others may be subject to general limitations of empirical observation (e.g., cognitive processes of opinion change). What we can observe, then, is the activities through which agents express their opinions. Depending on the focus of research, opinion dynamics, from an empirical point of view, may be understood descriptively (i.e., characterizing the aggregate opinion state, for instance in terms of consensus, polarization, or fragmentation of opinions), or it may refer to the changes of collective opinions expressed (e.g., the gradual acceptance of some information or rumor within an agent population), or the expression versus non-expression of opinions (e.g., leading to the emergence of a spiral of silence). Viewing opinion dynamics as an iterative process, the outcomes of one iteration (e.g., in terms of aggregate opinion changes) can feed back on the inputs of subsequent ones.

I argue that the affordances of social media can then be understood as causal mechanisms in their own right, which interact with and hence can affect opinion formation and diffusion processes as well as the entities that contribute to them. Key to that are the social networks that establish causal links between individual agents' micro-level behaviors and the observed macro-level social outcomes, which I explain in detail in the sections that follow.

3.3.2. The Role of Social Networks

The relationship between individual behaviors and social outcomes – the *micro-macro problem* – has been subject to much debate among social scientists. For my work, it comes down to the following question that pertains to the causal trajectories of explanation: how can we establish causality between individual-level entities and observed macro-level social outcomes?

Critical realism distinguishes between structures – including those that characterize the state of a social system – as entities within the domain of the real, and actions taken within the domain of the empirical. Structures can influence agents' behaviors and interactions through their causal powers and tendencies, which is, the causal mechanisms connecting the domains; where the empirically observed behaviors might feed back on the underlying structures and hence reinforce or modify them (Dobson, 2001). This general argument leaves a black box when it comes to modeling the actual relationships between structures and events. In my case, this refers to the assumptions regarding how agent, opinion, and social network entities feed into opinion formation and diffusion, and how these processes can in turn lead to manifest acts of opinion expression or change.

One way to approach this issue is through *social network theory* (Buch-Hansen, 2014). A social network, in general, is defined as "a finite set of actors and the relation or relations defined on them" (Wasserman & Faust, 1994, p. 20), where actors (or *nodes*) can refer to all kinds of social agents who might partake in opinion diffusion and formation processes (e.g., individuals, groups, or organizations), and relations (or *edges*) include, for instance affective, cognitive, or familial relationships that facilitate interactions between agents, and through which, in turn, resources such as information, beliefs, or social influence can become available to agents embedded in a social network (Borgatti & Halgin, 2011). In social media, digital profiles that represent different types of users are typically considered as actors, whereas edges may consist of all kinds of dyadic relations enabled by a platform, including proximities (e.g., shared group membership), online social relations (e.g., being friends with), interactions (e.g., direct messaging), and flows (e.g., of digital, user-generated content [Kane et al., 2014]). Social network theory can then account for how the relational structure of social networks and actors' position within that structure relate to specific social outcomes, especially through influencing the flow of resources among the agent population (Borgatti & Halgin, 2011).

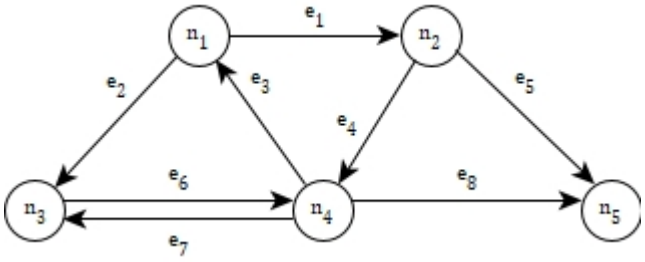
Following Emirbayer and Goodwin (1994), I argue that we can understand social relations as entities independent of the actors embedded within them, which can enable

and constrain these actors' behaviors and interactions, and hence contribute to the emergence of social outcomes. My position might be called a *formalist* one: I argue that characteristic patterns of social relations exist independently of the actors they connect; furthermore, I assume that these patterns enable and shape interactions in ways that can facilitate the emergence of specific social outcomes (Erikson, 2013; Erikson & Occhiuto, 2017). In line with Martin (2009), I delimit my argument to the latent relational structures that enable and shape interactions, rather than the occurrence of these interactions, which I interpret as the *events* that constitute opinion formation and diffusion.

In terms of critical realist ontology, the social network argument relates specifically to the social processes within the domain of the actual. First, it accounts for how the agent, opinion, and social network entities within the domain of the real contribute to the opinion formation and diffusion processes: the abstract agent population becomes a set of empirically observable actors, whose key attribute of interest is their opinions, which are operationalized in terms of beliefs or behaviors relevant within a given context. These actors interact along a specific set of relational connections that impose the restrictions defined by the social network attributes within the domain of the real. The basic parameters for modeling social networks are hence given through the conceptual framework of opinion dynamics outlined in Section 2. Second, social networks explain how agents develop and revise their beliefs, as well as make them available to other agents, based on the specific pattern of connections in which they are embedded. While not all steps of this process may ultimately be observed, social network theory gives structure to the abstract processes of opinion formation and diffusion. It hence allows describing in detail the operating logics of the mechanisms that underlie opinion dynamics.

Figure 8 on the following page shows an exemplary directed social network consisting of five nodes $\{n_1, \dots, n_5\}$ connected through eight edges $\{e_1, \dots, e_8\}$. Each node represents an actor participating in opinion formation and diffusion, and each edge stands for a latent social relation through which they can exchange opinions. Actors can be thought of holding one or more opinions, possibly distinguishing further between opinions as cognitive states and instances of opinion expression. Further individual-level attributes, such as access to private information or cognitive capabilities, can additionally be modeled.

Figure 8
Social network illustration



Interactions can take place along the edges through which actors are connected. The structure of relational connections hence imposes constraints on actors' exchanges that determine what information is available to them when making up their minds and how opinions can propagate among them. This pattern can be characterized using various measures from the field of social network analysis (e.g., Carrington et al., 2005; Scott, 2000; Wasserman & Faust, 1994), which allows drawing conclusions regarding the distribution of relevant resources in the network.

As explained in the previous section, actors are modeled conceptually distinct from the constituent agents. For instance, not all agents may be represented in the network due to design decisions, or transformations may be necessary to enable dealing with the complexity of data (e.g., Garton et al., 1997; Howison et al., 2011; Kane et al., 2014). However, viewing the abstract concepts of agents, opinions, and social networks from the perspective of social network theory makes it possible to analyze potential influences on the social processes taking place within these networks. The social network perspective thus allows locating causal influences more specifically within the opinion dynamics framework.

3.3.3. Introducing Procedural Influences

Ascribing causal powers to technological artifacts goes beyond understanding them as objects utilized by social agents to achieve their goals. Within the critical realist ontology, technological artifacts can be conceptualized as real entities (Williams & Wynn, 2018). Modeling technological – in addition to social – agents is not uncommon; among others, we find similar notions for instance in actor-network theory (Latour, 2005) and works on sociomateriality in IS research (e.g., Orlikowski, 2007). According to Williams and Wynn (2018), the causal powers that characterize technological agents are actualized through

interactions between social agents and technological artifacts. This basically implies that we interpret affordances as a specific type of mechanism which, when triggered in a particular situation, can influence other pertinent mechanisms, and hence the resulting social outcomes (Bygstad et al., 2016; Williams & Wynn, 2018).

My argument draws upon *procedural influences* to flesh out the causal autonomy dimension and argues how technological affordances might interact with opinion dynamics mechanisms. Procedural influences capture the idea that explicit and implicit rules of interaction – so-called *procedures* – affect the processes through which a group of agents arrives at consensual decisions (J. H. Davis, 1992). Procedures can be highly formalized, as for instance in standard operating procedures, or be based in commonly shared social norms and values (J. H. Davis et al., 1996). They can influence the interactions through which agents negotiate consensus, meaning that they can alter agents' behaviors and cognitions, and hence indirectly affect the social outcomes that arise from those. Alternatively, they can represent rules through which agents' opinions and other inputs are aggregated (Kameda, 1996).

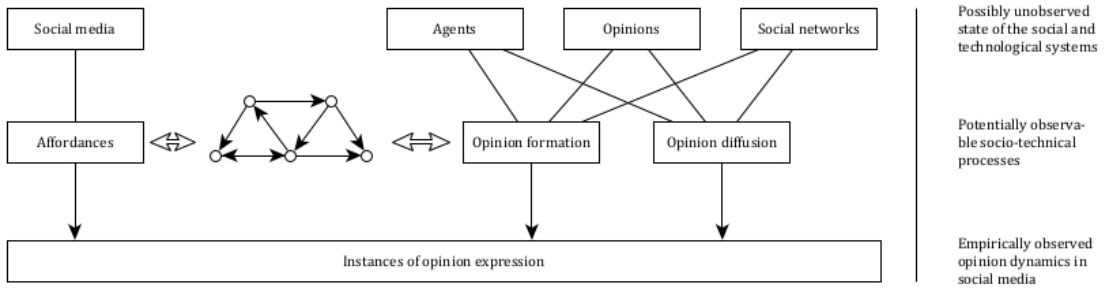
Inspecting classical procedures for regulating group discussions, as discussed for instance by Butler and Rothstein (1987), we find that they can directly influence the actors and relations that constitute a social network, as well as the interactions between them. For instance, procedures may encourage actors to express private information or to summarize public information. They may aim at defining sub-groups, or they may see to exclude specific actors or impose a break upon the group as a whole. Procedures may be applied temporarily or permanently, and their effects may be contingent on actors' opinions, for instance, if they regulate the order of opinion expression according to possibly opinion-related variables, such as actors' role or seniority. Procedures can hence affect how we define actors and relations, and affect the parameters of the opinion formation and diffusion processes operating within a social network, such as the sequence of interactions and logical and other constraints on opinion expression. In other words, procedures can not only determine what a social network looks like in terms of nodes and edges, but also the conditions under which interactions between the elements of that network take place.

I argue that just as formal and informal rules of interaction, social media can be interpreted as sources of procedural influence that can restructure opinion dynamics, based on the affordances they provide. In particular, I assume that these can impose rules of interaction that determine how opinion formation and diffusion can take place. Oh et

al. (2015), for instance, explain that social media provide a "technolinguistic grammar" that can shape their users' behaviors and interactions, based on how they interact with requirements such as character or format limitations, or conversational features such as #hashtags and @mentions to achieve their goals. Thus equating mechanisms with the affordances of social media can make mechanisms less abstract and easier to understand; furthermore, it describes mechanisms as attributes of empirically knowable agents and artifacts, which facilitates identifying and analyzing technologically induced procedures acting within a particular situation (Bygstad et al., 2016).

Figure 9 illustrates how social media can hence be integrated into my explanatory framework. In that view, social media platforms exist independently of the social processes among the agents, their opinions, and social networks that constitute opinion dynamics. However, their affordances are not independent of the social context, as they essentially describe the relationship between a technological artifact and its users (Evans et al., 2017). I assume that social media might hence influence opinion dynamics on the layer of the social and technological mechanisms, which interact to determine the actors, relational ties, and the operating logics of the processes through which they interact, working together to produce the empirically observed opinion dynamics outcomes. It is through this link that we move beyond the enabling view of social media.

Figure 9
Integrating social media as sources of procedural influences in social networks



There are certain narrative parallels between research on procedural influences and that on opinion dynamics in social media. The procedural influence lens was originally applied to investigate deliberative processes facing a fundamental tension: on the one hand, the idea that people come together for free and equal deliberation is intuitively appealing, as it fits well with commonly shared social values. On the other hand, the explicit as well as

implicit rules for task definition, discussion scheduling, and group decision-making that are nevertheless present can manipulate the outcomes of these discussions in seemingly harmless, though nevertheless fundamental ways (J. H. Davis, 1992). Similarly, social media are often interpreted as platforms that enable fundamentally democratic discourse among their users: they provide opportunities for people to participate in social, political, and economic processes, facilitate inclusion of otherwise marginalized stakeholders, empower affected people and communities, and increase the transparency of sense-making processes – even if the implications of their enabling role are often unclear (Dwivedi et al., 2018).

It is not possible, however, to transfer the concept of procedural influence to the realm of social media without further ado. Landemore (2012) argues that deliberative processes enabled by social media differ from those traditionally theorized along three dimensions: first, the number of actors involved in opinion formation and diffusion; second, the mode of aggregation; and, third, the role of social networks to enable interactions. First, as to the number of actors involved, social media allow participation of significantly larger groups (Landemore, 2012). While research into procedural influences has focused on small groups, opinion dynamics in social media are based on the contributions of online crowds, which is, large groups of heterogeneous actors who share an interest in an issue (which can be information-related, but also emotionally or otherwise motivated) and who are connected through their mutual presence in social media (Stage, 2013). Second, regarding the mode of aggregation, Landemore (2012) points out that opinion dynamics in social media may involve little to no direct deliberation in terms of goal-directed exchanges, but may be decentralized and distributed, and furthermore be affected by algorithms employed by a platform. Observed outcomes may hence emerge as unintended by-products of actors' seemingly independent usage behaviors and the digital traces they leave (Moussaid et al., 2009). Finally, regarding the role of social networks, the patterns of relational connections in which actors are embedded on a platform can determine the flow of social influence (Gruzd & Wellman, 2014); furthermore, emergent effects from actors' exchanges along their relational connections enabled by social media, such as informational cascades, can influence opinion dynamics (Guille et al., 2013).

Procedural influences hence provide a useful theoretical frame to capture a multitude of potential influences of technological artifacts on social mechanisms, and offers a certain degree of generality in developing explanations for how and why opinion dynamics occurred. It is sufficiently comprehensive to work together for instance with individualistic accounts of agent behavior or social theories of network dynamics to

account for the implications of technology adoption and use in a given situation. In the context of social media research, procedural influences extend the affordances approach by offering an explanation not only for how specific uses arise from the interplay between users and technological artifacts, but also for how these uses might interact with the social processes that follow from the individual users' behaviors.

My work is about identifying and analyzing the affordances through which social media can influence opinion dynamics, specifically in the context of crisis response and management. To that end, procedural influence lens must be adapted to account for altered group sizes and aggregation procedures, and especially the implications of social relations to enable and shape exchanges – the key concern of social network theory (Borgatti et al., 2014). In the following section, I delineate a research approach suited to engage in such efforts based on retroductive theorizing and analytic induction, which connects the papers and contributions of my thesis.

4. Research Approach

Being located within the domain of the actual, causal mechanisms may be partially observed, but typically, our knowledge of them will be incomplete. It hence makes sense to integrate all sources of information available – both manifest and antecedent (Williams & Wynn, 2018) – to analyze the existence and operations of the hypothesized mechanisms. Critical realist research therefore typically integrates various sources of information (Mingers et al., 2013). Its key characteristic is the combination of multiple methods through a retroductive research strategy. Below, I suggest a methodological approach that applies retroductive reasoning to explore and describe the role of social media in crisis response and management, theoretically re-describe and thus frame the phenomenon, and develop working hypotheses regarding potentially relevant mechanisms.

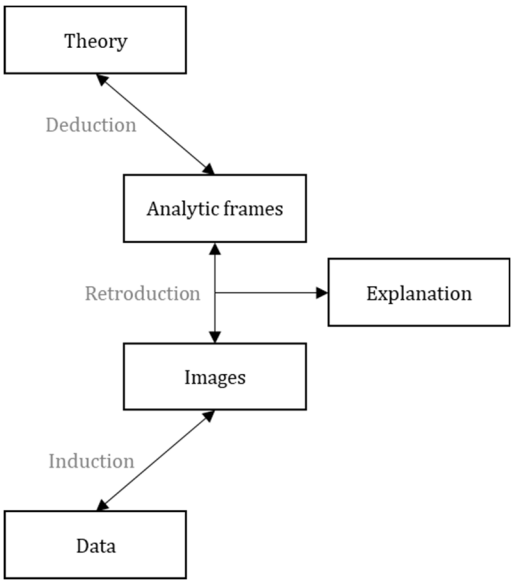
4.1. Retroductive Theorizing and Analytic Induction

Following the critical realist paradigm, I adhere to a research approach that is commonly known as *retroduction*: it integrates empirical observations of the phenomenon of interest and pre-existing theory to produce explanations that are both aligned with empirical data and analytically generalizable (Mueller & Urbach, 2017; Sæther, 1998). Retroduction requires that researchers move back and forth between theory, empirical

observation, and generalization thereof, and hence combines stages of inductive and deductive theorizing (Sæther, 1998).

Retroduction integrates manifest and antecedent knowledge of a phenomenon of interest (Williams & Wynn, 2018). Manifest knowledge, on the one hand, refers to knowledge gained through empirical observation or abstraction thereof; it comprises *data* gained through empirical obersvation, and idealized cases referred to as *images*, which are developed through abstracting from observations. Antecedent knowledge, on the other hand, refers to pre-existing *theory* and *analytic frames* deducted from it, which provide the conceptualizations needed for integrating ideas and observations (Ragin, 1994; Sæther, 1998). Retroduction hence helps identify and conceptualize the structures and mechanisms that, if valid, account for empirically observed phenomena (Sæther, 1998). Figure 10 illustrates the retroductive research approach.

Figure 10
Retroductive theorizing approach according to Ragin (1994) and Sæther (1998)



Retroduction involves an iterative research process and multiple engagements with both theory and data (Sæther, 1998). Broadly, the process starts with the observation of some phenomenon of interest within a given context, which is then framed from some meaningful theoretical point of view. Consulting both data and theory then allows for developing and continually refining explanations (Ochara, 2013).

Analytic induction, in particular, has been suggested as a methodological approach within the broader framework of retroduction (Mueller & Urbach, 2017). It was initially

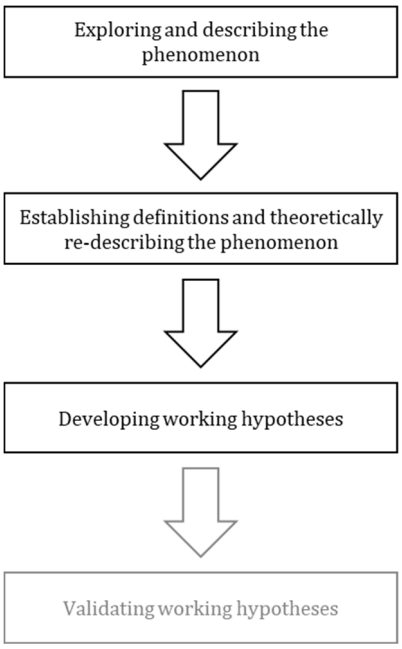
described by Znaniecki (1934) as "generaliz[ing] by abstracting", as it implies "abstract[ing] from the given concrete case characters that are essential to it and generaliz[ing] them, presuming that in so far as essential, they must be similar in many cases" (p. 251). Analytic induction hence seeks to transfer the essential characteristics of observed cases to other cases, thereby iteratively refining researchers' understanding of the theoretically relevant concepts and processes, to eventually arrive at generalizable statements (Goldenberg, 1993).

The analytic-inductive approach was substantially extended by Robinson (1951), who suggests the following steps to arrive at generalizable causal claims: starting with a provisional definition of the explanandum (i.e., phenomenon of interest) and a working hypothesis that explains it, one would apply the preliminary hypothesis to a selected case. If the hypothesis is rejected, he suggests to either modify the hypothesis or refine the definition of the phenomenon of interest. Otherwise, one would apply the hypothesis to further cases to iteratively refine and extend it.

More recent research within the critical realist tradition often adds an initial step of gathering knowledge of the empirical explanandum to identify and describe relevant entities and processes, prior to hypothesis development and empirical corroboration (e.g., Bygstad et al., 2016; Williams & Wynn, 2018; Wynn & Williams, 2012). In my research, I follow that approach and incorporate initial stages of exploring and describing the empirical phenomenon, including entities and relationships that might be relevant, and re-describing and re-framing it from a theoretical point of view. Figure 11 on the following page illustrates my research approach. While my focus is on the initial hypothesis development, empirical validation and continual refinement of hypotheses is an integral part of retroductive reasoning and should be seen a promising area of further research.

The particular strength of analytic induction lies in allowing mixed- and multi-method triangulation (S. I. Miller, 1982). In the papers contributing to my thesis, I have relied on multiple methods, integrating empirical approaches and agent-based simulation and modeling (ABSM) techniques. Below, in Sections 4.2 through 4.4, I describe how different methodologies have contributed to exploration, theoretical re-description, and hypothesis development. The key findings and contributions of each paper are described in more detail in Section 5.

Figure 11
Research approach summarized (gray color indicating aspects not covered in my thesis)



4.2. Exploring and Describing the Phenomenon

The first group of papers submitted as part of my thesis is dedicated to *exploring and describing* the phenomenon of interest, which is, broadly, the role of social media in crisis response and management. In critical realist theorizing, this corresponds to building knowledge about the empirical explanandum, such as to allow tracing the causal mechanisms that might contribute to its emergence (Williams & Wynn, 2018). I start by outlining the role of social media in crisis response and management and identifying the affordances that are empirically relevant within that context.

Paper 1 and Paper 2 are systematic literature reviews, where we have followed the methodologies suggested by Paré et al. (2015, 2016) to account for the role of information technologies in general and social media in particular in crisis response and management. The focus of Paper 1 (Eismann et al., 2021) is specifically on how social media can afford organizational learning in crisis response and management through opening learning processes across organizational boundaries. Based on a theoretical review and qualitative analysis of 128 papers published in renowned IS journals and leading conferences, we explain how social media affordances can hence allow organizations to harness external resources (*internalization*), provide access to organizational resources to users beyond their organizational boundaries (*externalization*), and facilitate collaboration across those boundaries (*collaboration*).

In contrast, Paper 2 (Fischer-Preßler et al., 2020) is about how technological artifacts – including, but not limited to social media – can support risk management in complex supply chains which, not least due to high levels of interdependencies between industries, are increasingly prone to disruptions in the wake of crises. Based on a scoping review and quantitative analysis of 55 papers, we show that social media currently only play a minor role in supply chain risk management, although they could be useful, among others, for tracing cases of impaired goods or for identifying potential security threats.

In Paper 3 (Eismann et al., 2022), we have employed disclosive computer ethics (Brey, 2000a, 2000b) to explore the implications of using mobile applications for COVID-19 contact tracing (*contact tracing apps*) from a normative point of view. Based on a qualitative content analysis of the documentations of apps deployed by five liberal democracies, we argue how these apps can be related to key information privacy concerns, following the Restricted Access / Limited Control framework proposed by Moor (1997) and Tavani and Moor (2001), and how competing design principles can contribute to app users' information privacy. We have hence explored and restructured the implications of using information technologies that share several of the main features of social media for users' behaviors and interactions during the COVID-19 pandemic.

4.3. Establishing Definitions and Theoretically Re-Describing the Phenomenon

Establishing a conceptual framework is the main subject of this introductory paper. Hassan et al. (2019) describe theorizing in terms of the interplay between foundational and generative discursive practices: *foundational practices*, on the one hand, aim at describing and characterizing some phenomenon of interest to establish a theoretically based scientific discourse, while *generative practices*, on the other hand, intend to influence that discourse once it has been established. In particular, in this introductory paper, I have:

- introduced key concepts and assumptions of opinion dynamics research from three pertinent reference disciplines, and thus established a consistent and theoretically meaningful frame for discussing opinion dynamics in social media also in IS research (*forming the discourse*);
- reviewed and scrutinized popular assumptions that implicitly underlie much IS research related to opinion dynamics in social media, especially what I refer to as the enabling view of social media (*problematizing the IS phenomenon*);

- tentatively located social media affordances in relation to the conceptual framework of opinion dynamics (*leveraging paradigms*);
- introduced procedural influences to conceptualize the influences of social media affordances on opinion dynamics processes among their users (*metaphorizing*); and
- integrated this antecedent knowledge of opinion dynamics and the potential influences of social media affordances to develop an explanatory framework rooted in a critical realist ontology and social network theory (*modelling and building the framework*).

The introductory paper hence presents the *analytic frame* for conceptualizing opinion dynamics and develop hypotheses within a specific context. Beyond that, the conceptual framework and the theoretical frame of explanation can open opportunities for further research, especially relating to the operationalization of concepts and alignment between the entities and processes evident from opinion dynamics and IS research into related phenomena, as discussed in detail in Section 6.

4.4. Developing Working Hypotheses

I have applied agent-based simulation and modeling (ABSM) techniques to develop hypotheses regarding the causal influence social media affordances on opinion dynamics in response to crises, based on my conceptual framing and empirical data. In brief, ABSM refers to a set of computational methods that allows researchers to model a system (e.g., a socio-technical system) as a collection of agents, each of which behaves according to a set of exogenously specified rules, such that we can infer the processes through which collective phenomena can arise from the dynamics of these agents' interactions (Bonabeau, 2002). It can facilitate bottom-up theory development based on the behaviors and interactions of autonomous, yet interdependent agents who follow simple behavioral rules while at the same time being capable of adaptation and learning (Macy & Willer, 2002).

The idea that simulation techniques can support theory building is not new to IS research (J. P. Davis et al., 2007). ABSM, in particular, is on the rise (Fischbach et al., 2021), and IS researchers are increasingly acknowledging its potential for analyzing the interdependent behavior of social and technical systems (Beese et al., 2019). It integrates induction (to develop models based on existing theory and data) and deduction (to analyze data generated through these models), and hence exemplifies the retroductive

research paradigm (K. D. Miller, 2015; Sætra, 2017). In terms of theorizing, ABSM does not allow quantification of statistical associations between events considered as causes and effects, respectively, but enables insights into the generative processes that contribute to the emergence of the latter, possibly incorporating nonlinear, conditional, and qualitative influences (E. R. Smith & Conrey, 2007). Furthermore, it can enhance ontological clarity through enforcing a focus on the specific attributes and behaviors of the constituent entities (K. D. Miller, 2015).

In light of that, Paper 4 (Eismann, 2019) can be understood as an initial attempt to specify a formal model of procedural influences on opinion dynamics, and on this basis analyze the implications of common interaction procedures. The key contribution of this paper lies in formalizing procedural influences and thus in providing the analytical means to investigate regular influences on social process (as opposed to factors that affect the constituent social entities), and in demonstrating how concepts discussed in small-group research can be applied to a social network setting, accommodating for one of the systemic differences between opinion dynamics in interacting groups and online crowds cited by Landemore (2012).

In Paper 5 (Eismann, 2021), I have relied on ABSM to develop hypotheses regarding how social media can influence how users make sense of rumors in the aftermath of crises, specifically through these platforms' *searchability* affordance, which allows users to gather information through dedicated search and query features rather than relying on interactions along their relational connections (boyd, 2011). Building upon the rumor communication model of F. Bloch et al. (2018) and relying on the PHEME rumor scheme data set (Zubiaga et al., 2016) for empirical validation, I analyze the spread of rumors in response to five crisis events. My findings suggest that searchability can facilitate self-correction primarily by motivating users to block unverified messages regardless of their veracity; beyond that, my work hints at several mechanisms through which interactions along their relational connections might enable users to identify trustworthy messages while blocking presumably untrustworthy ones.

5. Papers and Contributions

As part of this thesis, I submit a total number of five papers. Three of these papers are based on the contributions made by multiple authors. *I hereby declare that I have made substantial contributions to the conception and design of the work, material preparation, data collection, and data analysis, and drafting and critical revision of all manuscripts.*

Below, I delineate the key aspects of each paper in terms of the research problem addressed, its research methodology and findings, and contributions to the overall research question of my thesis.

Paper 1: Eismann, K., Posegga, O., & Fischbach, K. (2021). Opening Organizational Learning in Crisis Management: On the Affordances of Social Media. *The Journal of Strategic Information Systems*, *30*(4), Article 101692. https://doi.org/10.1016/j.jsis.2021.101692

Using social media to mitigate, prepare for, respond to, and recover from crises provides opportunities for opening organizational resources and processes to actors outside an organization. Hence, social media can facilitate collaboration across established organizational boundaries, such as between emergency response organizations and members of the public, and between different organizations involved in crisis response and management. This can lead to opening effects, such as transparency, interactivity, responsiveness, empowerment, and participation, which in turn can feed back on the openness of organizational resources and processes.

Social media can therefore enable organizations to learn about a crisis as it occurs, and furthermore facilitate strategic organizational adaptation by allowing them to integrate resources and processes that reside beyond their boundaries. However, IS research on crisis informatics has largely adopted an operational point of view, focusing on the immediate potentials of using social media to learn about crises, rather than its long-term implications for organizational change.

The focus of Paper 1 is on the strategic implications of social media for organizational learning in crisis management. In particular, we set out to describe the state of knowledge in IS research regarding how social media can afford organizational crisis learning, following the organizational learning framework of Crossan et al. (1999), and to explain how they might thus contribute to opening organizational resources and processes and facilitate the emergence of opening effects, based on the openness dimensions suggested by Schlagwein et al. (2017).

We have conducted a theoretical literature review (Paré et al., 2015, 2016) to identify and describe concepts evident from prior research and account for potential relationships between them. Based on a comprehensive keyword-based search in eight indexing databases, a rigorous screening procedure, and several rounds of forward and backward searches, we have identified a total number of 128 relevant papers published in renowned

IS journals and leading conferences, which we have analyzed inductively, following the recommendations of Miles et al. (2020) for qualitative content analysis.

As a result, we have identified a total of 15 affordances of social media pertaining to *internalizing* (i.e., for incorporating external resources that result from learning processes outside the organization), *externalizing* (i.e., for providing access to the outcomes of internal learning processes to parties outside the organization), and *collaborating* (i.e., for enabling learning processes spanning the boundaries between organizational units and sub-units). These include *monitoring the information stream*, *tapping collective intelligence*, *accessing information providers*, *contributing* and *forwarding information*, *framing narratives*, *negiating consensus*, and *integrating* and *crowdsourcing contributions*, among others. Furthermore, we elaborate upon open resources made accessible through, open processes facilitated, and opening effects enabled by social media. We discuss the implications of our findings for organizational learning in crisis management, and elaborate a research agenda that illustrates how we can move forward to investigate the feedback and feedforward relationships between the identified affordances.

With respect to my thesis, Paper 1 is key to *exploring and describing* the role of social media affordances in crisis response and management. Based on my work, I argue that crisis informatics research in the field of IS is fragmented not only in terms of theoretical frames, but also with regard to the integration of temporal dynamics and complex interdependencies between the underlying social processes. In our work, we have summarized and conceptually integrated the various affordances of social media relevant in crisis response and management, which, to the best of my knowledge, is a contribution currently unrivaled by other IS papers in that context. Beyond that, we have illustrated how social processes enabled by social media are related, and how they can work together to produce social and organizational outcomes.

Paper 2: Fischer-Preßler, D., Eismann, K., Pietrowski, R., Fischbach, K., & Schoder, D. (2020). Information Technology and Risk Management in Supply Chains. *International Journal of Physical Distribution & Logistics Management*, *50*(2), 233-254. https://doi.org/10.1108/IJPDLM-04-2019-0119

Not only have crises become increasingly common: due to high levels of global connectivity and interdependencies between organizational processes, even smaller risk events can have significant effects for instance on supply chain operations. Information technologies, including both including hardware (e.g., RFID) and software (e.g., ERP systems), as well as information systems (e.g., social media), can play a major role in

managing risks that result from disruptive events such as crises, as well as from operational risks inherent within the supply chain.

In Paper 2, we investigate how information technologies can support supply chain risk management, based on insights produced by prior research. In so doing, we describe and classify papers focused on information technology use for supply chain risk management, and furthermore explore research trends and promising areas for future research at the intersection of supply chain risk management and information technology use.

We have conducted a scoping literature review (Paré et al., 2015, 2016) to evaluate the extent to which prior research provides insights into the role of information technologies to support risk management along supply chains. We identified relevant papers through a systematic keyword-based search in 39 scientific journals covering prestigious IS and management outlets, in combination with a rigorous selection of relevant papers. Quantitative analyses were based on a total number of 55 papers. In analyzing those, we distinguished between operational and disruption risk types addressed (Tang, 2006), and between different stages of risk management according to Bandyopadhyay et al. (1999) supported by the various information technologies.

We find that the majority of analyzed papers covers information technology use within the context of operational risk. Disruption risks, as can emanate from crises, are typically researched, if at all, within the context of humanitarian relief chains, where challenges were found to arise especially from insufficiencies in collecting, processing, and sharing relevant information. Information technologies are hence discussed primarily as a means to reduce risk through facilitating information sharing and collaboration along the supply chain. Based on the review results and insights gained from discussions with senior employees and supply chain experts from German companies that participated in an international research project, we discuss potential strategies regarding how information technologies might be useful for managing supply chain risks beyond what is evident from existing research.

Regarding the overall research question of my thesis, Paper 2 contributes to *exploring and describing* the role of social media in managing crises within a more limited context. We find that few papers within the analyzed set explicitly address social media for managing supply chain risk, though our discussion suggests they might be useful for identifying and monitoring emerging risks. While the paper's focus is on information technologies in general, it yields insights into the potential of social media to support the management of crisis risks within the domain of supply chain management.

Paper 3: Eismann, K., Fischer-Preßler, D., & Fischbach, K. (2022). Applied Ethics and Digital Information Privacy: Informing the Design of COVID-19 Contact Tracing Apps. *Australasian Journal of Information Systems*, *26*. https://doi.org/10.3127/ajis.v26i0.3097

Social media can be defined broadly: as platforms that facilitate diffusion of digital content among a large number of users connected through their mutual presence on that platform. In Paper 3, we have investigated how mobile applications for contact tracing during the COVID-19 pandemic (referred to as *contact tracing apps*) protect their users' information privacy. People can use these apps to provide information about their health status (i.e., whether they have contracted COVID-19) and potentially further personal information, which the apps use to warn users who might be at risk of an infection due to prolonged encounters with infected users, measured, for instance, through physical proximity using Bluetooth technology. We hence address the implications of using social media, in a broader sense, to disseminate personal information related to a crisis.

Specifically, we analyze normative and technical design principles to protect users' information privacy that are evident from apps deployed in five liberal democracies, along with the conceptual implications for our understanding of information privacy evident from the design of these apps. Analyses are based on the Restricted Access/Limited Control framework of information privacy (Moor, 1997; Tavani & Moor, 2001) that distinguishes between the condition (i.e., the extent to which a given situation limits access to personal information in the first place) and management of information privacy (i.e., ways people can furthermore control how their personal information can be accessed and used, given they provide it in the first place).

We interpret instances of contact tracing app use as situations that can threaten users' information privacy by enabling unwarranted access to and use of their personal information, while at the same time protecting that information through both technical features and normative specifications. Within a disclosive computer ethics approach (Brey, 2000a, 2000b), we have qualitatively analyzed the official documentation of apps used in Australia, France, Germany, Japan, and New Zealand. Doing so, we have explored what types of personal information were collected by the apps, what kinds of information privacy violations were accounted for, and what – normative and technical – design principles were applied to protect users' information privacy from these violations.

Overall, our findings suggest that the apps rely on data minimization, data protection, and pseudonymization to restrict access to users' personal information, while encouraging voluntariness and transparency to prevent violations. Beyond that, apps may provide

opportunities for users to provide additional information to enhance data used for contact tracing. Apps vary regarding whether they focus on data minimization to restrict access to and use of users' personal information versus richness to enhance data quality and ensure adequate conclusions can be drawn from users' data. We discuss the implications of these contrasting design principles for privacy-sensitive app design, and how the trade-off between normative and technical design principles as well as different ways to implement them may affect the extent of information privacy afforded.

Within the context of my thesis, Paper 3 explores the implications of using information systems aimed at facilitating the diffusion of crisis-related, personal information, specifically, of the interactions between normative and technical design features on the one hand, and users' information-sharing behaviors on the other. The paper hence contributes to *exploring and describing* the affordances social media provide for disseminating crisis-related information, and the implications of actualizing them.

Paper 4: Eismann, K. (2019). Procedural Influence on Consensus Formation in Social Networks. In L.M. Aiello, C. Cherifi, H. Cherifi, R. Lambiotte, P. Lió, & L.M. Rocha (Eds.), *Complex Networks and Their Applications VII: Volume 2 Proceedings of the 7th International Conference on Complex Networks and Their Applications COMPLEX NETWORKS 2018* (pp. 287-299). Springer. https://doi.org/10.1007/978-3-030-05414-4_23

Key to my work is the concept of opinion dynamics, as described in detail in the previous sections. Prior works have explored, in detail, how changes in the underlying configuration of the social system – as characterized by its agent, opinion, and social network characteristics – can affect the outcomes of opinion formation and diffusion processes. In Paper 4, I investigate how opinion dynamics interaction procedures can furthermore alter the logics of the interactive processes that connect these entities.

In contrast to much prior research, I treat opinion formation and diffusion processes not as invariant, constant sequences of events inspired by social or psychological theory or empirical regularities, but rather as being subject to change themselves – to the point of strategic manipulation. In Paper 4, I explore how well-known interaction procedures– in particular, agenda influences, straw polling, and staged sub-group interactions (e.g., Kameda, 1996) – affect aggregate opinion outcomes within an agent population.

The key contribution of Paper 4 hence lies in illustrating how procedural influences on interaction procedures can be formally modeled, and how the implications of applying such procedures can be practically analyzed. Analyses rely on ABSM, using an extension

of the Friedkin-Johnsen model that incorporates interdependencies between different beliefs (Friedkin, Proskurnikov, et al., 2016; Parsegov et al., 2017), which due to its simplicity allows to clearly identify the effects of intervening interaction procedures.

Within the context of my thesis, Paper 4 introduces the analytic frame of my work, and can be seen as a first attempt to formally analyze procedural influences on opinion dynamics processes and outcomes. While it does not refer to social media, nor is it connected to empirical data, it is at the heart of my work, as it introduces and connects relevant concepts and establishes the basis for investigating the relationships of interest. Thus, it bridges between *theoretically re-describing the phenomenon*, in a formal way, and *developing working hypotheses* based on that re-description.

Paper 5: Eismann, K. (2021). Diffusion and Persistence of False Rumors in Social Media Networks: Implications of Searchability on Rumor Self-Correction on Twitter. *Journal of Business Economics*, *91*, 1299-1329. https://doi.org/10.1007/s11573-020-01022-9

The diffusion of rumors, in the sense of unverified information through which people make sense of uncertain situations such as crises, is one of the issues most frequently addressed by IS researchers when it comes to analyzing opinion dynamics in social media during or in the aftermath of crisis events. Despite their bad reputation, rumors are not necessarily false, and platforms provide numerous opportunities for users to engage with and scrutinize unverified information, and combat the propagation of misinformation and disinformation.

Against this background, Paper 5 is about how the searchability affordance of social media, which allows users to access digital content through their purposeful efforts to find or discover information, rather than by navigating their relational ties to others (boyd, 2011), can interfere with their ability to identify and impede the propagation of false rumors. In particular, I argue that searchability can affect the structure of relational ties through which rumors can propagate, thus possibly interrupting collective sense-making processes and allowing messages to bypass censorious users.

I employ again ABSM techniques, using the rumor communication model of F. Bloch et al. (2018) as a basis. That model, which can be located within the microeconomic research tradition on social learning, focusses specifically on individual agents' decisions to spread information, contingent upon the transmission history of that information, and hence allows analyzing the effects of different communication environments that represent the modes of information transmission available in social media. Approaching further the

issue of contextualization, I rely on the PHEME rumor scheme dataset (Zubiaga et al., 2016) for empirical calibration, which contains manually annotated conversational threads of Twitter rumor messages related to five crisis events in 2014 and 2015. My findings suggest that searchability can impede rumor transmission by incentivizing users to block all unverified messages, while personal communications along their relational connections may allow them to identify and share individually verified messages nevertheless (e.g., by creating trustworthy transmission pathways for individual messages, or spreading presumably true rumor messages among trustworthy users only).

In terms of contributions to my thesis, Paper 5 moves beyond the generic inspection of social media affordances and their potentials to support crisis response and management. by introducing a theoretically consistent focus. Based on that, I demonstrate how an empirically validated ABSM approach can be useful for analyzing and developing testable hypotheses regarding the implications of actualizing specific affordances of social media. The key contribution of Paper 5 hence lies in *developing working hypotheses* that can be tested and refined in future works.

6. Theoretical, Methodological, and Practical Implications

The central theme that connects the elements of my thesis is my approach to developing explanatory theory, which, according to Grover et al. (2008), is basically theory directed at explaining how and why phenomena occur. In their terminology, explanatory theory can be understood as "attempt[.] to build justified and valid knowledge claims that seek to explain causally *why* something occurred by means of an outcome, criterion, or dependent variable in the context of specific conditions that are captured as a set of antecedent variables" (p. 41).

Following Hassan et al. (2019), I understand theorizing as the interplay between foundational and generative discursive practices aimed at consistently integrating the various elements of theory (e.g., constructs, boundaries, and claims of causal relationships [Gregor, 2006]). Below, I evaluate the overall contributions and limitations of my thesis following from that theorizing approach.

6.1. Theorizing Overview

The introductory paper of my thesis primarily contributes to *foundational theorizing*, as it scrutinizes established assumptions regarding the role of social media for opinion

dynamics: I have developed a conceptual framework to identify and categorize relevant entities and processes, and proposed a theoretical frame of explanation that accounts for how the affordances of social media can influence opinion formation and diffusion processes among their users, based on extant literature in three reference disciplines. In terms of *generative theorizing*, I have outlined a theoretical argument that extends existing theory by establishing social media affordances as technological agents, based on critical realist ontology and the notion of procedural influences in social networks. The five papers submitted as part of my thesis further contribute to forming the discourse and problematizing the IS view on social media specifically in the context of crisis response and management, and to modeling technological affordances as sources of procedural influences on users' behaviors and interactions.

My argument relies on critical realist ontology, which distinguishes between events in the domain of the empirical (i.e., empirically observed instances of opinion expression and change), causal mechanism in the domain of the actual (i.e., opinion formation and diffusion processes that lead to these events), and the entities of the social system in the domain of the real (i.e., the underlying agents, opinions, and social networks), based on which the hypothesized mechanisms operate. In that view, the affordances provided by social media are interpreted as causal processes – referred to as *mechanisms* – that establish the link between the underlying configuration of the social system and the empirically observed opinion dynamics events. That allows ascribing causal powers to technological artifacts and hence integrate them theoretically (Grover & Lyytinen, 2015; Williams & Wynn, 2018).

As Weick (1995, p. 385) points out, the "[p]roducts of the theorizing process seldom emerge as full-blown theories". This is also true for the outcomes of my thesis. The focus of explanatory theory, in particular, according to Gregor (2006), is specifically on causal relationships; it not only specifies *what is* (i.e., it describes and analyzes empirical phenomena), but also provides an explanation of *how and why* the observed events occur. However, while explanatory theory can therefore enhance our understanding of events, it does not produce testable propositions or prescriptive statements (Gregor, 2006). Critical realist theorizing, in particular, aims specifically at identifying and describing the causal mechanisms that can account for phenomena of interest (Williams & Wynn, 2018).

6.2. Theoretical Concepts and Relationships

In Section 2, I have developed a conceptual framework that specifies and describes the entities and processes that underlie opinion dynamics. Following Gregor (2006), framework elements should be evaluated primarily based on their plausibility and credibility. The framework draws upon the contributions of mostly analytical research in three reference disciplines; it integrates key concepts from prior research, focusing on prestigious and often-cited works identified through on a survey of papers listed in a major interdisciplinary research database. It is hence meaningful insofar as we accept these prior works as relevant basis. My approach does not ensure *all* possibly relevant concepts are included; however, it lends credibility at the very least to the major categories of framework elements. Still, developing a framework based on prior research is prone to suffering from methodological limitations shared by review-based approaches, as the outcomes depend to a significant extent on whether I have successfully captured the relevant "theory ecosystem" (Larsen et al., 2019).

Framework development also opens the door to concerns related to the empirical relevance of concepts. That is, to what extent can we expect primarily theoretically motivated concepts to help us understand complex empirical socio-technical phenomena? And how can we decide which of the various theoretical assumptions that underlie the different models – such as microeconomic theories of agent behavior and theories of social network dynamics – are relevant in a given situation?

Regarding the question how the identified concepts can be applied to the realm of social media, I have followed prior research in equating agents with entities represented by digital profiles in social media (primarily the *users* of these platforms), and their express opinions with digital content created and shared by them. These assumptions already touch on existing discussions regarding the nature of information (e.g., Mingers & Standing, 2018) and social networks (e.g., Howison et al., 2011) in digital environments. However, theory testing and validation can take place only at the end, rather than at the beginning, of the theorizing process (Hassan et al., 2019), which is why I have not yet addressed issues related to the operationalization of theoretical concepts in detail. Exploring how the identified concepts translate into empirical constructs thus constitutes the logical next step within the proposed iterative research logic aimed at the continual refinement of theoretical concepts and relationships.

One example for how we might further investigate the empirical relevance of opinion dynamics concepts would be to start from the empirical side, by identifying and

integrating the constructs investigated by prior works within a specific context (e.g., crises). That could for instance result in a classification of empirical entities that can be matched with the elements of the conceptual framework to identify similarities and differences, and to develop a more unified view of the social dynamics at work. The conceptual framework presented in Section 2 could hence shed light on concepts potentially overlooked by empirical research, and help organize empirically relevant constructs. In Paper 1, we have pursued a related idea by integrating various processes from an organizational learning perspective. Future research might find it interesting to move beyond that theoretical lens. Following an iterative research logic, researchers could start from individual case studies and gradually refine concepts and relationships by transferring the study outcomes to further settings. In addition, IS researchers might find case studies that integrate multiple sources of data using mixed-methods or multi-methods approaches, as well as review and survey approaches, particularly attractive.

In addition, the theoretical contribution of a conceptual framework depends on how it affect the established causal claims regarding the relationships between its elements (Whetten, 1989). In that regard, the contribution of my work primarily lies in advancing a more unified view on the social dynamics enabled by social media. In particular, the conceptual framework facilitates identifying entities that might operate in similar ways, or that might fulfil similar functions within a social process, despite being treated as conceptually distinct by some model or framework; it helps refine assumptions regarding the characteristics and behaviors of related entities and locate gaps in a model or theory where additional factors might enhance its explanatory power. That allows integrating concepts in a theoretically meaningful way, rather than merely adding them to models as some kind of control or intervening variables. My work also facilitates understanding how seemingly distinct opinion formation and diffusion processes might be related, based on entities that contribute to multiple processes and inherent similarities between processes that can be understood as instances of the same class. That also promotes a more dynamic view on social processes enabled by social media that illustrates the interdependencies between the underlying processes.

Conceptualizing and classifying opinion dynamics entities and processes can furthermore enhance the conceptual rigor of research by demonstrating how seemingly distinct concepts might be related, both in a descriptive (i.e., specifying similarities regarding their attributes and their role within opinion formation and diffusion processes) and a causal sense (i.e., indicating the relations between the underlying entities and processes). This could, for instance, affect how researchers justify their choice of concepts and models.

Through further refinement and empirical validation of hypotheses generated from the conceptual framework, it can furthermore become possible to challenge established causal claims. For instance, the findings of Paper 5 illustrate that when social media users cannot verify the contents of some rumor circulating in the aftermath of a crisis event, how they evaluate other users' trustworthiness can be crucial for their decision to spread the word. That is opposed to the idea that users negotiate meaning to establish a shared understanding of events, as claimed, among others, by Jong and Dückers (2016) and Oh et al. (2015). However, it could help explain why official sources can play a major role in verifying and debunking rumors (e.g., Jung et al., 2020), how news aggregators can affect the diffusion of rumors and rumor corrections (e.g., Song et al., 2021), or how non-human agents such as *social bots* could help broker verified information (e.g., Alves de Lima Salge et al., 2022). The outcomes presented in the paper could serve as starting point for analyzing the settings in which communities can be expected to successfully debunk false rumors, and under what conditions crisis response organizations should dedicate resources to identifying and correcting false rumors (e.g., on what platforms or in the wake of what types of events).

6.3. Explanatory Potential of Causal Claims

We can furthermore discuss the explanatory potential of the causal claims I have made as part of my work – which is, the *how and why* that is at the heart of explanatory theory (Gregor, 2006). In particular, this refers to the specificity of assumptions about the objects of explanation and the causal link between cause and effects, and also the scope and parsimony of propositions (Bacharach, 1989); the latter aspect is also related to the boundaries of explanation (Weber, 2012), which I discuss in the subsequent section.

The explanandum of my work is the causal influence of social media, as characterized by their technological features and properties, on opinion dynamics among their users. In brief, it is hence about how a specific class of technological artifacts can affect the outcomes of social dynamics by influencing either the configuration of the social system in which it operates or by moderating the social processes themselves. My argument is unspecific with regard to the exact influences analyzed, which makes it easy to adapt to a variety of phenomena on the one hand, but on the other decreases its analytical rigor.

The works of Havakhor et al. (2018) and Heimbach and Hinz (2018) are two examples for theorizing platform influences more specifically. Their underlying rationales clearly have greater explanatory power within their respective settings, and hence advance theory in

ways that are easier to describe. In contrast, the theorizing approach I have presented should be understood as a broader framework of explanation, whose primary contribution lies in providing a generalizable argument that helps organize and develop explanations for a broader range of phenomena, rather than in accounting for the emergence of one or more precisely specified event(s).

As to the specificity of the causal argument itself, I have described in detail how social media, through their affordances conceptualized as socio-technical mechanisms, can affect both the underlying social and technological entities and other processes that might be at work. In Section 3, I have specified the ontological foundations of my argument and addressed aspects related to the causal ontology, causal trajectory, and causal autonomy dimensions described by Markus and Rowe (2018), in an attempt to develop a comprehensive theoretical account for technological influences on social dynamics. In so doing, I hope to contribute to understanding technological artifacts not merely as enablers of social behavior, but as causal agents in their own right.

Beyond that, Gregor (2006) points to the internal validity of explanation, meaning that "alternative explanations as to what caused a particular outcome should be examined and assessed" (p. 625). In critical realist research, internal validity refers to the extent to which some mechanism or set of mechanisms can be considered as sole cause(s) of an empirically observed event (S. P. Smith & Johnston, 2014). Within the context of my work, how we can integrate theoretical hypotheses and empirical data to assess the relevance of the assumed mechanisms is particularly interesting. In Paper 5, I have demonstrated how digital trace data can inform theorizing the role of relational connections between social media users propagating rumor messages in response to crisis events. Using ABSM techniques, I have harnessed empirical data to gain insights into the operating logics of the causal mechanisms at work, based on a small set of assumptions of agent behavior and the role of relational connections for the diffusion of messages. The outcomes of this study help refine the underlying theoretical assumptions on which further investigations can be based; furthermore, the paper demonstrates how empirical data can enhance our understanding of the causal processes at work.

In terms of methodology, the main contribution of my work hence pertains to ABSM. In particular, I have demonstrated the value of these techniques for developing and validating hypotheses inductively, rather than through deductive logic and correlational analyses. Whenever positivist claims for evaluating theory – in particular, regarding empirical falsification (e.g., Bacharach, 1989) – do not apply, ABSM can be useful for

uncovering and describing the processes that contribute to a phenomenon (E. R. Smith & Conrey, 2007). By producing a representation of the relevant entities and processes, along with the interactions between those, it can promote ontological clarity, and it can be particularly useful for exploring the implications of mechanisms at work within a particular setting (K. D. Miller, 2015). In the past, ABSM was was often seen as un-empirical, in the sense that models are useful primarily to exemplify and analyze theoretical assumptions (Macy & Willer, 2002). While Hedström and Manzo (2015) observe a trend towards integrating data through model calibration and validation, only few works so far employ that method for theory testing. The methodology I have employed in Paper 5 could be seen as a step towards exploring these possibilities.

6.4. External Validity and the Role of Context

Regarding the scope and parsimony of propositions, the causal claims put forth in the introductory paper rely on a small set of entities and processes, while at the same time potentially applying to a large spectrum of phenomena. My argument hence claims high levels of generality, which is actually quite typical for explanatory theorizing (Gregor, 2006).

According to Zachariadis et al. (2013), external validity, in the context of critical realist theorizing, can best be interpreted as following from evidence that the mechanisms identified within a particular research setting are causally relevant for similar or related events in other settings. Focusing on causal mechanisms, rather than on statistically significant correlations, drawing conclusions about the implications of using technological artifacts in unobserved settings is a desirable research objective, yet one that is complicated by the nature of mechanism-based theorizing itself (S. P. Smith & Johnston, 2014).

It hence makes sense to focus on the distinct boundaries of my argument, of which there are three overall: first, explanation is restricted to opinion dynamics processes. Broadly, this involves all kinds of activities through which agents develop and revise their beliefs, or interact with others to exchange related information. This restriction is meaningful especially in connection with the second boundary, which is, social media as information and communications platforms on which these activities take place. That encompasses a broad variety of social activities that take place in social media in various settings, including, but not limited, related to fostering situational awareness through accessing and providing timely and relevant information (e.g., Lamsal et al., 2023), facilitating

participative knowledge creation (e.g., Kallinikos & Tempini, 2014), enabling innovation through enhanced knowledge exchange (e.g., Leonardi, 2014) and crowdsourcing (e.g., Schlagwein & Bjorn-Andersen, 2014), and negotiating consensus through collective sense-making practices (e.g., Oh et al., 2015).

Information is clearly a key resource for all these activities, as it is essential to any kind of value creation from digitally enabled interactions (Faraj et al., 2016; Sundararajan et al., 2013). However, equating the diffusion of information with opinion dynamics implies that a large variety of interactions enabled by a platform are considered potentially relevant. This makes aspects related to the operationalization of concepts, as I have already briefly mentioned above, all the more important to determine the boundaries of analysis.

Consider, for instance, the question how users' opinions can be operationalized through digital, user-generated content in social media. The empirically observed digital traces generated by users as well as by the platforms themselves can affect users' behaviors and the flow of information, but they are far from being simple representations of users' opinions. On the contrary, we may expect complex interactions between that content and how agents define their identities and their relationships on a platform (Kane et al., 2014). The information that is represented by digital content created and shared by users, and transmitted through a platform's technological features is distinct from both the platforms *and* their users; simply equating content and opinions can therefore be problematic (Petter et al., 2018). The boundaries of analyzing opinion dynamics in social media will hence heavily depend on researchers' choice regarding the operationalization of theoretical concepts, most importantly, of agents' opinions.

The third boundary of my work is the crisis context. Affordances, such as those of social media, are meaningful only within a specific setting that can trigger these mechanisms to come into effect (Bygstad et al., 2016) and determines what further social and cognitive mechanisms may be relevant for understanding agents' behaviors (Evans et al., 2017). It is unsurprising that different affordances were found to be at work in different contexts. For instance, the affordances of social media I have identified within the context of organizational learning in crisis response and management in Paper 1 are similar, but still different from those found relevant for driving collective action by Sæbø et al. (2020) and Tim et al. (2018); they differ more substantially from the affordances discussed within the context of enterprise organization for instance by Majchrzak, Faraj, et al. (2013) and Leonardi and Vaast (2017). One possible conclusion could be that different affordances

might affect opinion dynamics in different ways, though similar affordances found to be relevant in different contexts could, ceteris paribus, operate in similar ways.

Beyond that, context also plays a role within the theorizing process itself. Theorizing as a discursive practice understands context as basis for both foundational and generative practices (Hassan et al., 2019). Thus, context not only serves as sensitizing device to determine the boundaries of theory, but guides all steps relevant for framing the explanandum, developing hypotheses, and approaching empirical validation. Retroductive theorizing based on alternating steps of induction and deduction meets these requirements (Sæther, 1998). Incorporating context into theory, rather than applying theory to a specific context, has various benefits. Amongst others, it can help develop models that are more accurate, and contribute to a more robust interpretation of research results. Furthermore, theory developed in such a way is said to be able to more easily account for unexpected or anomalous findings, shed light on how context affects our understanding of a phenomenon, and hence on whether causal relationships can be meaningfully transferred to other contexts. However, at the same time, such deep contextualization will typically not result in broad-range theory, as it conflicts with the quantification of cause-effect relationships, and therefore comes at the expense of generalizability and parsimony (W. Hong et al., 2014). There is a clear trade-off between contextual fit and scope of theorizing, which retroduction resolves in favor of the former.

6.5. Overall Theoretical and Practical Contribution

The key contribution of explanatory theory is to be new and interesting, or to explain phenomena that are thus far imperfectly understood (Gregor, 2006); it should advance knowledge in a scientific discipline and guide future research towards essential research questions (Van de Ven, 1989). My work makes theoretical contributions to two fields of study: first, the interdisciplinary body of opinion dynamics research, to which it offers a theoretical rationale for integrating technological influences on social dynamics, and, second, the IS discipline, to which it introduces a conceptual basis for analyzing opinion formation and diffusion processes enabled by social media.

In other words, I have “borrowed” (Whetten, 1989) opinion dynamics concepts from reference disciplines in which analytical research on the phenomenon has a long tradition, with the aim to establish that discourse in IS research, demonstrate how it can enhance our understanding of digitally enabled social dynamics, and argue how it can inspire future research by opening new research questions and tapping previously

underused methodological potentials. In that regard, I contribute to the reconceptualization of opinion dynamics in social media and to scrutinizing and challenging popular assumptions.

Following Corley and Gioia (2011), that contribution would be deemed incremental, rather than revelatory: while the dynamics of interest are neither new nor unknown, I contribute to their understanding by providing insights into the causal mechanisms at work, and by outlining a methodological approach for analyzing them, based on iterative theoretical refinement. In so doing, I go beyond merely attempting to replicate known effects and analyzing previously theorized relationships. Rather, my thesis sheds light on the causal role of technological artifacts that exceeds their role as enablers, moderators, or mediators of social behavior. Following from Colquitt and Zapata-Phelan (2007), the primary contribution of my work would thus be to reconceptualize what is known about the phenomenon of interest.

Corley and Gioia (2011) argue that beyond being original, theory should also be useful. Theory that is scientifically useful, according to them, improves conceptual rigor and enhances the specificity of an idea, or facilitates operationalization and testing of concepts and relationships. By conceptualizing opinion dynamics and specifying a theoretical rationale for how social media can influence the underlying entities and processes, my work clearly contributes to the former. In my thesis, I have furthermore outlined a program for validation based on the principle of analytic induction and a retroductive research approach. While I have not yet explored the operationalization of concepts and relationships in detail, my work lays the foundations for future efforts in that direction.

In contrast, theory that is practically useful, according to Corley and Gioia (2011), can be directly applied to the problems faced by managers or practitioners. The practical implications of my work primarily pertain to the field of crisis response and management. Managers and practitioners potentially interested in the outcomes of my work are members of emergency response and humanitarian relief organizations in the first place. Other organizations potentially affected by crises include business organizations, for instance, if crises disrupt the flow of commodities and goods along their supply chains, and hence cause urgent needs to respond to and contain disruptions, restore and secure operations, and mitigate damage to the organization's performance and reputation with consumers, contractors, and other stakeholders. Similarly, during the COVID-19 pandemic, both public and private organizations found it to be of uppermost importance to keep up communications with their staff, customers, the media and the wider public to

disseminate information about availability of products and services, opening hours, sanitary provisions, and hygiene measures. These are just a few example for how organizations might be affected by events they consider as crises, to which they must respond to (re-) establish operations and secure organizational survival.

Decision-makers confronted with such situations could find my work useful to gain a deeper understanding for how social media can help them achieve their goals. I do not provide an overview of social media functionalities and how to use them, as given for instance by Lindsay (2016). My focus, in contrast, is on the implications of crisis responders using social media to fulfil certain tasks. Paper 1, for instance, shows how the different affordances provided by social media can contribute to organizational learning processes. Organizational crisis responders using social media to spread information (e.g., situational updates or warnings) can for instance use these findings to learn how actualizing affordances not only for externalizing, but also for internalizing and collaborating, can help them increase the efficiency and effectiveness of communications during the immediate crisis response phase. Similarly, the findings of Paper 1 could prove useful for managers and practitioners facing a brand or reputational crisis in social media, as they illustrate how social media can help them maintain sovereignty of interpretation and prevent escalation. The outcomes of my work hence have implications for the field of organizational communication and can contribute to the conception or adaptation of job profiles, such as that of social media community managers. Beyond the crisis context, the insights can also be useful for managers and practitioners seeking to access and integrate community resources, for instance for crowdsourcing ideation (e.g., Majchrzak & Malhotra, 2013; Schlagwein & Bjorn-Andersen, 2014; Zuchowski et al., 2016).

Another example for how my findings could be useful for organizations is their using social media to gather first-hand information about a crisis from local users, as discussed for instance by Bergstrand and Stenmark (2016), Ludwig et al. (2015), and Tapia and Moore (2014). The findings of Paper 1 are relevant for organizational users trying to lay the foundations to gather situational awareness during crises, especially through actualizing interactive affordances for building community and establishing consensus with community members, which might encourage social reporting and increase the accuracy of crowdsourced intelligence. In the long run, organizations might also discuss how developing community with social media can contribute to broadening their understanding of organizational membership and allow them to devise new modes of membership based on social media activity. Relatedly, in Paper 2, we have touched upon the potential of thus monitoring social media to identify supply chain risks, such as cases

of intentional or unintentional contamination of food products in distribution. This case is one example in which strategic efforts to actualize the affordances provided by social media could prove useful to also mitigate potential crises.

Yet another example for how the findings of Paper 1 can support crisis response and management activities is the field of community self-organization. Local communities affected by crises are known to use social media to make sense of events, seek and provide resources, exchange social support, and organize crisis response activities, among others (e.g., Kaewkitipong et al., 2016; Leong et al., 2015; Torrey et al., 2007). Paper 1 illustrates how the various affordances provided by social media can support community self-organization; in addition, it sheds light the opportunities for action available, and hence opens opportunities to understand community building as strategic effort, as opposed to being restricted to the phase of immediate crisis response, and therefore contribute to developing community resilience.

In contrast to that, the findings of Paper 3 illustrate how the outcomes of actualizing the affordances of socio-technical platforms affect its users. In that paper, we have focused on how different design features are related to users' information privacy, in the sense that they restrict access to users' personal (e.g., health-related) information and grant them control over who can access and use that information in what ways. How apps protect users' information privacy is causally related to people's intentions to use a platform (e.g., Fischer et al., 2019). To maximize adopion, privacy-sensitive design is hence important for developers and organizations devising them. For the individual users, findings on the different – in parts conflicting – conceptualizations of information privacy can be useful to evaluate whether to share pieces of personal information, and as a consequence, affect what information they make available to others.

Similarly, the findings of Paper 5 have direct implications for emergency managers. In particular, the findings of that paper illustrate how different modes of accessing rumor-related information in social media can affect its further propagation. As mentioned above, managers and practitioners can use these insights to learn under what conditions rumors are likely to propagate in social media, and, thus, in what cases it makes sense to dedicate resources to rumor management. In addition, the findings provide the basis for further exploring how organizations might seek to position themselves within the network of communicating users to support the diffusion of verified (organizational) messages and prevent the propagation of false rumors. Thinking one step further, the findings of Paper 5 might also help organizations evaluate available platforms for internal

and external crisis communications, contingent upon the modes of information access they provide. The work of Yates (2016) is one example for how that might affect the accessibility of organizational knowledge.

Overall, my work hence contributes to understanding digitally enabled social dynamics in response to crises. The empirically observed digital traces used to generate the corresponding insights are of course snapshots; even if monitored over time, there are limitations to what conclusions we can draw regarding their underlying mechanisms. Nevertheless, the papers submitted as part of this thesis can help managers and practitioners in the field of crisis response and management, as well as community members affected by a crisis, to make the best use of the platforms available and take the best possible action in response to crisis events.

7. Conclusion

In my thesis, I set out to theorize the causal influence of social media platforms on opinion dynamics among their users. I have, relied on a critical realist ontology that interprets the foundational concepts of opinion dynamics – in particular, agents, opinions, and social networks – as entities within the domain of the real, based on which opinion formation and diffusion processes within the domain of the actual can lead to observable instances of opinion expression and change within the domain of the empirical. The affordances of social media (i.e. potentials for action that emerge from the interplay between the platforms and their users [Volkoff & Strong, 2013]) are interpreted as causal mechanisms that introduce procedural influences, which means that they can introduce formal and informal rules of interaction that affects users' behaviors and interactions, and thus interact with opinion formation and diffusion. I therefore view the affordances provided by social media platforms as causal agents in their own right, which cannot only *enable*, but furthermore *influence* social dynamics in a causal way (Williams & Wynn, 2018).

In Section 2, I have developed an integrated conceptual framework of opinion dynamics. Based on that, I have outlined a theoretical rationale that accounts for the causal influence of social media affordances in Section 3, incorporating a critical realist ontology, social network theory, and the notion of procedural influences. Applying this analytic frame to reconceptualize the influence of digital information and communications platforms on social dynamics is particularly appealing, given the narrative parallels between the two discourses; in particular, the emphasis on seemingly unmanipulated deliberation –

despite the possibility that interaction procedures might affect the outcomes of people's exchanges unnoticed – is striking.

We find that argument applied for instance within the context of crisis response and management, where social media are said to enable collaboration between users from within and across various organizations, as well as members of the public and provides opportunities for community self-organization (e.g., Leong et al., 2015; Nan & Lu, 2014; Tim et al., 2018). The field of crisis informatics provides the context for my research. In Section 4, I have delineated a research approach that can be used to model and analyze opinion dynamics specifically within that setting, based on retroductive reasoning (Sæther, 1998) and the principles of analytic induction (Robinson, 1951). In Section 5, I have outlinded the contributions of the five papers submitted as part of this thesis with regard to my overall research question and how they relate to describing the phenomenon of interest, defining and theoretically re-describing it, and developing working hypotheses aimed at causal explanation.

In Section 6, I have discussed the contributions and further theoretical, methodological, and practical implications of my work. In terms of theory, I make contributions, on the one hand, to the interdisciplinary field of opinion dynamics research, by offering a theoretical rationale to account for technological influences on social dynamics, and, on the other hand, to the IS discipline, to which I offer a well-founded conceptual framework and explain how we might incorporate technological influences into theories borrowed from other fields of research, thus moving beyond what I refer to as an *enabling view* of social media adoption and use. In terms of practical utility, the outcomes of my work are most relevant for managers and practitioners in the field of crisis response and management, who can use it to better understand social dynamics enabled by digital information and communications platforms in the wake of a crisis, and to learn about ways to manage and utilize such dynamics to enhance crisis mitigation, preparedness, response, and recovery efforts.

There are further limitations to my work beyond those discussed in the previous section, some of which are inherent to my overall rationale and research approach, and hence cannot be meaningfully resolved within the boundaries of my thesis. Some of these limitations relate to my theoretical framing of social media influences. I have argued that social media affordances can be interpreted as sources of procedural influence, and hence as causal agents in their own right. I do not intend that argument to *oppose* the enabling view on social media, however. Rather, I mean to argue how the impact of social media

goes beyond merely enabling social dynamics, and thus to enhance and complement often-read arguments. Still I find it useful to differentiate between these views to demarcate the differences between social media as enablers versus causal agents.

Another related concern pertains to the elements of my theoretical frame of explanation. The model I have presented in Section 3 is, of course, simplified; among others, it does not account for contextual and other influences, further cognitive and social processes, and other determinants of social media adoption and use. Identifying *all* entities and processes relevant for understanding opinion dynamics in a given situation, as well as their interplay with the opinion dynamics mechanisms at work in a narrow sense, is beyond the scope of my work.

In addition, I have thus far focused on developing an analytic frame to provide a meaningful background for discussing technological influences upon the corresponding entities and processes. Moving on, it would only be logical to engage in similar efforts to integrate IS research on opinion dynamics in social media to align and balance this analytically driven narrative and fully appreciate especially the empirical contributions made by IS researchers.

Regarding the theorizing process itself, a major limitation of counterfactual causal reasoning is its being limited to identifying sufficient – rather than necessary – conditions of events (Menzies & Beebee, 2020). Similar criticism is shared by the research logic of analytic induction: while intuitively appealing, it has been criticized for its lack of rigor and systematicity. As summarized by Goldenberg (1993), initial case selection may be crucial for the direction of theory development; furthermore, theories developed through the process of analytic induction may not be sufficiently generalizable if the cases used for validation are inadequately selected. Also, falsification of causal claims may prove difficult, given the potentially ever changing definitions and scope of explanation. As a method for causal analysis, analytic induction can again help identify necessary, but not sufficient conditions of causation, as it is limited to studying cases in which a phenomenon occurred (Robinson, 1951). Such criticism is generally shared by inductive research approaches, and while it is mostly uncritical for developing explanatory theory focussed on explaining (as opposed to predicting or prescribing [Gregor, 2006]), it still constitutes a potential limitation of my work.

Relating to theorizing as a set of discursive practices, as described by Hassan et al. (2019), this introduction to my thesis makes contributions specifically to forming the discourse, while the appending papers make further contributions to foundational and generative

practices of theorizing. My work hence can be seen as first step towards developing explanatory theory, especially by theoretically re-framing social media influences on social dynamics and developing corresponding working hypotheses. It is intended to encourage and guide future research, most importantly into the empirical validation of causal claims and the refinement of theoretical concepts and relationships.

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B. Appendix I: Papers

1. Paper 1: Opening Organizational Learning in Crisis Management (with Appendices)

Bibliographic Data

Eismann, K., Posegga, O., & Fischbach, K. (2021). Opening Organizational Learning in Crisis Management: On the Affordances of Social Media. *The Journal of Strategic Information Systems*, 30(4), Article 101692. https://doi.org/10.1016/j.jsis.2021.101692

Abstract

Research on the role of social media in crisis management has led to a deeper understanding of their affordances. This research, however, is fragmented, with a primary focus on crisis response. We lack a clear conceptualization of the affordances that social media offer by learning from them to prepare strategically for crises. Based on a systematic review of 128 papers, we inductively build a framework of social media affordances for organizational learning in crisis management. We discuss their role and interplay in strategic crisis management, focusing on organizational crisis learning, and outline avenues for future research based on this foundation.

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Introduction

Crises caused by infrastructure breakdowns, product and service failures, violent attacks, and natural disasters pose significant threats to organizations' strategic goals (Seeger et al., 1998). To prevent the occurrence and contain the impact of crises, organizations must respond swiftly to emergent and ongoing events so they can sustain or restore operations. Converting crisis experiences into actionable learnings helps organizations adapt to their environments strategically. All this translates into a continuous cycle of organizational renewal in which the occurrence or possibility of crisis can trigger organizational learning processes that in turn increase organizational resilience and enhance the ability to learn and prepare for future events (Lampel et al., 2009; Williams et al., 2017).

Information systems (IS) research and other disciplines have explored the potential of using information and communications technology (ICT) – most prominently, social media – to open organizational resources and processes to the public to support organizations responding to crises. For instance, social media enable organizations to exchange crisis-related information irrespective of established organizational boundaries and command structures (e.g., Yates & Paquette, 2011), exchange information and knowledge with the public (e.g., Liu & Xu, 2018), and crowdsource funds, materials, and volunteer resources (e.g., Brengarth & Mujkic, 2016). In addition, they empower the people and communities affected to reestablish communication ties interrupted by crises, establish outlets for sharing reliable information, and identify opportunities for community action (e.g., Ahmed & Sinnappan, 2013; Kaewkitipong et al., 2016; Leong et al., 2015). Thus, social media provide opportunities for organizations to access and draw upon information and other resources provided by non-organizational users, integrate contributions those users make, and encourage self-organization and novel forms of organizing that span established organizational boundaries (Tim et al., 2017).

Social media provide opportunities not only for organizations to learn about a crisis as it occurs (i.e., *intra-crisis learning*), but also to integrate information, knowledge, and collaborative processes that reside beyond their established structures. Thus, they can allow organizations to access resources provided by non-organizational users (i.e., *open resources*), support participative processes that integrate citizens and other users beyond an organization's scope (i.e., *open processes*), and facilitate collaborative structures that integrate organizational and non-organizational users equally (i.e., *opening effects*). We find, however, that the focus of most research is operational, and little attention has been

paid to how organizations can use social media to adapt to adverse environments beyond the threats posed by a particular crisis.

This review adopts a strategic perspective on the use of social media in organizational crisis management, focusing on the process of organizational learning. Our research question is: *What is the state of knowledge in IS research regarding how social media afford organizational crisis learning?*

Our conceptual framework combines organizational learning theory (Crossan et al., 1999), affordance theory (Volkoff & Strong, 2013), and openness (Schlagwein et al., 2017). This allows us to integrate insights from prior research to identify opportunities for action that social media may provide for organizational crisis learning, and to develop an understanding of how social media allow organizations to learn for and from crises, drawing upon open resources and processes and opening effects. To answer the research question, we employ a *theoretical literature review* aimed at synthesizing the contributions of prior research (Paré et al., 2015). The conceptual contribution of our work hence lies in providing an integrated perspective on how social media can afford organizational learning in crisis management, based on the rigorous and systematic analysis and integration of related IS research (MacInnis, 2011).

The remainder of this paper is structured as follows: Section 'Theoretical Background and Conceptual Framework' delineates the paper's theoretical background and conceptual framework. Section 'Literature Review and Analysis' describes our review methodology. Based on that, Sections 'Review Findings on Organizational Learning Affordances Provided by Social Media' and 'Review Findings on Open Resources, Open Processes, and Opening Effects Facilitated by Social Media' are overviews of the affordances of social media we have identified and the open resources, open processes, and opening effects they facilitate. Section 'Implications for Organizational Learning in Crisis Management: Discussion and Research Agenda' discusses the implications of our findings concerning how social media can hence support organizational learning through open resources and processes and opening effects, and spells out opportunities for future research. We conclude in Section 'Conclusions'.

Theoretical Background and Conceptual Framework

To provide a conceptual foundation for our review of social media affordances for organizational learning in crisis management, we outline our perspective on crises and

crisis management and provide background on organizational learning, social media affordances, and openness. We summarize our theoretical background in a conceptual framework.

Organizational Crises

An *organizational crisis* is defined as a "specific, unexpected, and nonroutine event or series of events that create high levels of uncertainty and threaten or are perceived to threaten an organization's high-priority goals" (Seeger et al., 1998, p. 233). This broad definition includes ecological crises, business and other economic failures, sociotechnical disasters, and hostile attacks and other violent behaviors (Richardson, 1994), and thus encompasses, among others, natural disasters, pandemics, infrastructure breakdowns, product and service failures, violent attacks, and social unrest (Seeger et al., 1998).

Organizations affected by such events – including high-reliability organizations, emergency response and humanitarian relief organizations, governments, businesses, and self-organized communities – must make efforts to prevent their occurrence and minimize their impacts. When faced with the immediate threat of a crisis, organizations must rise to the challenge and employ operational capabilities and resources to adapt to and confront the situation. Beyond that, they must take strategic measures to gather information about potential risk sources so they can plan for the occurrence of crises and build resilience, learn about ongoing events and their impacts to allocate resources and continue or restart operations, collaborate with stakeholders and other organizations to coordinate responses, and eventually draw lessons from their own and other organizations' experiences and prepare for future events (Comfort et al., 2001; Lalonde, 2011). Thus, responding to crises poses both strategic and operational challenges for organizations and requires systematic efforts to learn from past events.

Organizational Learning

Following Vera et al. (2012, p. 154), *organizational learning* is defined as "the process of change in individual and shared thought and action, which is affected by and embedded in the institutions of the organization." Organizational learning theory emphasizes the role of learning for strategic renewal (Crossan et al., 1999; March, 1991), that is, the continuous process of change that enables an organization to thrive in and adapt to its environment. This process is strategic in that it spans not only the individuals and groups within an organization but also the organization as a whole, at every level, including the

environment within which it is embedded (Duncan & Weiss, 1979). Two focal mechanisms drive the process: *exploration*, which includes the organizational activities aimed at identifying new opportunities for learning and integrating new learnings into the renewal process; and *exploitation*, the application of what has been learned (Crossan et al., 1999). Tensions arise between the two mechanisms from their ambidextrous nature and interdependence: they must be executed simultaneously and continuously to enable organizational learning and strategic renewal (Werder & Heckmann, 2019).

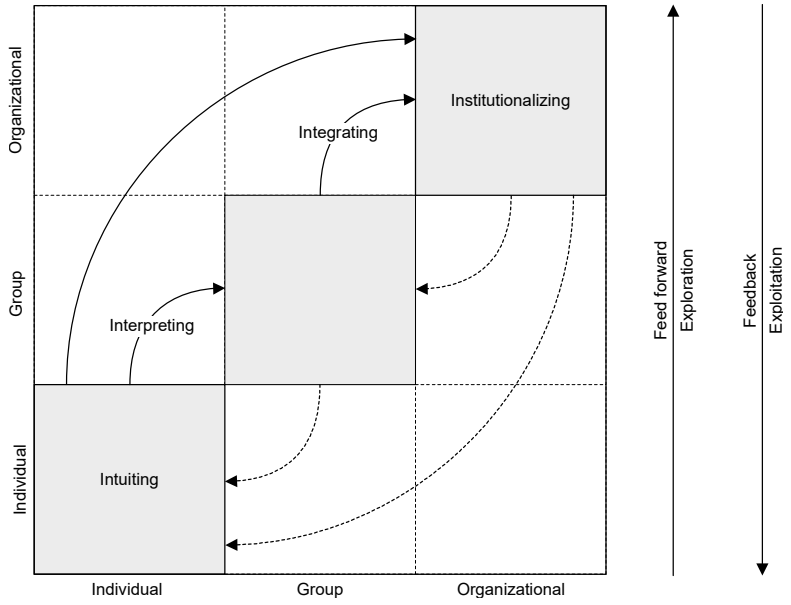
Conceptualized as a process, organizational learning comprises four stages: intuiting, interpreting, integrating, and institutionalizing (Crossan et al., 1999). *Intuiting* is the preconscious process through which individuals – within an organizational context – recognize patterns or possibilities from a personal stream of experiences. *Interpreting* is the process through which they explain the insights they gain from intuiting to themselves and others, both verbally and through other means of expression. *Integrating* is the process of developing a shared understanding and taking coordinated action based on that understanding as a result of spontaneous interactions among groups of actors. *Institutionalizing* is the process of establishing routinized action, which involves activities such as defining tasks, specifying actions to be taken, and establishing processes that ensure these activities and actions are enacted. Institutionalizing takes place within the confines of formal organization, characterized by continuous input-transformation-output relationships (Argyris, 1964).

These four processes are connected by *feedforward* and *feedback* mechanisms. The former refers to exploration routines that build on the output of learning processes at the individual (intuiting and interpreting) and group (integrating) levels to absorb them at an organizational level (institutionalizing); the latter, which work in the opposite direction, involves the diffusion of institutionalized learnings from the organizational to the individual level (Crossan et al., 1999). Figure B.1.1 summarizes the organizational learning framework and its core processes.

Organizational learning is a core mechanism in crisis management. Learning from crises is vital to develop the capabilities required to prevent their occurrence and limit their implications (Carley & Harrald, 1997). One defining characteristic of crises, however, is that *intra-crisis learning* – that is, learning to improve the response to a crisis as it occurs (Moynihan, 2009) – is notoriously difficult for organizations. Challenges are imposed in part by the disruptive nature of crises, which can prevent decision-makers from identifying and collecting the information required to inform and evaluate their actions.

In addition to the sheer impact of crisis events, other factors, such as limited experience in dealing with crises as well as both cognitive and operational restrictions to information collection and processing, pose strong barriers to organizational learning in the critical impact phase of crises (Moynihan, 2008). Likewise, *intercrisis learning* – that is, learning from crises to prepare for future events (Moynihan, 2009) – poses a challenge to most organizations. From a strategic point of view, the rigidity of an organization's core beliefs and assumptions, ineffective communication, and information difficulties, among others, can impede learning from crises (Smith & Elliott, 2007).

Figure B.1.1
Organizational learning process (Crossan et al., 1999)



The complexity of an organization's external environment is an important characteristic of crisis learning. Organizational learning theory accounts for *internal* and *external* learning domains: the former describes learning processes that take place within organizational boundaries (i.e., individual learning, intrafunctional learning, interfunctional learning, and multilevel learning), whereas the latter refers to learning from the external environment (i.e., customer learning, competitor learning, network learning, and institutional learning [Bierly & Hämäläinen, 1995]). The external environment becomes less well-defined during crises due to their complex and dynamic nature. As internal and external shareholders and stakeholders jointly participate in crisis-related activities, especially when using social media, the external domain quickly extends to the public and thus to a broad variety of individuals, communities, organizations, and institutions (Houston et al., 2015). Understanding how social media

blur organizational boundaries and open organizational learning processes to the external environment is important to understanding how organizations can improve learning about and from crises.

Social Media Affordances

A growing number of papers in recent years demonstrate how the use of ICT, especially social media, can facilitate various organizational processes in crisis management, ranging from knowledge management (e.g., Yates & Paquette, 2011) to crowdsourcing (e.g., Brengarth & Mujkic, 2016) to stakeholder conflict management (e.g., Hauser et al., 2017). They provide opportunities for organizational learning and adaptation in crisis management, most notably by enhancing organizational memory and supporting communication (Robey et al., 2000).

While social media facilitate organizational learning in crisis management, however, little is known about *what* exactly makes this possible. A closer look at prior work on the subject reveals that crisis informatics research in IS and other disciplines has investigated the various individual, organizational, and social outcomes of using social media in crises, but mostly in isolation from each other. We also observe that IS research has focused on the implications of using social media during the crisis response phase, that is, dealing with the immediate and operational impact of a crisis as it unfolds. While this phase is crucial for crisis management and thus important to understand, focusing primarily on crisis response can lead to overemphasizing operational aspects of crisis management. As a consequence, while we might gain a deeper understanding of affordances related to information sharing and communication during crisis response, we may deprive ourselves of the chance to capture the implications of social media use for organizational change and adaptation in crisis management. In an effort to move towards a more comprehensive picture of social media affordances in the aforementioned context, we aim to understand how those affordances relate to the organizational learning process.

In our review, we focus specifically on the *affordances* social media provide for managing organizational crises. We understand affordances broadly as "what is offered, provided, or furnished to someone or something by an object," in the sense that they refer to opportunities for action provided by an object (in our case, social media) that can, but need not, be actualized by goal-directed actors (Volkoff & Strong, 2013, p. 822). Affordances result from using ICT features to achieve some kind of outcome; as such, they

describe the actions users are enabled to pursue to achieve their goals using a platform's features (Leidner et al., 2018).

The concept of *openness* best describes one of the most prominent phenomena arising from the pervasiveness of social media and their affordances in organizational contexts. Schlagwein et al. (2017, p. 297) define openness as the "accessibility of knowledge, technology and other resources; the transparency of action; the permeability of organisational structures; and the inclusiveness of participation." As a higher-order concept, openness follows four principles: transparency, access, participation, and democracy. These apply to resources (e.g., access and transparency of information and knowledge), processes (e.g., transparency of and participation in crowdsourcing and open innovation), and effects (especially democratizing effects, such as open business, open education, open government, and open science [Schlagwein et al., 2017]). In practice, openness is a driving force of novel forms of organizing that thrive on the idea of strategically lowering organizational barriers and opening once exclusively internal resources and processes to participants outside the organizational container. Technologies such as social media play a focal role in this context, as they simultaneously enable and shape open phenomena, rendering the interplay between openness, ICT, resources, processes, and their outcomes – within and beyond organizational boundaries – a promising area of IS research (Schlagwein et al., 2017; Winter et al., 2014).

Conceptual Framework

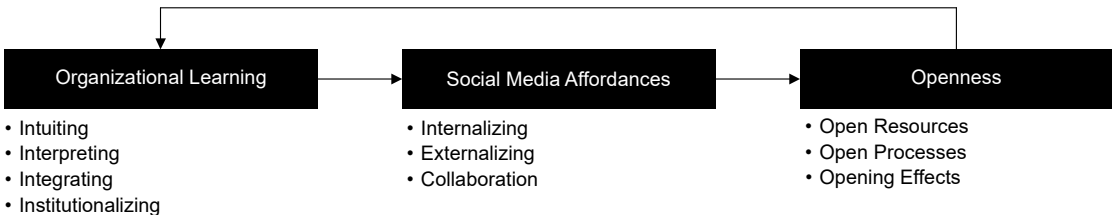
In the context of organizational learning in crisis management, we argue that the social media affordances provide the opportunity to open the organizational learning process by making it and the resources it requires and produces – such as information and knowledge – transparent and accessible to parties external to the organization. When referring to learning organizations, we focus on formal organizations that respond to organizational crises, such as businesses, emergency response organizations, and government agencies. External parties include a variety of actors that participate in crisis and disaster relief efforts, such as residents, communities, governments, news media, and other organizations (Houston et al., 2015).

Opening the learning process enables organizations to benefit from and contribute to simultaneously occurring learning processes within and outside of organizational boundaries through three classes of affordances, which we call internalization, externalization, and collaboration. *Internalization* refers to affordances that allow for the

accumulation and use of external resources, such as knowledge and information, which result from external learning processes. *Externalization* refers to providing access to the outcomes of internal learning processes to parties outside of organizational boundaries. *Collaboration* comprises affordances that enable collaborative and democratic learning processes that span the boundary between organizations and external parties. We propose that those affordances contribute to opening the organizational learning process and unlock previously untapped opportunities for organizational learning that – if managed strategically – might allow for realizing synergies between internal and external learning that exceed traditional boundaries of both learning types by spanning organizational and industrial boundaries and incorporating resources offered by the public and external actors.

Figure B.1.2 summarizes the conceptual framework used to structure our review of social media affordances for organizational learning in crisis management. Based on the affordances identified in our review, we discuss their implications for the four core processes of organizational learning: intuiting, interpreting, integrating, and internalizing.

Figure B.1.2
Conceptual framework



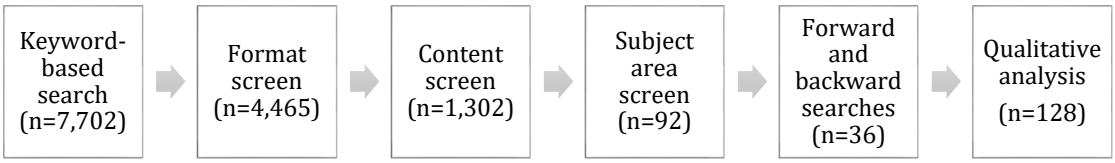
Literature Review and Analysis

We conducted a *theoretical review* to identify affordances social media provide for opening organizational learning in crisis management. Our goal was to synthesize the insights of conceptual and empirical studies from different strands of research, which provide the context for identifying, describing, and integrating concepts that are evident from prior research based on our conceptual framework (Paré et al., 2015, 2016). Theoretical reviews aim at explaining, that is, establishing the concepts that contribute to the dimensions of the conceptual framework and elaborating potential relationships between them (Rowe, 2014).

This goal distinguishes theoretical from other types of reviews, such as descriptive and scoping reviews, which aim at describing or understanding a field of research (Rowe, 2014; Templier & Paré, 2018). A significant difference between explanatory reviews and reviews aimed at understanding or describing is that they are concept-centric rather than paper- or author-centric (Rowe, 2014). While the latter, especially descriptive reviews, often rely on (primarily) quantitative research designs to provide insights into existing research on a specific topic, the former require in-depth analyses of the literature, including the interpretation, synthesis, and aggregation of previous works. Thus, theoretical reviews with the goal of explaining are ideally suited for qualitative research designs.

Following Paré et al. (2016), the review process consisted of a rigorous literature search and selection process that included a keyword-based search in eight indexing databases, systematic selection of relevant papers, iterative forward and backward searches based on the initially selected studies, and qualitative analysis of selected papers. Figure B.1.3 is an overview of the literature search, selection, and analysis process. Each step is detailed below.

Figure B.1.3
Overview of the literature review process



To identify relevant studies, we conducted a keyword-based search in eight indexing databases: the ACM digital library, AIS electronic library, EBSCOhost information services, EmeraldInsight, IEEE Xplore digital library, JSTOR, Science Direct, and the Social Science Citation Index. Search terms were built around the two core concepts of our study: *social media* (defined as "user-driven platforms that facilitate diffusion of compelling content, dialogue creation, and communication to a broader audience" [Kapoor et al., 2018, p. 536]) and *crises* (defined as "specific, unexpected, and nonroutine event[s] or series of events that create high levels of uncertainty and threaten or are perceived to threaten an organization's high priority goals" [Seeger et al., 1998, p. 233]). Through a series of preliminary searches, we determined frequently used synonyms for both concepts and searched for singular and plural forms of each term. We searched all permissible

combinations of the title, abstract, and keywords fields of each database without further restrictions on the types of entries, including all publications up to and including 2018. This resulted in a total of 7,702 hits across all eight databases. Appendix 'Search Terms and Hits per Database' includes the exact search phrases and the number of hits for each database.

From these initial hits, we selected relevant papers in three steps: format, content, and subject area screens. Appendix 'Inclusion and Exclusion Criteria in the Format, Content, and Subject Area Screens' details all inclusion and exclusion criteria. *Format screening* excluded all papers that were not peer-reviewed journal or conference papers, as well as those published in languages other than English. This allowed us to reduce the number of inclusion candidates to 4,465 papers.

Content screening excluded all papers we considered irrelevant to our research because they did not relate to both concepts of interest, namely, social media and crises. Two authors undertook content screening, simultaneously coding a subset of 10% (corresponding to $n = 770$ papers) of randomly selected papers to assess their relevance. After an initial round of training based on the codebook in Appendix 'Inclusion and Exclusion Criteria in the Format, Content, and Subject Area Screens', both coders reached a strong level of agreement in both code categories, which is supported by a Cohen's Kappa of 0.935 for the crisis criterion and 0.923 for the social media criterion, and a pairwise agreement of 96.7% and 96.2%, respectively. Differences in both categories were resolved through discussion until a consensus was reached. Each coder continued to apply the content screening criteria to one-half of the remaining papers. This process left 1,302 papers for further inspection.

Subject area screening aimed at reducing the number of papers to a reasonably manageable corpus while maintaining those studies likely of most interest to readers. We included only studies published in renowned IS journals and leading conferences. We relied on the Harzing journal list (66th ed. [Harzing, 2020]) to guide inclusion decisions in the subject area screen, maintaining all papers from outlets in the "Management Information Systems, Knowledge Management" subject area that had received rankings in the top half of the Australian Business Deans Council (ABDC) and at least one other qualitative ranking released since 2015. Furthermore, we included papers from the proceedings of the International Conference on Information Systems (ICIS) and the Hawaii International Conference on System Sciences (HICSS) to capture emerging trends. We imposed no further restrictions on the type of papers included, thus retaining

empirical, conceptual, design, and review papers. In a final round of data cleansing, we removed conference papers that were preliminary versions of journal articles already included in the corpus and substituted research-in-progress papers with their follow-up journal papers, leaving 92 papers for further processing.

In addition to the keyword-based search, we conducted forward and backward searches to identify papers that had cited previously included papers (through *Microsoft Academic*) or that had been cited by them. We repeated the process for three rounds until no further relevant articles could be identified. We selected from the remaining papers for further analysis all those that passed the same format, content, and subject area screening steps described above. This resulted in a total of 36 additional papers and a final set of 128 papers in total. Appendix 'Corpus of Papers' includes the complete list of papers included in the corpus.

Few of the selected papers refer explicitly to affordances provided by social media. Because these affordances result from the interplay between social media platforms and their technological features on the one hand, and their users' goal-directed behavior in a given context on the other (Evans et al., 2017), we assume that they constitute the *logical link* (Neuendorf, 2017) between social media technologies and the uses they provide, which can be identified through qualitative content analyses of the papers.

Following Miles et al. (2020), we engaged in multiple successive coding cycles to identify the affordances implicit in each paper. First, to pre-structure the data, we identified statements in which the papers referred to the uses of social media in the context of crises, which could range from phrases to sentences to paragraphs. To qualify as relevant for our analysis, statements had to refer to both social media technologies (e.g., naming specific platforms, types of platforms, or their features), and how they were used in the context of a crisis (e.g., describing usage behaviors or intentions, or digital traces produced through such usage). This corresponds to our conceptualization of affordances as the logical link between social media technologies and technology uses. The statements identified were then treated as units of analysis for subsequent coding cycles.

Next, we inductively assigned process codes to the identified statements to characterize the activities or potentials for action that produced the uses of social media described in the papers, and, if stated in the papers, how they enabled organizational learning processes. As we engaged with the papers, we continually compared emerging codes and identified similarities in the identified action potentials. Moving back and forth between the papers and statements allowed us to integrate codes that expressed coherent and

consistent themes and abstract from specific platforms, features, and uses. This resulted in a total of 15 codes, which correspond to the identified affordances of social media for internalizing, externalizing, and collaborating. These steps were then repeated to assign codes to how the identified affordances were related to open resources, open processes and opening effects in the papers. For those, analyses resulted in a total of 27 additional codes. Finally, we deductively grouped the identified affordances according to how they enabled organizational learning – that is, intuiting, interpreting, integrating, and institutionalizing – through open resources, open processes, and opening effects. Appendix 'Qualitative Content Analysis Process and Codebook' contains the codebook on which qualitative content analyses are based, along with the coding rules. Appendix 'Quantitative Summary of Coding Results' is a quantitative summary of coded themes. Appendix 'Coding Results' includes the table of codes and the complete list of matched references for each.

Review Findings on Organizational Learning Affordances Provided by Social Media

Based on the systematic literature review, we identified affordances of social media – five each pertaining to internalizing, externalizing, and collaborating processes. Below, we summarize our insights on each of them before discussing their relationship to open organizational learning in crisis management. We list selected references for each of the affordances in Tables B.1.1–B.1.3. Appendix 'Coding Results' includes the complete list of matched references.

Findings on Affordances for Internalizing

Affordances for internalizing allow organizations to access resources – primarily information and knowledge – shared by non-organizational users (e.g., community members, volunteers, media representatives, and responders from other organizations or organizational sub-units). Table B.1.1 is an overview of these affordances, with definitions and selected references.

Table B.1.1
Overview of social media affordances for internalizing

Affordances	Definitions	Selected references
(1) Monitoring the information stream	Observing crisis-related digital content contributed to social media	Abedin and Babar (2018); Carter et al. (2014); Chatfield et al. (2014); Kaewkitipong et al. (2016); Liu and

Affordances		Definitions	Selected references
			Xu (2018); Ludwig et al. (2015); Majchrzak and More (2011); Radianti et al. (2016)
(2)	Automatically processing big (social media) data	Utilizing technological artifacts for collecting, analyzing, and displaying crisis-related digital content contributed to social media	Anderson et al. (2015); Hong et al. (2018); Horita et al. (2016); Mittelstädt et al. (2015); Mondal et al. (2018); Pogrebnyakov and Maldonado (2018); Ragini et al. (2018); Rudra et al. (2018)
(3)	Tapping collective intelligence	Harnessing the outcomes of users' joint efforts to make sense of crises	Jong and Dückers (2016); Kaewkitipong et al. (2016); Leong et al. (2015); Majchrzak and More (2011); Nan and Lu (2014); Poblet et al. (2018); Subba and Bui (2017); Zhao et al. (2016)
(4)	Accessing information providers	Identifying and consulting presumably knowledgeable users	Abedin and Babar (2018); Kaewkitipong et al. (2016); Liu and Xu (2018); Ludwig et al. (2015); Power and Kibell (2017); Semaan and Mark (2011); Stewart and Gail Wilson (2016); Yates and Paquette (2011)
(5)	Evaluating crisis response	Analyzing experiences gained from prior uses of social media in response to crises	Lee et al. (2017); Lin, Spence, et al. (2016); Maresh-Fuehrer and Smith (2016); Martínez-Rojas et al. (2018); Meesters et al. (2016); Osatuyi et al. (2012); Spence et al. (2016); Stewart and Gail Wilson (2016)

In particular, social media enable users to observe digital content that non-organizational users have contributed to social media presences, such as their digital profiles or community or collaborative spaces (*monitoring the information stream*). They can, for instance, keep track of digital content that features event-related markers, such as hashtags (e.g., Chatfield et al., 2014; Lachlan et al., 2016; Radianti et al., 2016), watch updates contributed to wikis, forums, and collaborative maps (e.g., Majchrzak & More, 2011; Palen et al., 2007; Reuter et al., 2014), follow contributions to digital profiles or other presences (e.g., Liu & Xu, 2018; Oh, Agrawal, et al., 2011), join relevant groups (e.g., Ahmed & Sinnappan, 2013; Kaewkitipong et al., 2016; Neubaum et al., 2014; Tim et al., 2017), and establish relational ties to relevant users to receive automatic notifications of recent activities (e.g., Abedin & Babar, 2018; Getchell & Sellnow, 2016; Lai et al., 2017).

To facilitate monitoring, organizations can employ tools and methods for the automated collection and analysis of information streams (*automatically processing big (social media) data*). Actualizing this affordance can help organizations increase the efficiency of

data collection, aggregation, and visualization (e.g., Anderson et al., 2015; Ludwig et al., 2015; Mittelstädt et al., 2015), and can allow for classifying themes of communication (e.g., Horita et al., 2016; Pogrebnyakov & Maldonado, 2018; Rudra et al., 2018) and detecting events from patterns of user activity (e.g., Dutta et al., 2018; Hong et al., 2018; Mondal et al., 2018). Social media hence allow organizations to engage in activities such as social listening and sensing, which, in turn, can enhance their situational awareness by providing access to information that might not otherwise be available within organizational boundaries – for instance, reports that signal the occurrence of damage, local impacts, activities undertaken by community members and unaffiliated responders, and rumors circulating among the population (e.g., Hong et al., 2018; Ludwig et al., 2015; Mondal et al., 2018; Radianti et al., 2016; Wu & Cui, 2018).

Furthermore, social media allow organizations to harness the outcomes of sense-making processes through which non-organizational users scrutinize crisis-related information available from social media and other sources, connect information from different sources, identify evidence for conflicting claims and interpretations, and aggregate and filter available information (*harnessing collective intelligence*). This allows organizations to tap into non-organizational information-processing capabilities, especially in support of information integration, validation, and corroboration (e.g., Jong & Dückers, 2016; Leong et al., 2015; Majchrzak & More, 2011; Nan & Lu, 2014; Subba & Bui, 2017).

Beyond the mere collection and appraisal of crisis-related information that homogenizes all user-generated content available, social media enable organizations to obtain information specifically from users who have particular knowledge or intelligence (*accessing information providers*), such as responders on the ground, locals familiar with a particular place, social media influencers and gatekeepers, technical experts, and digital volunteers (e.g., Abedin & Babar, 2018; Kaewkitipong et al., 2016; Ludwig et al., 2015; Semaan & Mark, 2011). As a result, using social media can enhance not only organizations' situational awareness but also their ambient awareness by allowing them to identify users with particular information and retrace their connections to other users to locate particular information or knowledge (e.g., Day et al., 2009; Yates & Paquette, 2011). This, in turn, can facilitate actualizing affordances for collaborating, as it can enable establishing relational connections to sources of information outside an organization and interacting with non-organizational users to obtain relevant information from them (e.g., Lin, Spence, et al., 2016; Power & Kibell, 2017; Stewart & Gail Wilson, 2016).

Looking beyond the individual crisis, affordances for internalizing also allow organizations to analyze crisis response activities and outcomes (*evaluating crisis response*). Evaluation can be retrospective, such as through collecting and analyzing digital traces of organizations' own and other users' communications from prior events, as discussed by Spence et al. (2016), or prospective, using social media to conduct crisis simulations and exercises (e.g., Meesters et al., 2016; Osatuyi et al., 2012). Thus, organizations can integrate prior experiences using social media in response to crises to develop and adapt their structures and processes and refine operational routines and procedures for future uses of social media. Evaluating crisis response can allow organizations, for instance, to identify novel roles for crisis managers to adopt using social media (e.g., Brengarth & Mujkic, 2016; Power & Kibell, 2017), devise and review plans and communication strategies (e.g., Lin, Spence, et al., 2016; Maresh-Fuehrer & Smith, 2016; Stewart & Gail Wilson, 2016), and design and evaluate technological artifacts and social media platforms for future use (e.g., Ludwig et al., 2015; Reuter et al., 2014). Social media thus facilitate participatory research, allowing users to introduce their experiences and opinions into the organizational learning process.

Findings on Affordances for Externalizing

Affordances for externalizing can be actualized by organizations to make organizational resources, especially information and knowledge, available to non-organizational users. Table B.1.2 is an overview of these affordances, with definitions and selected references.

Table B.1.2
Overview of social media affordances for externalizing

Affordances		Definitions	Selected references
(6)	Contributing information	Making crisis-related digital content available to users through social media	Abedin and Babar (2018); Ahmed and Sinnappan (2013); Kaewkitipong et al. (2016); Liu and Xu (2018); Majchrzak and More (2011); Ogie et al. (2018); Shatte et al. (2016); Tim et al. (2017)
(7)	Forwarding information	Sharing previously contributed crisis-related digital content with users beyond its original audience through social media	Abedin and Babar (2018); Chatfield and Brajawidagda (2014); J. Kim et al. (2018); T. Kim (2014); Lai and Tang (2018); Li et al. (2014); Lin, Lachlan, et al. (2016); Xu and Zhang (2018)
(8)	Framing narratives	Contributing or forwarding digital content that conveys a particular interpretation of a crisis	Gaspar et al (2016); He et al. (2018); Manika et al. (2017; Mazer et al., 2015; Meng et al. (2016); Oh et al. (2015);

Affordances		Definitions	Selected references
			Omilion-Hodges and McClain (2016); Pang and Ng (2016)
(9)	Establishing digital presences	Setting up and promoting outlets for contributing and forwarding crisis-related digital content through social media	Abedin and Babar (2018); Ahmed and Sinnappan (2013); Kaewkitipong et al. (2016); Leong et al. (2015); Majchrzak and More (2011); Oh, Agrawal, et al. (2011); Palen et al. (2007); Tim et al. (2017)
(10)	Communicating a reputation	Signaling the status and legitimacy of users contributing or forwarding crisis-related digital content through social media	Abedin and Babar (2018); Jong and Dückers (2016); J. Kim et al. (2018); Lachlan, Spence, Edwards, et al. (2014); Lin, Spence, et al. (2016); Omilion-Hodges and McClain (2016); Power and Kibell (2017); Subba and Bui (2012)

Specifically, social media allow users to make crisis-related information available to non-organizational users through authoring or editing digital content that conveys information about a crisis event or response, such as status updates, blog posts, wiki entries, and labels on maps (*contributing information*). Again, the literature suggests that much of that information is situational, such as updates on crisis impacts and response operations, or contains warnings, instructions, or advice (e.g., Abedin & Babar, 2018; Ahmed & Sinnappan, 2013; Kaewkitipong et al., 2016). Contributing information to social media can allow organizations to disseminate information and contribute to non-organizational users' situational awareness, for instance, to inform and educate the public (e.g., Ahmed & Sinnappan, 2013; Carter et al., 2014; Liu & Xu, 2018). Moreover, using social media, organizations can lend credibility to their messages to increase users' compliance by, for instance, applying specific message formats (e.g., Chatfield et al., 2012), communicating in a regular and timely manner (e.g., Lachlan, Spence, Edwards, et al., 2014), and utilizing credentials to signal trustworthiness and authority (e.g., Lin, Spence, et al., 2016).

In addition, organizations can use social media to reshare previously contributed digital content to users beyond its original audience, thus increasing the reach of crisis-related information they approve of or support (*forwarding information*). This affordance can be actualized by re-tweeting digital content or forwarding it to users for whom some information might be relevant or who might distribute it further, among other ways (e.g., Chatfield & Brajawidagda, 2014; Lai & Tang, 2018; Oh, Kwon, et al., 2011). Social media can hence complement organizational crisis communications in other channels, allowing organizations to reach large and diffuse audiences efficiently (e.g., Abedin & Babar, 2018; J. Kim et al., 2018).

Contributing and forwarding digital content also allows organizations to communicate a particular interpretation of a crisis (e.g., its causes, implications, and actions to be taken), which in turn can influence how non-organizational users perceive an event or the focal organization's response (*framing narratives*). Thus, organizations can use social media to establish legitimacy of organizational goals and purposes, protect and enhance their reputation, and encourage particular behaviors or attitudes in non-organizational users, such as supporting an organization's response activities or taking particular actions such as avoiding certain products or seeking shelter (e.g., He et al., 2018; Omilion-Hodges & McClain, 2016; Yoo et al., 2016). Along the same lines, message frames can be used to influence the content and flow of crisis-related information in social media, with applications that include containing the spread of misinformation, disinformation, or hostile messages that question or attack an organization (e.g., Hauser et al., 2017; Oh et al., 2013; Stieglitz et al., 2018). The potential of using social media to frame crisis narratives implies that they can contribute to organizational risk and crisis communications beyond merely increasing the efficiency of information dissemination (e.g., Crijns et al., 2017; He et al., 2018; Ki & Nekmat, 2014; Roshan et al., 2016).

Beyond affordances that allow for different modes of information sharing, social media provide opportunities for organizations to operate dedicated presences through which they can provide crisis-related information (*establishing digital presences*), for instance, digital profiles such as Facebook pages (e.g., Ahmed & Sinnappan, 2013; Liu & Xu, 2018; Ross et al., 2018), Twitter handles (e.g., Abedin & Babar, 2018; Carter et al., 2014; Oh, Agrawal, et al., 2011), or group or collaborative spaces (e.g., Majchrzak & More, 2011; Palen et al., 2007; Tim et al., 2017). Creating such outlets can enable organizations to draw an audience, establish relations to non-organizational users, and hence spread messages more efficiently to those for whom they might be relevant (e.g., Power & Kibell, 2017; Stewart & Gail Wilson, 2016). Establishing digital presences can thus in turn influence affordances that enable information sharing through externalizing, and also facilitate affordances for collaborating through specifying dedicated communication channels (e.g., Lin, Spence, et al., 2016; Stewart & Gail Wilson, 2016).

What is more, social media also allow organizations to build a reputation as a trustworthy source of information (*communicating a reputation*). To that end, they can provide official contact information, issue regular information updates, utilize platform-specific credibility indicators such as audience counts, and so on (e.g., Lachlan, Spence, Edwards, et al., 2014; Lin, Spence, et al., 2016; Stewart & Gail Wilson, 2016). Again, this affordance can influence other affordances for externalizing and increase the efficiency of

information dissemination, increase organizations' influence over non-organizational users' sense-making, and facilitate collaborating with relevant audiences (e.g., Abedin & Babar, 2018; Ahmed & Sinnappan, 2013; Jong & Dückers, 2016; J. Kim et al., 2018).

Findings on Affordances for Collaborating

Affordances for collaborating allow users to align their activities in response to crises, putting forth and promoting novel modes of collaborative crisis management among and between established and emergent organizational actors as they build and expand upon the exchange of information and other resources afforded by social media. Table B.1.3 is an overview of these affordances, with definitions and selected references.

Table B.1.3
Overview of social media affordances for collaborating

Affordances		Definitions	Selected references
(11)	Negotiating consensus	Aligning perceptions and developing a shared interpretation of a crisis	Grabowski and Roberts (2011); Hauser et al. (2017); Heverin and Zach (2012); Jong and Dückers (2016); Leong et al. (2015); Mazer et al. (2015); Nan and Lu (2014); Purohit et al. (2013)
(12)	Integrating contributions	Registering, monitoring, and deploying resources provided by users in response to a crisis in a coordinated way	Currion et al. (2007); Horita et al. (2016); Majchrzak and More (2011); Osatuyi et al. (2012); Palen et al. (2007); Rudra et al. (2018); Subba and Bui (2010); White et al. (2008)
(13)	Crowdsourcing contributions	Calling for and incurporating resources to be provided by users in response to a crisis	Bergstrand and Stenmark (2016); Brengarth and Mujkic (2016); Chatfield and Brajawidagda (2014); Currion et al. (2007); Kaewkitipong et al. (2016); T. Kim (2014); Maresh-Fuehrer and Smith (2016); Poblet et al. (2018)
(14)	Developing community	Advancing connections, sense of community, and collective action among users in response to a crisis	Ahmed and Sinnappan (2013); Kaewkitipong et al. (2016); Lai et al. (2017); Leong et al. (2015); Liu and Xu (2018); Nilsen et al. (2018); Oh et al. (2015); Pang and Ng (2016)
(15)	Establishing norms	Developing and enforcing principles for using social media to respond to a crisis collaboratively	Abedin and Babar (2018); Carter et al. (2014); Lachlan et al. (2016); Lin, Spence, et al. (2016); Oh et al. (2015); Palen et al. (2007); Subba and Bui (2012); Torrey et al. (2007)

With respect to collaborating, organizational and non-organizational users can use social media to engage in conversations, offer their opinions, and express how they perceive a crisis, its causes and implications, and available response options, and discuss divergent

interpretations of events and responses (*negotiating consensus*). Thus, social media can support sense-making processes and enable users across established organizational boundaries to develop a shared understanding of a crisis as they express their views and share personal experiences, propose and evaluate possibilities for action, and explain how divergent and potentially conflicting narratives might be reconciled (e.g., Gaspar et al., 2016; Heverin & Zach, 2012; Nan & Lu, 2014; Torrey et al., 2007). This also allows users to develop a shared interpretation of what constitutes desirable or admissible uses of social media in crisis management, or frame users' perceptions of an organization's role within or in response to a crisis (e.g., Crijns et al., 2017; He et al., 2018; Ki & Nekmat, 2014; Meng et al., 2016; Ross et al., 2018).

Social media allow users across organizational boundaries to synchronize demands and requests for resources based on a shared purpose and understanding of how a crisis should be addressed in a bottom-up way (*integrating contributions*). This refers to informational resources made available for anyone to access and use, such as information about missing persons, the location of facilities, or personalized advice; beyond that, social media allow users across organizational boundaries to integrate and manage material resources and services, such as psychological counseling, sheltering, donations, and volunteer activities (e.g., Currion et al., 2007; Qu et al., 2009; Reuter et al., 2014; Subba & Bui, 2010; Torrey et al., 2007). This also includes organizations using social media to devise and realize joint efforts to respond to crises and promote the activities of other organizations or unaffiliated users (e.g., community response activities or digital volunteer initiatives) to facilitate their acquiring resources for a common purpose (e.g., Kaewkitipong et al., 2016; Radianti et al., 2016; Yates & Paquette, 2011).

Using social media, organizations can furthermore invite non-organizational users to contribute resources to particular crisis response activities; those users can then provide information and knowledge, volunteer to take on tasks, or donate funds (*crowdsourcing contributions*). Organizations can thus use social media to acquire information and other resources provided by non-organizational users who acknowledge and support their purpose to enhance their operational capabilities responding to a crisis, for instance, by validating information obtained from social media and other sources, registering volunteer workforces, collecting funds and materials, and assigning tasks to various organizational and non-organizational responders (e.g., Brengarth & Mujkic, 2016; Kaewkitipong et al., 2016; Mirbabaie et al., 2016; Poblet et al., 2018; Reuter et al., 2014).

In addition, social media can support the emergence of novel organizational actors who are connected through a shared understanding or shared identity, and whose missions, purposes, structures, and boundaries arise from users' repeated interactions enabled by social media (*developing community*). Thus, social media help (re-)establish communication ties between otherwise disconnected users, such as disconnected community members, users with different organizational backgrounds and affiliations, and international audiences (e.g., Pan et al., 2012; Tim et al., 2017; Yates & Paquette, 2011); express inner processes such as feelings and thoughts (e.g., Gaspar et al., 2016; Heverin & Zach, 2012; Neubaum et al., 2014); seek and share social and emotional support (e.g., Leong et al., 2015; Nilsen et al., 2018; Omilion-Hodges & McClain, 2016); and identify opportunities for community action and novel ways of engagement (e.g., Nan & Lu, 2014; Oh et al., 2015; Qu et al., 2009; Vaast et al., 2017). Thus, social media can facilitate identifying novel ways to undertake established tasks, such as distributing information to relevant audiences and co-producing information through social reporting (e.g., Chatfield et al., 2014; Currion et al., 2007; Majchrzak & More, 2011; Maresh-Fuehrer & Smith, 2016), and also determining novel tasks that can be addressed using social media, such as mitigating rumors or restraining incivility and otherwise destructive or violent behavior among community members (e.g., Kaewkitipong et al., 2016; Subba & Bui, 2012, 2017; Zhao et al., 2016).

Finally, social media allow communities of interacting users to develop, adapt, and enforce commonly accepted standards for their interactions, such as rules of conduct, workflows, and roles for moderating discussions (*establishing norms*). Such norms may emerge from users' repeated interactions or be imposed by organizations or authoritative users; for instance, users may converge towards the use of a particular hashtag or other markers for seeking and sharing information related to a crisis through social activity (e.g., Heverin & Zach, 2012; Lachlan, Spence, Edwards, et al., 2014; Oh et al., 2015), or organizations may ask them to do so to facilitate dissemination (e.g., Abedin & Babar, 2018; Chatfield & Brajawidagda, 2014; Lin, Spence, et al., 2016). Similarly, users may identify and report inappropriate content and sanction or encourage others to follow community norms, or group members may adopt the roles of moderators or administrators and take action to enforce rules (e.g., Subba & Bui, 2010, 2012; Torrey et al., 2007).

Review Findings on Open Resources, Open Processes, and Opening Effects Facilitated by Social Media

According to our conceptual framework, we assume that the affordances social media provide for internalizing, externalizing, and collaborating affect organizational learning especially through open resources, open processes, and opening effects. Below, we summarize our insights on each aspect of openness and explain how actualizing the affordances provided by social media might help achieve them. We list selected references for each resource, process, and effect in Tables B.1.4–B.1.6. Appendix 'Coding Results' includes the complete list of matched references.

Findings on Open Resources

Open resources refer to various means of facilitating crisis management that are made accessible to or that can be used by anyone, or at least an a priori undefined group of people, through social media. Table B.1.4 is an overview of these resources, with definitions and selected references.

Table B.1.4
Overview of open resources provided by social media

Open resources		Definitions	Selected references
(A)	Information	Digital content that conveys users' insights related to a crisis, in particular:	
(A1)	Situational information	Information pertaining to crisis events, related resources, or activities	Abedin and Babar (2018); Chatfield and Brajawidagda (2013); Hong et al. (2018); Kaewkitipong et al. (2016); Lu and Yang (2011); Ludwig et al. (2015); Majchrzak and More (2011); Ogie et al. (2018)
(A2)	Geo-location information	Information about the location of crisis events, related resources, or activities	Abedin and Babar (2018); Chatfield et al. (2014); Currion et al. (2007); Hong et al. (2018); Majchrzak and More (2011); Mirbabaie et al. (2016); Ogie et al. (2018); Reuter et al. (2014)
(A3)	User identity information	Information about users' online or offline identities, roles, behaviors, or resources related to a crisis	Anderson et al. (2015); Day et al. (2009); J. Kim et al. (2018); Nilsen et al. (2018); Shatte et al. (2016); Subba and Bui (2017); Takahashi et al. (2015); White et al. (2008)
(A4)	Social network information	Information about users' connections and positions within the information-sharing and	Ahuja et al. (2018); Day et al. (2009); Getchell and Sellnow (2016); J. Kim et al. (2018); Lai et al. (2017); Semaan and

Open resources		Definitions	Selected references
		communication network in social media	Mark (2011); Tyshchuk et al. (2012); Yates and Paquette (2011)
(A5)	Sense-making information	Information that helps users interpret and give meaning to crisis events or related activities	Gaspar et al. (2016); Heverin and Zach (2012); Jong and Dückers (2016); Manika et al. (2017); Mazer et al. (2015); Pang and Ng (2016); Simon et al. (2016); Vaast et al. (2017)
(A6)	Curated information	Crisis-related information that has been pre-processed by users before they contribute or forward it	Lai and Tang (2018); Leong et al. (2015); Oh, Kwon, et al. (2011); Osatuyi et al. (2012); Palen et al. (2007); Power and Kibell (2017); Rice and Spence (2016); Subba and Bui (2010)
(B)	Knowledge	Crisis-related information users have obtained through personal familiarity	Brengarth and Mujkic (2016); Currion et al. (2007); Kaewkitipong et al. (2016); Leong et al. (2015); Ludwig et al. (2015); Majchrzak and More (2011); Semaan and Mark (2011); Yates and Paquette (2011)
(C)	Authority	Users' power to influence others' interpretations or behaviors related to a crisis	Abedin and Babar (2018); Carter et al. (2014); Jong and Dückers (2016); J. Kim et al. (2018); Lachlan, Spence, Edwards, et al. (2014); Lin, Spence, et al. (2016); Subba and Bui (2017); Torrey et al. (2007)
(D)	Social support	Statements that express informational, emotional, appraisal, or instrumental support, or request or assure corresponding resources in response to a crisis	Ahmed and Sinnappan (2013); Gaspar et al. (2016); Grabowski and Roberts (2011); Heverin and Zach (2012); Leong et al. (2015); Liu and Xu (2018); Nilsen et al. (2018); Omilion-Hodges and McClain (2016)
(E)	Workforce	Users that undertake activities in response to a crisis	Brengarth and Mujkic (2016); Currion et al. (2007); Kaewkitipong et al. (2016); Lambert (2016); Leong et al. (2015); Majchrzak and More (2011); Radianti et al. (2016); Reuter et al. (2014)
(F)	Goods and materials	Equipment that can be utilized to respond to a crisis	Brengarth and Mujkic (2016); Currion et al. (2007); Kaewkitipong et al. (2016); Leong et al. (2015); Radianti et al. (2016); Torrey et al. (2007); Vaast et al. (2017); White et al. (2008)
(G)	Funds	Financial means that can be utilized to respond to a crisis	Brengarth and Mujkic (2016); Grabowski and Roberts (2011); Nan and Lu (2014); Qu et al. (2009); Radianti et al. (2016); Roshan et al. (2016); Subba and Bui (2010); Takahashi et al. (2015)

Our results suggest that information is a key resource made accessible to users across organizational boundaries through using social media. This information includes *situational information*, such as warnings, updates, or first-hand reports (e.g., Liu & Xu, 2018; Ludwig et al., 2015), *geo-location information*, such as road or place names or geo-location tags (e.g., Abedin & Babar, 2018; Chatfield et al., 2014; Majchrzak & More, 2011), *user identity information*, for instance, users' digital profile information, interaction histories, and other kinds of digital traces (e.g., Lin, Spence, et al., 2016; Shatte et al., 2016; Torrey et al., 2007), *social network information*, such as users' contacts, frequency or intensity of interaction, and degree or other centrality within the communication network (e.g., Getchell & Sellnow, 2016; J. Kim et al., 2018; Lai et al., 2017), *sense-making information*, such as opinions, personal interpretations, and criticism (e.g., Heverin & Zach, 2012; Jong & Dückers, 2016; Vaast et al., 2017), and various forms of pre-processed or *curated information* that has been evaluated, filtered, aggregated, annotated, or combined with other sources of information (e.g., Lai & Tang, 2018; Oh, Kwon, et al., 2011; Rice & Spence, 2016). Information is transmitted through digital content in various formats, such as text messages and graphical materials, including photos and videos (e.g., Bergstrand & Stenmark, 2016; Carter et al., 2014; Chatfield & Brajawidagda, 2014; Kaewkitipong et al., 2016; Tim et al., 2017).

Beyond mere information, social media facilitate access to *knowledge* that users have acquired through familiarity with aspects of a crisis or crisis management, for instance, through professional activities or prior experiences dealing with a crisis (e.g., Ludwig et al., 2015; Semaan & Mark, 2011; Tim et al., 2017; Yates & Paquette, 2011). Digital content may also convey users' authority, that is, their power to influence others' perceptions of or responses to a crisis. Authority may be based on users' offline identities, such as being a member of an emergency response organization, a media representative, or a specialist on some topic, online roles, such as being an influencer or digital volunteer, usage behaviors, such as issuing regular updates, responding to audiences' questions, and engaging in interactive dialogue, and content format criteria, such as using pre-defined formats for warnings and other messages or employing message credibility characteristics (e.g., Abedin & Babar, 2018; Chatfield & Brajawidagda, 2013; Jong & Dückers, 2016; Lachlan, Spence, Edwards, et al., 2014; Lin, Spence, et al., 2016; Stewart & Gail Wilson, 2016).

Other resources that can flow through or be made available across organizational boundaries through the use of social media include *social support*, such as encouragement, sympathies and condolences, expressions of gratitude or relief, community appeals, or

provision of relevant services (e.g., Gaspar et al., 2016; Leong et al., 2015; Nilsen et al., 2018; Omilion-Hodges & McClain, 2016), as well as various non-informational resources, in particular, *workforce*, such as employees or volunteers who can be assigned to a task, such as constructing barriers or providing relief (e.g., Brengarth & Mujkic, 2016; Currion et al., 2007; Kaewkitipong et al., 2016; Reuter et al., 2014), *goods and utilities*, such as materials donated by non-organizational users, for instance, tools, food, or clothing (e.g., Brengarth & Mujkic, 2016; Radianti et al., 2016; Vaast et al., 2017; White et al., 2008), and *funds*, such as charity donations (e.g., Grabowski & Roberts, 2011; Qu et al., 2009; Subba & Bui, 2010; Takahashi et al., 2015).

Findings on Open Processes

Open processes are goal-directed activities to manage crises in which anyone, or at least an a priori undefined group of people, can participate through using social media. Table B.1.5 is an overview of these processes, with definitions and selected references.

Open processes can take place at all levels of organization: individual, group, and organizational. At the individual level, actualizing affordances for externalizing facilitates *disseminating* crisis-related information, which means that social media can complement established channels of risk and crisis communication and facilitate tasks such as informing and educating the public. In particular, social media can help organizations increase the reach and speed of communications (e.g., Abedin & Babar, 2018; Ahmed & Sinnappan, 2013; Kaewkitipong et al., 2016; Power & Kibell, 2017; Tim et al., 2017) and involve non-organizational users in forwarding messages (e.g., Abedin & Babar, 2018; Chatfield et al., 2014; T. Kim, 2014).

Table B.1.5
Overview of open processes facilitated by social media

Open processes		Definitions	Selected references
(H)	Disseminating	Contributing and forwarding digital content to make crisis-related information and other resources available to users through social media	Abdullah et al. (2017); Chatfield and Brajawidagda (2013; 2014); Choudhary et al. (2012); J. Kim et al. (2018); Li et al. (2014); Lin, Lachlan, et al. (2016); Tyshchuk et al. (2012)
(I)	Social sensing	Accessing digital content contributed to social media to gather or generate resources through further activity	Carter et al. (2014); Drasch et al. (2015); Hong et al. (2018); Ludwig et al. (2015); Pogrebnyakov and Maldonado (2018); Radianti et al. (2016); Veenstra et al. (2014); Wu and Cui (2018)

Open processes		Definitions	Selected references
(J)	Social reporting	Accessing digital content contributed to social media specifically with the purpose to be put to use in response to a crisis to gather or generate resources through further activity	Bergstrand and Stenmark (2016); Chatfield et al. (2014); Currion et al. (2007); Majchrzak and More (2011); Maresh-Fuehrer and Smith (2016); Poblet et al. (2018); Reuter et al. (2014); Tim et al. (2017)
(K)	Sense-making	Interacting with other users to develop an understanding of crisis events and related resources and activities	Hauser et al. (2017); Heverin and Zach (2012); Jong and Dückers (2016); Mazer et al. (2015); Oh et al. (2013; 2015); Purohit et al. (2013); Vaast et al. (2017)
(L)	Gatekeeping	Selecting and filtering crisis-related digital content to be contributed to or forwarded through social media	Abdullah et al. (2017); Carter et al. (2014); J. Kim et al. (2018); T. Kim (2014); Lai and Tang (2018); Oh, Kwon, et al. (2011); Power and Kibell (2017); Rice and Spence (2016)
(M)	Translating	Synthesizing and explaining messages conveyed by crisis-related digital content in social media by expressing them in terms that are generally comprehensible	Ahmed and Sinnappan (2013); Carter et al. (2014); Kaewkitipong et al. (2016); Leong et al. (2015); Oh et al. (2013); Subba and Bui (2017); Tim et al. (2017); Yates and Paquette (2011)
(N)	Decision-making	Interacting with other users to analyze problems related to crises, identify and evaluate potential solutions, and reach agreement regarding solutions to be implemented	Leong et al. (2015); Liu and Xu (2018); Maresh-Fuehrer and Smith (2016); Nan and Lu (2014); Power and Kibell (2017); Qu et al. (2009); Seeber et al. (2017); Torrey et al. (2007)
(O)	Relief coordination	Acquiring and deploying resources according to insights about requests and contributions acquired through social media	Currion et al. (2007); Kaewkitipong et al. (2016); Maresh-Fuehrer and Smith (2016); Meesters et al. (2016); Osatuyi et al. (2012); Ragini et al. (2018); Reuter et al. (2014); Yates and Paquette (2011)
(P)	Digital volunteerism	Contributing resources to another organizations' crisis response activities, undertaking related services, or signaling a willingness to do so using social media	Currion et al. (2007); Kaewkitipong et al. (2016); Leong et al. (2015); Majchrzak and More (2011); Meesters et al. (2016); Mirbabaie et al. (2016); Subba and Bui (2012); Torrey et al. (2007)
(Q)	Participatory research	Systematically inquiring about crisis response activities while integrating the responses of non-organizational users through social media	Lee et al. (2017); Lin, Spence, et al. (2016); Maresh-Fuehrer and Smith (2016); Meesters et al. (2016); Osatuyi et al. (2012); Power and Kibell (2017); Spence et al. (2016); Yates (2016)

In contrast, actualizing affordances for internalizing, organizations can gain access to information and knowledge provided by non-organizational users through *social sensing* and *social reporting*. While social sensing – for instance, through monitoring the information stream – considers such information as passive resource that can be collected and harnessed by organizations, social reporting – for instance, through establishing digital presences to which relevant information can be delivered – allows organizations to involve non-organizational users actively in the co-production and further dissemination of informational resources (Poblet et al., 2018). Thus, organizations may draw on the resources provided by non-organizational users to enhance their own situational awareness and contribute to that of others (e.g., through the interplay of contributing and forwarding information on the one hand, and monitoring the information stream on the other), as well as their ambient awareness (e.g., through identifying relevant users and information providers, establishing connections to them, and integrating the information and other resources provided by them).

At the group level, social media support *sense-making* – as the primary mode of social information processing – and *gatekeeping* processes and also facilitate *translating specific knowledge*. This implies that social media enable users to interact with others to develop an understanding of crisis events and related activities, such as through organizing, relating, and validating information that is available from social media and other sources (e.g., Heverin & Zach, 2012; Jong & Dückers, 2016; Majchrzak & More, 2011), selecting information to disseminate to others (e.g., Abedin & Babar, 2018; Lai & Tang, 2018; Oh, Kwon, et al., 2011), and explaining their insights to non-organizational users and wider audiences, such as through specific language or content formats, including videos or infographics (e.g., Leong et al., 2015; Tim et al., 2017; Yates & Paquette, 2011). In that regard, actualizing affordances for internalizing and externalizing allows users to collect and disseminate relevant information; however, it is affordances for collaborating – especially for negotiating consensus through repeated interactions – that facilitate convergence towards a shared understanding, which constitutes the basis for the alignment of goals and activities (e.g., Getchell & Sellnow, 2016; Grabowski & Roberts, 2011).

Finally, moving toward the organizational level, social media can help organizations implement specific steps in the *decision-making* process. For instance, they can use social media to crowdsource ideation (e.g., Maresh-Fuehrer & Smith, 2016) or tap users' collective information-processing capabilities to validate information obtained by monitoring the information stream (e.g., Power & Kibell, 2017). Social media not only

allow established organizations to facilitate, enrich, or outsource decision-making processes; for emergent organizations – such as associations of community members and digital volunteers – that address established or novel tasks in response to a crisis, social media provide opportunities to identify and discuss opportunities for action, evaluate suggestions, and comment and vote on proposals by actualizing affordances for collaboration (e.g., Leong et al., 2015; Nan & Lu, 2014; Qu et al., 2009).

Beyond that, social media can facilitate *relief coordination*, for instance, through monitoring the information stream to determine opportunities for action, identifying relevant actors and establishing connections to them, acquiring resources, and implementing concerted actions (e.g., Kaewkitipong et al., 2016; Maresh-Fuehrer & Smith, 2016; Reuter et al., 2014). In addition, they can provide opportunities to engage in *digital volunteerism* – for instance, by enabling novel ways of engagement, such as moderating communities, validating and disseminating information, and garnering support for organizational activities (e.g., Chatfield et al., 2014; T. Kim, 2014; Majchrzak & More, 2011; Oh, Kwon, et al., 2011; Torrey et al., 2007) – and allow organizations to engage in *participatory research*, through ex-post analysis of digital traces, by facilitating crisis simulations and exercises, by identifying potential study participants, and so on (e.g., Meesters et al., 2016; Osatuyi et al., 2012; Spence et al., 2016). In that regard, affordances for collaborating are again crucial for aligning resource demands and provisions, so that users can request and contribute required information, knowledge, goods, and other resources.

Findings on Opening Effects

Finally, opening effects are ways in which using social media to open resources and processes can lead to inclusive and participative shifts in the paradigms of organizational learning. Table B.1.6 is an overview of these effects, with definitions and selected references.

Table B.1.6
Overview of opening effects enabled by social media

Opening effects	Definitions	Selected references
(R) Transparency	Accessibility of information pertaining to organizational resources and processes with respect to crisis response	Abedin and Babar (2018); Ahmed and Sinnappan (2013); Getchell and Sellnow (2016); Liu and Xu (2018); Majchrzak and More (2011); Radianti et al. (2016); Roshan et al. (2016); Yates and Paquette (2011)

Opening effects		Definitions	Selected references
(S)	Interactivity	Reciprocal engagement of organizational and non-organizational users to access and provide crisis-related information and other resources	Abedin and Babar (2018); Ahmed and Sinnappan (2013); Crijns et al. (2017); Jong and Dückers (2016); Kaewkitipong et al. (2016); Ki and Nekmat (2014); Ross et al. (2018); Shatte et al. (2016)
(T)	Responsiveness	Timely, appropriate, and sympathetic reactions to non-organizational users' inputs and requests	Brengarth and Mujkic (2016); Lachlan, Spence, and Lin (2014); Lin, Spence, et al. (2016); Liu and Xu (2018); Ludwig et al. (2015); Meesters et al. (2016); Stewart and Gail Wilson (2016); Tim et al. (2017)
(U)	Empowerment	Crisis response activities undertaken by non-organizational users independent of organizational resources and processes	Ahmed and Sinnappan (2013); Chatfield and Brajawidagda (2013); Fischer (2018); Kaewkitipong et al. (2016); Leong et al. (2015); Majchrzak and More (2011); Semaan and Mark (2011); Tim et al. (2017)
(V)	Participation	Involvement of non-organizational users in organizational crisis response	Chatfield et al. (2014); Currion et al. (2007); Liu and Xu (2018); Meesters et al. (2016); Mirbabaie et al. (2016); Osatuyi et al. (2012); Reuter et al. (2014); Seeber et al. (2017)

Overall, we have identified five potential opening effects. The first is *transparency*, which means that resources and processes organizations employ to respond to crises become visible to non-organizational users, while organizations may learn about resources and processes beyond their boundaries. Informational resources can thus be accessed and utilized directly by actualizing affordances for internalizing (e.g., Ludwig et al., 2015; Radianti et al., 2016), while other resources, such as workforce, goods and utilities, and funds can be acquired by acting upon such information (e.g., Brengarth & Mujkic, 2016; Currion et al., 2007; Kaewkitipong et al., 2016; Leong et al., 2015).

The second opening effect is *interactivity*, which means that organizations can engage in dialogue with non-organizational users, responding to their requests, providing targeted information, and adapting responses to users' behaviors and identities. This implies that using social media facilitates developing a shared understanding across boundaries, shaping non-organizational users' perceptions and responses, and building community with stakeholders (e.g., Abedin & Babar, 2018; Ahmed & Sinnappan, 2013; Ki & Nekmat, 2014; Meng et al., 2016; Ross et al., 2018).

The third effect is *responsiveness*, which – in contrast to transparency and interactivity – captures organizations' reacting to non-organizational users' communications. For

instance, organizations may dispatch resources to locations indicated by non-organizational users, clarify conflicting information and resolve rumors reported to them, and involve community actors and digital volunteers in validating and disseminating information (e.g., Ahmed & Sinnappan, 2013; Liu & Xu, 2018; Pogrebnyakov & Maldonado, 2018; Power & Kibell, 2017; Zhou et al., 2013).

The fourth effect we have identified is the *empowerment* of non-organizational users. Using social media, organizations can provide opportunities for non-organizational users to contribute to their efforts to respond to a crisis, such as through crowdsourcing resources (e.g., Brengarth & Mujkic, 2016; Kaewkitipong et al., 2016; Maresh-Fuehrer & Smith, 2016). Beyond that, social media may open novel ways of engagement, especially for individual users and communities. In particular, the literature discusses self-organization of community relief activities that can supplement, or even replace, organizational crisis response (e.g., Leong et al., 2015; Nan & Lu, 2014; Semaan & Mark, 2011).

The final effect we have identified and that is evident from the literature is *participation*, which means that organizations can use social media to involve non-organizational users in organizational crisis response. This effect goes beyond merely repurposing external resources; social media may lead organizations to adapt their structures and routines to involve affected citizens, volunteers, businesses, and other organizations, and approach joint ownership of crisis management. For instance, organizations can use social media to establish and promote coalitions of responders, maintain relational ties to stakeholders that can be activated in case of a crisis, and devise dedicated roles that can be taken by external actors in support of organizational crisis management (e.g., Liu & Xu, 2018; Power & Kibell, 2017; Reuter et al., 2014).

Implications for Organizational Learning in Crisis Management: Discussion and Research Agenda

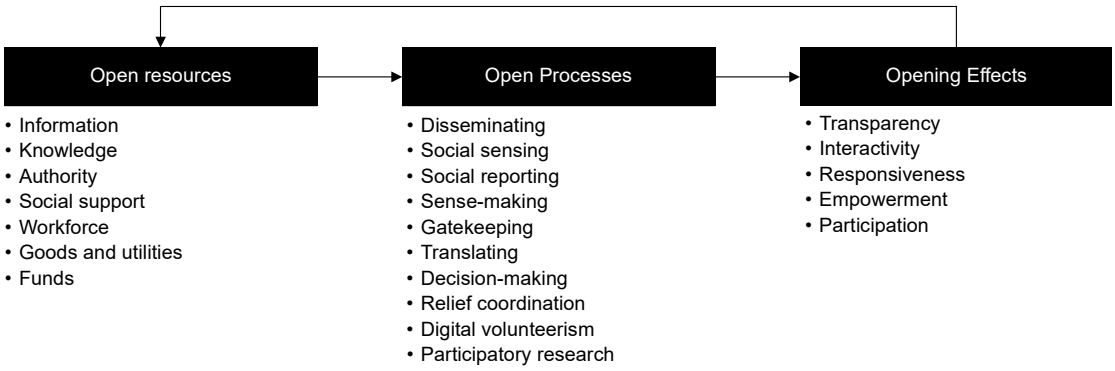
The goal of our systematic literature review is to consolidate prior contributions of IS research with respect to what they reveal about how social media afford organizational learning in crisis management, especially through providing access to open resources, facilitating open processes, and promoting opening effects. Overall, we have identified and described 15 affordances for internalizing, externalizing, and collaborating that are evident from prior research that contribute to opening organizational learning in the context of crisis events, along with the resources, processes, and effects they might enable.

Below, we summarize our insights and outline how actualizing the affordances provided by social media might contribute to opening organizational learning in terms of intuiting, interpreting, integrating, and institutionalizing processes.

Discussion

Following from the conceptual framework, open resources constitute the basis for open processes, which, in turn, facilitate opening effects on organizational learning in crisis management. Strategic implications that affect the underlying paradigms of organizational learning, in turn, can provide further possibilities for opening resources and processes in crisis management for participation across organizational boundaries. Figure B.1.4 illustrates this process.

Figure B.1.4
Summary of open resources and processes and opening effects in organizational learning in crisis management



Actualizing affordances for internalizing, externalizing, and collaborating allows organizations to access open resources and engage in open processes, and eventually leads to the emergence of opening effects. Table B.1.7 summarizes our insights into how actualizing the identified affordances can contribute to opening organizational learning in crisis management; below, we address prominent research themes for each.

First, in support of *intuiting*, our findings suggest that organizations can benefit from social media through enhancing their own and other users' situational and ambient awareness. Actualizing affordances for externalizing allows organizations to open organizational information and knowledge to non-organizational users and thus increase the transparency of crisis management resources and processes. Research related to this aspect of crisis management typically addresses audiences' information needs (e.g., Hong et al., 2018; Pogrebnyakov & Maldonado, 2018; Ragini et al., 2018; Rudra et al., 2018) and factors that influence the reach and speed of information propagation (e.g., J. Kim et al.,

2018; Oh et al., 2015; Tanaka et al., 2014; Zeng et al., 2016), as well as the effectiveness of organizational communications (e.g., He et al., 2018; Lai & Tang, 2018; Meng et al., 2016; Stieglitz et al., 2018). Factors related to the propagation and persuasive power of organizational crisis communications include, for instance, strategies for signaling credibility (e.g., Lachlan, Spence, Edwards, et al., 2014; Lin, Spence, et al., 2016), positioning within the communication networks (e.g., Getchell & Sellnow, 2016; Lai et al., 2017), and message design and channel choice (e.g., Han et al., 2015; Osatuyi et al., 2012).

Table B.1.7
Summary of review findings

Organizational learning	**Intuiting**	- Social media grant access to external *information and knowledge* resources. - Harnessing these resources can increase organizational users' *situational and ambient awareness*.	- Affordances for internalizing facilitate resource acquisition through *social sensing* and *social reporting*. - Affordances for externalizing provide organizations with an alternative channel for *information dissemination*.	- Availability of and access to information and knowledge resources across and beyond organizational boundaries can increase the *transparency* of crisis management resources and processes.
	Interpreting	- Along with crisis-related information and knowledge, digital content can convey its originator's *authority*. - This provides opportunities for organizations to influence audiences' *perceptions of and responses to a crisis* and facilitate the emergence of a *shared understanding* across organizational boundaries.	- Affordances for externalizing facilitate *gatekeeping* and allow *translating specific knowledge*. - Affordances for collaborating enable collective *sense-making* practices.	- Requesting and providing access to targeted information and knowledge resources contributes to the *interactivity* of crisis communications.
	Integrating	- Social media enable access to resources that can be used to respond to a crisis, in particular: *specific information and knowledge*, *social support*, *workforce*, *goods and utilities*, and *funds*. - Social media can hence enhance organizations' operational crisis response capacities.	- Affordances for collaborating support *group decision-making* and allow organizations to outsource organizational decision-making. - Furthermore, they facilitate *coordinated relief provision* and allow non-organizational users to identify opportunities for action and engage in *digital volunteerism*.	- Addressing the requests of non-organizational users can enhance the *responsiveness* of organizational crisis communications. - Identifying opportunities for action facilitates *user and community empowerment* in crisis response. - Novel ways of engagement allow for the *participation and involvement* of non-organizational users in organizational crisis response.

	Institutionalizing	- Social media provide access to *digital traces* from prior events, as well as to information about users who have participated in crisis communications during prior events or exercises. - Access to external resources can inform strategic organizational adaptation and change processes, and hence enhance operational capabilities in response to future crises.	- Affordances for internalizing allow organizations to integrate users' contributions, for instance, through *participatory crisis research*. - Adaptation of organizational structures, roles, and routines helps unlock the potential of opening organizational learning in response to future crises.	- Integrating external actors and resources into organizational structures and processes facilitates opening organizational learning in crisis management in response to future crises.
		Open resources	**Open processes**	**Opening effects**
		Openness		

Furthermore, actualizing affordances for internalizing allows organizations to harness external information and knowledge resources. Papers we have reviewed often address issues related to information overload and approaches to evaluating the relevance and trustworthiness of user-generated content, along with the design of technological artifacts that automate monitoring (e.g., Anderson et al., 2015; Ludwig et al., 2015; Mittelstädt et al., 2015). Other questions addressed in IS research include how users who could make a meaningful contribution can be identified, and how they could be motivated to contribute relevant information and knowledge (e.g., Chatfield & Brajawidagda, 2014; Ogie et al., 2018; Poblet et al., 2018). While collaborative activities, such as crowdsourcing and establishing connections to stakeholders, are frequently referenced in that regard, they are typically considered avenues for organizations to take as part of their ad-hoc operational crisis response activities (e.g., Bergstrand & Stenmark, 2016; Brengarth & Mujkic, 2016; Kaewkitipong et al., 2016).

Second, with respect to *interpreting*, organizations can use social media to share information that conveys a particular interpretation of a crisis and use their authority to influence non-organizational users' perceptions of and responses to a crisis. Key to this are affordances for externalizing, which allow organizations to apply message frames and forward information and knowledge they approve, and which enable them to tailor messages towards their intended audiences in particular. Related research has addressed the role of non-organizational users as gatekeepers who select, curate, and forward potentially relevant information (e.g., Lai & Tang, 2018; Oh, Kwon, et al., 2011), as well as how particular content formats, such as videos and infographics, can help translate and explain specific knowledge to non-organizational users (e.g., Leong et al., 2015; Yates &

Paquette, 2011). Beyond that, IS researchers have discussed strategies for organizations to build a reputation as trustworthy sources of information and hence increase non-organizational users' compliance with organizational crisis communications (e.g., Lachlan, Spence, Edwards, et al., 2014; Lin, Spence, et al., 2016), as well as for framing organizational crisis communications, especially in the context of business failures (e.g., He et al., 2018; Ki & Nekmat, 2014; Meng et al., 2016; Roshan et al., 2016; Stieglitz et al., 2018; Xia, 2013).

Beyond that, affordances for collaborating allow users to interact to establish consensus regarding crisis events, related activities, and implications. In particular, social media enable collective sense-making practices through which users can seek and share information that helps them understand and interpret their environment – for instance, personal opinions, criticism, and relevant situational information. Key to this is the interactivity of social media, which means that users not only can provide information for others to access and use, but also respond and reply to others' statements, clarify conflicting information, and address rumors and misinformation that might be circulating. Prior research has addressed, for instance, how organizations can identify rumors based on users' collective behaviors (e.g., Mondal et al., 2018; Oh et al., 2013) and harness the collective intelligence that is available from non-organizational users' joint efforts to make sense of available information, such as to validate information (e.g., Jong & Dückers, 2016; Leong et al., 2015). Research also suggests that interactivity might help organizations develop community and align perceptions with external audiences (e.g., Crijns et al., 2017; Getchell & Sellnow, 2016; Hauser et al., 2017; Ki & Nekmat, 2014).

Third, for *integrating*, there is considerable research on affordances for collaborating that allow users to identify opportunities for action and collaborate activities and contributions from organizational and non-organizational users. Relevant resources run the gamut from specific information and knowledge needed to accomplish particular tasks to social support (e.g., providing instrumental support), workforce (e.g., volunteers), goods and utilities (e.g., equipment), and funds (e.g., donations) that can be requested and promised through social media. Thus, affordances for collaborating allow organizations to access external resources when providing crisis relief and employ available resources where they are needed, based, for instance, on stakeholders' requests (e.g., Abedin & Babar, 2018; Chatfield et al., 2014; Liu & Xu, 2018; Ludwig et al., 2015). Social media contribute to opening organizational learning in particular through enhanced responsiveness and integrative relief provision and coordination. In that respect, existing research has prominently addressed issues related to crowdsourcing,

through which non-organizational users can be accessed to provide goods and services (e.g., Brengarth & Mujkic, 2016; Kaewkitipong et al., 2016) and contribute and disseminate relevant information (e.g., Chatfield et al., 2014; Majchrzak & More, 2011; Tim et al., 2017).

Beyond that, research suggests that social media enable users to identify and realize novel opportunities to participate in crisis response and hence empower non-organizational users and communities. Those can, for instance, use social media to fulfill social functions in a crisis event, such as providing instructional materials (e.g., Semaan & Mark, 2011), or take up activities in social media to engage as digital volunteers, for instance, through aggregating, evaluating, and distributing crisis-related information (e.g., Chatfield et al., 2014; T. Kim, 2014; Mirbabaie et al., 2016; Oh, Kwon, et al., 2011). Social media can also facilitate novel forms of collective engagement in response to a crisis (e.g., Nan & Lu, 2014; Vaast et al., 2017).

Finally, for *institutionalizing*, our findings suggest that evaluating crisis response – that is, analyzing patterns of information sharing and communication from past events, designing and evaluating technological artifacts for information collection and collaboration, and using social media to conduct crisis simulations and exercises – should enable organizations to learn from their experiences and implement necessary changes, and open organizational learning, for instance, through facilitating participatory research (e.g., Spence et al., 2016; Stewart & Gail Wilson, 2016). Again, non-organizational users can participate in organizational learning by providing resources – in particular, their personal experiences and interpretations – that can then be incorporated into strategic organizational adaptation.

Beyond that, works such as that of Kaewkitipong et al. (2016) suggest that establishing connections to and building coalitions with non-organizational actors, such as local communities or social media influencers, can allow organizations to gain permanent access to external resources, which means that they might rely on these users' information, knowledge, authority, and other resources to facilitate intra-crisis learning during future events, for instance, by integrating social media into strategic organizational decision-making processes (e.g., Lin, Spence, et al., 2016). Thus, establishing open processes within organizational structures and routines – for instance, by adapting operational roles and procedures (e.g., Power & Kibell, 2017; Stewart & Gail Wilson, 2016) – is key for opening organizational learning in crisis management prospectively. Experiences using social media in response to a crisis might then facilitate

spillover effects on future opening effects with respect to transparency, interactivity, responsiveness, empowerment, and participation.

Research Agenda

Overall, our findings suggest that social media use is typically considered an opportunity for intra-crisis learning, while less is known about how using social media might increase organizations' operational capacities strategically through inter-crisis learning. Table B.1.8 addresses opportunities for researching strategic issues based on feedback and feedforward relationships between affordances.

First, as for *intuiting*, prior research has prominently investigated how organizations might access external resources – especially situational information and relevant knowledge – through actualizing affordances for internalizing, and making organizational information and knowledge resources available to non-organizational users through affordances for externalizing. With respect to open resources, we might ask, therefore, how relevant resources can be made accessible for organizations to use strategically within internal learning processes, for instance, for evaluating organizational goals, adapting structures and routines, and continuing education of personnel between crises – an issue that has been approached thus far only by Yates (2016). Further, research on how continued engagement to make organizational knowledge and information available to external users can affect learning and adaptation in the external domain, both in the short and the long run – for instance, to increase audiences' preparedness and community resilience – could make a valuable contribution.

Table B.1.8
Opportunities for strategic research on social media use for organizational learning in crisis management

Organizational learning	**Intuiting**	- How can external information and knowledge resources be made accessible for strategic internal learning processes? - How does opening internal information and knowledge facilitate external learning?	- How can organizations use social media to build community with stakeholders to facilitate social sensing and reporting? - What are the strategic requirements for actualizing collaborative affordances to facilitate access to external resources?	- How can transparency be measured and analyzed? - How does transparency stimulate internal learning?

	Interpreting	- How can organizations use social media to open internal resources for sense-making to non-organizational users? - What styles and formats of digital content afford easy comprehension and understanding for organizational and non-organizational users?	- How can non-organizational users and communities be integrated into organizational crisis communications strategically? - How can non-organizational users be adequately integrated into organizational sense-making processes?	- How does interactivity allow integrating internal and external learning processes? - In what ways do social media enable organizations to access and utilize interactive processes and outcomes ex post?
	Integrating	- What effects does access to and use of external resources have on the effectiveness and efficiency of relief provision? - How can organizations use social media to secure access to external resources strategically?	- How can organizations use social media to design and implement crowdsourcing processes beyond ad-hoc ideation and co-creation? - How can social media promote inter-organizational collaboration between both established and emergent organizations?	- How can organizations use social media to open internal resources and processes to increase non-organizational users' crisis response capacities strategically? - What organizational structures and activeties can be devised to integrate non-organizational users with varying degrees of engagement and commitment?
	Institutionalizing	- What further resources can support strategic organizational learning from prior uses of social media in response to crises? - How do social media afford identifying and accessing relevant resources in a strategic perspective?	- How do social media affordances for operational crisis response complement internal learning processes in established organizations? - How can operational affordances be perpetuated so as to advance organizational learning and development in emergent organizations?	- What are the causal relationships between the identified opening effects? - What are potential further opening effects of using social media for organizational learning in crisis management?
		Open resources	**Open processes**	**Opening effects**
		Openness		

Pertaining to open processes, the narrow focus on intuiting for intra-crisis learning impedes a strategic perspective. While other disciplines have long discussed strategies for instance for nonprofit organizations to communicate and socialize with audiences to facilitate access to external resources prospectively (e.g., Lovejoy & Saxton, 2012), only a few papers in IS research address the question of how relevant processes could be perpetuated. Thus, drawing upon collaborative affordances to engage with stakeholders and develop community might allow organizations to harness the contributions of preexisting groups committed to their purposes, such as communities of practice or local communities, as well as emergent actors such as citizen volunteers, and hence gain access

to more focused (and therefore more valuable) contributions. Furthermore, research into how affordances for collaborating, such as crowdsourcing, could complement unidirectional processes such as social sensing and reporting, and how organizations could adopt social media strategically to prepare for such avenues before crisis strikes, could shed light on profound organizational changes required to enhance operational intuiting capabilities, for instance, through the adaptation or creation of novel job descriptions, the adaptation of operational guidelines, strategic investment in corresponding technological artifacts, and recruitment and training of personnel.

Finally, as for opening effects, we argue that that transparency might be treated as the most basic aspect of opening crisis management. In fact, enhanced access to crisis-related information across organizational boundaries is evident from basically all papers we have analyzed. However, we have interpreted transparency broadly, and how exactly transparency should be measured and analyzed is not yet clear; for instance, what information has to be provided by organizations to claim a sufficient level of transparency?

Furthermore, existing research does not reveal whether transparency leads to further opening effects and learning. While researchers recommend that organizations fully integrate insights gained through intuiting into the decision-making process (e.g., Lin, Spence, et al., 2016), whether they take action in response to social sensing and reporting is rarely discussed. However, further opening effects – especially interactivity and responsiveness, which would signal to non-organizational users that organizations take action and respond to external input – could be contingent upon organizations' succeeding to incorporate insights gained through using social media. We hence argue that IS research would benefit from further insights into how access to external information and knowledge resources translates into actionable learnings.

Second, regarding *interpreting*, the focus of current research is on sense-making – in particular, how social media enable users across organizational boundaries to collaborate to develop a shared understanding, how organizations can tap collective sense-making activities to generate insights, and how they can influence such processes among their stakeholders to shape audiences' perceptions and responses in a meaningful way. Most papers thus introduce a distinction between internal and external resources and processes; that is, between information and knowledge resources that reside and take place within and outside the focal organization. This is unfortunate, as it means that the full potential of available information-processing resources remains untapped. In

particular, non-organizational users are usually unable to access an organization's internal pool of sense-making information. For instance, community members who attempt to debunk a rumor will typically rely on public information sources, even if emergency response organizations might have access to more substantive information (e.g., Jong & Dückers, 2016; Mazer et al., 2015; Oh et al., 2013).

To unlock the full potential of collaborative sense-making processes, it would hence be advisable to open internal organizational resources to non-organizational users in a more comprehensive way. In addition, the sense-making focus of prior research implies that less insights are available on other aspects of interpreting, in particular, gatekeeping and translating specific knowledge. This lack of insights could negatively affect the effectiveness of organizational communications, as it could imply that their messages are less well understood and less often selected for further propagation by non-organizational users. While the design of organizational communication strategies is not at the heart of IS research, the discipline could help enhance the effectiveness of risk and crisis communications through further insights into how situational information is perceived by organizational and non-organizational users, especially in the context of complex crises characterized by high levels of time pressure, risk, and dynamically changing requirements, and what message and content formats might afford higher levels of comprehension within recipients.

As for open processes, much research – especially in the domain of business and other economic failure crises – adopts a hegemonic focus, with organizational communications as the key determinant of stakeholders' behavior and responses, even if communications are in principle interactive (e.g., Crijns et al., 2017; Ki & Nekmat, 2014). Organizational users are hence seen in the primary position to explain events and provide and translate specific knowledge, while non-organizational users may make secondary contributions, such as forwarding organizational messages (e.g., Abedin & Babar, 2018; Chatfield et al., 2014; T. Kim, 2014). Organizations might thus forgo opportunities to involve non-organizational users in crisis communications, for instance, as credible advocates for organizational goals and values (e.g., Brengarth & Mujkic, 2016; Hauser et al., 2017). This would require, however, to effectively align internal and external stakeholders' perceptions and understanding of strategic threats to organizational goals. In consequence, further research into how non-organizational users, such as online community members, can participate in organizational sense-making processes to foster their commitment, build community, and enhance their understanding of appropriate communication styles and strategies could make a valuable contribution.

With respect to opening effects, key to the interpreting stage of organizational learning is interactivity. It seems, however, that organizations occasionally consider interactivity as means to placate external stakeholders, such as customers, who voice criticism or express undesirable opinions (e.g., Crijns et al., 2017; Ki & Nekmat, 2014; Roshan et al., 2016). In those cases, we are hesitant to claim opening effects, but instead raise the question of how interactivity could help organizations establish an interface between internal and external learning processes, and hence produce insights that can be fed back into those processes. Furthermore, interactive communications are, by their very nature, highly dynamic and transient. This can make it difficult for organizations to access collaborative processes and outcomes again at a later time; for instance, to generate insights and draw conclusions from collective sense-making processes to enrich intuiting, or to build upon users' shared understanding to advance community or encourage non-organizational users to make further contributions. Based on our review, we call for future research to explore how social media might afford securing the outcomes of interactive communications, for instance, through promoting easily retraceable formats of interaction (e.g., through corresponding conversational norms) or types of social media – for instance, forums or wikis – that offer higher degrees of persistence.

Third, with respect to *integrating*, much IS research has investigated the potentials of social media to identify opportunities for action, and also to enable novel forms of engagement, such as digital volunteerism. Regarding open resources, existing research makes clear that non-organizational users can provide information and knowledge resources directly through social media, while they can promise further resources, such as workforce, materials, and funds, which can then be provided through other means. However, what happens with resources that are hence pledged or provided is less clear; in particular, it would be interesting to learn how deploying external resources can advance or otherwise affect their response. For instance, measurable increases in the effectiveness and efficiency of relief provision have yet to be documented. Such insights could provide valuable to answer the question of whether and under what conditions social media should be adopted in crisis response, which, apart from the work of Kirac et al. (2015), is typically answered through common-sense and responders' personal evaluations in IS research.

In addition, acquiring external resources is typically considered an avenue for operational crisis response. However, as Day et al. (2009) suggest, it might be useful to employ social media strategically, to identify users who can make a contribution and build commitment even before a crisis. Thus far, we observe attempts to register and monitor volunteer

workforces (e.g., Reuter et al., 2014; White et al., 2008) and make contact with social media influencers who might forward organizational messages (e.g., Power & Kibell, 2017); however, much could be gained from an organizational view if the potentials social media provide to identify external resources and secure access to them – for instance, through researching past events, identifying and approaching strategically relevant actors, or building community with relevant stakeholders – were better understood.

For open processes, we find that social media provide two ways to access resources from organizational users: first, through purposive calls for contributions (e.g., through crowdsourcing), and second, through the self-organized coordination of needs and contributions. Our findings suggest that crowdsourcing is currently a theme of major interest among IS researchers. However, likely due to the heavily operational focus of crisis response, calls for participation are typically short-term. For instance, while users may contribute situational information or pledge resources, organizations do not seem to follow up on these contributions, such as allowing users to evaluate ideas or make suggestions for the particular design of a solution. While this is common practice in other domains (e.g., Majchrzak & Malhotra, 2013; Schlagwein & Bjorn-Andersen, 2014), organizations seem to forgo this opportunity when it comes, for instance, to evaluating opportunities for organizational or community engagement, devising instructive materials, or designing technological artifacts for collaborating. Furthermore, discussions thus focus on integrating the contributions made by non-organizational users (e.g., community members) in organizational crisis management. This leaves two gaps: how organizational resources can enhance community response and contribute to community empowerment, and what opportunities social media provide for furthering inter-organizational collaboration. While members of established organizations may rely on existing channels of communication to interact, it is definitely an opportunity for future IS research to investigate how social media can complement and enhance them.

Responsiveness, empowerment, and participation are the opening effects with respect to integrating. The transition between these effects may be floating; for instance, responding to stakeholders' requests may provide them with the resources they need to identify opportunities to contribute to organizational crisis response or devise their activities. Looking beyond the individual crisis, organizations might want to open crisis management even further, such as by providing community members or digital volunteers with resources to build up capacities and connections that can be harnessed during future events, or promoting community structures that increase resilience. At the same time, one might ask how social media could allow non-organizational users to get

involved further in organizational crisis management, such as through devising novel models for organizational membership and identifying tasks that can be conducted by unaffiliated responders using social media.

Fourth, *institutionalizing* is the most strategic avenue to organizational learning in crisis management. The results of our review suggest that organizations can use social media to access information about non-organizational users' behaviors during prior events or exercises (e.g., from their digital traces) or learn about their perceptions or responses (e.g., through conducting survey research). However, while researchers have suggested that organizations should utilize their experiences strategically to learn from crises (e.g., Lin, Spence, et al., 2016; Stewart & Gail Wilson, 2016), we lack evidence on how organizations might succeed in doing so. In particular, while access to previously contributed digital content is supported by the persistence affordance of social media, evaluating processes ex post could prove difficult, especially if experiences are to be gained from real crises – which usually do not allow for setting up additional mechanisms for recording and transcribing experiences – rather than from simulated events. While it might be possible to reconstruct complex interactions from digital traces, the technical expertise and resources that are necessary to do so cannot be expected to be available within all organizations. Relevant questions are, hence, what further internal and external resources organizations would have to access to learn from past events, and how the affordances social media provide could help them identify and acquire relevant resources. Examples for such resources could be, for instance, other users' or organizations' experiences, technical infrastructure and expertise, and opportunities for practice and training.

As for open processes, we wonder how the affordances we have identified could not only enhance operational crisis management, but furthermore contribute to organizational learning processes. Depending on the organizational context – especially whether organizational learning follows established routines and procedures – those affordances could facilitate internal learning. With regard to emergent organizations that have formed based on the operational uses afforded by social media, the question is how those could succeed in converting these ad-hoc collaborative uses into organizational learning process that facilitate further organizational development.

Finally, regarding opening effects, existing research does not allow for drawing valid conclusions about further steps in opening crisis management, such as joint ownership and other constructs. While much evidence is available regarding effects that result from

information sharing and communication – in particular, transparency and interactivity – research on responsiveness, empowerment, and participation is more fragmented. In that regard, it might constitute a promising avenue for future research to evaluate whether the identified opening effects are mutually dependent, thus that hierarchical or other causal relationships might exist among them. Looking further into the future, organizations who have learned for, from, and through using social media in response to crises might be able to unlock further opening effects. IS researchers could pursue such avenues, drawing upon insights into openness in other organizational contexts (e.g., open innovation or open government) to help organizations gain momentum in opening crisis management.

Conclusion

We have presented the results from a systematic literature review that integrates insights from IS research investigating the use of social media in crises. We have summarized the affordances social media provide for the organizational learning process across established organizational boundaries along three classes of affordances for internalizing, externalizing, and collaboration. We discuss how actualizing these affordances can facilitate organizational learning processes – in particular intuiting, interpreting, integrating, and institutionalizing – which allow organizations to access open resources, facilitate open processes through which they can integrate information, knowledge, and other resources provided by non-organizational users, and promote the emergence of opening effects, in particular: transparency, interactivity, responsiveness, empowerment, and participation. Based on our review, we outline directions for future research pertaining to all four processes.

Our review does not come without limitations. Key among them is the literature search and selection process, which was based on keyword-based searches, systematic selection, and forward and backward searches. As we conducted a rather comprehensive and rigorous search, we identified a large number of relevant and peer-reviewed papers, the analysis of which was beyond the limits of manual coding. Our results are based, therefore, on a subset of papers from outlets close to the field of IS research, which means that the generalizability of results is limited to these outlets, just as making claims regarding research gaps is limited. Given that crisis informatics research itself is a heterogeneous field that has emerged from multiple disparate streams and disciplines unified by a shared research interest, alternative approaches based on citation analysis of

a limited set of influential core papers, such as suggested by Larsen et al. (2019), are hardly feasible.

Furthermore, our interpretation of prior research is limited in two distinct ways. First, we focused on affordances that can be related to organizational learning enabled by providing access to open resources, facilitating open processes, and promoting opening effects in crisis management. This precludes findings on other aspects regarding social media in crisis management that may be of interest to IS researchers. We are happy to refer readers to previously published review papers that might be of interest (e.g., Alexander, 2014; Houston et al., 2015; Reuter et al., 2020; Veil et al., 2011; Wukich, 2015). In addition, as we focused on learning processes facilitated by social media, our understanding is necessarily incomplete. Crisis learning is not limited to the realm of social media; actors can learn about crises from other sources as well. Furthermore, we have not discussed the social and cognitive processes that lead users to adopt and subsequently actualize the affordances provided by social media, nor have we discussed the nature of learning beyond organizational boundaries (especially in emergent groups and communities in the public). Nevertheless, we believe our framework can help in understanding how social media might complement existing organizational learning processes from a strategic standpoint.

Our insights can help crisis informatics researchers, especially in the IS community, to integrate their own work into the corpus of knowledge systematically, as we illustrate how the different uses afforded by social media can be related to distinct individual, social, and organizational outcomes. We expect this to be useful in developing a more coherent understanding of what social media can and cannot do when employed to learn for, from, and about crises. Furthermore, it allows us to understand the implications of using social media in crisis management more fully, as we demonstrate how different affordances can work together to enable strategic renewal.

Beyond that, our work illustrates how ICT can be useful to connect seemingly disparate processes to achieve organizational goals. Understanding how organizational behavior and sense-making results in specific organizational outcomes is not trivial (Maitlis & Christianson, 2014). In particular, we see our main contribution as explaining how ICT usage can contribute to organizational change and the emergence of novel forms of organizing in a real-world context in which understanding the implications of ICT use can save lives and mitigate the impacts of crises. For IS researchers, our insights create opportunities to delve further into the relationship between different affordances,

focusing on, for instance, the characteristics and effects of technologically mediated psychological, organizational, and social processes that lead to the emergence and institutionalization of novel forms of organization.

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Appendix to Paper I: Search Terms and Hits per Database

We searched the titles, abstracts, and (if available) keywords of all database entries in eight information systems and social science databases: the ACM digital library, the AIS electronic library, EBSCOhost Information Services (all databases), EmeraldInsight, the IEEE Xplore digital library, JSTOR, ScienceDirect, and the Social Science Citation Index. We searched all database entries published up to and including 2018.

The generalized search phrase was: *("social media" OR "social network*") AND (cris?s OR disaster* OR emergenc* OR catastrophe*)*

We imported the hits from the keyword-based search in all databases into a reference management software (*Mendeley*). We then merged duplicate entries detected by the reference management software across different databases (i.e., papers that were indexed by more than one of the databases). The total number of hits excluding such duplicates was 7,702.

Table B.1.9 is an overview of the search phrases and search fields we used to comply with the requirements of each database, and the number of hits we obtained from each database.

Table B.1.9
Search results per database

Database	Search phrase	Search fields	Number of hits
ACM digital library	("social media" OR "social network") AND (cris?s OR disaster* OR emergenc* OR catastroph*)	acmdlTitle, recordAbstract (all combinations)	194
AIS electronic library	("social media" OR "social network") AND (crisis OR crises OR disaster* OR emergenc* OR catastroph*)	Title, abstract (all combinations) *Keywords field not available*	86
Ebscohost Information Services (all databases)	("social media" OR "social network*") AND (cris?s OR disaster* OR emergency OR emergencies OR catastroph*)	Title, abstract, subject terms (all combinations)	5,000
EmeraldInsight	("social media" OR "social network") AND (cris?s OR disaster* OR emergency OR emergencies OR catastroph*)	Content item title, abstract, keywords (all combinations)	183
IEEE Xplore digital library	("social media" OR "social network*") AND (cris?s OR disaster* OR emergency OR emergencies OR catastroph*)	Metadata	958
JSTOR	("social media" OR social network*~0) AND (cri?s OR disaster* OR emergency OR emergencies OR catastroph*)	ti, ab (all combinations) *Keywords field not available*	446
ScienceDirect	("social media" OR "social network") AND (crisis OR crises OR disaster OR emergency OR emergencies OR catastroph)	Title, abstract, keywords (all combinations) *As of 2020, ScienceDirect advanced search is no longer available. Basic search now provides a "Title, abstract or author-specified keywords" field.*	614
Social Science Citation Index	("social media" OR "social network*") AND (cris?s OR disaster* OR emergency OR emergencies OR catastroph*)	Topic	1,731
Total (excluding cross-database duplicates)			7,702

Appendix to Paper I: Inclusion and Exclusion Criteria in the Format, Content, and Subject Area Screens

Overview: Literature Selection Process

We provide an overview of the literature selection process in the methods section of the manuscript. In summation, the process starts with a keyword-based search, followed by three screening phases, i.e., *format screen, content screen,* and *subject area screen,* which we designed to identify relevant papers. After screening the search results, we conducted backward and forward searches for all selected papers to include relevant papers we might have missed otherwise. In the following, we provide the full details on all three screening phases.

Phase 1: Format Screen

The first screening phase aimed at excluding all articles that are not relevant based on their format. We excluded all articles that did not meet the standards of the *peer-review* and *language criterion* (see Table B.1.10 and Table B.1.11).

Table B.1.10
Format screen: peer review criterion

Criterion	Peer-Review
Definition	To be considered relevant, papers must have undergone a peer-review process before publication.
Inclusion criterion	Include papers that have undergone scrutiny by independent scholars in the field of study (i.e., other than editors, editorial board members, program committee members, publisher staff etc.). Peer review must apply to full papers (as opposed to abstracts or proposals only) and must take place prior to publication (as opposed to post-publication review). Different formats of peer review, such as double-blind, single-blind, and open peer review fulfil the peer-review criterion.
Exclusion criterion	Exclude papers that were accepted for publication by members of editorial or publisher staff without consulting peer reviewers beforehand, either because they were published in outlets that do not provide peer review by default (e.g., books and book chapters, theses, magazines, news reports, and grey literature) or that are excepted from peer review (e.g., editorials, book reviews, and letters to the editors).

Table B.1.9
Format screen: language criterion

Criterion	Language
Definition	To be considered relevant, papers must be published in English.
Inclusion criterion	Include papers whose full text was published in English. Translations declared as secondary publications of a paper (e.g., as part of a reprint) comply with the language criterion.
Exclusion criterion	Exclude papers published in other languages than English. English-language abstracts or summaries do not fulfil the language criterion if the full text is not in English. Also, related papers published in English, but not marked as faithful translations of an original article by either the author(s) or the publisher(s) do not fulfil the language criterion.

Phase 2: Content Screen

The second phase of screening was dedicated to the evaluation of the topical fit of potentially relevant papers. To be determined topically relevant, papers must cover issues related to a) organizational crises (*crisis criterion*) and b) social media (*social media criterion*).

Two authors were involved in evaluating the content screening criteria. To decide on the inclusion of a paper, they proceeded as follows: First, they carefully read the titles and, if available, the abstracts and the keywords of each paper. Based on that, they evaluated for each paper if it fulfilled the crisis and the social media content criteria. If the information from the papers' titles, abstracts, and keywords did not warrant an inclusion or exclusion decision, the authors obtained a copy of the full text and screened the full paper. Content screening criteria were applied broadly; that is, the authors also included borderline papers. In case of doubt (e.g., when a paper did not clearly specify the context of study or properties of a technology in question), the authors discussed the paper in question until a consensual decision could be made. The content screening process is illustrated in Figure B.1.5.

Figure B.1.5
Content screening process

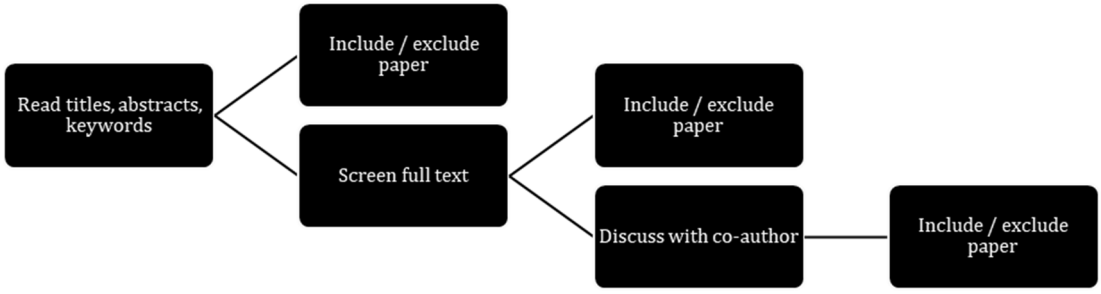

Table B.1.12 and Table B.1.13 provide the definition, inclusion, and exclusion guidelines for each criterion.

Table B.1.10
Content screen: crisis criterion

Criterion	Crisis
Definition	To be included, a paper must be related to *organizational crises*, defined as "specific, unexpected, and nonroutine event or series of events that create high levels of uncertainty and threaten or are perceived to threaten an organization's high-priority goals" (Seeger et al., 1998, p. 233). *Events* that trigger crises must be identifiable in terms of place, time, and agents (Shrivastava et al., 1988). *Uncertainty* refers to an ambiguity of cause, effect, and means of resolution (Pearson & Clair, 1998).
Inclusion criterion	Include papers that deal with a) *crises*, in terms of low-probability, high-impact situations that are perceived by critical stakeholders to threaten the viability of an organization, that are subjectively experienced by these individuals as personally and socially threatening, and that, as a consequence of increased levels of uncertainty, can cause disillusionment, loss of psychic and shared meaning, and shattering of commonly held beliefs and values and individuals' basic assumptions (Pearson & Clair, 1998); b) *people's or organizations' perceptions of or responses to crises* (including, but not limited to dedicated crisis management activities), or c) *other aspects* related to how crises affect people and/or organizations, or how they perceive or respond to them. The term "organization" should be interpreted broadly, referring to all kinds of social organization, including, but not limited to families, business organisations, societies, and humankind as a whole (Richardson, 1994a). Papers may refer to one or more stages of crisis development that can broadly be classified as *before, during, and after crisis*, as well as to activities or other aspects related to one or more of these stages (Seeger et al., 2003). Inclusion is not limited to specific types of crises but applies to the implications of triggering events located within or outside and organization, which may derive from technical and/or economic factors on the one hand, and personal, social, and/or organizational factors on the other (Mitroff et al., 1987). In particular, papers may refer to ecosystem disasters, business-economic failure crises, socio-technical disasters, and/or sociopathic attacks (Richardson, 1994a): - *Ecosystem disasters* arise from organizational activity and threaten the widespread destruction of life forms or their habitats. - *Business-economic failure crises* arise when business conditions around an organization change and impact adversely on an unresponsive and unprepared organization. - *Socio-technical disasters* are organization-specific incidents that usually involve massive economic and social costs and the loss of human life. - *Sociopathic attacks* on an organization are rooted in the complex personalities of dangerous persons. The following are *examples* for events that can trigger organizational crises (in alphabetical order): bankruptcy, computer or information systems breakdowns, copyright infringement, counterfeiting, executive kidnapping, extortion, hostile

Criterion	Crisis
	takeovers, illegal organizational activities, information leakage, government crises, international crises, labor strikes, leakage of hazardous materials, malicious rumors, market shifts, miscommunications, occupational health diseases, personnel or customer assaults, plant and factory failures, product or service boycotts, product recalls, sabotage, security breaches, sexual harassment, terrorist attacks, transport failures, vehicular fatalities (Mitroff et al., 1987; Pearson & Clair, 1998; Pearson & Mitroff, 1993; Richardson, 1994b). In addition, *natural disasters* can trigger organizational crises if they disrupt major products or services, destroy the organizational information base, degrade an organizations' headquarter, or eliminate key stakeholders (Pearson & Clair, 1998). Natural disasters are events caused by geophysical (e.g., earthquakes, dry mass movements, volcanic activity), hydrological (e.g., floods, landslides, wave action), meteorological (e.g., storms, extreme temperatures, fog), climatological (e.g., drought, glacial lake outburst, wildfires), biological (e.g., animal accidents, epidemics, insect infestation), or extra-terrestrial (e.g., space weather, impacts) hazards (Centre for Research on the Epidemiology of Disasters & United Nations Office for Disaster Risk Reduction, 2015).
Exclusion criterion	Exclude papers that do not refer to one or more specifiable events or the implications thereof, but to long-term negative states or trends (e.g., climate change, low stages of development, demographic change) if the authors do not reference events or types of events that (potentially) follow from these developments. This also means that papers dealing with long-term processes of adaptation to changing conditions, such as market shifts or social or political change, or emergent threats, such as cyber threats or misinformation (e.g., strategic political measures, processes of cultural adaptation, new styles of communication, emergence or formation of new cultural or professional understandings), are to be excluded if there is no explicit reference to the crisis itself (however, papers in which such processes are clearly taken in response to or to prepare for a crisis – for instance, resilience measures – are included). Also, exclude papers that investigate routine events and/or events that do not cause extraordinary levels of uncertainty (e.g., road accidents, emergency medical care, ordinary waves of influenza, regular elections, or major events). Furthermore, exclude papers that investigate events that do not threaten strategic organizational goals (e.g., the bullwhip effect, supply and demand uncertainty, asymmetric information, change of suppliers, customer complaints, return shipments, and individual crises such as depression, bereavement, alcoholism, or loneliness). Also, exclude papers that make mention of crisis events (e.g., in the motivation or in the research outlook), but do not contribute insights into crises or their implications. In particular, exclude papers that cover issues such as brand management, reputation management, social media management, customer relationship management, but do not explicitly refer to crises. Finally, exclude papers that investigate abstract threats (e.g., cyber-attacks, fake news), but do not explicitly refer to (potential) crises caused by these threats (e.g., because they focus on technical details of the threat itself).
Borderline criterion	Include papers that investigate, for instance, threats that may, but need not trigger events that rise to the level of crises, and events whose crisis character is ambiguous and subject to interpretation (e.g., the spread of a rare but non-lethal disease, or abstract threats resulting from long-term negative states), as well as

Criterion	Crisis
	papers that cover both crisis and non-crisis events or that use crisis events as an illustration for other research outcomes (e.g., methods or tool development).

Table B.1.11
Content screen: social media criterion

Criterion	Social Media
Definition	To be included, a paper must be related to *social media* defined as "various user-driven platforms that facilitate diffusion of compelling content, dialogue creation, and communication to a broader audience […] essentially a digital space created by the people and for the people, and [.] an environment that is conducive for interactions and networking to occur at different levels (for instance, personal, professional, business, marketing, political, and societal)" (Kapoor et al., 2018, p. 536).
Inclusion criterion	Include papers that investigate *digital platforms* that enable their users (e.g., individuals, communities, emergency responders, business organizations, governments, and news media [Houston et al., 2015]) to *create, access, and spread digital content* and to *interact and connect with others* from a broader audience for different purposes that may, but need not be related to a crisis event or crisis management. Papers may cover well-known platforms (e.g., Facebook, Twitter, YouTube, Instagram, Flickr) and established types of social media, such as social media networks, blogs, content sharing sites, collaborative projects, virtual worlds, open source software communities, and social bookmarking sites (Kaplan & Haenlein, 2010; Mangold & Faulds, 2009), but also newly developed and less popular platforms (e.g., applications that support crisis communication with digital volunteers). This definition also includes *online communities* enabled by social media.
Exclusion criterion	Exclude papers that refer to analogue rather than digital means of communication (e.g., landlines, analogue radio, bulletin boards) and interactions that are not enabled by digital means of communication (e.g., command and control and other kinds of organizational structures or hierarchies, and various kinds of social networks, such as kinship, collaboration, or social support networks). Also, exclude papers that investigate digital platforms that do not allow their users to create and exchange digital content and/or connect with others from a broader audience, such as professional content platforms, digital radio, and e-mail communications. Finally, exclude papers that cover social network analysis and its applications without reference to social media.
Borderline criterion	Include borderline papers that investigate, for instance, hybrid forms of communication, that use social media to illustrate other research outcomes (e.g., emergent forms of organization or patterns of crisis communication), or that apply tools or methods using digital trace data in the first place.

Phase 3: Subject Area Screen

The *subject area screening* had two goals: First, to reduce the number of papers to a reasonably manageable corpus, maintaining those studies that are likely of most interest to readers and the discourse on the topic; second, to limit the analysis to high-quality

publications, focusing on the established state of the art. To realize those goals, we screened all publications that passed the previous phases based on the Harzing journal list (66th ed. [Harzing, 2020]). We included papers in the "Management Information Systems, Knowledge Management" subject area that had received rankings in the top half of the ABDC and at least one other qualitative ranking released since 2015. The rankings (and corresponding ranks) were:

- VHB 2015 (A+, A, B)
- EJL 2016 (P*, P, P A)
- ABS 2018 (4*, 4, 3)
- ABDC 2019 (A*, A)
- CNRS 2019 (1*, 1, 2)
- FNEGE 2019 (1*, 1, 2)

To account for community-specific contributions in earlier stages of development and maturity, we included full papers from the proceedings of the International Conference on Information Systems (ICIS) and the Hawaii International Conference on System Sciences (HICSS).

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Appendix to Paper 1: Corpus of Papers

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Appendix to Paper 1: Qualitative Content Analysis Process and Codebook

We describe the qualitative content analysis process in the manuscript. In the first step, we pre-structured the papers to identify statements in which they referred to the uses of social media in the context of crises. In the second step, we assigned inductive codes that correspond to the affordances social media provide for internalizing, externalizing, and collaborating, and the open resources, open processes, and opening effects that follow from actualizing these affordances. In the last step, we deductively associated each code with the stages of organizational learning to which they pertain (i.e., the intuiting, interpreting, integrating, and institutionalizing processes that constitute organizational learning). Figure B.1.6 illustrates this process.

Figure B.1.6
Qualitative content analysis process

Table B.1.14 and Table B.1.15 contain the codebooks for social media affordances and openness, respectively, along with the coding rules.

Table B.1.12
Codebook: social media affordances

Code labels	Definitions
Affordances for internalizing are opportunities for action social media provide for accessing external resources and harnessing the outcomes of external learning processes. They include:	
(1) Monitoring the information stream	Observing crisis-related digital content contributed to social media
Coding rules: - *Description:* accessing information related to a crisis event, response activities, or relevant resources or processes in ways that do not require interacting with users - *Examples:* following crisis-related markers (e.g., hashtags), observing contributions to collaborative spaces (e.g., wikis, maps), community spaces (e.g., groups), or digital presences (e.g., digital profiles, channels), establishing relational connections to other users to receive automated updates - *Apply if* the described usage behaviors imply monitoring, but do not describe monitoring activities in detail (e.g., referring to using social media to access crisis-related information broadly)	

Code labels		Definitions
- *Apply if* a statement refers to the automated collection of digital content (e.g., through accessing an API) that explicitly relies on the monitoring affordance - *Do not apply if* the described behavior implies actively engaging with users to acquire information (e.g., messaging or tagging them, crowdsourcing information)		
(2)	Automatically processing big (social media) data	Utilizing technological artifacts for collecting, analyzing, and displaying crisis-related digital content contributed to social media
Coding rules: - *Description:* references to all kinds of technological artifacts that facilitate monitoring (e.g., their design or use), as opposed to monitoring activities that require user activity - *Examples:* artifacts for data collection, management, pre-processing, aggregation, visualization - *Apply to* advanced artifacts that automate the entire monitoring process as well as those that support only parts of the process - *Apply to* well-established artifacts for social media monitoring (e.g., Radian 6) as well as niche products and specialized tools - *Do not apply* to artifacts that facilitate other aspects of crisis management (e.g., inter-organizational collaboration) - *Do not apply if* technological artifacts are used as part of a paper's data collection, but not related to crisis management activities		
(3)	Tapping collective intelligence	Harnessing the outcomes of users' joint efforts to make sense of crises
Coding rules: - *Description:* accessing information that has been pre-processed through users' interactions (i.e., curated information) - *Examples:* information that has been filtered, validated, or augmented references to credible information sources or other evidence - *Apply if* curative behavior can be presumed, but is not explicitly mentioned (e.g., users' forwarding information) - *Apply if* interactive behavior can be presumed, but is not explicitly mentioned (e.g., users' contributing sense-making information to collaborative spaces, where it can be processed further by others) - *Apply if* the aggregate outcomes of collective sense-making processes (e.g., retweet counts) are accessed and used (e.g., for evaluating information), but the sense-making process itself is not described - *Do not apply if* information clearly results from individual users' independent information-sharing behaviors.		
(4)	Accessing information providers	Identifying and consulting presumably knowledgeable users
Coding rules: - *Description:* approaching other users to acquire information from them - *Examples:* messaging or tagging users, requesting information specifically from particular users (e.g., from emergency response organizations) - *Apply if* direct contact between users can be presumed, but is not explicitly referenced (e.g., adding digital content to a particular user's digital profile to inquire some information) - *Apply if* social media facilitate identifying and accessing information providers (e.g., retracing users' connections to identify relevant stakeholders without actually approaching them) - *Do not apply if* accessing information relies on collaborative behavior; in particular, joint production of information resources by a larger group of users (e.g., through crowdsourcing)		

Code labels		Definitions
(5)	Evaluating crisis response	Analyzing experiences gained from prior uses of social media in response to crises

Coding rules:

- *Description:* accessing information from past crises to generate insights in response to present events or to prepare for future occurrences
- *Examples:* conducting crisis simulations or exercises, analyzing digital traces from past events, surveying non-organizational users' perceptions and responses
- *Apply to* descriptions of learning from an organization's own as well as others' experiences (e.g., vicarious learning)
- *Do not apply to* papers that reference organizational adaptation in general, but do not imply learning from prior experiences
- *Do not apply to* general research concerned with analyzing crisis management, as opposed to papers that investigate the actual uses of social media related to evaluating crisis response

Affordances for externalizing are opportunities for action social media provide for granting access to internal resources and enabling external actors to tap internal learning processes. They include:

(6)	Contributing information	Making digital content available to users through social media

Coding rules:

- *Description:* authoring digital content and making it available for other users to access and use through social media
- *Examples:* composing status updates (e.g., tweets), authoring blog posts, creating or editing contributions to group or collaborative spaces
- *Apply to* all kinds of information (i.e., situational, geo-location, user profile, social network, sense-making, and curated information)
- *Apply to* activities through which users contribute to or enrich digital content originally contributed by other users (e.g., commenting or responding to other users' status updates, answering questions)
- *Apply to* digital content that is introduced to social media by a user who has not authored it originally (e.g., sharing news reports)
- *Apply if* the particular type of contribution is implied rather than described explicitly (e.g., referring to contributions to a conversation or hashtag broadly)
- *Apply to* digital traces that result from users' contributions even if users' information-sharing behaviors are not explicitly described
- *Do not apply if* users forward other users' digital contributions (e.g., retweeting other users' posts or other forms of information curation)

(7)	Forwarding information	Sharing previously contributed crisis-related digital content with users beyond its original audience through social media

Coding rules:

- *Description:* passing previously contributed information along to other users
- *Examples:* re-sharing digital content (e.g., retweeting), forwarding digital contributions to individual other users through direct messages or tagging
- *Apply to* cases in which users re-share digital content that was originally created by them (e.g., re-sharing their own status updates)
- *Apply to* activities that do not rely on built-in features of social media (e.g., retweeting), but result in making digital content available to other audiences (e.g., copying and pasting)
- *Apply to* other forms of information curation that implicitly require forwarding (e.g., gatekeeping)

Code labels		Definitions
- *Do not apply if* users revise digital content or add further information to it through contributing (e.g., adding clarifying information or evidence to digital content that conveys a rumor)		
(8)	Framing narratives	Contributing or forwarding digital content that conveys a particular interpretation of a crisis
Coding rules: - *Description:* using particular language, symbols, or message styles to shape audiences' perceptions of crisis-related information contributed or forwarded by them - *Examples:* emotional language, organizational crisis communication styles (e.g., with reference to Situational Crisis Communication Theory), standardized message structures (e.g., for warning messages) - *Apply in addition* to affordances for contributing and forwarding digital content through which users make it available to others in the first place - *Apply to* digital content through which users explicitly or implicitly attempt to influence audiences' perceptions or responses (e.g., organizational crisis communications) - *Apply to* digital content through which users express their personal standpoints or interpretations, and hence explicitly or implicitly attempt to persuade others (e.g., personal opinions) - *Apply to* message frames that are conveyed through non-textual media (e.g., graphics or reactions) - *Do not apply to* factual (situational) information, even if it covers only specific aspects of crisis, if no particular language, symbols, or message styles are applied - *Do not apply to* curated information if no particular language, symbols, or message styles are applied		
(9)	Establishing digital presences	Setting up and promoting outlets for contributing and forwarding crisis-related digital content through social media
Coding rules: - *Description:* establishing digital profiles or community or collaborative spaces which allow contributing and forwarding information, and to which information can be reported - *Examples:* creating a Facebook page or a Twitter handle through which information can be disseminated, and to other users can contribute information (e.g., through contributing digital content to those profiles, or through interacting with the respective users), setting up a wiki or forum, or creating pages within those to facilitate exchanging crisis-related information, creating a map that displays user contributions - *Apply to* all kinds of digital places to which crisis-related information can be contributed by those who have established them or other users - *Apply to* continuing or promoting existing digital presences, rather than establishing new ones (e.g., attracting followers to existing presences) - *Do not apply to* user or message characteristics (e.g., user identities, language style, keywords) that pertains to digital content contributed to or available from digital presences - *Do not apply to* conversational norms that facilitate information flow contingent upon the existence of digital presences (e.g., use of hashtags and other crisis-related markers)		
(10)	Communicating a reputation	Signaling the status and legitimacy of users contributing or forwarding crisis-related digital content through social media
Coding rules: - *Description:* using credibility indicators provided by a platform or resulting from a user's identity, behaviors, or social network position to convey their authority		

Code labels	Definitions
- *Examples:* confirmed profile identities, follower counts, trustworthy message and communication styles (e.g., communicating on a regular basis, responding to audiences' inquiries), interaction histories, user testimonials - *Apply to* both user and message characteristics that convey the authority of a user or a particular message authored by them - *Apply to* status indicators that refer directly to a user (e.g., follower count, confirmed offline identities, such as being a journalist or an approved spokesperson of an emergency response organization) or that result from their usage behaviors and interactions (e.g., long-term membership within an online community, digital traces that demonstrate continued engagement) - *Apply to* users who have exceeding influence over the dissemination of crisis-related information (e.g., digital volunteers, gatekeepers, opinion leaders) - *Apply in addition to* the affordance for establishing digital presences if acquiring or communicating a reputation implicitly or explicitly requires the existence of a digital presence (e.g., setting up a digital profile to attract followers in the first place) - *Do not apply to* digital presences that do not signal the user's reputation (e.g., digital profiles that make further contributions to a conversation) - *Do not apply to* large quantities of digital content, activity spikes, trends, etc. (e.g., number of messages sent by a particular user, number of contributions to a hashtag, number of retweets of a particular piece of digital content)	
Affordances for collaborating are opportunities for action social media provide for mutual access to and joint production of resources and allowing for integrative learning processes across organizational boundaries. They include:	
(11) Negotiating consensus	Aligning perceptions and developing a shared interpretation of a crisis
Coding rules: - *Description:* engaging in conversations and interacting with other users to make sense of a crisis and arrive at a shared understanding of crisis events and related activities - *Examples:* explaining the causes and implications of events, providing evidence for disputed statements, asking for clarifications for ambiguous or conflicting information (including rumors), inquiring further information for incomplete statements, contributing to a hashtag, commenting or responding to other users' contributions, tagging other users to involve them in a conversation - *Apply to* interactions (e.g., conversations, contributions to a hashtag) that are open to the contributions of groups of users (as opposed to private conversations between individual users), even if only one or a few users actually make contributions - *Apply to* interactions surrounding crisis-related information, as opposed to other resources, such as workforce, goods and utilities, and funds - *Also apply if* convergence towards a shared understanding is a plausible outcome, but not explicitly referenced in the paper - *Also apply to* activities through which users try to influence others' perceptions of or response to a crisis (e.g., through framing narratives) - *Do not apply to* information-sharing activities individual users engage in independent of the ongoing discourse (e.g., forwarding presumably relevant information to keep audiences up to date) - *Do not apply to* information-sharing activities that are open to only one or a few users that other users can monitor, but not make own contributions to (e.g., contributions to a closed digital profile) - *Do not apply to* digital content contributed or forwarded without reference to an ongoing conversation or discourse (e.g., breaking news, situational updates)	

Code labels		Definitions
- *Do not apply to* users seeking or sharing social and emotional support or coordinating self-help or relief activities based on a shared understanding of the situation (e.g., asking for donations or volunteers, crowdsourcing resources, expressing condolences or support)		
(12)	Integrating contributions	Registering, monitoring, and deploying resources provided by users in response to a crisis in a coordinated way
Coding rules: - *Description:* acquiring, managing, and utilizing information and other resources based on contributions made through social media - *Examples:* registering volunteers, inventtorying goods and materials pledged by users, deploying organizational resources to respond to requests and calls for help received through social media - *Apply to* resources users provide through social media, either directly (e.g., informational resources) or indirectly (e.g., promising donations or material contributions) - *Apply to* resources that can be utilized to respond to a crisis or that help coordinate and target crisis response activities (e.g., information that raises awareness for particular audiences' needs) - *Apply to* activities through which resources are provided or otherwise made available, registered, inventoried, or applied to respond to crisis using social media - *Apply to* the bottom-up harmonization of resources provided and requested and the matching of demands and supplies, including, but not limited to, self-organized community response activities - *Do not apply* to resources that are specifically requested for a particular purpose in the first place (e.g., through crowdsourcing)		
(13)	Crowdsourcing contributions	Calling for and incorporating resources to be provided by users in response to a crisis
Coding rules: - *Description:* asking users to provide resources to be used in crisis response activities, and making resources available in response to such calls - *Examples:* photos of crisis impacts and locations, donations, volunteering efforts, goods and materials - *Apply to* contributions in the form of informational as well as other resources - *Apply to* calls for resources to be incorporated as well as for particular contributing behaviors in social media (e.g., for forwarding particular messages to increase their reach) - *Do not apply to* the bottom-up coordination of resource needs and available contributions without explicit call or encouragement to contribute particular resources - *Do not apply to* conversational sense-making activities, even if those involve inquiries regarding incomplete or conflicting information		
(14)	Developing community	Advancing connections, sense of community, and collective action among users in response to a crisis
Coding rules: - *Description:* (re-) establishing relational ties to other users and harnessing benefits that result from that - *Examples:* trust, sense of community, collective and connective action, social capital - *Apply to* activities that advance community within and across organizations (e.g., among self-organized community members, between responders from different organizations, between an organization and its external stakeholders)		

Code labels		Definitions
- *Apply to* communications and other kinds of relational ties that facilitate interactions between two or more users - *Apply to* establishing and substituting communication and other relational ties between individual users without further (social) effects - *Apply to* organizations' efforts to advance community with external stakeholders (e.g., customers), for instance, through interactive communications - *Do not apply to* negotiating consensus and developing a shared understanding on which community could be based - *Do not apply to* coordinating or crowdsourcing resources to be used in response to crisis		
(15)	Establishing norms	Developing and enforcing principles for using social media to respond to a crisis collaboratively
Coding rules: - *Description:* negotiating, announcing, applying, and enforcing norms that regulate interactions - *Examples:* promoting hashtags and other markers to be used to refer to crisis, reprimanding users for using violent speech, moderating online community activities - *Apply to* norms that are explicitly set by users as well as usage conventions that emerge from their repeated interactions (e.g., community rules, hashtag use) - *Apply to* activities through which users negotiate norms, make contributions in line with existing norms, or impose them upon others (e.g., through reproaching or sanctioning non-compliant users) - *Apply to* activities undertaken by regular users as well as to users taking dedicated roles to supervise compliance with norms (e.g., community moderators or administrators) - *Do not apply to* sense-making activities through which users negotiate a shared understanding of crisis, rather than determining admissible ways to engage in conversations and interactions - Do not apply to conventions or recommendations for responding to a crisis, as opposed to using social media (e.g., warnings, advice)		

Table B.1.13
Codeobok: openness

Code labels		Definitions
Open resources are means that can be utilized in supply or support of crisis response, and that are made accessible to anyone, or at least an a priori undefined group of users, through social media. They include:		
(A)	Information	Digital content that conveys users' insights related to a crisis, in particular:
(A1)	Situational information	Information pertaining to crisis events, related resources, or activities
Coding rules: - *Description:* digital content related to crisis events or response activities - *Examples:* warnings, updates, eyewitness reports, impact descriptions, ongoing activities (e.g., search and rescue), availability of services and supplies (e.g., emergency medical care, shelters) - *Apply to* information related to crises but not covered by other codes (e.g., papers referring to the exchange of crisis-related information in general) - *Apply to* instructions and advice if they convey prescribed or routine ways of responding (e.g., warnings) - *Apply to* resource requests (e.g., calls for help) from which users can learn about the situation		

Code labels		Definitions
- *Apply to* patterns of user activity (e.g., activity spikes) from which users can draw conclusions about the location and intensity of a crisis - *Apply to* non-textual digital content that conveys corresponding information (e.g., photos, videos, infographics) - *Do not apply to* statements that convey personal interpretations, message frames, or emotional responses		
(A2)	Geo-location information	Information about the location of crisis events, related resources, or activities
Coding rules: - *Description:* digital content that describes the location of crisis impacts, response activities, or resources - *Examples:* road or place names, geo-tags, profile location information, map indicators - *Apply in addition to* situational information if a statement refers to the location of events or activities (e.g., of crisis impacts, relief activities, supplies) - *Apply to* information provided by users (e.g., through their digital traces) or supplied by an artifact (e.g., location stamps) - *Do not apply to* conversational themes surrounding a particular location (e.g., using a hashtag indicating the location of an event)		
(A3)	User identity information	Information about users' online or offline identities, roles, behaviors, or resources related to a crisis
Coding rules: - *Description:* digital content that pertains to a user's individual and social identities, their authority and other resources, or roles taken in response to a crisis - *Examples:* being a member of an emergency response organization, a journalist, or a local resident, being associated with a social group, commanding particular knowledge or other resources, serving as a digital volunteer - *Apply to* individual users who constitute actors in social media, as opposed to non-users or organizations with which users might be affiliated - *Apply to* user-identifying information that is actively provided by users (e.g., through their digital profiles), that is evident from their digital traces (e.g., their interaction histories), or that can be otherwise inferred through social media - *Do not apply to* statements merely mentioning users without further investigating their identities - *Do not apply to* users' chosen or assigned screen names - *Do not apply to* actors outside social media		
(A4)	Social network information	Information about users' connections and positions within the information-sharing and communication network in social media
Coding rules: - *Description:* digital content that allows insights about a users' communication ties and their position within the network of crisis-related information-sharing and communication - *Examples:* user's contacts, content and frequency of interpersonal communications, degree and other social network centrality scores - *Apply to* insights into users' dyadic interactions that pertain to their actual communications (e.g., from their digital traces) as well as to their relational ties to others that facilitate interactions (e.g., their being friends with or following other users) - *Apply to* both public (e.g., contributions to others' digital profiles) and private dyadic interactions (e.g., direct messages)		

Code labels		Definitions
- *Do not apply to* aggregate measures that do not allow conclusions about a users' connections to others (e.g., follower counts) - *Do not apply to* public conversations among multiple users and messages directed towards an unspecified audience		
(A5)	Sense-making information	Information that helps users interpret and give meaning to crisis events or related activities
Coding rules: - *Description:* digital content that conveys a user's personal perceptions and experiences - *Examples:* opinions, criticism, calls for political action, feedback, arguments and evidence - *Apply to* all pieces of information through which users explain their understanding of a crisis or crisis response to others - *Apply to* rumors, sentiments, sarcasm, and personalized recommendations and advice - *Apply to* reports of personal experiences and activities - *Apply to* annotations through which users complement available information to explain their understanding to others (e.g., adding symbols to a map, sharing annotated reports) - *Do not apply to* first-hand reports that document crisis impacts or related aspects - *Do not apply to* emotional content, humor, and statements that refer to users' coping behaviors		
(A6)	Curated information	Crisis-related information that has been pre-processed by users before they contribute or forward it
Coding rules: - *Description:* digital content that users have selected, filtered, aggregated, or evaluated before they make it available to others to access and use - *Examples:* retweeting presumably relevant information, introducing information from online or offline news sources into social media, integrating and validating information from different sources - *Apply in addition to* situational or other information categories, if appropriate - *Apply if* an intentional act of curating can be presumed, but is not explicitly described in the paper (e.g., retweeting digital content more generally) - *Apply to* information that is processed (e.g., selected and aggregated) by human users and by advanced artifacts - *Do not apply to* digital content that explains, paraphrases or summarizes information - *Do not apply to* digital content that is originally authored by a focal user		
(B)	Knowledge	Crisis-related information users have obtained through personal familiarity
Coding rules: - *Description:* information obtained through personal experience or acquaintance - *Examples:* professional knowledge, skills, technical expertise - *Apply if* knowledge is transmitted directly or made available indirectly through using social media (e.g., offering to contribute one's technical skills) - *Do not apply to* descriptions of a user's experiences responding to a crisis - *Do not apply to* general instructions and advice		
(C)	Authority	Users' power to influence others' interpretations or behaviors related to a crisis
Coding rules: - *Description:* social influence conveyed by a user or digital content contributed or forwarded by them		

Code labels		Definitions
- *Examples:* online or offline identities, platform-generated credibility indicators (e.g., follower counts, activity scores), message and communication styles, digital traces and interaction histories, other users' testimonials - *Apply to* authority of both users and digital content - *Apply if* popularity of digital content suggests some degree of influence of its originator over other users' responses - *Do not apply to* retweet counts and other descriptive measures of content popularity or propagation		
(D)	Social support	Statements that express informational, emotional, appraisal, or instrumental support, or request or assure corresponding resources in response to a crisis
Coding rules: - *Description:* digital content through which users exchange social or emotional support, or through which they express their personal response or coping behaviors - *Examples:* feelings, condolences, encouragement, community appeals, mourning, psychological counseling, inquiries after others' well-being - *Apply to* digital content through which users seek or share social support - *Apply to* services offered or provided in response to users' need - *Apply to* individual coping behaviors, humor, and community building - *Do not apply to* digital content that conveys personal opinions or interpretations - *Do not apply to* activities through which users (self-) organize crisis response activities		
(E)	Workforce	Users that undertake activities in response to a crisis
Coding rules: - *Description:* working hours provided by users to respond to crises - *Examples:* volunteering, deployment of personnel - *Apply to* both online activities (e.g., serving as a digital volunteer) and workforce that is pledged through social media (e.g., volunteering to clean-up) - *Apply to* workforces provided by organizations (e.g., personnel) and non-organizational users (e.g., volunteers) - *Do not apply to* information-sharing and communication behaviors that do not aim at crisis response, but, for instance, personal coping or sense-making - *Do not apply to* goods and materials, monetary funds, and informational resources		
(F)	Goods and materials	Equipment that can be utilized to respond to a crisis
Coding rules: - *Description:* Tools, equipment, and supplies that facilitate crisis response - *Examples:* sandbags, food, clothing, tents, medication - *Apply to* goods provided by organizations (e.g., through emergency medical care or evacuation sheltering) and non-organizational users (e.g., donations) - *Do not apply to* services provided as part of social support - *Do not apply to* workforce, monetary funds, and informational resources		
(G)	Funds	Financial means that can be utilized to respond to a crisis
Coding rules: - *Description:* money that is provided by users to facilitate crisis response - *Examples:* donations, fundraising, insurance claims - *Do not apply to* workforce, goods and materials, and informational resources		

Open processes are goal-directed activities in response to crisis to which anyone, or at least an a priori undefined group of users, can contribute through social media. This includes:

(H)	Disseminating	Contributing and forwarding digital content to make crisis-related information and other resources available to other users through social media

Coding rules:
- *Description:* making digital content available to other users to increase its reach and enhance the effectiveness of communications (e.g., contribute to other users' situational awareness)
- *Examples:* authoring blog posts, editing wiki entries, updating locations on a map, sharing status updates
- *Apply to* the propagation of all kinds of crisis-related information
- *Apply to* activities through which users make digital content available to others, as well as to descriptions of digital content that can be accessed by users
- *Do not apply to* dyadic or private conversations through which information is made available only to particular users

(I)	Social sensing	Accessing digital content contributed to social media to gather or generate resources through further activity

Coding rules:
- *Description:* utilizing digital content that other users have contributed for their own reasons (e.g., sense-making, coping)
- *Examples:* monitoring the information stream to follow hashtags, read contributions to digital profiles, observe contributions to community and collaborative spaces
- *Apply to* all activities related to monitoring the information stream and automatically processing big (social media) data
- *Apply if* users' activities presume social sensing without explicit descriptions of such behaviors (e.g., making decisions based on information they have acquired from social media)
- *Do not apply to* utilizing information that has been provided in response to a specific call or other type of request (e.g., through crowdsourcing)

(J)	Social reporting	Accessing digital content contributed to social media specifically with the purpose to be put to use in response to a crisis to gather or generate resources through further activity

Coding rules:
- *Description:* utilizing digital content that other users have provided for that purpose
- *Examples:* crowdsourcing damage reports or evidence of local impacts, providing a hashtag to which local updates or calls for help can be addressed
- *Apply to* activities through which users request contribution as well as activities through which they make contributions
- *Apply if* information is reported without an explicit call for contributions
- *Do not apply to* activities through which users access information that is generally available (e.g., through monitoring the information stream)

(K)	Sense-making	Interacting with other users to develop an understanding of crisis events and related resources and activities

Coding rules:
- *Description:* conversational activities through which users establish what information is relevant for interpreting a crisis, discuss and evaluate related aspects, and develop a shared understanding of events
- *Examples:* negotiating rumor veracity, discussing response options, providing information to gain a more complete understanding, validating information from different sources

- *Apply to* interactions that result in the exchange of information based on users' particular needs, for instance, activities related to seeking and sharing information to evaluate the veracity of digital content or close gaps in one's understanding (e.g., asking and answering questions)
- *Apply to* activities through which users negotiate consensus
- *Do not apply to* activities related to disseminating information to a broader audience or monitoring the information stream

(L)	Gatekeeping	Selecting and filtering crisis-related digital content to be contributed to or forwarded through social media

Coding rules:

- *Description:* processing previously contributed digital content to make it available to further audiences or provide further related information through contributing or forwarding it
- *Examples:* retweeting digital content, forwarding it to users for whom it might be relevant, selecting information from external sources to be shared with one's followers, establishing collections of related information sources, consolidating potentially conflicting information from different sources
- *Apply to* contributing and forwarding activities based on previously available digital content and information from other sources
- *Do not apply to* creating or forwarding (e.g., re-sharing) digital content that was originally authored by a focal user
- *Do not apply to* conversational sense-making activities through which users evaluate digital content

(M)	Translating	Synthesizing and explaining messages conveyed by crisis-related digital content in social media by expressing them in terms that are generally comprehensible

Coding rules:

- *Description:* using particular language, symbols, or message or communication styles or formats to explain crisis-related information to other users
- *Examples:* creating infographics, re-phrasing organizational communications, using emoticons to convey meaning
- *Apply to* digital content that explains previously contributed information through language or other message characteristics, possibly in addition to gatekeeping
- *Do not apply to* conversational sense-making activities that do not involve editing or otherwise processing previously available digital content
- *Do not apply to* digital content through which individual users explain their perceptions and views, including follow-ups on original contributions

(N)	Decision-making	Interacting with other users to analyze problems related to crises, identify and evaluate potential solutions, and reach agreement regarding solutions to be implemented

Coding rules:

- *Description:* determining solutions to a common problem
- *Examples:* making suggestions for activities, voting on proposals, assigning work groups and tasks
- *Apply to* interactions through which users deliberately negotiate solutions to shared problems and converge towards a shared course of action
- *Apply to* interactions that allow users to engage in particular step in problem-solving only (e.g., ideation, evaluation)
- *Apply to* organizational activities to involve non-organizational users in organizational decision-making (e.g., through crowdsourced ideation)

- *Apply in addition to* sense-making activities, if appropriate
- *Do not apply* to interactions that are not directed towards identifying and implementing solutions to commonly shared problems
- *Do not apply to* suggestions or calls for action unrelated to a group's or organization's decision-making process (e.g., customer comments provided to a non-responsive company's digital presence)

(O)	Relief coordination	Acquiring and deploying resources according to insights about requests and contributions acquired through social media

Coding rules:
- *Description:* accessing information about available resources, registering and managing available resources through social media, or deploying available resources in response to information obtained from social media
- *Examples:* registering volunteers, retracing users' connections to identify actors who can provide required resources, determining locations to deploy supplies and personnel
- *Apply to* activities for integrating contributions
- *Apply to* calls for help or other requests from which users can identify opportunities for action
- *Do not apply to* sense-making activities through which users inquire information aimed at generating a better understanding

(P)	Digital volunteerism	Contributing resources to another organizations' crisis response activities, undertaking related services, or signaling a willingness to do so using social media

Coding rules:
- *Description:* using social media to engage in activities that facilitate crisis response
- *Examples:* aggregating and evaluating information, crowdsourcing relief, distributing information to relevant stakeholders
- *Apply to* activities that require using social media (e.g., gatekeeping), as opposed to non-digital volunteerism (e.g., building dams)
- *Apply to* workforce offered by non-organizational users (i.e., volunteers)
- *Do not apply to* activities undertaken by organizational users or responders
- *Do not apply to* activities undertaken beyond social media

(Q)	Participatory research	Systematically inquiring about crisis response activities while integrating the responses of non-organizational users through social media

Coding rules:
- *Description:* using social media to inquire users' perceptions and responses to a crisis, evaluate the effectiveness of communications, or identify opportunities for learning and adaptation based on prior experiences
- *Examples:* conducting simulations and exercises, providing training, evaluating digital traces from past events, distributing surveys among users
- *Apply to* activities for evaluating crisis response
- *Apply to* efforts to make sense of, draw lessons from, and generate learnings from prior crisis experiences
- *Apply to* both own and others' (e.g., vicarious) experiences
- *Do not apply to* research that analyzes crisis response broadly without investigating organizations' research activities

Opening effects are ways in which open resources and processes can contribute to the emergence of collaborative organizational structures, activities, and values that integrate actors across and beyond organizational boundaries through social media. This includes:

(R) Transparency — Accessibility of information pertaining to organizational resources and processes with respect to crisis response

Coding rules:
- *Description:* availability of crisis-related information, which can be provided by all kinds of users, and which hence can be openly accessed by other users through social media
- *Examples:* information about an organizations' crisis response activities (e.g., deploying resources, establishing relief funds), insights into non-organizational users' and self-organized community responses (e.g., services provided, resources required), information about relevant actors that contribute to crisis response (e.g., digital volunteers, social media influencers), identifying emergent threats from user contributions (e.g., through local activity spikes)
- *Apply if* papers refer to disseminating information and digital content that can be accessed through monitoring or social sensing by anyone, or at least an a priori undefined group of users, through social media
- *Apply to* all kinds of crisis-related information made accessible through social media (e.g., situational information, sense-making information, informational social support)
- *Apply to* information that is made available to users across organizational boundaries (e.g., between community members, organizations, media), as opposed to intra-organizational communications and interactions between individual users

(S) Interactivity — Reciprocal engagement of organizational and non-organizational users to access and provide crisis-related information and other resources

Coding rules:
- *Description:* using social media to respond to other users' requests and inquiries
- *Examples:* communicating with stakeholders (e.g., answering customers' or affected citizens' questions), developing a shared understanding through conversational activities
- *Apply if* statements refer to conversations or other interactions between users within or across organizations, i.e., to activities based on affordances for collaborating
- *Apply to* organizations' efforts to build community with stakeholders

(T) Responsiveness — Timely, appropriate, and sympathetic reactions to non-organizational users' inputs and requests

Coding rules:
- *Description:* taking action in response to users' requests and inquiries (e.g., providing relevant information, deploying resources, identifying people in need)
- *Examples:* deploying resources in response to users' needs (e.g., sending search and rescue teams to a particular location or restocking supplies), providing information and other resources non-organizational users require to respond to crises (e.g., sharing organizational knowledge with self-organized communities)
- *Apply to* activities based on affordances for integrating or crowdsourcing contributions
- *Do not apply to* interactive conversations (i.e., responding to stakeholders through conversations and other interactions in social media)

(U) Empowerment — Crisis response activities undertaken by non-organizational users independent of organizational resources and processes

Coding rules:
- *Description:* providing opportunities for non-organizational users to respond to crises using their own or tapping an organization's resources and processes (e.g., coping, self-organized community relief activities, collective action)

- *Examples:* providing social and emotional relief, organizing response activities (e.g., constructing barriers, rescuing victims), establishing community outlets for seeking and sharing relevant information (e.g., groups, wikis)
- *Apply to* activities related to community engagement and digital volunteerism
- *Apply to* integrating contributions outside an organization's boundaries
- *Do not apply to* organizational activities, or activities through which non-organizational users contribute to an organization's response efforts

(V)	Participation	Involvement of non-organizational users in organizational crisis response

Coding rules:
- *Description:* providing opportunities for non-organizational users to contribute to organizational crisis response
- *Examples:* contributing situational information to inform organizational decisions (e.g., through crowdsourcing), volunteering to participate in response activities
- *Apply to* activities through which non-organizational users provide resources that can be used by organizations to respond to a crisis (e.g., through crowdsourcing)
- *Apply to* organizational activities that integrate the input of non-organizational users (e.g., decision-making)

Appendix to Paper 1: Quantitative Summary of Coding Results

Table B.1.16 and Table B.1.17 summarize the frequency of codes assigned to papers for both social media affordances and openness, both in isolation and in combination with other codes respectively. The papers to which codes were assigned are indicated in Appendix 'Coding Results'.

Table B.1.14
Quantitative summary of codes: social media affordances (number of papers with code assigned at least once)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
(1)															
(2)	28														
(3)	24	9													
(4)	16	3	7												
(5)	12	5	5	5											
(6)	70	21	32	17	11										
(7)	32	8	22	12	6	48									
(8)	42	12	17	7	6	57	28								
(9)	32	4	14	12	4	36	19	23							
(10)	29	6	19	12	6	48	34	31	23						
(11)	37	8	22	8	7	53	28	47	20	25					
(12)	27	9	14	10	6	34	15	20	15	14	21				
(13)	24	8	16	7	4	28	16	18	14	13	19	18			
(14)	48	11	23	13	7	60	31	46	29	34	44	26	21		
(15)	25	3	11	9	4	26	16	16	18	17	15	13	12	21	
Total	**79**	**28**	**35**	**20**	**12**	**103**	**54**	**68**	**37**	**51**	**65**	**35**	**32**	**66**	**26**

(1) Monitoring the information stream; (2) Automatically processing big (social media) data; (3) Tapping collective intelligence; (4) Accessing information providers; (5) Evaluating crisis response; (6) Contributing information; (7) Forwarding information; (8) Framing narratives; (9) Establishing digital presences; (10) Communicating a reputation; (11) Negotiating consensus; (12) Integrating contributions; (13) Crowdsourcing contributions; (14) Developing community; (15) Establishing norms

Table B.1.15
Quantitative summary of codes: openness (number of papers with code assigned at least once)

(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)	(Q)	(R)	(S)	(T)	(U)	(V)
29																			
14	19																		
7	11	14																	
9	15	14	9																
48	54	27	17	16															
33	41	24	15	13	80														
18	27	20	11	8	38	33													
36	44	24	13	15	76	60	30												
29	26	15	6	7	51	32	20	39											
6	5	6	3	3	9	7	5	8	8										
5	8	6	5	4	8	9	9	8	2	2									
21	24	23	14	15	46	43	25	34	22	7	8								
9	14	17	7	6	18	17	16	16	12	4	3	14							
4	3	3	3	1	7	8	7	5	3	0	2	5	3						
53	58	28	17	16	108	89	41	82	53	9	12	49	19	8					
37	47	25	13	14	77	56	32	71	38	9	8	35	17	5	83				
12	17	15	11	10	26	24	19	20	11	5	6	26	7	5	29	22			
10	25	14	6	8	32	27	15	31	19	7	5	17	13	1	32		31	8	
20	20	17	10	8	31	25	33	25	19	4	4	24	11	7	35	29	19	8	
53	**58**	**28**	**17**	**16**	**109**	**90**	**42**	**83**	**54**	**9**	**12**	**50**	**19**	**8**	**127**	**83**	**29**	**33**	**35**

	(A1)	(A2)	(A3)	(A4)	(A5)	(A6)	(B)
(A1)							
(A2)	33						
(A3)	32	14					
(A4)	8	1	6				
(A5)	82	23	26	8			
(A6)	34	16	11	3	29		
(B)	17	8	6	2	12	9	
(C)	49	14	21	5	14	19	8
(D)	56	17	19	4	47	18	10
(E)	28	15	9	1	23	15	11
(F)	17	7	6	1	14	7	6
(G)	16	4	6	0	15	5	3
(H)	100	31	30	9	80	36	16
(I)	87	29	29	5	67	27	14
(J)	41	21	12	3	33	20	11
(K)	72	23	21	10	77	28	12
(L)	50	16	16	8	40	31	11
(M)	9	4	4	2	9	5	6
(N)	10	2	4	1	11	3	2
(O)	48	23	18	5	36	18	13
(P)	19	12	6	0	16	14	8
(Q)	8	5	5	0	8	5	1
(R)	112	33	33	10	92	37	16
(S)	73	24	22	8	70	28	15
(T)	27	13	8	1	23	11	8
(U)	32	9	7	4	30	16	10
(V)	32	17	15	4	27	16	10
Total	**113**	**33**	**33**	**11**	**93**	**37**	**17**

(A1) Situational information; (A2) Geo-location information; (A3) User identity information; (A4) Social network information; (A5) Sense-making information; (A6) Curated information; (B) Knowledge; (C) Authority; (D) Social support; (E) Workforce; (F) Goods and utilities; (G) Funds; (H) Disseminating; (I) Social sensing; (J) Social reporting; (K) Sense-making; (L) Gatekeeping; (M) Translating; (N) Decision-making; (O) Relief coordination; (P) Digital volunteerism; (Q) Participatory research; (R) Transparency; (S) Interactivity; (T) Responsiveness; (U) Empowerment; (V) Participation

Appendix to Paper 1: Coding Results

Table B.1.16
Overview of papers that contribute to each code: social media affordances (indicating papers with codes assigned at least once)

	Social media affordances														
	Affordances for internalizing					**Affordances for externalizing**					**Affordances for collaborating**				
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**	**(13)**	**(14)**	**(15)**
[1]			X				X			X				X	
[2]	X			X		X	X		X	X				X	X
[3]	X			X		X	X		X	X		X	X	X	X
[4]				X		X	X	X		X	X	X		X	
[5]	X	X												X	
[6]	X					X		X	X	X			X		
[7]			X	X		X	X			X		X	X	X	
[8]	X	X				X	X	X		X	X	X		X	
[9]	X	X						X					X		
[10]	X					X	X		X	X				X	X
[11]	X					X		X			X			X	
[12]	X					X	X		X					X	X

	Social media affordances														
	Affordances for internalizing					Affordances for externalizing					Affordances for collaborating				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
[13]	X					X	X	X	X	X			X		X
[14]	X			X		X	X		X	X					X
[15]							X								
[16]							X								
[17]						X	X			X					
[18]	X	X				X	X	X	X					X	
[19]						X	X	X		X	X			X	
[20]								X			X			X	
[21]						X						X	X		
[22]				X											
[23]	X	X				X		X							
[24]	X	X				X		X						X	
[25]	X					X					X			X	
[26]						X		X			X			X	
[27]	X					X	X		X	X				X	
[28]	X		X			X	X	X			X		X	X	
[29]						X									
[30]								X		X	X			X	
[31]								X			X				
[32]	X		X			X	X	X			X		X	X	X
[33]	X	X													
[34]				X		X				X				X	
[35]	X	X													
[36]			X			X						X			
[37]			X			X	X			X	X				
[38]	X		X	X		X	X	X	X	X		X	X	X	X
[39]								X			X			X	
[40]							X						X		
[41]						X	X			X					
[42]								X			X			X	
[43]	X					X									
[44]						X		X			X				
[45]						X				X	X				
[46]	X					X									
[47]	X					X		X							X
[48]	X					X	X			X				X	
[49]	X			X			X								
[50]	X	X	X			X						X	X	X	
[51]						X	X				X				
[52]	X	X	X		X	X	X				X	X	X	X	
[53]	X		X			X	X	X	X	X	X	X	X	X	X

	Social media affordances														
	Affordances for internalizing					Affordances for externalizing					Affordances for collaborating				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
[54]						X	X	X		X	X				
[55]						X		X			X				
[56]						X	X	X		X					
[57]	X		X	X	X	X	X	X	X	X	X			X	X
[58]	X		X	X		X		X	X			X	X	X	
[59]	X					X					X	X		X	
[60]	X	X	X	X	X	X	X			X		X			
[61]	X		X			X	X		X		X		X		
[62]								X			X				
[63]	X				X	X					X		X	X	
[64]	X	X	X		X	X									
[65]	X		X			X	X	X		X	X			X	X
[66]	X				X	X	X	X		X	X	X	X	X	X
[67]	X					X		X		X	X			X	
[68]	X	X	X							X			X		
[69]	X	X													
[70]	X	X						X			X				
[71]	X	X				X	X	X			X	X	X	X	
[72]	X		X			X		X	X		X			X	
[73]	X					X		X	X		X	X		X	
[74]	X					X		X	X	X	X			X	
[75]						X							X		
[76]	X			X		X			X		X		X		X
[77]			X			X		X		X	X			X	
[78]	X					X		X			X			X	X
[79]						X	X								
[80]						X		X	X	X				X	
[81]	X	X			X	X	X					X			X
[82]	X					X		X	X		X	X		X	X
[83]	X					X									
[84]	X		X			X	X	X		X	X			X	
[85]	X	X	X			X							X		
[86]	X	X				X								X	
[87]	X	X	X	X	X	X		X	X	X	X		X	X	X
[88]	X	X	X			X	X				X				
[89]	X		X			X	X	X	X	X	X	X	X	X	X
[90]	X					X		X			X	X	X	X	X
[91]	X	X				X		X				X			
[92]	X				X	X		X	X		X	X		X	
[93]						X			X	X					
[94]	X					X		X	X					X	

	Social media affordances														
	Affordances for internalizing					Affordances for externalizing					Affordances for collaborating				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
[95]						X		X	X	X				X	
[96]	X	X				X									
[97]	X	X				X									
[98]									X		X	X	X		
[99]	X		X	X		X	X		X		X	X		X	X
[100]	X		X			X		X	X	X		X		X	X
[101]						X		X			X			X	
[102]	X	X	X			X	X	X	X	X	X		X	X	
[103]			X			X	X		X	X	X				
[104]	X			X	X										
[105]	X			X	X	X	X	X	X	X	X			X	
[106]	X					X	X	X		X	X			X	
[107]	X		X			X			X		X	X		X	
[108]	X		X			X	X	X	X	X				X	X
[109]	X					X		X	X	X	X	X	X	X	X
[110]						X	X	X		X	X				
[111]						X		X			X	X	X	X	
[112]							X	X			X				
[113]	X			X		X	X	X	X		X	X	X	X	
[114]			X			X				X	X	X	X	X	X
[115]			X			X	X			X					
[116]			X			X	X	X			X	X	X	X	
[117]						X	X	X		X				X	
[118]	X			X		X						X			
[119]	X	X				X		X							
[120]								X			X				
[121]						X	X	X		X					
[122]	X				X	X		X		X		X			
[123]	X	X		X		X			X	X	X	X		X	X
[124]	X					X					X				
[125]			X			X	X	X			X				
[126]								X			X				
[127]			X								X				
[128]	X	X				X		X				X			

(1) Monitoring the information stream; (2) Automatically processing big (social media) data; (3) Tapping collective intelligence; (4) Accessing information providers; (5) Evaluating crisis response; (6) Contributing information; (7) Forwarding information; (8) Framing narratives; (9) Establishing digital presences; (10) Communicating a reputation; (11) Negotiating consensus; (12) Integrating contributions; (13) Crowdsourcing contributions; (14) Developing community; (15) Establishing norms

Tabelle B.1.19
Overview of papers that contribute to each code: openness (indicating papers with codes assigned at least once)

	Openness																								
	Open resources												**Open processes**									**Opening effects**			
	(A1)	**(A2)**	**(A3)**	**(A4)**	**(A5)**	**(A6)**	**(B)**	**(C)**	**(D)**	**(E)**	**(F)**	**(G)**	**(H)**	**(I)**	**(J)**	**(K)**	**(L)**	**(M)**	**(N)**	**(O)**	**(P)**	**(Q)**	**(R)**	**(S)**	**(T)**	**(U)**	**(V)**
[1]	X				X	X							X			X	X					X				
[2]	X	X			X	X		X	X	X			X				X				X	X	X		X	X
[3]	X				X	X	X	X	X	X		X	X		X	X	X	X	X	X		X	X	X	X	
[4]				X	X				X							X						X	X		X	
[5]	X		X		X									X					X			X				
[6]	X				X			X							X	X						X	X			X
[7]	X				X		X	X	X	X	X	X	X			X	X			X		X	X	X		X
[8]	X			X	X			X					X	X		X	X	X		X		X	X		X	
[9]	X				X				X					X	X				X			X				
[10]	X	X	X		X		X	X					X	X		X	X	X		X		X	X	X		X
[11]	X				X				X				X	X		X						X	X		X	
[12]	X							X					X	X			X			X		X				
[13]	X	X	X					X	X				X		X		X			X		X				X
[14]	X	X						X	X				X		X		X			X		X	X	X		X
[15]	X								X								X					X				
[16]	X								X								X					X				
[17]	X					X		X					X	X			X					X				
[18]	X	X	X		X	X							X	X		X	X					X	X			
[19]	X	X			X	X		X	X				X	X		X	X					X			X	
[20]	X				X				X				X			X						X	X			
[21]	X	X					X			X	X		X	X	X					X	X	X	X	X		X
[22]			X	X															X	X		X				
[23]					X									X		X				X		X		X		
[24]	X		X		X			X	X				X	X						X		X				
[25]	X				X				X				X			X						X	X		X	
[26]	X				X				X				X	X		X						X	X		X	
[27]	X		X	X	X								X	X		X	X			X		X				X
[28]	X				X	X			X			X	X	X		X	X			X		X	X			X
[29]	X												X									X	X			
[30]					X			X								X						X	X			X
[31]					X			X					X			X						X	X			
[32]	X	X			X				X				X		X	X	X					X	X			
[33]	X				X									X								X				
[34]	X	X	X		X			X	X				X	X	X	X						X	X			
[35]	X													X						X		X				
[36]	X	X	X										X	X						X		X	X			
[37]	X			X	X			X	X				X			X	X					X	X			
[38]	X				X	X	X		X	X	X	X	X		X		X	X		X	X	X	X	X	X	X

	Openness																								
	Open resources												Open processes									Opening effects			
	(A1)	(A2)	(A3)	(A4)	(A5)	(A6)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)	(Q)	(R)	(S)	(T)	(U)	(V)
[39]					X								X			X	X						X	X			
[40]	X				X	X		X					X				X			X			X	X			
[41]	X		X	X				X	X				X			X	X						X	X			X
[42]					X											X							X	X			
[43]	X												X	X						X			X				
[44]					X								X			X							X	X			
[45]	X							X					X										X				
[46]	X													X						X			X		X		
[47]	X	X							X				X	X	X								X				
[48]				X		X		X					X			X	X						X	X			X
[49]						X							X				X						X				
[50]	X					X	X		X	X			X	X	X	X	X				X		X	X		X	X
[51]	X				X								X				X						X				
[52]	X	X			X	X				X			X	X	X	X	X			X	X	X	X	X	X		X
[53]	X				X	X	X	X	X	X	X		X	X	X	X	X	X	X		X		X	X		X	
[54]	X				X			X					X			X	X						X				
[55]	X				X			X								X							X	X			
[56]	X		X		X				X				X	X			X						X				
[57]	X		X		X	X		X	X				X	X	X	X	X					X	X	X	X		X
[58]	X				X				X				X	X	X	X			X	X			X	X	X	X	X
[59]	X				X		X		X				X	X		X							X	X		X	
[60]	X	X	X				X	X	X				X	X						X			X	X	X		X
[61]	X	X				X	X			X			X	X	X	X	X			X	X		X	X		X	
[62]					X				X				X			X							X	X			
[63]	X	X			X								X	X	X	X			X	X		X	X	X			X
[64]	X				X								X	X						X			X	X	X		
[65]	X				X	X			X				X			X	X						X	X		X	
[66]	X	X	X		X	X			X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X
[67]	X				X			X					X			X	X						X	X			
[68]	X	X			X	X		X		X				X	X	X	X				X		X	X			X
[69]	X	X												X									X				
[70]	X				X									X									X				
[71]	X	X			X	X			X				X	X	X	X	X			X			X	X	X	X	
[72]	X				X				X	X	X	X	X	X	X	X			X	X			X	X	X	X	
[73]	X		X		X				X				X	X		X							X	X		X	
[74]	X		X	X	X				X				X	X		X							X	X		X	
[75]	X	X	X										X	X	X								X				
[76]	X				X				X		X		X	X	X	X					X		X				
[77]	X				X			X	X				X	X		X							X	X			
[78]	X				X								X	X		X		X					X	X		X	

	Openness																								
	Open resources											Open processes										Opening effects			
	(A1)	(A2)	(A3)	(A4)	(A5)	(A6)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)	(Q)	(R)	(S)	(T)	(U)	(V)
[79]						X		X					X				X						X				
[80]	X							X	X				X		X								X	X			
[81]	X	X			X	X					X		X	X	X					X		X	X		X		X
[82]	X	X			X	X	X		X				X	X	X	X				X	X		X	X		X	
[83]	X												X	X									X				
[84]	X		X		X	X		X	X				X	X	X	X	X						X	X			X
[85]	X	X			X	X				X			X	X	X	X				X	X		X				
[86]	X							X	X				X	X									X		X		
[87]	X	X	X		X	X		X	X	X	X		X	X	X	X			X	X	X	X	X	X	X		X
[88]	X					X							X	X		X	X			X			X	X		X	
[89]	X				X			X	X	X	X	X	X	X	X	X			X	X			X	X	X		
[90]	X				X			X	X	X	X	X	X	X	X	X				X			X	X	X		X
[91]	X	X								X	X	X	X	X		X				X			X		X		
[92]	X	X			X					X			X	X	X	X				X			X	X	X		X
[93]	X					X		X					X	X			X						X				
[94]	X				X				X	X		X	X	X		X							X	X			
[95]	X				X			X	X				X	X		X							X	X			
[96]	X												X	X									X				
[97]	X							X					X	X									X				
[98]					X										X				X				X		X		X
[99]	X			X	X		X						X	X	X	X	X			X						X	
[100]	X	X	X		X	X		X					X	X		X				X			X	X			
[101]	X				X								X	X		X	X						X	X		X	
[102]	X	X			X	X	X	X	X	X			X	X	X	X	X			X	X		X	X		X	X
[103]	X				X			X					X			X							X	X			
[104]	X		X		X			X					X	X	X							X	X				X
[105]	X		X		X			X	X			X	X	X		X				X			X	X	X		X
[106]	X		X		X	X		X	X				X	X		X	X						X	X			
[107]	X				X	X			X	X		X	X	X	X	X				X	X		X	X	X	X	X
[108]	X		X		X			X	X	X		X	X	X	X	X	X			X	X		X	X		X	
[109]	X	X	X		X			X	X	X		X	X	X		X	X	X		X	X		X	X		X	
[110]	X				X			X					X	X		X							X				

	Openness																								
	Open resources												Open processes									Opening effects			
	(A1)	(A2)	(A3)	(A4)	(A5)	(A6)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)	(M)	(N)	(O)	(P)	(Q)	(R)	(S)	(T)	(U)	(V)
[111]	X	X	X		X			X	X	X	X	X	X	X		X				X			X				X
[112]	X				X								X	X		X	X					X	X			
[113]	X	X	X		X	X	X	X	X	X			X	X	X	X	X	X		X	X		X	X	X	X	X
[114]	X		X		X			X	X	X	X	X	X	X		X			X	X	X		X	X		X	
[115]	X		X	X	X	X		X					X		X	X	X						X	X			
[116]	X				X	X					X		X	X		X	X						X	X		X	
[117]	X								X				X	X	X								X	X			
[118]	X		X				X			X	X		X	X						X			X	X			X
[119]	X	X			X				X				X	X		X							X	X			
[120]					X								X	X		X							X	X			
[121]	X		X		X	X		X					X	X			X						X				
[122]	X		X		X		X	X						X								X	X				
[123]	X	X	X	X	X	X	X			X	X		X	X	X	X	X	X		X			X	X	X		X
[124]	X												X	X									X				
[125]	X				X								X	X		X	X						X	X			
[126]					X								X	X		X							X	X			
[127]	X				X								X	X		X							X	X		X	
[128]	X				X								X	X		X				X			X		X		

(A1) Situational information; (A2) Geo-location information; (A3) User identity information; (A4) Social network information; (A5) Sense-making information; (A6) Curated information; (B) Knowledge; (C) Authority; (D) Social support; (E) Workforce; (F) Goods and utilities; (G) Funds; (H) Disseminating; (I) Social sensing; (J) Social reporting; (K) Sense-making; (L) Gatekeeping; (M) Translating; (N) Decision-making; (O) Relief coordination; (P) Digital volunteerism; (Q) Participatory research; (R) Transparency; (S) Interactivity; (T) Responsiveness; (U) Empowerment; (V) Participation

2. Paper 2: Information Technology and Risk Management in Supply Chains

Bibliographic Data

Fischer-Preßler, D., Eismann, K., Pietrowski, R., Fischbach, K., & Schoder, D. (2020). Information Technology and Risk Management in Supply Chains. *International Journal of Physical Distribution & Logistics Management*, *50*(2), 233-254. https://doi.org/10.1108/IJPDLM-04-2019-0119

Abstract

Purpose: This paper reviews and classifies research connecting supply chain risk management (SCRM) and information technology (IT) and derives a structured proposal for fruitful research directions. **Design/methodology/approach:** The authors conducted a systematic literature review of the interplay of SCRM and IT, drawing from major journals in the relevant fields. These findings are enriched by experiences from a three-year international research project. **Findings:** Current research focuses on the role of IT for risk reduction, rather than for risk identification, analysis and monitoring. While much research has investigated operational supply chain risk, fewer insights into disruption risk are available. There is little research on the role of IT in SCRM beyond its potential to enhance information sharing among supply chain partners. To address these gaps, the paper proposes a two-dimensional framework to categorize IT potential for SCRM according to the source and impact of disruption risk on physical supply chain flows, which suggests promising directions for future research. **Originality/value:** The paper offers a systematic review to further our understanding of the relationship of SCRM and IT. In addition, it presents and discusses nine areas for further research aimed at mitigating the gaps identified at the intersection of SCRM and IT.

3. Paper 3: Applied Ethics and Digital Information Privacy

Bibliographic Data

Eismann, K., Fischer-Preßler, D., & Fischbach, K. (2022). Applied Ethics and Digital Information Privacy: Informing the Design of COVID-19 Contact Tracing Apps. *Australasian Journal of Information Systems*, *26*. https://doi.org/10.3127/ajis.v26i0.3097

Abstract

To counteract the spread of COVID-19, many countries have introduced mobile applications for contact tracing, which raises considerable questions about how these apps protect users' information privacy. Through an exploratory analysis of COVID-19 contact tracing apps being used in Australia, France, Germany, Japan, and New Zealand, we identify normative and technical principles for the design of privacy-sensitive contact tracing apps. Based on a Restricted Access/Limited Control (RALC) account of information privacy, we discuss how the apps protect users' information privacy through limiting access to and allowing users to actively manage their personal information. Our findings illustrate what understanding of information privacy is evident from the various designs of COVID-19 contact tracing apps, and how competing design principles can contribute to users' information privacy. From a practical perspective, our findings can inform the design of contact tracing apps and the development of privacy approaches that can be applied in particular contexts. Our work thus bridges the gap between ethical design guidelines and technical analyses of specific implementations.

[B.3.1] https://creativecommons.org/licenses/by-nc/3.0/au/

Introduction

The coronavirus pandemic has confronted public health officials throughout the world with the urgent need to contain infections and stop the spread of the highly contagious and harmful COVID-19 disease. As it spread across the globe, borders were closed, social and economic life came to a standstill, and health infrastructures nearly collapsed. Almost a year into the pandemic, neither medication nor vaccinations were available; in February 2021, the World Health Organization (WHO) had registered more than 105 million cases and more than 2.2 million fatalities due to COVID-19 worldwide (WHO, 2021b).

To counteract further spread of the virus and prevent sustained economic damage and the loss of human life, public health interventions through which people can avoid exposure to the coronavirus – such as *cordons sanitaire*, traffic restrictions, and social distancing – have gained momentum (e.g., Di Gennaro et al., 2020; Pan et al., 2020). Beyond that, the WHO has established *contact tracing* as a key strategy for interrupting transmission chains, as people who have been in contact with an infected person can be identified and advised to quarantine to prevent further transmissions (WHO, 2021a).

However, classical procedures for identifying the contacts of an infected person can be ineffective, if, for instance, a person's contacts are unknown or low levels of automation cause delays in the identification and contacting of people at risk (WHO, 2021a). Therefore, governments have considered, and some have implemented, mobile applications – so-called *contact tracing apps* – to trace infections and provide health advice to citizens. Mobile applications reduce reliance on human recall and hence can be more effective than classical procedures for contact tracing, especially in densely populated areas with high degrees of mobile connectivity (Budd et al., 2020). These digital tools were thus ascribed an important role in limiting the propagation of the pandemic (WHO, 2021a).

Contact tracing apps are applications that run on a smartphone and allow tracing encounters between users. They are a technical approach to tracking epidemic chains of infection and stopping the spread of COVID-19. Basically, they are used to alert users who have been in contact with another infected user, but may not (yet) show typical symptoms of the COVID-19 disease. Those users can then be advised to self-isolate and get tested. Users receive a warning via the app that they might be at risk of an infection if they have been close (e.g., within a couple of meters) to another user diagnosed with COVID-19 if that proximity was for an epidemiologically relevant time interval (e.g., 15 or more minutes) within a relevant timeframe (e.g., an estimated incubation period of 14 days for

the infected person). Users so warned can then seek medical advice and take appropriate action. If they are themselves diagnosed with COVID-19, they can update their status within the app so others who have been close can also receive warnings (Ahmed et al., 2020).

To enable effective tracing, however, apps need to collect sensitive personal data, which includes records of users' health, movements, and social interactions (Morley et al., 2020). Experts warned early on that personal information collected through contact tracing apps could be exposed to a number of security risks that threaten users' information privacy. Privacy could be compromised due to, for instance, technical problems or cyberattacks, potential misuse of personal data due to large-scale social surveillance, and illegitimate repurposing of the information collected (e.g., Klar & Lanzerath, 2020). Concerns over data protection and information privacy norms could negatively affect people's intention to use these apps (e.g., Chan & Saqib, 2021; Fischer et al., 2019; Fodor & Brem, 2015), which, in turn, could lower the efficacy of app-based contact tracing (Trang et al., 2020).

Several guidelines have been developed, both by researchers (e.g., Floridi, 2020; Klar & Lanzerath, 2020) and public health institutions (e.g., European Commission, 2020; WHO, 2020), to promote the design of apps for COVID-19 contact tracing that preserve users' information privacy. Still, analyses suggest that despite government claims to honor citizens' information privacy, several apps have failed to meet essential requirements of privacy-sensitive design (e.g., Hatamian et al., 2021; Woodhams, 2020). Clearly, the risk of information privacy violations cannot be eliminated through technical implementation alone, but relies on a shared understanding of what constitutes information privacy violations through illegitimate access and use of personal information.

Our work bridges the gap between ethical design principles for and technical evaluations of COVID-19 contact tracing apps. Based on the *Restricted Access/Limited Control* (RALC) framework of information privacy (Moor, 1997; Tavani & Moor, 2001), we evaluate the normative and technical design principles that have – explicitly or implicitly – guided the development of apps deployed as early as during the second half of 2020 in five liberal democracies. Our analyses are based on two complementary research questions:

RQ1: What normative and technical design principles to protect information privacy are evident from COVID-19 contact tracing apps?

RQ2: What understanding of information privacy is evident from the design of COVID-19 contact tracing apps?

Going beyond purely normative approaches, we establish a frame of reference that explicates standards of privacy-sensitive design from the perspective of real-world mobile applications, thus emphasising principles that are both technically applicable and in line with the ethical standards of liberal democracies. In contrast to mere technical analyses, we elaborate how the identified design principles relate to ethical information-privacy requirements, and discuss how they might contribute to the achievement of normative goals.

Our research approach is one of *explicit morality* (Stahl, 2012), as we explicate the normative understanding of information privacy that is evident from the design of existing COVID-19 contact tracing apps. Thus, we aim to clarify what users can expect with respect to the protection of their personal information when using these apps. While developing full-fledged ethical theory is beyond the scope of this paper, we identify normative and technical design principles that can guide the design of technical artifacts that allow large-scale collection of sensitive personal data. Finally, our work demonstrates how concepts of normative theory can be analysed based on empirical design choices, which can encourage researchers to abstract information privacy conceptualisations and possible breaches within a certain artifact under investigation and evaluate alternative solutions in terms of how they afford information privacy.

We apply *disclosive computer ethics* to analyse information privacy conceptualisations evident from existing COVID-19 contact tracing apps, as described by Brey (2000a, 2000b). Key to our work is the assumption that while the apps have been designed to preserve information privacy in line with pertinent laws and social norms (e.g., European Parliament, 2020), their design and other features determine the extent of information privacy when using the apps. Based on an exploratory analysis of information-privacy principles evident from the five apps, we evaluate how the measures implemented relate to normative and technical protections of information privacy, as conceptualised by the RALC framework, and discuss how normative theory can hence guide the design of privacy-enhancing artifacts.

Below, we briefly delineate the theoretical notion of information privacy that underlies our work, and how COVID-19 contact tracing apps might violate it. Furthermore, we explain how normative and technical design principles, according to the RALC framework, could help protect information privacy. On that basis, we describe our research methodology and the findings of the exploratory analysis and theoretical evaluation, and discuss the theoretical and practical implications of our work.

Information Privacy in the Context of COVID-19 Contact Tracing

Information privacy is a subset of general privacy (Bélanger & Crossler, 2011) that refers specifically to personal information (Smith et al., 2011), which, in turn, implies "facts about a person which most individuals […] do not want widely known about themselves" (Parent, 1983, pp. 269–270). In a normative sense, information privacy is one of liberal societies' key moral values, whereas in a descriptive sense, it refers to a quality of a situation that can be present or absent (Becker, 2019). Thus, information privacy comprises "the claims of individuals that data about themselves should generally not be available to other individuals and organisations, and that, where data is possessed by another party, the individual must be able to exercise a substantial degree of control over that data and its use" (Clarke, 1999, p. 60).

Digitally enhanced means of information sharing and communication are widely believed to threaten people's information privacy, especially because they enable constant and unobtrusive monitoring and profiling (Becker, 2019). They make it easy to record, analyse, and share personal information about users, retain it for an indefinite time, match it with data from secondary sources, and thus generate novel and possibly revealing insights about users (Nissenbaum, 1998). In addition, they may incentivise users to contribute additional information about themselves to facilitate interactions (Volokh, 2000) – a condition commonly known as the "commodification of privacy" (Campbell & Carlson, 2002).

Information privacy is only one among several ethical issues that require consideration with COVID-19 contact tracing apps (Floridi, 2020). In fact, Blasimme and Vayena (2020, p. 761) conclude that most of these apps "are built with a proactive commitment to privacy-preserving technological features (privacy by design) and only use strictly necessary data (privacy by default)." Existing COVID-19 contact tracing apps have typically been developed with an explicit commitment to pertinent privacy laws and regulations; many, if not most, have been subjected to intensive public debate and scrutiny to enhance their compliance with commonly shared social norms (e.g., European Parliament, 2020).

Still, the risk of misuse and vulnerability of personal information collected on a large scale (e.g., due to hacking or cyberattacks) remains (Klar & Lanzerath, 2020). Furthermore, absent evidence on the efficacy of the apps, users' information privacy may be threatened by a lack of proportionality, as well as the risk of function creep if the data collected

through the apps is repurposed, potential ignorance of sunset clauses and continued use of the apps even after the COVID-19 pandemic is declared contained, and the risk of unrevealed non-voluntariness if social or economic conditions render the use of the apps obligatory in some *de facto* way (Ishmaev et al., 2021). Furthermore, information privacy risks arise in cases where malevolent users can infer from the app who may be infected, state-level agents or service providers can access personal user information illegitimately, or if such information is leaked due to negligence or malicious attacks (Boutet et al., 2020). Rowe (2020) also observes that governments tend to overemphasise the potential short-term benefits of using COVID-19 contact tracing apps, while downplaying long-run threats to information privacy.

COVID-19 contact tracing apps can threaten users' information privacy in two fundamental ways: they can interfere with users' ability to control access to their personal information (*privacy as control*); and they can facilitate the access by others to personal information about a user in a given situation (*privacy as a state*). While the former defines information privacy in terms of the ability of agents to control access to information about themselves, the latter understands it as a condition in which access to personal information is limited to some extent (Smith et al., 2011). Both conceptions of information privacy have their roots in historical privacy theories, and both come with a number of theoretical virtues and drawbacks (Tavani, 2007, 2008). However, understanding information privacy merely in terms of control is problematic when agents deliberately relinquish control over information about themselves (Tavani & Moor, 2001).

In the *Restricted Access/Limited Control* (RALC) framework of information privacy, by contrast, Moor (1997) and Tavani and Moor (2001) define information privacy primarily in terms of limited access to personal information. They recognize that while perfect control over personal information may be impossible when it comes to digital information and communications technologies, people should be able to rule out undesired access to and use of information about themselves. The RALC framework integrates two elements: the *condition of privacy* – the extent to which information privacy is present in a particular situation, and which relies on the absence of access to personal information; and the *management of privacy* – people's ability to determine who can access information about them for what purpose and in what ways, which requires that information subjects have control over their personal information. Through actively managing access to personal information, agents are hence assumed to determine the amount of information privacy in a given situation.

According to the RALC framework, information privacy is a characteristic of situations in which people are normatively protected from intrusion, interference, and information access by others. Situations are the key unit of the RALC framework; they can comprise locations, relationships, and activities. Situations can be *naturally private*, meaning there are natural or physical circumstances that protect people from intrusion or observation. In naturally private situations, privacy exists as a matter of fact. When others gain access to information about a person in such situations, that person's privacy is lost but not violated, as they do not have a normative claim to it. In contrast, in *normatively private* situations, personal information is protected through norms that determine who may access it. These norms constitute a person's right to privacy in a particular situation; privacy is violated only when pertinent norms are trespassed (Moor, 1997; Tavani & Moor, 2001).

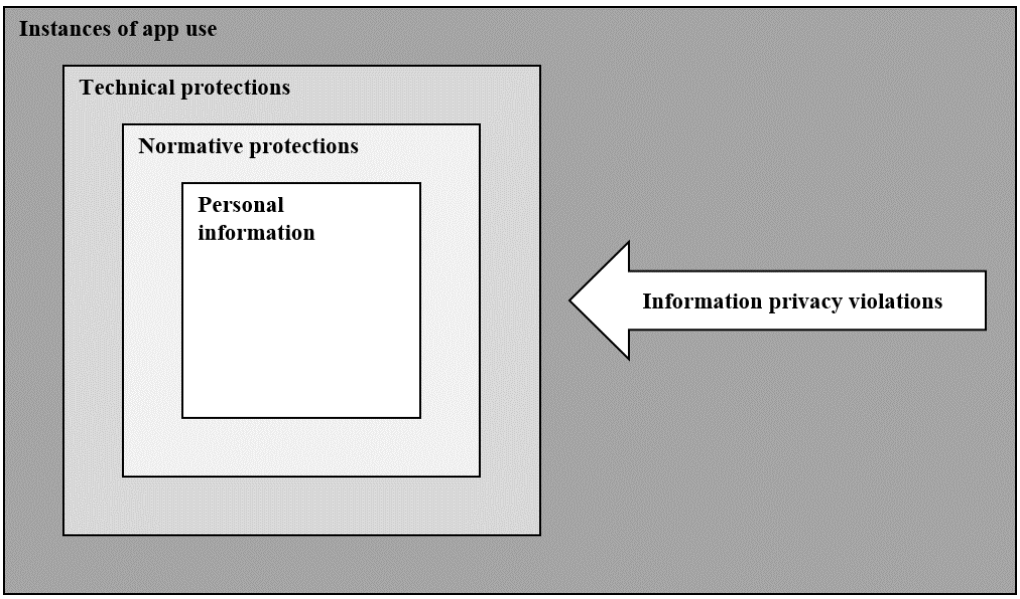
RALC introduces three mechanisms of individual control through which actors can achieve an adequate level of information privacy, although they do not constitute a right to privacy beyond what is granted by situational norms: *choice* over situations that offer the desired level of information privacy; *consent* to give up the right to information privacy in a particular situation; and *correction* of personal information collected (Tavani & Moor, 2001).

Just as in the case of offline social relations, interactions enabled by digital information and communications technologies can constitute situations (Tavani, 2007). Thus, from a RALC perspective, using a contact tracing app can constitute both a naturally and a normatively private situation, depending on the context of app use and the specific design of the app. While pertinent social and legal norms and a shared understanding that users must somehow be able to determine to whom their personal information is made available are the basis for normative protection of their information privacy, it is the app's technical features that determine the extent to which users are actually protected from intrusion, and hence render app usage naturally private. Figure B.3.1 illustrates how the use of COVID-19 contact tracing apps can be interpreted within the RALC framework.

In our work, it is instances of app use that constitute the situations to be analysed. Those are characterised by two key attributes: *personal information* that is exposed to potential information privacy violations, and the *information privacy violations* that potentially apply. Personal information is embedded within two layers of protection. The first layer is *normative protections of information privacy*, which consists of norms – broadly defined as principles of action that specify appropriate behaviour in a given society – that

determine what information about users may be legitimately accessed through the app, by whom, and under what conditions. Access to personal information contravening these norms is considered to violate users' information privacy. The second layer is *technical protections of information privacy*, which comprise the particular technical features through which personal information is protected from unwarranted access. These constitute natural barriers in the RALC terminology: they do not grant users a normative right to information privacy, but nevertheless can be effective in preventing access to their personal information.

Figure B.3.1
A RALC perspective on information privacy in the context of COVID-19 contact tracing app use



Below, we explain how we have analysed these key elements of existing COVID-19 contact tracing apps, following a disclosive research approach, and elaborate on what our insights reveal about the understanding of information privacy that is evident from the apps' design.

Research Methodology

Disclosive Computer Ethics

In our research, we have followed the tenets of disclosive computer ethics, assuming that technological artifacts are not morally neutral, but may have hidden moral properties that can be uncovered through disclosive analysis (Brey, 2000a, 2000b). Basically, technological artifacts are assumed to serve as mechanisms that constrain people's

individual and social behaviors, and hence can enforce or promote normative action (Brey, 2000b).

Studies in disclosive computer ethics require a two-step approach. Relying on an inductive approach, in the first step, a technological artifact is analysed from the perspective of some moral value to draw preliminary conclusions regarding the relationship of the artifact's features to the moral value of interest. Then, in the second step, moral theory can be applied to evaluate more specifically the artifact's normatively relevant features and properties, which also creates the potential for further developing existing theory (Brey, 2000a, 2000b).

Below, we explain how we have analysed the normative and technical design principles that determine how the technological artifacts in our work – mobile apps for COVID-19 contact tracing – protect information privacy, based on the RALC framework delineated above.

Case Selection and Data Acquisition

Our analyses are based on COVID-19 contact tracing apps from five liberal democracies (according to Freedom House [Repucci & O'Toole, 2020]) that released the apps for their residents to use as early as the second half of 2020: Australia, France, Germany, Japan, and New Zealand. We selected these countries because they provide early examples of privacy-sensitive design for COVID-19 contact tracing apps (as opposed to digital tools applied for other purposes, such as outbreak detection and case identification [Budd et al., 2020]) against a somewhat comparable socio-political background.

These countries' governments have all stated that the apps comply with national privacy laws and regulations, and were designed especially to meet pertinent norms of information privacy. In the European Union, for instance, the ROBERT (ROBust and privacy-presERving proximity Tracing) protocol was established to facilitate developing privacy-preserving contact tracing apps in line with the pertinent General Data Protection Regulation (GDPR), and governments have established *a priori* guidelines to guide that work (e.g., European Parliament, 2020). The approaches taken to protect information privacy, however, vary. This *purposive sample* of COVID-19 contact tracing apps thus allows us to draw conclusions about the implementation of information privacy concerns in liberal democracies based on cases with maximum possible heterogeneity at the time. Table B.3.1 is an overview of the apps analysed.

Table B.3.1
Overview of COVID-19 contact tracing apps

Country (app name)	Description	Responsible institutions	Information sources used
Australia (COVIDSafe)	- To use the app, users must register and provide personally identifying information that is used to contact them in case they are at risk of infection; the information is stored on a central server. - Within the app, each user is represented by an automatically generated ID that changes at regular intervals to prevent users from inferring their own or others' IDs. - The app uses Bluetooth to detect other users nearby. In case of an encounter, it saves these users' IDs, the date and time of contact, phone model, and Bluetooth signal strength. - Infected users are notified by human contact tracers and asked to upload their encounter information to a central server. If they consent to do so, they receive a PIN to authorise the transmission. - Contact tracers then use the encounter information and personal ID information of other users to identify and prioritise persons who may have been in contact and advise them of their risk status.	Australian Government Department of Health	Australian Government (2020); Australian Government Department of Health (2020)
France (StopCovid)	- Once installed, the app creates a unique identifier that represents the user. - The app uses Bluetooth to detect other users nearby. In case of an encounter, it saves these users' IDs, the date and time of contact, and the inferred distance between users based on Bluetooth signal strength. - Infected users receive a QR code or similar proof from public health services, which they can use to update their health status within the app. - If they update their status, the infected user's encounter history is uploaded to a central server and warnings are sent to the devices of other	Ministry of the Economy, Finance and Recovery	Inria (2020a, 2020b, 2020c); Ministére de l'économie des Finances et de la Relance (2020a, 2020b)

Country (app name)	Description	Responsible institutions	Information sources used
	users for whom an encounter was registered.		
Germany (CoronaWarn)	- Each user is represented within the app by an automatically generated ID, which changes at regular intervals to prevent users from inferring their own or others' IDs. - The app uses Bluetooth to detect other users nearby. In case of an encounter, it saves these users' IDs, the date and time of contact, and the inferred distance between users based on Bluetooth signal strength. - Infected users receive a QR code or similar proof from public health services, which they can use to update their health status within the app. - If they update their status, the infected user's ID is uploaded to a central server, which in turn makes it available to others' devices, which compare it with those users' own encounter histories and generate warnings if they have registered an encounter with the infected user.	German Federal Government	Corona Warn App Open Source Project (2020); The Federal Government (2020a, 2020b)
Japan (COCOA – COVID-19 Contact)	- Each user is represented within the app by an automatically generated ID, which changes in regular intervals to prevent users from inferring their own or others' IDs. - The app uses Bluetooth to detect other users nearby. In case of an encounter, it saves these users' IDs, the date and time of contact, and the inferred distance between users based on Bluetooth signal strength. - Infected users can register with their email address or phone number to receive a processing number from public health services, which they can use to update their health status within the app. - If they update their status, an infected user's ID is uploaded to a central server, which in turn makes it available to others' devices, which compare it with those users' own encounter histories and generate warnings if they have registered an encounter with the infected user.	Ministry of Health, Labour and Welfare	Ministry of Health, Labour and Welfare (2020a, 2020b)

Country (app name)	Description	Responsible institutions	Information sources used
New Zealand (NZ COVID Tracer)	- Users must sign up with their email addresses to use the app. They can add further personally identifying information to their profiles. - The app allows users to keep a digital diary of locations visited, which they can enter by scanning QR codes or manually adding entries of places, activities, dates, and times visited. - Users who are confirmed or deemed likely to be infected are notified by contact tracers to upload their location history to a central server. - If they update their status, human contact tracers evaluate the location history and identify locations at which persons in contact with an infected user would have been at risk of infection. These locations are made available to users' devices, which in turn generate warnings if they detect a match between their own location entries and a relevant exposure location and timeframe.	Ministry of Health	Ministry of Health (2020a, 2020b)

The five apps we studied are applications for contact tracing that analyse physical contacts between people, using Bluetooth, for instance, to measure the distance between smartphones on the basis of signal strength and thus detect potential encounters between users (i.e., *proximity tracing*). Unlike other mobile apps that track people's geo-locations (i.e., *tracking apps*), proximity tracing apps cannot be used to create detailed movement profiles to monitor people's behaviors, for instance, to ensure compliance with quarantine orders. While both involve sensitive data, privacy concerns for the two types of applications differ, and proximity tracing apps are considered, by design, to be more privacy-sensitive (Taddeo, 2020) and also more compatible with privacy expectations in liberal democracies than tracking solutions that have been used in South Korea, Taiwan, and Israel, among other countries (Zastrow, 2020).

We downloaded the official documentation provided by the institutions in each country responsible for the development, infrastructure, and service provision of the apps (date of reference: 2020-06-30). We analysed English versions of the documents, using machine translations (*Google Translate*) when English texts were not available.

Exploratory Analysis

Following from the RALC framework (Moor, 1997; Tavani & Moor, 2001), we understand information privacy in terms of limited access to information about a person, with the subjects of the information being able to determine by whom, in what ways, and to what end that information is accessed and used. This definition is thus in line with prior research in information systems (Smith et al., 2011), but also broad enough to encompass different understandings of what information is subject to privacy concerns, what constitutes unwarranted access to and use of personal information, and how apps can be designed to protect users' information privacy.

We used a multistage qualitative coding procedure to analyse the apps. In the first stage, we identified statements that referred to personal information about users from each app's documentation. In the second stage, we used these statements to develop inductive codes that describe what information about app users was specified as collected or not collected, what kind of access to or use of that information might violate users' information privacy, and what normative and technical design principles were applied to afford information privacy protection. In the third stage, we summarised these descriptive codes into coherent categories, which we describe in the following section. Two of the paper's authors undertook qualitative coding, with one in charge of each coding stage and the other reviewing and revising the codes. Disagreements were resolved through consensual discussion.

Below, we summarise our findings on the types of personal information collected by these COVID-19 contact tracing apps, the violations of users' information privacy accounted for, and the different approaches to preventing violations spelled out in the documentation.

Results of the Exploratory Analysis of COVID-19 Contact Tracing Apps

Personal Information Collected

The COVID-19 contact tracing apps we studied collect different types of personal information: *person identifying information* that allows for identifying a particular person who may be using the app (i.e., users and other persons about whom information is collected through the app*); user identifying information* that allows for identifying a particular user or device on which the app is installed; *encounter information* about contacts between users through which COVID-19 might be transmitted; *user profile information* about user preferences and activities using the app; and *health status*

information about a user's actual or potential COVID-19 infection. Table B.3.2 provides an overview of the types of personal information collected by the analysed apps.

Table B.3.2
Personal information collected by COVID-19 contact tracing apps

Countries	AUS	FRA	DEU	JPN	NZL
Person identifying information					
Name	X				
Age range	X				
Post code	X				
Phone number	X	X		X	
Email address		X		X	X
Social contacts					X
User identifying information					
Device model	X				
Location					X
Activities					X
Encounter information					
Date and time	X	X	X	X	X
Spatial proximity	X	X	X	X	
Duration of contact	X	X	X	X	
User profile information					
User identifier	X	X	X	X	
Encounter history	X	X	X	X	
User interests					X
Health status information					
Positive test result	X	X	X	X	X
Risk status (binary)		X	X	X	
Risk status (qualitative)	X				X
Health record				X	

Only the Australian app requires users to enter a name, age range, postal code, and contact phone number to facilitate tracing. The New Zealand app allows users to enter personal details and information about their social contacts to identify other people who might be at risk; users must also provide an email address to complete the registration. The French and Japanese apps require an email address or mobile phone number so infected users can receive a verification code to authorise health status updates that indicate they have become infected. The German app does not collect person identifying information.

Both the Australian and the New Zealand apps collect information that can be used to trace individual users. The Australian app registers the model of the smartphone on which the app is installed, and the New Zealand app asks users to enter information about their locations and activities to detect potential encounters. In contrast, the French, German,

and Japanese apps stress that no information is collected that would enable identifying the user or the device on which the app is installed. None of the analysed apps collects geolocation information.

In addition to person and user identifying information, all the apps except the New Zealand app create unique identifiers for each user. These are linked to the records of users' previous encounters and are exchanged between nearby devices to constitute encounters; they use Bluetooth to record the dates, times, and estimated duration of encounters and proximity of contact based on Bluetooth signal strength. The New Zealand app does not record encounters directly; rather, it allows users to keep a digital diary of places they have visited and infers from that possible encounters with other users who have checked in at the same location at the same time.

Finally, all the apps allow users to update their health status if they have tested positively for COVID-19. This information is then combined with encounter information to evaluate users' risk status and issue warnings accordingly. Estimated risk status can be binary, as in the French, German, and Japanese apps – that is, the app differentiates only between users who are at risk of infection (because they have been close to an infected user for an epidemiologically relevant period) and those who are not. The Japanese app allows users who have received a warning to enter further information about their health status and possible symptoms so they can be provided with more tailored advice.

The Australian and New Zealand apps allow for more detailed qualitative risk assessments. Risk status with the Australian app is evaluated by human contact tracers, who get in touch with users who might be at risk of infection based on their encounter information and other information, such as the number of encounters, duration of contact, and estimated distance between users during an encounter. For the New Zealand app, contact tracers evaluate the locations at which an infection was likely to occur, and issue warnings selectively to persons potentially at risk.

Accounting for Potential Information Privacy Violations

The COVID-19 contact tracing apps we studied account for three broad types of information privacy violations: *illegitimate acquisition of personal information* without a justified cause or in an unjustified way; *misrepresentation of personal information* respectively users based on information that is collected by the app but does not accurately describe the user or their condition; and *misuse of personal information* by processing or utilising it in an unjustified way or for an unjustified purpose. Table B.3.3 is

an overview of information privacy breaches for which we found precautions spelled out in the official documentation of the analysed COVID-19 contact tracing apps.

Table B.3.3
Information privacy violations accounted for by COVID-19 contact tracing apps

Countries	AUS	FRA	DEU	JPN	NZL
Illegitimate acquisition of personal information					
Forced use of the app	X	X	X	X	X
Forced self-disclosure	X	X	X	X	X
Uneconomic data collection		X	X	X	
Prolonged data collection	X	X			
Misrepresentation of personal information					
Unauthorised registration and use of the app	X				X
Misreporting personal information	X	X	X	X	X
Misuse of personal information					
Illegitimate access	X	X	X	X	X
Aggregation		X			
Recombination		X	X	X	
Repurposing	X		X	X	X

The institutions responsible for all five apps agree that installation and use of the app must be voluntary. Furthermore, they state that users must not be forced to provide any personal information. In particular, they must not be obligated to provide information about their health status, disclose test results within the app, or share any personal data with health authorities or other agents.

In the documentation for the French, German, and Japanese apps, collecting data beyond what is absolutely necessary and relevant to enable contract tracing is considered a violation of users' information privacy. For the Australian and French apps, prolonged data collection beyond the duration of the coronavirus pandemic is characterised as a potential breach of information privacy.

The documentation also accounts for the fact that misrepresenting users based on the personal information collected could potentially threaten the integrity of the apps, and so information collected must be accurate, complete, and up to date. For the French, German, and Japanese apps, this refers in particular to encounter information and information about a user's health status and test results – users are encouraged to submit timely information about positive test results. False reports regarding positive tests for COVID-19 are prevented by enabling the update of the infection status only through a code provided by the responsible health institution. The documentation for the Australian and

New Zealand apps states that misrepresenting person or user identifying information that is used to identify potential contacts is not approved.

The accompanying documentation for all five apps addresses illegitimate access to personal information as a violation of information privacy: other app users, service providers, health authorities, and third parties are not allowed unauthorised access to personal information, nor may this information be made available or transmitted to them. In addition, the French app's documentation explicitly forbids data aggregation, which means personal information must not be accumulated in a way that allows clustering of users based on that information (e.g., compiling lists of infected users). The French, German, and Japanese apps further prohibit the recombination of personal information – that is, associating or matching personal information to make inferences about other users' personal attributes (e.g., their health status or social contacts). Finally, the documentation for all but the French app discourage the use of personal information provided through the app for purposes other than COVID-19 contact tracing (e.g., preventing access to restaurants and other facilities, or monitoring user compliance with quarantine orders), although data are generally used to provide use statistics and improve app functionality. While we expect that the same holds true for the French app, we were not able to identify corresponding statements in the documentation.

Design Principles to Protect Users' Information Privacy

The analysed apps are based on several design principles aimed at protecting personal information from illegitimate access and use. These include *voluntariness*, that is, no one is compelled to install or use the app or add personal data, any information entered can be deleted, and the app can be uninstalled at any time. The apps are based on *transparency* that makes the manner in which the app collects and uses personal information known to users. *Data minimisation* ensures that only data that are absolutely necessary and relevant for contact tracing are collected. The app design can include *pseudonymisation* – only user-chosen or automatically generated pseudonyms are used to refer to users. The *protection of personal information* from unwarranted access by users and others is part of the apps' design and, finally, can enable users to verify, review, and correct their personal information. Table B.3.4 is an overview of the design principles through which the analysed COVID-19 contact tracing apps seek to prevent violations of information privacy.

Table B.3.4
Principles to protect users' information privacy in COVID-19 contact tracing apps

Countries	AUS	FRA	DEU	JPN	NZL
Voluntariness					
Voluntary use of the app	X	X	X	X	X
Voluntary self-disclosure	X	X	X	X	X
Discontinuance of use	X	X	X	X	X
Transparency					
Transparent privacy standards	X	X	X	X	X
Government approval	X	X	X	X	X
Agency involvement		X	X		
Open source development		X	X		
Data minimisation					
Qualitative data collection thresholds		X	X	X	
Quantitative data collection thresholds		X	X	X	
Temporally restricted storage	X		X	X	
Discontinuance of service provision	X	X			
Data protection					
Encrypted storage	X	X	X	X	X
Decentralised storage			X	X	X
Centralised storage	X	X			
Restricted device-to-device transmission	X	X	X	X	X
Secure transmission			X	X	
Pseudonymisation					
Personal pseudonyms	X				
Random user identifiers	X	X	X	X	
Dynamical user identifiers	X		X	X	
Logical disconnectedness		X	X	X	
Data quality enhancement					
Technical redundancies		X	X	X	X
Verification	X	X	X	X	X
Revision	X				X

To implement the principle of voluntariness, the adoption and use of all analysed apps is left to people's discretion: neither governments nor other agents may force or otherwise exert pressure on people to install the apps. Further, providing personal information within the apps – particularly about a user's health status and a potential COVID-19 infection – is optional. Users may uninstall the app at any time, and doing so will delete all personal information stored on their devices; if information pertaining to them is stored on some central server, they can request its deletion.

All the responsible institutions emphasise transparent design. Privacy information is made available to users both within the app and online. Applicable privacy laws and regulations are explicitly referenced, and contacts for privacy-related inquiries are

provided. Furthermore, governments have approved the design of the apps, either implicitly or explicitly; for instance, French and German government and civil agencies responsible for information privacy and data protection were involved in their country's app development to ensure compliance with privacy standards. Furthermore, the French and German apps are open source, meaning the source code and technical specifications of the apps are publicly available, and community members and external experts are encouraged to review and comment on the code.

The French, German, and Japanese app documentation strongly emphasises minimisation with respect to data collection. These apps do not require user identifying information to be entered to use the app, and only minimal person identifying information is required for the setup. Furthermore, they impose quantitative thresholds on data collection, which implies that encounters are recorded and stored only when some threshold values in proximity and duration are exceeded (less than 1 meter for 15 minutes or more for the French and Japanese apps, and more than 10 minutes for the German app). Both the Australian and the New Zealand app documentations, in contrast, emphasise data richness to allow for graded risk assessment. While they do not track users' geolocations, both collect data that could be used to identify particular users.

The Australian, German, and Japanese apps store encounter information only for a limited period (14 days for Germany and Japan; 21 days for Australia). While we cannot rule out the possibility that the other apps impose similar restrictions, we were not able to confirm that based on official documentation. Furthermore, the Australian and French apps, according to official announcements, are to be discontinued at the end of the COVID-19 pandemic, including automatic deletion of all personal information stored. We were not able to identify similar statements regarding the other apps.

Pseudonymisation is another measure taken to protect users' information privacy. The Australian app allows users to enter false names or self-chosen pseudonyms upon registration. Other apps employ user IDs that are generated automatically within the app and are linked to users' digital profiles, which allows for retracing a user's encounters. With the exception of the New Zealand app, all apps analysed use these randomly generated identifiers. The accompanying documentation for the Australian, German, and Japanese apps also state that these identifiers change at regular intervals to prevent users from identifying nearby other users or retracing infected users.

Documentation of the apps also stresses that user pseudonyms are logically disconnected from other pieces of personal information, which means they are inherently unrelated. For instance, in the French, German, and Japanese apps, user identifiers are generated randomly and are not based on any person identifying information. Similarly, the codes that users enter to verify test results are independent of these identifiers, so servers or users' devices can only know that some user has tested positively for COVID-19, but cannot infer that user's identity. While the Australian app also uses randomly generated identifiers for exchanges between users, those are connected to person identifying information made available to contact tracers, which means they can infer the identity of infected or potentially infected users. Similarly, for the New Zealand app, contact tracers know the identities of infected users, although they cannot directly identify users at risk. None of the apps provides real-time alerts, which means that the apps cannot be used to detect infected persons in a user's proximity.

For all apps, encrypted storage is key to protecting personal information from unwarranted access. Apps differ, however, in their data storage models: the German and Japanese apps use decentralised storage of personal information, which means that as little information as possible is transmitted from the individual users' devices to central servers. Instead, the identifiers of infected users are uploaded so other devices can compare them with their own encounter histories. Similarly, users of the New Zealand app who have tested positive for COVID-19 can upload their location histories so that warnings can be generated for particular locations and other users' devices can compare their own entries. The French app, in contrast, asks infected users to upload their encounter histories; each device knows only its own encounters, and matching is performed on a central server. The Australian app relies even more on a central server infrastructure: upon registration, users provide person identifying information, which is stored centrally. In case of an infection, users are asked to upload their encounter histories, and both sources of information are matched by human contact tracers to identify and prioritise contacts.

Secure transmission between devices and servers can be an issue, although only the German and Japanese app documentation refers explicitly to secure device-to-server transmission, and only the latter mentions prospective security measures to obscure transmissions (e.g., sending false notifications that are discarded on the server to create background noise).

Both storage models are generally motivated in terms of information privacy concerns. Decentralised storage, on the one hand, minimises the threat that health agencies or service providers can access personal information stored on a central server, or that sensitive data could be released unintentionally if servers are compromised. Centralised storage, on the other hand, can hinder individual users from accessing user identifying information (e.g., their identifiers), reduces information privacy risks from smartphone security holes and loss or theft of devices, and allows for bundling the responsibility for data protection with one or a few dedicated agents. Decentralised storage does not imply that no personal information is transmitted to a central server; at the very least, all apps that rely on this approach use central servers to verify test results and make the identifiers of users diagnosed with COVID-19 available to others' devices. Similarly, centralised storage does not mean that no information is stored on users' devices, but that information about which users are infected is not made available to others.

Furthermore, all the apps, to a greater or lesser degree, restrict the information that is exchanged between devices. The New Zealand app allows no information to be exchanged between devices, but encounters are inferred ex post based on shared attributes (i.e., locations and activities recorded by each user). Device-to-device transmissions are limited in the other four apps analysed: the only information exchanged are the user identifiers required to represent encounters (possibly contingent on further thresholds of data collection).

Finally, some measures exist within all the apps to ensure the accuracy and completeness of personal information. To enhance data integrity, the Australian, Japanese, and New Zealand apps require some type of initial verification to set up the app. The French, German, and Japanese apps require users to verify their test results when declaring themselves infected with COVID-19. To do so, they receive a one-time code that can be entered in multiple ways to prevent misreporting and ensure that information is entered reliably. Similarly, the New Zealand app provides multiple ways to enter locations and activities and to add supplementary information to encourage completeness. It also lets users review their digital profiles and revise and complement their visits and other information. Similarly, the Australian app allows users to reinstall the app to correct personal information. As a rule, however, all the apps – except for the one deployed in New Zealand – store encounter information in a secure section of the device that cannot be accessed by users; this prevents users from re-identifying other users, particularly infected persons.

Theoretical Evaluation of Information Privacy in the Context of COVID-19 Contact Tracing Apps

Thus far, we have analysed design principles evident from existing COVID-19 contact tracing apps, based on the broad understanding of information privacy as limited access to information about a person (*condition of privacy*) who might be able to control, to a certain extent, how that information is accessed and used (*management of privacy*). Table B.3.5 summarises the normative and technical design principles to protect users' information privacy.

Table B.3.5
Normative and technical design principles to protect users' information privacy

	Normative design principles to protect information privacy	**Technical design principles to protect information privacy**
Design principles aimed at limiting access to personal information (*condition of privacy*)	*Does not apply.*	- Data minimization - Data protection (centralised vs. decentralised) - Pseudonymisation
Design principles aimed at granting users control over their personal information (*management of privacy*)	- Voluntariness - Transparency	- Data quality enhancement

Based on the findings of the exploratory analysis, we conclude that the understanding of limited access to personal information that is evident from the apps varies along two dimensions. The first is the *centralised-decentralised dimension*. The Australian and French apps in particular pursue a centralised approach, meaning that they do not transmit information about infected users to others' devices, but perform all matching and processing of personal information on central servers. In contrast, the decentralised approach of the German and Japanese apps, and, somewhat differently, the New Zealand app, entrusts users' devices with these tasks, largely reducing central servers to a transmittal function.

The second dimension, which we refer to as the *data minimisation-richness dimension*, is based on the data minimisation and pseudonymisation design principles evident from our analyses. Along this dimension, the German, French, and Japanese apps limit access to personal information by minimising the information collected and through effective use of logically disconnected user pseudonyms to eliminate illegitimate access to person or user identifying information. In contrast, the Australian and the New Zealand apps

specifically ask users to contribute personal information to be used for enhanced risk assessment and contact tracing.

With respect to the management of information privacy, the voluntariness and transparency principles relate to choice and consent; they enable users to control whether and what information about themselves they make available in the first place. *Voluntariness* implies that users can choose whether to use the apps and, if they do so, whether to provide the requested information. For instance, users who test positive for COVID-19 can decide whether to make that information available to others or can use the app without doing so and still receive warnings – although the effectiveness of contact tracing would clearly suffer. *Transparency* implies that users can make informed decisions about using the app based on the information provided.

In contrast, measures that allow for *enhancement of data quality* relate to the ex-post correction of personal information that has been collected. While this does not protect users from illegitimate access and use of their personal information, it does enable them to ensure that such information is accurate, complete, and up to date, and hence that adequate conclusions (in particular about their own and others' risk status) can be drawn. This tradeoff between design principles for limiting and managing access to personal information indicates that the former may come at the expense of generating more precise and targeted warnings.

The design principles for limiting access to users' personal information we identified are, in principle, technical, as they can – depending on the effectiveness of their implementation – reduce exposure to unwarranted access to and prevent accumulation and recombination of personal information. Such technical measures can only help constitute naturally private situations, where users' personal information is protected from particular violations as a matter of fact, but implemented protections do not grant normative rights to information privacy. Similarly, design principles related to correction through data quality enhancement are inherently technical, as they provide actual opportunities for users to revise and complement personal information. In contrast, design principles for managing information privacy through choice and consent are primarily normative. While the documentation for all the apps state that voluntariness and transparency are desirable, they do not describe measures taken to ensure they are obeyed. For instance, it is beyond the scope of app design to ensure that health agencies and other agents do not take measures to enforce app use.

Discussion

Our insights into the normative and technical design principles are clearly related to the broader discourse in information systems and other disciplines regarding the adoption and use of mobile applications for contact tracing, and parallel the findings of prior research on information privacy in the context of COVID-19 contact tracing apps.

Our findings confirm that the design of apps deployed early on by five liberal democracies considers key ethical principles identified in the literature. In particular, the documentation we analysed stress the role of *voluntariness*, which is deemed crucial for privacy-sensitive design. The voluntariness principle goes beyond the mere adoption of an app, but includes people's decisions to carry a smartphone, download and install the app, leave the app operating in the background, react to alerts, share contact logs if they test positive, and uninstall the app together with removing collected data (Klar & Lanzerath, 2020).

However, voluntariness only protects people's information privacy in a normative sense. As Ishmaev et al. (2021) point out, even if adoption and use of apps for COVID-19 contact tracing is declared non-mandatory, social or economic conditions may still create pressure to do so. Voluntariness is also contingent on users' understanding of how and what information is accessed by the apps. In an early analysis, Zhang et al. (2020) conclude that the privacy-related information provided by the Australian and New Zealand app documentation, for instance, may be too complex for users to read and understand. Also, only two of the apps have open source code, meaning that in-depth inspection of the apps' functionalities even by experts is not always possible, leaving the implementation of normative information-privacy protections to the responsible institutions' goodwill and competences.

What is more, proportionality is a key criterion for privacy-sensitive app design (Morley et al., 2020). However, concerns were raised that contact tracing apps may not be effective in containing the spread of COVID-19 because they can make a real difference only if a significant percentage of the population (e.g., 56% or more) use them (Hinch et al., 2020). If that threshold is not met – as was the case in the five countries at the time of our study – a potential sacrifice of information privacy may be unjustified.

Overall, many privacy-related aspects – in particular, voluntariness, user consent, anonymity (in terms of pseudonymisation), purpose specification, provision of app providers' contact information, and specification of data retention parameters and the

decommissioning process (Klar & Lanzerath, 2020; Morley et al., 2020) – have been systematically addressed by the apps analysed. However, not all have adopted corresponding design principles in equal measure, and other potential threats to users' information privacy, such as special protection of data collected from children, updates to the apps' privacy policy changes, and privacy breach notices (e.g., Hatamian et al., 2021; Kolasa et al., 2021), are not explicitly evident from the apps' accompanying documentation. While we expect that such issues have been addressed since our study was completed, it is revealing how even proactive privacy-sensitive app design may deviate at least from some of the previously suggested ethical standards.

In addition, works such as that of Hatamian et al. (2021) suggest that the extent to which the applied design principles are actually suited to limit access to personal information depends considerably on their actual implementation – which, according to them, still leaves room for improvement. In addition, further measures that could be taken, such as data protection through random noise signals (e.g., Sharma & Bashir, 2020), have not (yet) been explicitly addressed by the majority of apps we have analysed.

Our findings hint at an unsurprising but nevertheless critical tension between normative and technical design principles: if normative principles, such as voluntariness and transparency, are not supported by technical measures, the risk of information privacy violations could be real. If, for instance, information-privacy policy documentation is insufficient, or people are encouraged to use the app to avoid other constraints, these principles could be undermined. However, if technical protections such as secure storage and pseudonymisation lack normative justification, they can only be evaluated against the benchmark of the efficacy of implementation – which is not feasible for laypersons, and which may undergo unnoticed changes at any time.

Contrasting the design principles identified from the apps analysed, we find striking similarities between the information-privacy standards they set. This is likely due to the homogeneous sample of apps originating from liberal democracies. It is hence not unexpected that these apps afford similar levels of information privacy. Still, from a theoretical point of view, it is interesting to see what the apps' design reveals about the understanding of information privacy. One aspect in this regard is the distinction between centralised and decentralised storage. Both approaches can, in principle, be privacy-preserving (WHO, 2020); still, they are based on different assumptions regarding the origins of potential information privacy threats. While centralised design stresses the risk that individual users might recombine distinct pieces of information about others and

thus re-identify other users and draw conclusions about their health status, decentralised design emphasises threats due to the existence of central stores of aggregated information that, if compromised, could expose a large number of users.

Another aspect relevant for our theoretical understanding of information privacy is the tension between data minimisation and pseudonymisation, on the one hand, and the data richness demand posed by several apps, on the other. The former stresses the condition of privacy, where access to personal information is largely restricted. It is in line with the postulate to favor privacy by default to ensure exposure to potential information-privacy violations is effectively minimised, and it is clearly in line with much prior research that interprets information privacy in terms of autonomy, or the absence of intrusion into users' private sphere (Becker, 2019).

While all the apps analysed generally agree that certain types of personal information, such as GPS data, is not necessary to enable contact tracing and hence should not be collected (WHO, 2021a), the data richness postulate indicates a more differentiated view regarding what constitutes illegitimate access to and use of users' personal information, such that particular types of personal information (e.g., health status information) demand higher levels of protection than others that may be shared more carelessly. It hence shifts the focus of information privacy from autonomy to integrity, ensuring appropriate representation of users through their personal information based on a notion of information privacy as effective control over the flow of such information in a given context (as postulated by, for instance, Floridi [2006]).

Conclusion

In summary, we have analysed the normative and technical design principles through which COVID-19 contact tracing apps deployed in five liberal democracies aspire to protect information privacy: voluntariness, transparency, data minimisation, pseudonymisation, protection of personal information (through centralised and decentralised designs), and data quality enhancement.

The contributions of disclosive computer ethics studies can be found at three levels: the *disclosure level*, which explicates the hidden moral properties of the technological artifacts under study; the *theoretical level*, which refines and further develops existing theory; and the *application level*, which refers the theoretical insights back to the disclosure level (Brey, 2000a, 2000b). At the disclosure level, in response to RQ1, we have

spelled out the normative and technical design principles through which the apps analysed protect information privacy. At the theoretical level, in response to RQ2, we have explained what these principles reveal about the understanding of information privacy that has, explicitly or implicitly, guided the design of these apps, and how this relates to the condition and management of information privacy according to the RALC framework. Furthermore, we have discussed how the principles identified complement or contradict each other, and how these evident tensions can enrich our theoretical understanding of information privacy in the given context. Finally, at the application level, we expect that our insights can inform the design of contact tracing apps and help evaluate the measures taken to protect users' information privacy both in newly released apps and in updated versions of the apps analysed.

The contribution of our work lies in the space between normative papers that develop design guidelines from an ethical perspective (e.g., Morley et al., 2020) and technical papers that analyse how those guidelines are implemented (e.g., Hatamian et al., 2021). Our work is intended to inform app design by providing real-world examples of privacy-sensitive design that are motivated by well-grounded ethical theory and inspired by practical examples. Thus, we approach the refinement of ethical theory to develop and evaluate design principles for actually usable technological artifacts, as demanded, amongst others, by Bélanger and Crossler (2011).

Our argument is based on the RALC framework of information privacy (Moor, 1997; Tavani & Moor, 2001), which conceptualises information privacy in terms similar to much information systems research: as a state in which access to information about a person is limited, or in which people are able to control information about themselves (Popovič et al., 2017; Smith et al., 2011). It captures the potential of technological artifacts to threaten information privacy while also providing opportunities for users manage it actively, and is said to be sufficiently comprehensive to apply to a wide range of related concerns (Tavani, 2007).

As Solove (2006) explains, privacy theories will typically have problems to apply to information privacy in digital environments, as the corresponding information and communications technologies have capacities to collect, store, process, and disseminate information about their users that go well beyond those of the means of communication addressed in the original debates. In addition, few existing theories recognise privacy breaches that result from practices such as the constant and unobtrusive surveillance of users, data mining, and user profiling, which are nonetheless key information privacy

concerns put forth in the given context (e.g., Clarke, 2019; Stahl, 2011; Volokh, 2000). Still, our theoretical perspective implies that the interpretations put forth in this paper are meaningful only in the context of the RALC framework, which, as we have discussed, may have issues accounting for the trade-off between users' autonomy and the integrity of representation.

Another limitation comes from the small sample of apps we analysed. Our results are based on apps deployed as early as June 2020 in liberal democracies, which means that our contribution is restricted to outlining example design principles rather than providing a representative summary. Further, different countries will typically continue to pursue different approaches to the development of apps, owing to social and cultural preferences and path dependencies. To raise awareness of alternative approaches and justifications, we have articulated what we think are the evident design choices. Our results are by no means final, as apps are typically developed further while in use, and new contact tracing apps have become available since we conducted our study. What is more, while official documentation is an informative source of information, complementary analyses would be required to determine, for instance, the effectiveness of how the principles we identified were implemented.

Our work is also relevant for the design of digital information and communications technologies in other social and economic settings with the potential for large-scale data collection and public surveillance, which are on the rise. For instance, fitness apps enable the large-scale collection of fitness and health data: where, when, and for how long users are active and with whom they compare themselves. Widely used dating apps enable matches between users based on their geographical locations and other criteria. Restaurants and hotels use apps and similar tools to manage reservations digitally, saving customer data that is often poorly protected in cloud services with little regard for or even awareness of information privacy issues (Chaos Computer Club, 2020). For those, knowledge of existing conceptualisations of information privacy and corresponding design principles could be particularly useful.

Information privacy is of growing interest in information systems research, as the digitisation of different sorts of information increases, along with the use of technology and methods for capturing information, such as online platforms and big data analysis. We responded to calls for more context-specific research in this area: that digital artifacts and privacy-related practices need to be analysed within the context they are used; and that theories from other fields need to be applied meaningfully given that information

security is an interdisciplinary research field (e.g., Bélanger & Crossler, 2011; Lowry et al., 2017). We focused on disclosing and integrating moral properties evident from existing technological artifacts, and so the outcome of our work cannot be characterised as full-fledged ethical theory. Rather, we have illustrated how ethical theory can inform the design of technological artifacts in general, and how empirical design choices can contribute to advancing such theory vice versa.

In ethical terms, privacy theory must include not only a descriptive account of but also a normative justification of privacy (Parent, 1983). In this paper, we have clearly focused on the former. A normative justification that clarifies not only whether information privacy is present in a certain artifact, but also the extent to which there is a justifiable claim to information privacy in a certain use context, would be valuable, especially for COVID-19 tracing apps. With respect to COVID-19, there are alternative approaches (e.g., tracking apps) that are generally regarded as less privacy friendly than the tracing apps we have analysed, and by far not all countries deploy those apps on a voluntary basis for people to use at their own discretion. Our work should hence be seen as an initial step towards challenging and refining existing ethical theory.

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4. Paper 4: Procedural Influence on Consensus Formation Social Networks

Bibliographic Data

Eismann, K. (2019). Procedural Influence on Consensus Formation in Social Networks. In L.M. Aiello, C. Cherifi, H. Cherifi, R. Lambiotte, P. Lió, & L.M. Rocha (Eds.), *Complex Networks and Their Applications VII: Volume 2 Proceedings of the 7th International Conference on Complex Networks and Their Applications COMPLEX NETWORKS 2018* (pp. 287-299). Springer. https://doi.org/10.1007/978-3-030-05414-4_23

Abstract

How do the rules of interaction influence consensus formation in a social network? In this paper, I analyse procedural influence – a construct that is well-established within the group decision-making research tradition – in the context of networked consensus formation. I argue that interaction procedures regulate the flow of social influence among actors, which, in turn, potentially affects collective outcomes. Based on this, I explain how procedural influence can be integrated into a formal model of social influence. I then utilise an agent-based simulation (ABS) to quantify the effects of three exemplary interaction rules on the formation of consensus in a social network. My findings indicate that applying these rules to regulate interactions has mixed effects on the overall consensus outcomes, but consistently negative effects on the efficiency of consensus formation.

5. Paper 5: Diffusion and Persistence of False Rumors in Social Media Networks

Bibliographic Data

Eismann, K. (2021). Diffusion and Persistence of False Rumors in Social Media Networks: Implications of Searchability on Rumor Self-Correction on Twitter. *Journal of Business Economics*, 91, 1299-1329. https://doi.org/10.1007/s11573-020-01022-9

Abstract

Social media networks (SMN) such as Facebook and Twitter are infamous for facilitating the spread of potentially false rumors. Although it has been argued that SMN enable their users to identify and challenge false rumors through collective efforts to make sense of unverified information – a process typically referred to as self-correction – evidence suggests that users frequently fail to distinguish among rumors before they have been resolved. How users evaluate the veracity of a rumor can depend on the appraisals of others who participate in a conversation. Affordances such as the searchability of SMN, which enables users to learn about a rumor through dedicated search and query features rather than relying on interactions with their relational connections, might therefore affect the veracity judgments at which they arrive. This paper uses agent-based simulations to illustrate that searchability can hinder actors seeking to evaluate the trustworthiness of a rumor's source and hence impede self-correction. The findings indicate that exchanges between related users can increase the likelihood that trustworthy agents transmit rumor messages, which can promote the propagation of useful information and corrective posts.

[B.5.1] https://creativecommons.org/licenses/by/4.0/

Introduction

How rumors – that is, "item[s] of circulating information whose veracity status is yet to be verified at the time of posting" (Zubiaga et al., 2018, p. 2) – diffuse and persist among the users of social media networks[B.5.2] (SMN) such as Facebook and Twitter is a timely subject of research. While rumors are, by definition, neither necessarily false nor harmful, they are often referred to in the same breath as fake news, hoaxes, and other forms of misinformation, and their impact on people's decisions is seen as potentially critical (Zannettou et al., 2019).

Despite their bad reputation, rumors may actually help people manage and make sense of situations they perceive as individually or collectively threatening (DiFonzo & Bordia, 2007a). Still, rumors propagating through SMN can cause severe problems in many social and economic settings, such as when people rely on unverified information to make critical decisions in acute situations such as social crises (e.g., K. H. Kwon et al., 2016; Oh et al., 2013). In the runup to the 2012 and 2016 U.S. presidential elections, platforms such as Facebook and Twitter were used not only to distribute confirmed political news, but also to spread unverified and occasionally false information about candidates, which could easily be mistaken for factual information (e.g., Allcott & Gentzkow, 2017; Shin et al., 2017). In a business context, online rumors and firestorms that are not addressed adequately can have severe negative consequences for companies, including the loss of trust between management, staff, and shareholders, and sustained personal and corporate reputational damage (e.g., Kimmel & Audrain-Pontevia, 2010; Pfeffer et al., 2014).

Capitalizing on the topology of the social network of users, rumors can spread quickly in SMN, reaching a large audience in a relatively short time (Doerr et al., 2012). Yet both research and conventional wisdom have come to note that SMN not only can promote, but potentially also could counteract, rumor propagation: by discussing them together with others, users are said to be able to identify, challenge, and eventually correct false rumors and other forms of misinformation through an ongoing process of collective sense-making typically referred to as *self-correction* (e.g., Arif et al., 2017; Jong & Dückers, 2016; Wang

[B.5.2] Following Kane et al. (2014), social media networks are defined as digital platforms that enable their users to set up unique user profiles, access digital content and protect it from various search mechanisms provided by the platform, establish relational connections to other users, and view and navigate these connections. This definition does not abandon the concepts of online social networks and social network(ing) sites, but rather draws a line between platforms whose functionalities rely to a significant degree upon users' relational connections – including, among others, Facebook, LinkedIn, Pinterest, Tumblr, and Twitter – and other types of social media such as weblogs, wikis, content communities, and virtual worlds.

& Zhuang, 2018). Nevertheless, evidence suggests that while there is reason to expect users will stop supporting rumors that have been proven false, they may fail to distinguish between true and false rumors beforehand (Zubiaga et al., 2016a).

In this paper, I investigate why users may fail to identify and correct false rumors although they may actually scrutinize unverified information. Explanations for this can be found in the *source and message characteristics* that can affect users' inclination to spread or otherwise respond to a rumor (e.g., Lee et al., 2015; B. Li & Chong, 2019; Oh et al., 2013). In addition, the *relational ties* that connect users in SMN (e.g., being friends with or following others, sending messages, or being members of the same group) can influence the flow of digital content through which a rumor is conveyed to users (Kane et al., 2014). The formation of relational ties is, in turn, contingent on the *affordances* of SMN that arise from the interactions between the platforms and their technological features, on the one hand, and user attributes and abilities on the other (Evans et al., 2017). Affordances can determine relevant actors, audiences, and publics, and thus shape the discourse that is at the very heart of self-correction (Baym & boyd, 2012).

This paper focuses on the *searchability affordance* of SMN, which allows users to access digital content through their purposeful efforts to find or discover information, rather than by navigating their relational ties to others (boyd, 2011). Using dedicated platform features such as keyword searches and automated information streams (e.g., news feeds and trending topics [Kane et al., 2014]), users can follow conversations and access information shared by otherwise unrelated others, which is crucial to enable and sustain collective sense-making practices among a larger number of users (Oh et al., 2015). Searchability is also important for the propagation of false rumors, which users rarely pick up from their direct contacts (S. Kwon et al., 2017). Searchability can hence create opportunities for rumors to spread into distant parts of the network. This means that while searchability can enrich an ongoing discourse by integrating a wider audience, it may also interrupt or bypass collective sense-making processes. This leads to the research question: *How does searchability interfere with rumor self-correction in SMN?*

While few would likely argue that rumor dynamics are independent of the capabilities of the platforms that enable and sustain them, developing consistent and coherent explanations for how information and communications technologies (ICT) can affect social processes is a theoretical challenge. Widely used models of opinion dynamics, such as bounded confidence and voter models, do not come with inherent theories of ICT impact, which means that assumptions must be adapted from media effects and other

theories – which themselves do not clearly and unambiguously account for the potential implications of SMN for networked opinion dynamics (Valkenburg et al., 2016). Affordance theory, which is well established in information systems and communications research, offers a theoretical lens for analyzing the interplay between ICT and the individual and social dynamics of human behavior, and could therefore help fill this explanatory gap. Yet to date, many of the mechanisms through which SMN might interfere with social dynamics are more or less hypothetical (Leidner et al., 2018).

This paper's goal is to identify the explanatory mechanisms through which searchability can shape the user discourse that makes sense of a rumor, and hence explain how using platform features such as keyword searches and trending topics might affect social outcomes. Agent-based simulations (ABS) are used to analyze how different modes of information access might impact collective sense-making practices in SMN. ABS are based on computer models that replicate the evolution of social systems based on the iterated and adaptive interactions of their constituent elements (i.e., *agents* [Klein et al., 2018]). They hence allow for deconstructing social dynamics that arise from the behaviors and interactions of autonomous but interdependent actors (Macy & Willer, 2002) – in this case, how collective judgments regarding the veracity of a rumor arise from individual users' efforts to make sense of it. ABS thus facilitate elaborating and exploring theoretical explanations through computational experimentation (Davis et al., 2007).

Beginning from a simple theoretical rationale of how searchability might interfere with naturally occurring social influence processes, computer experiments are used to identify five theoretically and empirically plausible scenarios that characterize rumor propagation on the platform Twitter. The findings suggest that relying on dedicated content access features can enable users, under certain circumstances, to arrive at accurate rumor veracity judgments, but it can also make it difficult for them to evaluate the trustworthiness of rumor sources. Thus, searchability can help contain the propagation of false rumors, but can also prevent the spread of true rumors and corrective posts that have not (yet) been verified. The insights of this study can inform technological design and managerial governance decisions to contain the propagation and manage the adverse impacts of false rumors in SMN. In addition, they shed light on the causal mechanisms through which platform features can contribute to the emergence of social outcomes, and thus advance the theoretical integration of technological affordances and social dynamics.

In Section 'Characterizing Rumor Self-Correction in Social Media Networks', I revisit major themes in prior research to facilitate a shared understanding of rumor self-correction in SMN. Based on that, I explain in Section 'Searchability, Social Influence, and Self-Correction of Rumors' how the use of dedicated content access features might divert the flow of social influence among users, based on a simplified version of the rumor communication model proposed by Bloch et al. (2018). The simulation approach is outlined in Section 'Methodology'. Subsequently, in Section 'Implications of Searchability for the Self-Correction of Rumors', I analyze the implications of searchability for five distinct scenarios of rumor propagation on Twitter, derived from the PHEME rumor scheme dataset (Zubiaga et al., 2016b), and argue how searchability might interfere with the manifestation of self-correction in each. In Section 'Discussion and Conclusion', I discuss the paper's contributions and limitations.

Characterizing Rumor Self-Correction in Social Media Networks

According to the popular definition of DiFonzo and Bordia (2007b, p. 13), rumors are "unverified and instrumentally relevant information statements in circulation that arise in contexts of ambiguity, danger, or potential threat and that help people make sense and manage risk." Analyzing, discussing, and questioning rumors together with others can help people make sense of uncertain situations and understand what is going on around them (Bordia & DiFonzo, 2004). It can assist users of SMN who contribute to a conversation, as well as those following it, in keeping track of what is going on and learning about others' views, such as during crisis and disaster events (e.g., Heverin & Zach, 2012; Stieglitz et al., 2018). Establishing consensus regarding the veracity of a rumor is a key element of this collective sense-making process (Bordia & DiFonzo, 2004).

The term *self-correction* was first used by Starbird et al. (2014) to describe users disseminating corrections to false rumors on Twitter. Jong and Dückers (2016) refer to self-correction more specifically as the processes through which communities of users distinguish between true and false rumors, in the course of which senders of incorrect or misinterpreted posts as well others actively try to make sense of and validate that information. Similarly, Arif et al. (2017, p. 157) explain that through self-correction, crowds of users can "identify, challenge, and eventually correct misinformation." Somewhat in contrast, Wang and Zhuang (2018) argue that it is the particularly knowledgeable users from among a broader population who are enabled to identify and

correct false rumors by engaging in discussions with others. Herein, the term self-correction refers to conversational practices sustained by SMN through which users resolve false rumors circulating on a platform.

Self-correction can denote different types of user behaviors. Arif et al. (2017), for instance, argue that users take actions to correct themselves as well as other users and the social information space by pointing out that they have shared false information before, deleting previously shared information, providing correct information, and addressing other users who share false information. Friggeri et al. (2014) suggest that users engage in what is called *fact-checking interventions*, posting references to fact-checking websites (e.g., Hoax-Slayer.com, FactCheck.org, PolitiFact.com, Snopes.com, and TruthOrFiction.com in the United States; Mimikama.at, HOAXmap.org, and several websites run by public service broadcasting authorities in Europe) to provide information on the veracity of a rumor.

Research, however, yields mixed evidence on user capability to distinguish between true and false rumors. Zubiaga et al. (2016a) claim that Twitter users tend to support every unverified rumor, suggesting that while they may not uphold false rumors once debunked, they are mostly incapable of distinguishing true and false rumors a priori. But while users may not be able to resolve a rumor right from the start, they may finally succeed in doing so through their concerted efforts to make sense of it. Procter et al. (2013) interpret rumor trajectories in light of a consensus-seeking process in which users gradually exchange arguments to arrive at a collective decision regarding a rumor's veracity. This is roughly in line with what Maddock et al. (2015) refer to as the *collective sense-making signature* – corrections eventually catching up with and overtaking false rumors. Castillo et al. (2013) support this claim, arguing that the overall share of tweets confirming a rumor is significantly higher if it is true, whereas there is a higher portion of posts that deny or question a false rumor.

Nevertheless, the diffusion of corrective posts was found repeatedly to lag behind that of false rumors, at least in time and occasionally also magnitude (e.g., Maddock et al., 2015; Takayasu et al., 2015). This suggests that such revisions are often less popular than the rumors they intend to correct. Inspecting rumor dynamics over time, S. Kwon et al. (2017) and Shin et al. (2018) find that rumor propagation can have multiple spikes, which indicates that rumors draw user attention repeatedly until they are eventually resolved. Jong and Dückers (2016) refer to this as *echo effects* – outdated and otherwise obsolete information being reshared even when an update is available from the original source.

Latecomers picking up an outdated post (Procter et al., 2013), old information being repackaged by partisan websites to look like news (Shin et al., 2018), and news media coverage that draws attention to an unresolved rumor (Spiro et al., 2012) are all potential explanations for such effects. Zhao et al. (2016) identify a disparity between users' intention to correct false rumors and their actual rumor-combating behaviors, which means that although they might be aware of the negative consequences of false rumors and feel obliged to correct them, they may be reluctant to take action. Also, official accounts and professional journalists were found to play a major role in rumor correction (e.g., Andrews et al., 2016; Starbird et al., 2018), which casts doubts regarding the bottom-up nature of self-correction.

Further issues also arise regarding fact-checking interventions. Findings indicate that referencing fact-checking websites to debunk a false rumor does not have a significant long-term effect on the likelihood of it being reshared (Friggeri et al., 2014). Shin et al. (2017) show that the percentage of tweets rejecting a false rumor increases only slightly in response to a fact-checking intervention, and that a small percentage of users even casts doubts over these interventions' veracity. Overall, only few of the addressed users respond to such interventions in a conversation (Hannak et al., 2014) and, even if they do, responses are most often negative (Zollo et al., 2017). Also, as Wang and Zhuang (2018) suggest, most users who spread false rumors do not take corrective actions to accommodate for a debunking comment, and neither delete nor clarify rumor-supporting posts.

One possible explanation for the limited impact of fact-checking interventions is that they are rarely used to support a user, but rather to challenge others' views (Friggeri et al., 2014; Hannak et al., 2014). Furthermore, they are typically made by otherwise unrelated users (Hannak et al., 2014), which is problematic because recipients are less likely to accept objections issued by strangers rather than by their friends or followers (Margolin et al., 2018). What is more, rumor corrections cannot only fail to take effect, but may even reinforce people's misperceptions, especially if they contradict their preexisting worldviews (Lewandowsky et al., 2012), which is known as *backfire* or *boomerang effects* (e.g., Hart & Nisbet, 2012; Nyhan & Reifler, 2010).

In summary, there is evidence that while self-correction can emerge from users' collective efforts to make sense of ambiguous information, their ability to identify and debunk false rumors may be limited. Studies have focused mostly on individual users' cognitive and behavioral shortcomings that might prevent them from adequately judging rumor

veracity. However, they have largely considered SMN as platforms that allow users to exchange information, but do not shape their discourse. In the following section, I argue that SMN, by enabling their users to learn about a rumor not only from others with whom they share a relational connection, but also through dedicated search and query features, can help bypass social influence processes that would otherwise allow them to arrive at accurate rumor veracity judgments.

Searchability, Social Influence, and Self-Correction of Rumors

Theoretical Rationale

Rumors can spread through SMN when users not previously aware of them learn about their existence through digital content available to them, and then decide to support the rumors themselves (Maddock et al., 2015). For instance, users can add corroborating comments to digital content that conveys a rumor, rate it positively, or reshare it, depending on a given platform's features (Lerman & Ghosh, 2010). Doing so, they cannot only spread a rumor beyond the audience of an original post, but also join or follow rumor-related conversations (e.g., boyd et al., 2010; Honey & Herring, 2009).

Users' stance towards digital content is not merely an expression of their independent beliefs, however, but can – at least to some extent – be influenced by the opinions of others (H. Li & Sakamoto, 2014). *Social influence* captures the idea that an individual's beliefs, attitudes, and behaviors can be affected by others for reasons that are essentially founded in social psychology (Cialdini & Goldstein, 2004). In SMN, social influence can flow when information about the activities of a user becomes available to others (Garg et al., 2011). Thus, if a user decides to support a rumor in one way or another, others can learn about that, such as when they inspect digital content posted by those they follow (i.e., their *followees*), read personal messages, or monitor contributions to a group (Kane et al., 2014). In addition, features such as status updates and notifications, as well as conversational practices like tagging, can raise user awareness of others' activities and facilitate interactions (e.g., Ellison et al., 2015; Huang et al., 2010).

Interactions along users' relational ties are frequently treated as the main mechanism of information diffusion in SMN, where the topology of ties, their contents, directionality, and the strength of information flow can shape diffusion (Garton et al., 1997). However, users' dyadic interactions typically account for only a fraction of rumor retransmissions in SMN (S. Kwon et al., 2017). Instead, as evidence suggests, users who spread false rumors often learn about them through dedicated content access features (e.g., Castillo et

al., 2013; Gupta et al., 2013; Vosoughi et al., 2018). Searchability might hence help spread a rumor beyond its original audience, based on platform features such as keyword searches and trending topics that make it easy for users to locate digital content beyond their direct contacts (boyd, 2011). Thus, searchability could divert the flow of social influence among users, which means it could affect collective sense-making by manipulating the structure of interactions and what information is available to actors when making up their minds (Mason et al., 2007).

Another question is whether searchability could imply qualitative changes in the operating logic of social influence. Expanding on Garg et al. (2011), one might argue that users who discover information using dedicated content access features do not observe others' behaviors, but rather see decontextualized content that does not transmit social influence. However, in contrast to web searches, for instance, information obtained through the dedicated content access features of SMN cannot be expected to come detached from its social context (e.g., Elsweiler & Harvey, 2015; Teevan et al., 2011). For one, many of these features rely on users' connections to identify potentially relevant content (Kane et al., 2014). Furthermore, it is not necessary for two actors to be related directly to influence each other, as mechanisms such as structural equivalence (e.g., Zhang et al. 2018) and information sampling (e.g., Denrell & Le Mens, 2017) can result in their adapting to a shared social environment.

From a theoretical standpoint, this issue is about the distinction between *peer influence* (i.e., behavioral adaptation motivated by social conformity) and *social learning* (i.e., behavioral adaptation based on rational deliberation). Both model the adjustment of actors' attitudes or behaviors in response to information available to them from others. The main difference is that models of peer influence tend to focus on the social processes through which actors' relationships determine information exchanges, whereas social learning approaches typically emphasize the decision-making rules through which actors revise their beliefs based on different sources of public and private information. Thus, the question is not whether actors' judgments can be affected by those of others, but rather how such opinion changes and the information behaviors that result from those changes might ultimately be motivated.

I hence argue that searchability can alter the path through which social influence, in a broad sense, is transmitted among SMN users: dedicated content access features create the conditions for users to learn about a rumor before they might otherwise have from their direct or indirect contacts, or find out about responses that differ from the views

expressed within their immediate social environment. On the one hand, this could increase the variety of opinions and allow a larger number of users to participate in collective sense-making, which in turn could enhance the quality of discourse and support the spread of corrections to false rumors. On the other hand, however, false rumors already debunked in one part of the network could be transferred into others, and an unsolicited influx of arguments could prolongate collective sense-making. Searchability could, therefore, not only promote the diffusion and persistence of false rumors, but also help maintain high levels of uncertainty, which is problematic if it prevents users from taking appropriate actions.

I formalize these assumptions below, based on the rumor communication model of Bloch et al. (2018). This model is the basis for using ABS to identify the mechanisms through which changes in the structure of information flow might counteract conversational practices that are typically referred to as self-correction.

Model Formulation

Most research has relied on social contagion models to analyze rumor dynamics in SMN (Serrano et al. 2015). These models' assumptions, however, stand in stark contrast to the notion of social influence delineated above, relying on mere contact rates between users to account for diffusion rather than on social forces that drive adaptation (Young, 2009). Alternative models of networked opinion dynamics make claims that are more sophisticated in this regard; still, they lack assumptions about people's rumor-spreading behaviors and motives, and they rarely account for the impacts of ICT beyond maybe that of mass media (Sîrbu et al., 2017).

This paper hence relies on a simplified version of the rumor communication model suggested by Bloch et al. (2018), who describe rumor propagation in social networks and public broadcast environments based on actor decisions to create and forward rumor messages according to their immanent behavioral intentions and the messages' presumed veracity. SMN are incorporated as a hybrid of networked and public broadcast environments in which users' relational ties introduce instances of networked communication that complement information access through dedicated content access features.

The model is based on a population of $N = \{1, \dots, n\}$ agents inhabiting a world with two possible states of nature $\theta \in \{0,1\}$. Let $x_i(t)$ denote the ith agent's belief that $\theta = 1$ at time $t \in \{0,1,2, \dots\}$, where agents share a prior belief $x(t = 0) = \pi \; \forall \; i \in N$, $0 < \pi < 0.5$. In the

context of this paper, agents represent the individual users of SMN, and the state of nature θ corresponds to the veracity of a rumor. To facilitate the subsequent explanations, let $\theta = 1$ denote that a rumor is true. At $t = 0$, one agent privately receives a perfect signal $s \in \{0,1\}$ that corresponds to the true state of nature. Each agent is equally likely to receive this signal. The recipient agent i then creates a message $m_i(t = 0|s) \in \{0,1\}$ that passes the rumor to other agents within the population.

Each agent obeys the rules of one of two communication strategies. *Unbiased agents* share only information they believe to be true. If an unbiased agent receives the initial signal, they pass it on without modification, as its veracity is undisputable, which implies that $m_i^u(t = 0|s) = s$. *Biased agents*, in contrast, have a special interest in spreading the word that a rumor is true. Thus, if a biased agent receives the initial signal, that agent always creates the message $m_i^b(t = 0|s) = 1$. In the context of SMN, users might, for instance, want to provide others with timely and presumably relevant information about an uncertain event, such as a natural disaster (e.g., Abdullah et al., 2017; H. Li et al., 2014). Biased agents' behavior can thus be interpreted as a function of their individual motives rather than as attempts to achieve some sort of collective outcome, and without implying a normative judgment.

Once a message has been created, it is disseminated to other agents within the population, who then decide whether to propagate it further. Rumor transmission takes place in discrete time, where at each time step $t + 1$, every agent j who has received a message $m_i(t)$ from a preceding agent i, $i, j \in N$, $i \neq j$, decides whether to retransmit it. Agents can decide either to relay or block a message, which is denoted as $m_j\big(t + 1\big|m_i(t)\big) \in \{m_i(t), \emptyset\}$. Agents, though, cannot alter the message contents. Thus, once a message has been created that does not correspond to the true state of nature (i.e., a *false rumor*), it remains in circulation, although further messages might be created subsequently to correct it.

Again, biased agents only spread the message that a rumor is true, regardless of their veracity beliefs. This results in the communication strategy:

Equation B.5.1

$$m_j^b(t + 1|m_i(t)) \begin{cases} m_i(t) \text{ if } m_i(t) = 1 \\ \emptyset \text{ else.} \end{cases}$$

Unbiased agents spread a message only if they believe it to be true. Otherwise, they do not retransmit the message. Upon receiving a message $m_i(t) = 0$, unbiased agents always

retransmit the rumor, as it could only have been created and passed on by unbiased agents, which means that it definitely corresponds to the true state of nature. If, however, they receive a message $m_i(t) = 1$, they will relay it only if the likelihood that it was created by a biased agent is sufficiently low. This corresponds to the communication rule:

Equation B.5.2

$$m_j^u\big(t+1\big|m_i(t)\big) = \begin{cases} m_i(t) \text{ if } m_i(t) = 0 \\ m_i(t) \text{ if } m_i(t) = 1 \text{ and } x_j(t+1) > 0.5 \\ \emptyset \text{ else.} \end{cases}$$

Unbiased agents are crucial to keeping diffusion alive: they can disrupt propagation, but if they continue to spread the message that a rumor is true, it abets the efforts of biased agents who themselves wish to propagate that message. Thus, self-correction essentially depends on unbiased agents' ability to evaluate the veracity of a rumor message effectively.

Agents apply Bayes' rule to revise their rumor veracity beliefs according to $x_j(t+1) = \pi/(b_j(t^*) + \big(1 - b_j(t^*)\big) * \pi)$, where $b_j(t^*)$ denotes the percentage of biased agents among those who have at some prior $t^* \in \{0, \dots, t\}$ participated in the rumor transmission process. Following Bloch et al. (2018), rumor propagation can take place in networked and public broadcast environments. In both settings, the identity of the agent who has received the initial signal is unknown and must be inferred by subsequent agents. In the *public broadcast environment*, agents' messages can be transferred to one or more other agents simultaneously. This corresponds to situations in which information diffuses through broad-based media, such as websites, newspapers, or dedicated content access features in the context of SMN. In this case, only the message itself is transferred, and the communication strategies of agents who (re)transmit it are private knowledge. Assuming that the overall number of biased agents within the population $B \subset N$ is commonly known, the probability that a message was originally created by a biased agent is $b_j(t^*) = |B|/(|n| - 1)$ for any unbiased agent j.

In the networked communication environment, agents communicate pairwise (e.g., in personal conversations, via e-mail, or through dyadic interactions in SMN), and their communication strategies are commonly known. This implies that all pathways through which a rumor could potentially have been transmitted to a recipient agent j can be retraced, except again for the original source of information. In other words, agents are assumed to keep track of who has been involved in the transmission of a rumor message, although they may not pay heed to the exact transmission sequence. In the context of SMN,

this corresponds to the ability of users to view and traverse their relational connections, as well as those made by others on the platform (Kane et al., 2014). Let $G(N, t^*)$ represent the directed social network that results from agents' dyadic interactions along their relational ties, where $g_{ij}(N, t^*) \in \{0,1\}$ represents the communication link between two agents i and j, $i, j \in N$, $i \neq j$, and where $g_{ij}(N, t^* = 1)$ if agent i has previously transmitted at least one message to agent j, and $g_{ij}(N, t^*) = 0$ else.

For any unbiased agent j who has received the message $m_i(t) = 1$ from one of their neighbors i, $b_j(t^*)$ depends on the communication strategies of the agents along the communication pathway who might have received the initial signal. If, for instance, j has received the message that a rumor is true from an unbiased neighbor i who in turn has previously interacted with a biased agent k, the signal could originally have been created either by j (in which case it is definitely true) or by k and then transmitted to j (in which case k could have misrepresented the signal in the first place).

The subset of potential rumor origins for a focal agent j who has received a message $m_i(t)$ is denoted as $N_j(i, t^*) = \{k | g_{ij} \in G(N, t^*) \wedge g_{ki} \in G(N, t^*)^{[R]}\}$, $i, j, k \in N$, $j \neq i, k$, which describes the set of all agents k who are directly or indirectly connected to j through i, including i themselves (the reachability matrix $G^{[R]} = \{g_{ki}^{[R]}\}$ denotes the direct and indirect connections between any two agents in the network, where $g_{ki}^{[R]} = 1$ if a directed path of arbitrary length exists from k to i, and $g_{ki}^{[R]} = 0$ else [Wasserman & Faust 1994]). This results in $b_j(t^*) = \left|B_j(i, t^*)\right| / |N_j(i, t^*)|$ for the networked communication environment, with $B_j(i, t^*) \subset N_j(i, t^*)$ denoting the subset of biased agents among those who could have received the initial signal of a message that was transmitted to j through i at time t. Agents do not discount messages received repeatedly from potentially the same source, which can increase the relative influence of well-connected agents (DeMarzo et al., 2003).

Bloch et al. (2018) demonstrate that unbiased actors can effectively prevent the spreading of false rumors if the likelihood that a biased agent created the message is sufficiently low. In the public broadcast environment, agents evaluate the veracity of a rumor based on the overall share of such agents across the population, whereas in a networked setting, retracing the potential transmission paths of a rumor enables them to block rumors from parts of the network that are dominated by biased agents. Therefore, both communication environments provide mechanisms that allow truth-seeking agents to hinder the propagation of false rumors.

This paper introduces *hybrid communication environments*, which relax the assumption that agents can keep track of *all* agents who have been involved in rumor communication while granting them the ability to follow conversations among their direct and indirect neighbors. In a hybrid communication environment, an agent j who receives a message from a directly related agent i can retrace the potential diffusion pathways over all agents who are directly or indirectly connected to i, just as in the networked setting. If there are however further unrelated agents, it is possible that *any one* of them could have received the initial signal, which would then have been taken up by an agent from within their connected component. Hence, in addition to the set of directly and indirectly connected agents, j would also have to consider the likelihood of an unconnected information source being biased to evaluate the veracity of a message, which is denoted as:

Equation B.5.3

$$b_j(t^*) = \frac{|B_j(i,t^*)| + (|B| - |B_j(i,t^*)|)/(|N| - |N_j(i,t^*)| - \mathbf{1})}{\left|N_j(i,t^*)\right| + \mathbf{1}_{\mathbb{N}}(|N| - |N_j(i,t^*)| - \mathbf{1})}$$

The indicator function in the denominator is equal to one if $|N| - \left|N_j(i,t^*)\right| > 1$, which is, if $N_j(i,t^*)$ is a proper subset of N. Equation B.5.3 thus denotes the overall likelihood that the original source of a rumor message transmitted to an unbiased agent j in a hybrid communication environment at a time t is biased. It combines the share of biased agents within the focal agent's connected component and the probability that an agent in the remainder of the population is biased, assuming that either one of j's direct or indirect neighbors or one other agent could have received the initial signal. If the share of biased agents differs substantially between the focal agent's connected component and in the remainder of the population, this could interfere with unbiased agents' ability to evaluate the trustworthiness of transmitters. Hybrid communication structures that allow agents to learn about a rumor both through interactions between personally known others and from public information sources that obscure message creators' credibility could hence disrupt the chain of accountability between related agents, and shift the ratio of biased and unbiased agents in the inferred transmission pathway. Thus, searchability might divert the flow of social influence in a way that counteracts self-correction.

The model does not explain, however, *how* searchability might affect self-correction. This is where ABS come in: they serve as analytical tools to analyze the communication structures that result from different modes of information access, and evaluate their potential implications for the flow of social influence. The methodological approach is described in the section that follows.

Methodology

Research Approach

The purpose of this paper is to develop a theoretical explanation of how the searchability affordance of SMN – that is, users relying on dedicated content access features, rather than their relational ties to other users, to learn about and make sense of a rumor – might divert the flow of social influence and hence impede self-correction. Thus far, I have proposed a formal model for how searchability can influence the decisions of actors who seek to support true rumors while blocking the forwarding of false ones (i.e., of *unbiased agents*). This section discusses the use of ABS to analyze this model and identify parameter ranges that are both theoretically plausible and realistic in that they can reproduce the macro-level characteristics of empirically observed rumor conversations on Twitter.

ABS rely on computer simulations to analyze social dynamics based on the behaviors and interactions of autonomous, yet interdependent, actors (i.e., the *agents* that constitute a social system) that follow simple behavioral rules and adapt to how they experience their environment (Macy & Willer, 2002). The key benefit of ABS is that they allow for describing and analyzing emergent macro-level behaviors based on the micro-level behaviors of the constituent agents, even when the mathematical descriptions of these behaviors are not analytically tractable (Klein et al., 2018). Thus, ABS can facilitate insights into the generative processes that lead to emergent social behaviors, including nonlinear, conditional, and qualitative effects (Smith & Conrey, 2007)

Computational model representations can run the gamut from highly abstract *toy models* to empirically rich descriptions of real-world social systems (Klein et al., 2018). The present work is a *typification* that investigates the properties of a broader class of diffusion phenomena (Boero & Squazzoni, 2005), and is hence situated in between: while analyses rely on the PHEME rumor scheme dataset (Zubiaga et al., 2016b) to place analyses in a real-world context, ABS are used to reveal the causal mechanisms that might underlie self-correction, rather than describe or predict how false rumors diffuse or persist in SMN.

Below, I describe the computer model's main constructs, parameters, and procedures and the steps that were taken to validate and calibrate the model.

Computational Representation

Rumor messages created by the members of a denumerable agent population constitute the basic construct of the simulation model. Messages are distinguished according to the information they convey (i.e., whether they state that a rumor is true or false) and their veracity (i.e., whether this information corresponds to the true state of nature). Rumor transmission is modeled based on the pathway through which a message spreads from an external source of information along a *sequence of agents* who retransmit it. Individual agents are characterized by their communication strategy, as described in Section 'Model Formulation': biased agents retransmit messages according to which a rumor is true, regardless of its veracity; unbiased agents evaluate the veracity and retransmit only if they believe the rumor to be true. The likelihood of an agent being biased p_{bias} is exogenously specified.

The model's main boundary condition is the *mode of information access*. Agents have two options to receive rumor messages: they can learn about a rumor from other agents with whom they share a relational connection, or they can gain access to the messages created by *any* other agent through dedicated information access mechanisms. Whether unbiased agents arrive at an adequate judgment of a rumor's veracity thus depends on (a) their prior beliefs regarding rumor veracity, (b) the relative share of biased agents within their connected component and in the remainder of the population, and (c) the agents' positions within the retransmission sequence.

This setup implies that manifested information exchanges between agents are analyzed, rather than the latent structure of *relational ties* that enable them. The relational ties between any two agents in the network are characterized by an exogenously specified likelihood p_{tie}, $0 \leq p_{tie} \leq 1$, with which they are activated, where $p_{tie} = 0$ corresponds to the ideal-type public broadcast environment and $p_{tie} = 1$ represents the networked communication environment. In addition, homophily h (i.e., the extent to which agents prefer connecting with similar others in terms of the communication strategy pursued [McPherson et al., 2001]), $0 \leq h \leq 1$, determines whether ties are activated, conditional on the agents' communication strategies, where $h = 0$ implies that agents activate relational ties to biased and unbiased agents with the same probability and $h = 1$ indicates that they only connect to similar agents, provided there are any such agents. In the context of the model, homophily can help unbiased agents prevent the spread of false rumors by blocking messages from parts of the network dominated by biased agents (Bloch et al., 2018).

At the setup of each simulation run, one agent is created, who then learns about a rumor from an exogenous source (i.e., the computer program) and initializes a rumor message according to that agent's communication strategy. In each subsequent iteration, one further agent is created and receives a rumor message from a previous agent, either by activating a relational tie to one randomly selected prior agent or by accessing the message created by the directly preceding agent, contingent on p_{tie} and h. Upon receiving a message, agents revise their beliefs and create their own messages in accordance with their communication strategies. Biased agents who receive the message that a rumor is false, as well as unbiased agents who arrive at the belief that the message does not correspond to the truth, do not create messages, but exit the simulation. A simulation run ends when unbiased agents' beliefs are stable and no longer subject to changes in further iterations. Rumor self-correction is said to be effective if, as a result of the retransmission process, an arbitrary unbiased agent would arrive at a veracity judgment that corresponds to the true state of nature, that is, if $\lim_{t\to\infty} x_i = \theta$. To evaluate this criterion, an additional unbiased agent is created after each iteration; those agents update their beliefs according to the same rules as regular agents, but exit the model immediately after updating and thus have no further implications for rumor propagation.

In the following section, I describe the structural validation steps taken to ensure that the computer model truthfully represents the theoretical model described in Section 'Model Formulation'.

Structural Validation

The goal of structural validation is to ensure that the computer model resembles the assumed propagation processes as closely as possible (Manson, 2003). The model was implemented in *NetLogo* (version 6.0.2 [Wilensky, 1999]). Experiments were implemented and run using *R* (version 3.6.1 [R Core Team, 2019]) and the package *nlrx* (Salecker et al., 2019). For *face validation*, the computational routines were continually traced to ensure they produced the intended behaviors. Subsequently, for *sensitivity analysis*, a wide range of input parameter configurations were tested to compare simulation outcomes with the analytical results (Kleijnen, 1995), which are available from Bloch et al. (2018) for the ideal-type networked and public communication environments.

Following the recommendations of Marino et al. (2008) and Thiele et al. (2014), Latin Hypercube Sampling was used to generate $N = 5{,}000$ model input parameter configurations for both communication environments, namely, for agents' prior beliefs,

the likelihood of their being biased, and for the extent of homophily (in the networked communication environment only). As an outcome variable, the veracity judgments at which an arbitrary unbiased agent would arrive at the end of a simulation run (i.e., whether they believed a rumor to be true or false) were measured. Logistic regressions were fitted to determine the strength of impact of each of the model input parameters on unbiased agents' emergent veracity beliefs. Table B.5.1 shows the parameter estimates.

Table B.5.1
Logistic regression coefficients of unbiased agents' emergent rumor veracity beliefs in the public broadcast and networked communication environment ($\boldsymbol{N = 5,000}$ each)

	Public broadcast environment $\widehat{\boldsymbol{\beta}}$	**Networked communication environment $\widehat{\boldsymbol{\beta}}$**
Intercept	-0.862^{***}	0.752^{**}
$\boldsymbol{p_{bias}}$	-13.799^{***}	-9.007^{***}
$\boldsymbol{\pi}$	14.747^{***}	7.144^{***}
$\boldsymbol{h}$	—	-0.146
$\boldsymbol{p_{bias} : \pi}$	16.118^{***}	4.278^{***}
$\boldsymbol{p_{bias} : h}$	—	-0.870
$\boldsymbol{\pi : h}$	—	2.162
McFadden's $\boldsymbol{R^2}$	0.598	0.478

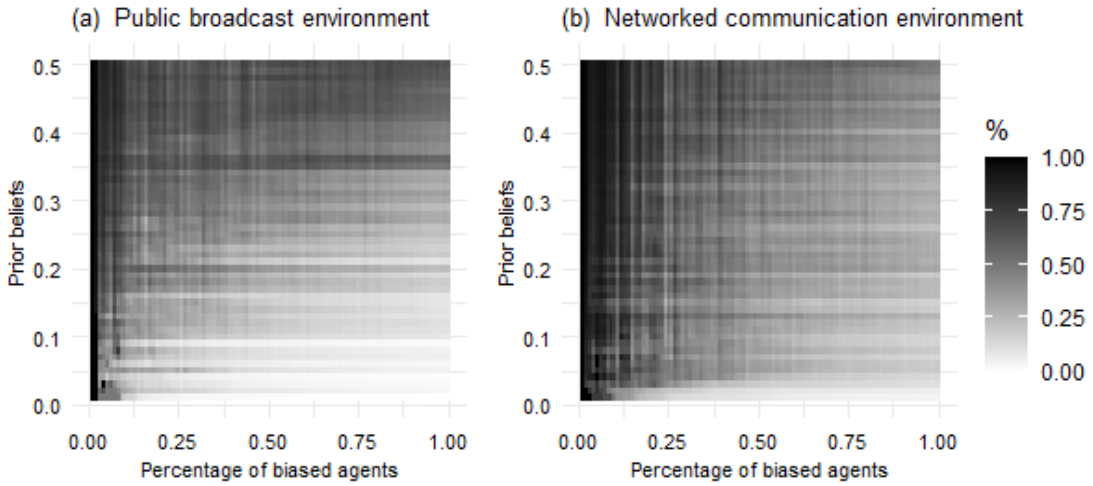
$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < .1$

Overall, unbiased agents arrived at veracity judgments that corresponded to the rumors' actual veracity in 43.8% of all simulation runs. Numbers differ significantly across the two communication environments: In the public broadcast environment, agents arrived at correct judgments in 47.6% of the experiments, whereas in the networked communication environment, they did so in only 40.1% ($p < 0.01$). In total, rumor self-correction was hence effective in a little less than half of all cases. This is not a pessimistic outcome, seeing that unbiased agents are naïve in the sense that their prior beliefs are not correlated to rumor veracity and they are unable to learn (e.g., to improve their prior beliefs incrementally or to restrict communications to a subset of evidently trustworthy agents).

Inspecting the logistic regression coefficients as well as the distribution of emergent beliefs in Figure B.5.1 supports the conclusion that unbiased agents in both communication environments are more likely to believe a rumor to be true if the percentage of biased agents is low, and if furthermore their prior beliefs are in favor of that judgment. This pattern is robust when controlling for rumor veracity. A lower share of biased agents does not in all cases, therefore, promote the emergence of correct veracity judgments, as it can also mislead unbiased agents to spread untruthful messages.

The outcomes are approximately in line with the full communication equilibrium identified by Bloch et al. (2018), according to which unbiased agents would spread the message that a rumor is true iff $b_j(t^*) \leq \pi/(1-\pi)$.

Figure B.5.1
Percentage of experiments in which unbiased agents judged a rumor to be true, public broadcast (a) vs. networked communication environment (b)



Homophily does not have a significant impact on unbiased agents' veracity judgments in the networked communication environment, although it should enable them to evaluate the reliability of potential rumor origins more accurately. However, it is possible that the relationship between rumor veracity and unbiased agents' judgments is not monotonic: homophily might not only make it easier for them to block false messages, but also to put faith in true ones, which means that positive and negative effects of homophily might cancel each other out. The implications of homophily are discussed in more detail in Section 'Implications of Searchability for the Self-Correction of Rumors'.

Below, I describe how the computer model was then calibrated, using the PHEME rumor scheme dataset (Zubiaga et al., 2016b) to match it with empirical patterns of rumor propagation on Twitter.

Empirical Calibration

Analyses rely specifically on those parameter configurations for which the computational model can reproduce the patterns of empirically observed rumor conversations. The micro-level model constructs are not empirically observable; therefore, the *indirect calibration* approach described by Windrum et al. (2007) was used to identify input parameter ranges that produce outcomes in line with two macro-level stylized facts,

namely, the average number of messages that support (rather than deny or comment on) a rumor, and the relative likelihood with which users participate in a conversation in response to a message from a user with whom they share a relational connection (rather than unrelated others). Overall, five clusters of parameter configurations were identified that are consistent with the observed macro-level patterns, which are then used to develop explanations about the implications of network connectivity for the self-correction of rumors on the platform Twitter.

The model was calibrated using the PHEME rumor scheme dataset, which contains tweets and annotations for the propagation of rumors associated with nine breaking news events on Twitter (Zubiaga et al., 2016b). While Twitter is generally oriented toward digital content rather than the connections between users, it has adopted networking features characteristic of SMN (Berger et al., 2014), and is therefore typically treated as an instance of SMN (e.g., Kane et al., 2014; Karahanna et al., 2018). Details on data collection and annotation are available from Zubiaga et al. (2015; 2016a).

Analyses rely on a subset of tweets in English pertaining to rumors regarding five breaking news events (as opposed to longstanding rumors): the unrest in Ferguson, Missouri in 2014; shootings on Parliament Hill in Ottawa, Canada in 2014; the Lindt Cafe siege in Sydney, Australia in 2014; the Charlie Hebdo shooting in Paris in 2015; and the crash of a Germanwings passenger aircraft in 2015. The basic units of analysis are the *conversations* pertaining to each event, based on which it is possible to analyze how users relate to each other in their rumor responses (Kogan & Palen, 2018). Each conversation consists of a source tweet that started a rumor and one or more tweets that responded using Twitter's *@reply* feature. After removing conversations in which the source tweet did not take a clear stance on a rumor (and in which it was therefore not possible to determine whether subsequent messages agreed with it), a total of 266 conversations and 4,744 tweets remained for empirical calibration.

Empirical calibration is based on annotated information that classifies tweets with respect to whether their authors agreed with a rumor and whether they responded to a tweet of a user with whom they were connected through a unidirectional follower relationship. The latter corresponds to the density of the information flow network, assuming that users learned about a rumor from their followees who have responded to it previously (S. Kwon et al., 2017). Table B.5.2 is an overview of the macro-level attributes of the conversational threads.

Table B.5.2
Overview of the macro-level attributes of rumor conversations associated with five breaking news events

Breaking news event	#Threads	#Tweets	Density			Rumor support		
			Min.	Avg.	Max.	Mi.n	Avg.	Max.
Ferguson unrest	41	1,159	0.000	0.350	0.800	0.051	0.191	0.529
Ottawa shooting	58	844	0.000	0.316	1.000	0.000	0.273	0.833
Sydney siege	71	1,236	0.000	0.426	1.000	0.029	0.246	0.750
Charlie Hebdo shooting	72	1,204	0.000	0.547	1.000	0.000	0.281	0.895
Germanwings plane crash	24	301	0.000	0.373	0.875	0.047	0.326	0.750

The software tool *BehaviorSearch* (version 1.10 [Stonedahl & Wilensky, 2010]) was used for input validation – that is, to explore the parameter space and identify parameter configurations that produce the desired macro-level outcomes (Fagiolo et al., 2019) – using Genetic Algorithms. The model is underdetermined, as multiple combinations of the same micro-level input parameters can produce each macro-level outcome. For instance, unbiased agents might judge a rumor to be false because their prior beliefs regarding rumor veracity are low or because most agents who could have created the message are biased. Similarly, they might activate relational ties to unbiased rather than biased agents because the level of homophily is high or because there are only a few biased agents overall to whom they might connect. To identify as many plausible input parameter configurations as possible, parameter identification was repeated ten times for each of the conversations, treating the outcomes of each cycle as independent inputs for the subsequent analyses.

Many parameter configurations that reproduce the empirically observed macrolevel outcomes are similar, which implies that there might be distinct patterns that underlie rumor propagation. Five consistent clusters were detected using hierarchical agglomerative clustering with Ward's minimum variance method (cophenetic correlation $c = 0.710$). The characteristic structures that result from the parameter configurations within each cluster are hereafter referred to as *scenarios*. Table B.5.3 is an overview of the clusters identified.

Each cluster corresponds to a set of micro-level input parameter ranges that reproduce approximately the observed macro-level patterns of rumor propagation. They should not be understood as descriptions of the real-world social system. Instead, the scenarios are used to characterize the structures of information flow that result from different configurations of network connectivity and explain how these different patterns might be

related to the manifestation of self-correction. While the identified parameter configurations could serve as inputs for further experimentation and analyses (Melamed et al., 2012), this would merely allow for quantifying effect strengths within the narrow boundaries of the theoretical model. This paper, conversely, develops a theoretical rationale for the implications of different modes of information access on collective sense-making outcomes.

Table B.5.3
Input parameter ranges identified through empirical validation

	p_{bias}			π			p_{tie}			h	
Min.	**Avg.**	**Max.**	**Min.**	**Avg.**	**Max.**	**Min.**	**Avg.**	**Max.**	**Min.**	**Avg.**	**Max.**
Cluster 1 (24.1%)											
0.730	0.894	0.990	0.010	0.054	0.180	0.000	0.079	0.190	0.820	0.963	1.000
Cluster 2 (21.5%)											
0.440	0.793	0.940	0.010	0.047	0.170	0.000	0.031	0.140	0.190	0.396	0.670
Cluster 3 (11.3%)											
0.190	0.301	0.370	0.010	0.048	0.070	0.000	0.030	0.090	0.300	0.489	0.890
Cluster 4 (23.1%)											
0.860	0.885	0.920	0.120	0.197	0.390	0.000	0.016	0.070	0.340	0.659	0.750
Cluster 5 (20.0%)											
0.840	0.921	0.970	0.030	0.099	0.120	0.190	0.227	0.450	0.400	0.451	0.490

In the following section, I discuss the characteristic structures of information flow that result from the input parameter configurations for each scenario. Based on that, the potential implications of searchability for unbiased agents' emergent veracity judgments are analyzed.

Implications of Searchability for the Self-Correction of Rumors

Scenario Overview

The two input parameters that have the strongest impact on unbiased agents' emergent rumor veracity beliefs in the ideal-type public and networked communication environments are the share of biased agents (i.e., of agents who would spread rumor messages regardless of their veracity) and agents' prior beliefs (i.e., their a-priori expectations that a rumor is true). The input parameters for the *share of biased agents* are higher than 75%, on average, in all scenarios except Scenario 3, which is characterized by a moderate share of biased agents of about 30%, on average. As regards agents' *prior beliefs*, in all scenarios except Scenario 4, prior beliefs of less than 10%, on average, produce outcomes that resemble the empirically observed conversation patterns; in

Scenario 4, unbiased agents assign an a-priori likelihood of about 20% to a rumor being true, on average.

The subsequent explanations focus on how different patterns of information flow network connectivity might affect self-correction. Connectivity depends on two model input parameters. The first is *network density*, which describes the likelihood with which agents activate their relational ties to others to learn about a rumor; it is below 10% in Scenarios 1 through 4, on average, whereas Scenario 5 is characterized by an average density of about 23%. The second is *homophily*, for which there is considerable variation across the scenarios. Three scenarios – Scenarios 2, 3, and 5 – are characterized by moderate extents of homophily of between 40 and 50%, on average, which implies that unbiased agents are about twice as likely to receive information from other unbiased agents if they activate their relational ties to others rather than obtaining information from an unconnected member of the agent population. In Scenario 4, average input values for homophily are about 65%, and in Scenario 1 about 96%.

Below, I discuss the patterns of network connectivity that result from the respective parameter configurations, and how they might affect unbiased agents' ability to distinguish between true and false rumors.

Implications of Searchability in Each Scenario

Insights from the Scenarios 1 and 2

The first scenario, which comprises about 24% of the input parameter configurations identified, is characterized by low values of network density, low prior beliefs, and high shares of biased agents. The extent to which homophily dictates tie formation is high. Unbiased agents are hence, on average, more than 90% more likely to learn about a rumor from a trustworthy agent than from a random member of the agent population if they rely on their relational ties to access information. The network structures that result from these parameter values resemble the ideal-type public broadcast environment, as agents receive information from their followees only sporadically. It is hence unlikely that unbiased agents would support a rumor regardless of its veracity, as the likelihood that it was initially released by a biased agent is unduly high. This implies that while false rumors would be effectively blocked, unbiased agents would support neither true rumors nor corrective posts.

However, occasional instances of networked communication could help unbiased agents distinguish between true and false rumors, as the likelihood that they will receive trustworthy information through their relational connections is considerably higher than when accessing information from unrelated others. Buskens (1998), for instance, finds that agents' ability to communicate their trustworthiness (i.e., their communication strategies) to those with whom they are connected is positively related to the level of trust in the network, which in turn can increase the quality of information transferred between actors (Droege et al., 2003). Knowing whether those who could have created a message would be willing to spread misinformation could thus allow agents to place trust more selectively.

As for self-correction, this insight implies that social relationships that allow agents to receive information – preferably from trustworthy others – might enable them to recognize true rumors more easily and selectively support those messages. Dyadic exchanges might therefore create trustworthy transmission pathways for individual messages. This mechanism depends not only on the relative frequency of networked communication, but also on whether agents can depend on their relational ties to provide them with information from trustworthy others. While lower values of network density may limit the rates at which this mechanism is activated, it might still be effective if tie formation is subject to high levels of homophily.

Figure B.5.2 illustrates this mechanism. The example consists of $n = 10$ nodes who participate in a rumor conversation, 6 of which are biased and 4 unbiased. Undirected edges represent the relational connections along which agents can retrace communications. In an ideal-type public broadcast environment, the share of biased agents who could have received the initial signal would be $b = 0.667$ for any unbiased agent, which means they would not spread the message that a rumor is true. However, occasional instances of networked communications allow unbiased agents to distinguish between messages originating from different parts of the network: if, for instance, $U1$ learns about a rumor from neighbor 2 , the likelihood that it was created by a biased agent (i.e., by $B1$ or one of the unconnected agents) drops to $b_{U1} = 0.458$. If all agents in the population were directly or indirectly related to the focal agent, it would allow them to evaluate rumor veracity even more accurately, as rumors originating in parts of the network dominated by biased agents could be blocked (Bloch et al., 2018). In the hybrid case, however, dyadic exchanges can open up pathways for individual messages to be transmitted through a sequence of largely trustworthy agents.

Figure B.5.2
Rumor transmission along agents' relational ties creates trustworthy transmission pathways for individual messages, even when most agents are biased

The second scenario accounts for about 22% of the input parameter configurations identified and is similar to the first, except for its lower values of homophily of about 40%, on average. Just as in the first scenario, relying on dedicated content access features prevents unbiased agents from spreading a rumor. However, lower values of homophily imply that the way unbiased agents learn about a rumor does not make a large difference. This indicates a positive relationship between the extent to which tie formation is subject to homophily and whether it provides agents with meaningful information about the trustworthiness of a rumor source: for lower values of homophily, the likelihood of receiving trustworthy information either from a direct contact or from unrelated others converges. Therefore, even if unbiased agents receive information from their neighbors, they may not be able to determine whether it was transmitted through an uninterrupted chain of trustworthy others. While this would still allow them to impede the propagation of false rumors, as they would simply assume all messages to be false, it would not enable them to promote true rumors and corrective posts.

Insights from the Scenarios 3 and 4

The third scenario accounts for about 11% of the input parameter configurations identified and is similar to the first two, except that the share of biased agents is lower as, on average, only about 30% of the agent population is biased. The third scenario is hence the only one in which the majority of agents is unbiased, which implies that there might be cases covered by the full communication equilibrium (i.e., in which unbiased agents would spread the message that a rumor is true). Unbiased agents' prior beliefs are still low; on average, they expect a rumor to be true with an a-priori likelihood of about 5%. In the ideal-type public broadcast environment, full communication would hence be possible for a sufficiently low share of biased agents. However, depending on the composition of agents within their connected component, instances of networked communication could lower the threshold value for the share of biased agents for which unbiased agents would continue to spread rumor messages.

Figure B.5.3 is an example of how social networks might motivate unbiased agents to spread rumor messages. The population consists again of $n = 10$ agents, 5 of which are

biased and 5 unbiased each. The overall likelihood that a rumor message was created of $b = 0.556$ for any unbiased agent in the public broadcast environment. If, however, a focal agent $U1$ can rule out the possibility that a rumor was created at least by *some* biased agents whose communications that focal agent can monitor, it could increase the trust in messages received from the remainder of the network. In the example, two edges suffice to decrease the likelihood of a biased message source for a message received an *unrelated* agent to $b_{U1} = 0.429$. Agents whose prior beliefs are sufficiently in favor of a rumor could thus be convinced to keep spreading messages.

Figure B.5.3
Rumor transmission along agents' relational ties rebalances the shares of biased and unbiased agents

In contrast to the first two scenarios, this mechanism is not so much about spreading individual messages through a sequence of trustworthy agents, but rather about creating a communication environment in which unbiased agents are generally willing to spread a rumor, as occasional instances of networked communication manipulate the relative share of unbiased agents within their connected component and the population as a whole in favor of messages' presumed veracity.

The fourth scenario accounts for about 23% of the input parameter configurations identified; its parameters are again similar to the first two scenarios. What distinguishes this scenario is that unbiased agents' prior beliefs are more moderate as, on average, they expect a rumor to be true in about 20% of the cases. Therefore, the unbiased agents' prior beliefs provide the opportunity to move unbiased agents towards the full communication equilibrium by increasing the threshold value of biased agents for which they would support a rumor, along the lines of the explanatory mechanism hypothesized for the third scenario.

Insights from Scenario 5

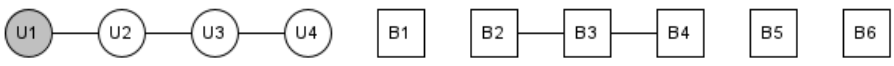
The fifth and final scenario accounts for about 20% of the parameter configurations identified; it is distinct from the others as the overall likelihood with which agents activate their relational ties to access information is higher. In about 23% of the cases, on average, they rely on their social relationships rather than dedicated features for accessing digital content. The other input parameters are similar to the other scenarios: there is a high

percentage of biased agents, and unbiased agents' prior beliefs that a rumor might be true are low. Tie formation is subject to moderate degrees of homophily.

The patterns that could emerge from users' relational ties in this scenario are interesting because network theories typically discuss the implications of macro-level structures of connectivity, rather than those of occasional dyadic connections. The key argument is that network closure can facilitate social action, as it supports trustworthy interactions based on shared social norms and expectations (Coleman, 1988; Granovetter, 1985). While the identified ranges of network connectivity might not be sufficient to ensure consistently high levels of exchange, they are not overly low when compared to empirically observed sparse social networks in which communities of actors are rarely connected to the remainder of the network (Leskovec et al., 2008).

Considering the potential implications of homophily, agents are again about 45% more likely to receive messages from trustworthy agents through their relational ties. Interactions with similar others might therefore allow unbiased agents to spread presumably true rumors among communities of unbiased agents, although false rumors might continue to propagate among biased agents. Figure B.5.4 illustrates this mechanism, based on a network with $n = 10$ agents, 6 of whom are biased and 4 unbiased. Only agents of the same type are connected through relational ties. In an ideal-type public broadcast environment with the same agent composition, the likelihood that a message was created by a biased agent is $b = 0.667$ for all unbiased agents. However, for messages transmitted only among unbiased agents, the likelihood that it was initially created by a biased agent is much lower, namely $b_{U1} = 0.250$. Therefore, relying on their relational connections to others they know to be trustworthy, users can safely transmit true rumors and rectifications.

Figure B.5.4
Rumor transmission along agents' relational ties enables unbiased agents to communicate trustworthy messages amongst themselves



The percentage of biased agents within this scenario is highest across all scenarios: on average, only about 8% of the agents are unbiased. This implies, first, that although networked communications exchanges might support unbiased agents in spreading truthful messages amongst themselves, false rumors might still prevail within the population as a whole. Second, if overall there are only few unbiased agents from whom

information is available, the relative influence of these agents could be disproportionately high. In fact, the parameter configurations identified could facilitate at least moderately centralized patterns of information flow in which emergent beliefs might be biased towards the beliefs of a few influential agents (Golub & Jackson, 2010).

Discussion and Conclusion

If users learn about a rumor circulating in SMN through dedicated platform features for accessing digital content (e.g., keyword searches and automated information streams such as trending topics), rather than through interacting with others with whom they share a relational connection (e.g., with whom they are friends or whom they follow on a platform), it can divert the flow of social influence among them and hence affect how they evaluate rumor veracity. Inspection of five scenarios of rumor propagation on Twitter reveals that the primary mechanism through which searchability can facilitate self-correction is *motivating users to block unverified messages regardless of their veracity*. If users are generally suspicious of rumors, they may simply choose not support them because of an unwillingness to risk that they might turn out to be false. On the one hand, this can prevent false rumors from spreading; on the other, it makes bottom-up self-correction difficult to achieve. This insight could help explain why statements from official sources and professional journalists play a major role in enabling self-correction (e.g., Andrews et al., 2016; Starbird et al., 2018), and why users may have difficulties distinguishing between true and false rumors a priori, as claimed by Zubiaga et al. (2016a).

In addition, the results point to three mechanisms through which communication among users who share a relational connection can facilitate identifying true rumors. First, such interactions can *create trustworthy transmission pathways for individual messages* transmitted through a sequence of (mostly) trustworthy users. Second, they can *create a communication environment in which truth-seeking agents are willing to spread rumor messages*, as shifts in the relative share of agents who potentially spread false rumors within and outside their connected component can alter their assessment of potential rumor sources' trustworthiness. Finally, communication along their relational ties can also *enable truth-seeking agents to spread presumably true rumor messages amongst themselves*. If trustworthy agents connect primarily with similar others, it could allow them to keep spreading a rumor, regardless of the communication among the rest of the population.

These insights suggest that when users cannot verify the information conveyed by a message itself, it is crucial that they be able to evaluate the trustworthiness of those who have transmitted it. However, empirical research suggests that the interactions between actors who maintain a relational connection play a minor role in the retransmission of rumor messages (e.g., Castillo et al., 2013; S. Kwon et al., 2017; Vosoughi et al., 2018). It is therefore unlikely that interpersonal trust regarding others' rumor-spreading behaviors and intentions will emerge through social enforcement and network closure, as claimed, for instance, by Coleman (1988) and Granovetter (1985).

However, trust does not result only from agents' social relationships, but also from their preexisting dispositions, social norms, the threat of formal sanctions or reputational damage, and role expectations (Droege et al., 2003). Furthermore, as Burt (2001) points out, trust can facilitate informational benefits that result from network brokerage rather than closure. In the context of SMN, Grabner-Kräuter and Bitter (2015) argue that it is users' *initial trust* in others, based on their foremost perceptions of trust-relevant attributes (e.g., others' competence, benevolence, honesty, and predictability [McKnight et al., 1998]), that might encourage them to acquire information from others. SMN can support the formation of initial trust among users by providing them with cues that help them evaluate the trustworthiness of an information source, such as their connectedness, authority status, identifiability, and others' recommendations of digital content created by them (e.g., Lin et al., 2016; Westerman et al., 2012; Winter et al., 2016). In line with that, Kim et al. (2019) suggest that features that allow users to rate each other might help prevent the spread of content created by untrustworthy actors – even though a prominent finding of their study is that *confirmation bias* can still prevent users from adopting truthful information that is inconsistent with their preexisting beliefs.

One way out of this might be to move toward more institutionalized forms of trust that do not require users to establish relational ties a priori. Turcotte et al. (2015), for instance, suggest that recommendations from perceived opinion leaders can increase other users' trust in digital content. This implies, however, that those opinion leaders would have to acquire a credible reputation a priori. This approach is currently pursued by websites such as *Snopes.com* and journalists who try to establish themselves as fact-checking institutions in SMN as well as in other online and offline channels. Similarly, social bots might serve as trustworthy intermediaries that enable users to distinguish between true and false rumors more easily (e.g., Ciampaglia, 2018; Mønsted et al., 2017).

Furthermore, the findings suggest that apart from users' mere connectivity, sufficiently high levels of *homophily* are crucial to ensure that those actors who seek the truth behind a rumor primarily receive trustworthy information from their direct and indirect contacts. While homophily does not ensure that all actors will arrive at adequate veracity judgments, it allows truth-seeking agents to establish trustworthy transmission pathways for particular messages and to communicate such information amongst themselves.

However, a tendency to connect to those who hold similar information preferences can also lead to the emergence of so-called *echo chambers* – polarized communities of actors that hold common views but who are unlikely to adopt information shared by others outside their communities (e.g., Bakshy et al., 2015; Del Vicario et al., 2016; Schmidt et al., 2017). The same mechanisms that can enable agents to focus on trustworthy information hence imply that they might disengage from the general discourse. Thus, even if unbiased agents arrive at adequate veracity judgments, it does not necessarily imply a consensual outcome. On the contrary, false rumors may persist within different communities or may even be held by a majority of users.

Using ABS, I have thus disclosed qualitative tendencies, but not quantified the presumed the relationship between searchability and rumor self-correction in SMN, which is a major limitation of this paper. The propagation scenarios identified are based on input parameter configurations that can reproduce empirically observed patterns of rumor propagation on Twitter, but they do not actually describe users' behaviors, and having identified certain parameter ranges a given number of times does not correspond to a meaningful percentage of observations. For instance, while four of the five identified scenarios point to mechanisms through which searchability might impede self-correction, knowing that does not allow for predicting its occurrence. What is more, outcomes can be interpreted validly only within the boundaries of the theoretical model, which is an abstract and simplified representation of the real-world social system. While the study thus yields insights into the existence and direction of effects, measurement and falsification necessarily lie within the domain of empirical research rather than that of simulation models.

Furthermore, empirical validation is a major issue when using ABS to identify and illustrate causal mechanisms (Beese et al., 2019). The present study relies on indirect calibration because restrictions in the availability of secondary data have prevented validating the micro-level model constructs directly. The empirical validity of a model that is in qualitative agreement with macro-level patterns of observations is, however,

naturally limited (Fagiolo et al., 2019). Furthermore, the insights are contingent on the operating logics of Twitter and the diffusion of rumors pertaining to breaking news events. To some extent, further empirical studies – for instance, case studies or field experiments that collect data from different platforms or that employ longitudinal analyses of communication patterns – could increase confidence in the theoretical mechanisms at work. Beyond that, additional validation steps could be taken to curtail input parameter ranges even further. Still, typification models such as used in this paper can help increase our understanding of the emergent properties of social processes (Boero & Squazzoni, 2005). Furthermore, this paper focuses on a theoretical explanation rather than an empirical description or prediction, and so it makes sense to confine to structural validation and empirical calibration (Manson, 2003).

In the ongoing debate surrounding collective intelligence and the wisdom of crowds in SMN, this work provides insights into how the affordances of popular and widely used platforms might affect the flow of social influence and, consequently, affect collective sense-making. Network dynamics are certainly only one of several factors that promote the propagation of false rumors in SMN, along with, for instance, individual actors' cognitive limitations (e.g., Mannes, 2009) and normative social influences (e.g., Nolan et al., 2008); still, understanding the social dynamics that can emerge from people's interdependent interactions is crucial for explaining social outcomes (Lorenz & Neumann, 2018).

The collective sense-making processes that can lead to the manifestation of self-correction in SMN have previously been interpreted in terms of a Habermasian public sphere (Fuchs, 2017), yet whether SMN sufficiently enable rational deliberation among their users is the subject of an ongoing dispute (Dahlberg, 2011). The normative evaluation of the implications of ICT affordances on online deliberation and public opinion is not the focus of this paper, however, and must hence be left to future research. By way of an epistemic justification, Gelfert (2013) explains that rumors may convey information to actors that they could not otherwise obtain from official sources, which is in line with the more general claim that they can provide people with what might be relevant information about an uncertain and potentially threatening event or situation (DiFonzo & Bordia, 2007a). As Coady (2012, p. 92) puts it, "no rumor could survive *as a rumor* […] if most of those spreading it were completely indifferent to whether it was true." However, users spreading rumors for reasons other than their presumed veracity can be epistemologically problematic (Goldman, 1995). The present study has referred to actors who might be willing to spread false rumors for desires or preferences that are

other than truth-related as *biased* agents. While their motives to spread rumors might be as honorable as those of unbiased agents, they still may take advantage of truth-seeking agents' uncertainty to promote the spread of misinformation in SMN.

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C. Appendix II: German Summary (Deutsche Zusammenfassung)

Die vorliegende Dissertation beschäftigt sich mit dem kausalen Einfluss von Social-Media-Plattformen auf Prozesse der Meinungsbildung und –verbreitung unter den Nutzerinnen und Nutzern dieser Plattformen. Im Fokus stehen *Social-Media-Netzwerke*, also Plattformen, die im Wesentlichen darauf ausgerichtet sind, den Nutzerinnen und Nutzern Möglichkeiten zur Erstellung und Verbreitung von digitalen Inhalten zu bieten und darüber hinaus Interaktionen zwischen ihnen zu begünstigen. Je nach Definition zählen dazu verschiedene Plattformen, die beispielsweise direkte Kommunikation (z.B. durch den Austausch von Nachrichten oder das Kommentieren von Beiträgen), relationale Verbindungen (z.B. durch das Eingehen von Freundschafts- oder *Follower-Followee*-Beziehungen) oder die Herstellung sozialer Zusammenhänge (z.B. durch den Beitritt zu Gruppen) zwischen Nutzerinnen und Nutzern ermöglichen, darunter etwa Facebook, Twitter, Instagram, Reddit und LinkedIn (Kane et al., 2014).

Das Explanandum der Arbeit stellen die auf Social-Media-Plattformen zu beobachtenden Meinungsdynamiken (*Opinion Dynamics*) dar. Diese beinhalten sowohl Prozesse der Meinungsbildung (*Opinion Formation*) als auch der Meinungsverbreitung (*Opinion Diffusion*) unter den Nutzerinnen und Nutzern der Plattformen. Erstere beziehen sich auf Aktivitäten, durch die Akteure Meinungen – im weiteren Sinne definiert als Vorstellungen in Bezug auf ihre Umwelt – bilden, letzere auf solche, durch die sie ihre Meinungen mit anderen Akteuren teilen. Meinungsbildungs- und Meinungsverbreitungsprozesse interagieren, indem Akteure unter anderem Informationen über die Meinungen anderer zur Meinungsbildung nutzen, die ihnen durch Kommunikation oder andere Arten der Interaktion zugänglich sind, und die auf dieser Grundlage gebildeten Meinungen wiederum die Grundlage für den Austausch mit anderen Akteuren darstellen.

Den Rahmen für die einleitende Schrift (Kapitel A) und die fünf Einzelarbeiten der kumulativen Dissertation (Kapitel B) bildet eine übergeordnetete, diskursiv-theoriebildende Vorgehensweise (*Theorizing*). Diese beinhaltet grundlegende Prozessschritte (*Foundational Practices*), die den Gegenstand der Theoriebildung für den Diskurs in der Disziplin *Information Systems* erschießen, und generative Prozessschritte (*Generative Practices*), die die grundlegenden Konzepte und die sie verbindenden kausalen Beziehungen in einen theoretischen Zusammenhang bringen (Hassan et al., 2019).

Die einleitende Schrift identifiziert zunächst grundlegende theoretische Konzepte der Meinungsbildung und –verbreitung sowie Annahmen bezüglich relevanter Ursache-Wirkungs-Beziehungen zwischen diesen. Grundlage dafür ist die einschlägige Literatur in drei Referenzdispziplinen, die eine nennenswerte analytische Forschungstradition in den

Bereichen *Opinion Dynamics*, *Opinion Formation* und/oder *Opinion Diffusion* aufweisen. Ausgehend von Arbeiten in der Kleingruppen- und frühen Netzwerkforschung (insbes. French, 1956; DeGroot, 1974; Friedkin & Johnsen, 1990; 1999) finden sich Beiträge insbesondere im interdisziplinären Forschungsfeld Soziophysik (u.a. Varianten des *Wählermodells* [z.B. Sznajd-Weron & Sznajd, 2000; Galam, 2002; Castellano et al., 2009], *Social-Impact*-Modelle [z.B. Kacperski & Hołyst, 1996], *Bounded-Confidence*-Modelle [z.B. Hegselmann & Krause, 2002]), in der verhaltensorientierten Ökonomik unter dem Begriff des *Social Learning* (u.a. Arbeiten zu Bayesianischem Lernen, Informationskaskaden und Herdenverhalten [z.B. Banerjee, 1992; Bikhchandani et al., 1992] und zu Verbreitungsprozessen in sozialen Netzwerken [z.B. Bala & Goyal, 1998; DeMarzo et al., 2003]) sowie in der Forschung zur logikbasierten Informationsintegration in der Informatik (z.B. Christoff & Hansen, 2015; Hansen, 2019; Liu et al., 2014). Der daraus abgeleitete konzeptionelle Argumentationsrahmen benennt *Agenten*, *Meinungen* und *soziale Netzwerke* als Kernentitäten von Meinungsbildungs- und Meinungsverbreitungsprozessen und identifiziert Parameter, die diese Prozesse beeinflussen. Diese beziehen sich insbesondere auf den *Modus der Meinungsübertragung* (z.B. Beobachtung, Kommunikation, Ansteckung) sowie die *Logik der Meinungsänderung* (z.B. Imitation, Mehrheitsentscheidungen, Orientierung am Mittelwert, Anwendung des Satz von Bayes).

Darauf aufbauend beschäftigt sich die einleitende Schrift mit der Frage, wie Social-Media-Plattformen die so definierten Meinungsbildungs- und -verbreitungsprozesse beeinflussen können. Die Dissertation stellt das kausale Argument dabei dem sogenannten *Enabling View* gegenüber: Statt die der Meinungsbildung und –verbreitung zugrunde liegenden sozialen Interaktionen lediglich zu *ermöglichen* („enable“), wird angenommen, dass das Zusammenspiel von technologischen Plattformattributen und dem Verhalten der Nutzerinnen und Nutzer in einer systematischen Veränderung der beobachteten sozialen Dynamiken resultieren kann. Die Dissertation interpretiert dazu die *Affordances* von Social-Media-Plattformen (übersetzbar etwa als Handlungspotenziale, die sich als potenziell nicht intendierte Folge des Wechselspiels zwischen technologischen und sozialen Agenten manifestieren [Volkoff & Strong, 2013]) als *Mechanismen*, also Abfolgen von Ereignissen, mit deren Hilfe sich Kausalketten abbilden und somit Ursache-Wirkungs-Zusammenhänge herstellen lassen (Hedström und Ylikoski, 2010).

Der Erklärungsansatz führt dabei drei theoretische Elemente zusammen. Auf der Grundlage einer kritisch realistischen Argumentation (z.B. Mingers et al., 2013) werden erstens die grundlegenden theoretischen Konzepte auf drei ontologischen *Strata* verortet, sodass Meinungsbildungs- und Meinungsverbreitungsprozesse als Bindeglied zwischen kausal

ursächlichen Strukturen (konkret den zugrunde liegenden Agenten, Meinungen und sozialen Netzwerken sowie spezifischen Eigenschaften dieser Entitäten) und empirisch beobachteten Ereignissen (wie etwa Akte der Meinungsänderung oder der Informationsweitergabe) fungieren. Zweitens wird die Theorie sozialer Netzwerke (z.B. Borgatti & Halgin, 2011) herangezogen, um Zusammenhänge zwischen individuellem Verhalten und sozialen Phänomenen herzustellen. Relevante Agenten werden hierbei als Akteure definiert, welche die *Knoten* eines sozialen Netzwerks darstellen, während soziale Beziehungen und andere Verbindungen zwischen ihnen als *Kanten* verstanden werden, die Interaktionen und damit den Austausch von Meinungen ermöglichen. Im dritten Schritt wird die Rolle von *Affordances* als kausale Mechanismen herausgearbeitet: Diese können, wenn sie in einer spezifischen Situation aktiviert werden, die Wirkungsweise unabhängig von ihnen operierender sozialer und psychologischer Mechanismen beeinflussen (z.B. Bygstad et al., 2016; Williams & Wynn, 2018). Somit können *Affordances* Auswirkungen auf die Interaktionen von Akteuren in einem sozialen Netzwerk und somit auf die zugrunde liegenden Prozesse der Meinungsbildung und –verbreitung haben. Die Argumentation zieht Parallelen zur Diskussion um Verfahrenseinflüsse (*Procedural Influences*) in der Sozialpsychologie (z.B. Davis, 1992): Wie diese werden *Affordances* als möglicherweise implizite Einflüsse auf kognitive und behaviorale Konstrukte sowie individuelles und soziales Verhalten verstanden.

Die Methodik der Dissertation beruht auf dem Prinzip der *Retroduktion* (z.B. Sæther, 1998). Aufbauend auf einer analytisch-induktiven Forschungslogik gliedern sich die weiteren Arbeiten in drei Schritte: 1) Exploration und Beschreibung, 2) Definition und theoretisches Framing und 3) Hypothesenbildung. Der in der einleitenden Schrift entwickelte Erklärungsansatz deckt dabei Schritt 2 ab. Die Schritte 1 und 3 sind im Wesentlichen Gegenstand der weiterführenden Einzelarbeiten.

Den empirischen Kontext der Arbeit bildet der Einsatz von Social-Media-Plattformen als *Kriseninformationssysteme*. Ereignisse wie Waldbrände, Hochwasser, Erdbeben oder auch terroristische Anschläge stellen die von ihnen betroffenen Organisationen – von Familien über *Communities* bis hin zu Wirtschaftsunternehmen und der öffentlichen Verwaltung – vor enorme Herausforderungen. Plattformen wie Facebook und Twitter kommen dabei seit einigen Jahren verstärkt zum Einsatz, um etwa Warnmeldungen und andere Informationen effizient zu verbreiten, Unterstützung für Betroffene zu organisieren und emotionale Verbundenheit herzustellen (Houston et al., 2015). Die Interaktionen zwischen den Nutzerinnen und Nutzern der Plattformen können dabei spezifische soziale Dynamiken in Gang setzen.

Ein Beispiel hierfür ist die Verbreitung von Gerüchten: Während oder kurz nach einem Krisenereignis sind aktuelle und offiziell bestätigte Informationen oft rar. Wenn direkt oder indirekt Betroffene oder auch Vertreterinnen und Vertreter der Medien und die breitere Öffentlichkeit angesichts der Informationsknappheit auf Social-Media-Plattformen zurückgreifen, um Informationen zu suchen oder mit anderen zu teilen, können auch unbestätigte Informationen und Falschmeldungen ein großes Publikum erreichen. Dabei ist davon auszugehen, dass dies nicht im eigentlichen Interesse der Nutzerinnen und Nutzer liegt, sondern dass diese vielmehr versuchen, sich auf der Basis einer Vielzahl von Informationen ein Bild der Lage zu machen, widersprüchliche Aussagen zu validieren und die auf einer Plattform verfügbaren Inhalte zu filtern, also nur solche Inhalte weiter zu verbreiten, die ihrer Meinung nach der Wahrheit entsprechen (z.B. Oh et al., 2013; Jong und Dückers, 2016).

Artikel 1 (Eismann et al., 2021) identifiziert auf der Grundlage einer systematischen Literaturanalyse *Affordances* von Social-Media-Plattformen, die die Öffnung von Lernprozessen vor, während und nach Kriseneignissen in verschiedenen Organisationskontexten unterstützen. *Artikel 2* (Fischer-Preßler et al., 2020) erarbeitet ebenfalls auf Basis einer Literaturanalyse Einsatzmöglichkeiten für Informations- und Kommunikationstechnologien für das Risikomanagement in Organisationen mit komplexen Lieferketten, auch im Zusammenhang mit Krisenereignissen. Artikel 1 und 2 beziehen sich daher direkt auf die *Exploration und Beschreibung* von Meinungsbildungs- und Meinungsverbreitungsprozessen auf Social-Media-Plattformen speziell im Kontext von Krisenereignissen.

Artikel 3 (Eismann et al., 2022) beschäftigt sich speziell mit der Nutzung von Smartphone-Applikationen (*Apps*) zur Weitergabe auch persönlicher Informationen (z.B. über den eigenen Gesundheitszustand) während der Corona-Pandemie. Der Fokus liegt auf den Implikationen der App-Nutzung für die Privatsphäre der Nutzerinnen und Nutzer und der Bedeutung verschiedener Interpretationen dieses eigentlich normativen Konzepts für das Design digitaler Artifakte. Damit ist auch der Beitrag von Artikel 3 im Bereich der *Exploration und Beschreibung* zu verorten.

Gegenstand von *Artikel 4* (Eismann, 2019) ist hingegen die Modellierung von Verfahrenseinflüssen auf Meinungsbildungs- und Meinungsverbreitungsprozesse mithilfe eines agentenbasierten Simulationsmodells. *Artikel 5* (Eismann, 2021) beschäftigt sich darüber hinausgehend mit dem Einfluss verschiedener Arten des Informationszugangs auf die Verbreitung von Gerüchten im Zusammenhang mit Krisenereignissen auf der Social-Media-Plattform Twitter. Dabei werden direkte Interaktionen zwischen Nutzerinnen und

Nutzern und der öffentliche Informationszugang (z.B. über die Suchfunktion der Plattform) gegenübergestellt und mithilfe eines empirisch validierten agentenbasierten Simulationsmodells kausale Einflüsse auf die Weitergabe unbestätigter Informationen identifiziert. Artikel 4 und 5 leisten somit einen Beitrag zur induktiven *Hypothesenbildung*.

Der theoretische Beitrag der Dissertation liegt somit im Bereich der Theorieentwicklung. Konkret erarbeitet die einleitende Schrift die konzeptionelle Grundlage sowie eine theoretische Argumentation, die den Einfluss von digitalen Technologien auf sozialen Dynamiken verortet und einen kohärenten Rahmen für die weitere Analyse dieses Einflusses entwickelt. Praktisch relevant sind insbesondere die Beiträge zur Erforschung der Einsatzmöglichkeiten von Social-Media-Plattformen in der Krisenbewältigung.

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