7-1-2022

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Risk Analysis, Vol. 42, No. 7, 2022 DOI: 10.1111/risa.13831

Social Perception of Systemic Risks

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The article distinguishes between two types of risks: conventional and systemic risks. Conventional risks can be contained in space and time, follow linear cause–effect relationships and can be addressed with effective and pointed interventions into the cause–effect chain. Systemic risks, however, are characterized by high complexity, transboundary effects, stochastic relationships, nonlinear cause–effect patterns with tipping points, and are often associated with less public attention than they require. The article addresses the reasons why systemic risks seem to be attenuated in public perception. The article goes on to consider how the social amplification of risk framework is useful in the context of systemic risks and describes needed extensions of that framework. It identifies practical tools for assessing the significance of perceptions for systemic risk situations. Finally, it argues that a graphic representation and simulation of evolving systemic risks and potential countermeasures as well as a participatory deliberative approach of inclusive risk governance are suitable governance strategies for preventing, mitigating, or managing systemic risks.

KEY WORDS: Inclusive risk governance; risk perception; social amplification/attenuation of risk; systemic risks

1. INTRODUCTION

At first glance, risk analysis is a success story. Many risks, for example, occupational health risks and risks related to transportation and mobility, which had threatened human well-being to a large extent during the past decades, have been identified and reduced significantly (Renn, 2014). Along with medical advances, risk analysis has been successful in developing public regulations and institutions that have been able to reduce risk so considerably that most countries in the world still experience increasing life expectancy from one year to the next. Between 2000 and 2016, global life expectancy at birth, for both sexes combined, increased by 5.5 years, from 66.5 to 72.0 years (World Health Organization, 2019, p. 2). Conventional risks are regulated within a specific regime that can be contained in time and space and linked to a specific sector. Consequentially, casualties related to occupational risks, car accidents, technological incidents, or other safety failures decreased significantly. The largest declines in risk exposure from 2010 to 2019 were among a set of risks that are strongly linked to improvements in social and economic development as well as more effective regulation concerning, for example, household air pollution and unclean drinking water. Global declines also occurred for tobacco smoking and lead exposure (Abbafati et al., 2020).

Despite these successes, many individuals have come to believe that risks have increased in number and severity, making life more dangerous (Sadiq, Tharp, Graham, & Tyler, 2016). Despite increasing life expectancy worldwide, studies indicate that individuals are concerned about risks that harm only a relatively small number of people (e.g., crimes committed by refugees and chemical residue in

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 0272-4332/22/0100-1455$22.00/1

foodstuffs) while disregarding other risks that affect a large number of people (e.g., lifestyle risks such as smoking and sunbathing) (Ropeik, 2010, p. 68ff.; Renn, 2014, p. 143). Risk perception and empirical evidence seems to be at odds. This discrepancy has been termed the risk paradox (Renn, 2014).

This paradox has been thoroughly investigated and empirical studies have revealed many qualitative attributes, such as voluntariness and perceived dreadfulness, that impact risk perception in addition to perceived magnitude and probability (reviews in: Breakwell, 2014, p. 20f.; Gardner, 2009, p. 70f.; Siegrist & Arvai, 2020). However, in our view, the paradox may also be triggered by another aspect: complex causal structures and cascading effects of risk creating ripple effects from one domain to other domains (Lucas, Renn, & Jaeger, 2018). Familiar procedures of risk assessment and risk management have resulted in major risk reductions with respect to conventional risks. However, these procedures are not sufficient for handling risks that transgress domain boundaries, that are embedded in a complex relationship with socioecological, sociotechnical, or cultural transformations, and that tend to lead to a series of secondary and tertiary impacts. Those risks provide a major challenge for scientific methods of risk assessments as well as measures for risk management and regulation. They have been subsumed under the category "systemic risks." Systemic risks are complex, transboundary, and nonlinear risk phenomena with potential tipping points (Renn, Lucas, Haas, & Jaeger, 2017). They are likely to cause cascading events that lead to negative effects across various societal domains (Kaufman & Scott, 2003). This feature has been particularly highlighted by analysts of the financial market and its collapse in 2008 (Liow, Liao, & Huang, 2018). Part of the challenge is that there is also often a lag in public perceptions and regulatory effort, despite the potential devastating effects of systemic risks (Schweizer, 2021).

The original motivation for developing the social amplification of risk framework (SARF) came from observations that gaps between public perceptions of risk and expert perceptions based on empirical measures have practical consequences (Kasperson et al., 1988; Pidgeon, Kasperson, & Slovic, 2003). According to the SARF, reduced or attenuated perceptions of risk may impede risk management, leading to heightened (amplified) empirical risks that can be measured quantitatively. Similarly, heightened (amplified) perceptions may also interfere with risk management, causing new risks to emerge. This article outlines the dynamic processes of social perception of systemic risks and investigates the reasons for a lack of attention to systemic risks by policymakers and the public; in the language of social amplification, we intend to demonstrate that perceptions of systemic risks are more likely to be attenuated than amplified. This attenuation may result in an amplification of risks as measured empirically, for example, current climate change mitigation efforts are inadequate for meeting the Paris Agreement temperature goals while climate engineering techniques cannot be relied on to contribute significantly toward meeting these goals (Lawrence et al., 2018). Attenuation of systemic risks goes beyond reductions in affect, that is, the level of concern that people have. There will also be difficulty and divergence in people's defining or framing of a systemic risk. Such divergence will weaken public support of regulatory effort. The article argues that a graphic representation and simulation of evolving systemic risks can be a useful tool for better understanding the impact and likely consequences of systemic risks. Gaming tools and virtual simulations are also excellent instruments for informing a participatory deliberative approach of inclusive risk governance (Gordon & Manosevitch, 2010; Gupta, Bouvier, & Gordon, 2012).

2. SYSTEMIC RISKS

Systemic risks are characterized by five attributes (Schweizer, 2021). Each of these attributes needs to be met to some degree to make a risk systemic, yet one attribute can partially compensate for the other. The distinction between conventional and systemic risks is not clear cut, it is rather a continuum than a distinctive binary relationship: however, for a risk to be called systemic it must meet the conditions of demonstrating high complexity with respect to causal or functional relationships, high dependency on contextual factors, and being associated with cascading impacts within the domain in which the risk is located and beyond this domain (ripple effects) (Renn et al., 2020). These ripple effects illustrate the link to the framework of social amplification of risk, which focuses on amplification and attenuation processes beyond the subsystem in which the risk originated (Renn, Burns, Kasperson, Kasperson, & Slovic, 1992). The multitude of intervening variables between causes and effects make it very difficult to reconstruct causalities, to understand triggers, consequences, feedback loops, and impacts of systemic risks (Lucas et al., 2018; Renn et al., 2017).

Complexity gives rise to an entanglement of intervening factors that interact with each other, that reinforce each other, and attenuate or amplify the given causal relationships. This level of complexity creates uncertainty beyond the usual level associated with statistical confidence intervals. Identical causes may lead to different effects, depending on the initial situation of a systemic risk. This feature is known from multiagent, multimoderator risks such as the effects of chemical mixes on human health (National Academies of Sciences, Engineering, and Medicine, 2017). Furthermore, with systemic risks, there is high uncertainty about both magnitude and probability of expected adverse effects. Probabilities and distributions of occurrences often shift rapidly which makes it difficult to extrapolate from past distributions to future events.

Systemic risks are transboundary or cross-sectoral. They may originate in the environment, human-made systems, or biological systems, yet their ripple effects spread out toward other systems where they have an impact to a greater or lesser extent (Aven & Renn, 2019). The cascading effects of systemic risks can cut across national as well as sectoral boundaries, possibly increasing in intensity and impact. Systemic risks can transcend boundaries of jurisdiction, nationality, or sectoral responsibility and therefore often call for multilevel governance (Hooghe & Marks, 2001, 2003) and international cooperation. The COVID-19 pandemic demonstrates these transboundary effects of systemic risks rather well.

In addition, many systemic risks come along with tipping points or tipping corridors. The system changes irreversibly once a tipping point has been reached. These changes in condition may even include a complete collapse of the system (Lenton et al., 2008). The developments leading up to a tipping point are incremental and often go undetected. Human learning processes are not well suited for dealing with tipping points. Humans learn from past experience based on trial and error (Anderson, 1993). However, once a tipping point has been reached it is too late to adapt and reverse the consequences. Useful learning needs to happen before a tipping point will be reached despite weak feedback signals.

In essence, there is little scientific uncertainty and ambiguity about the conventional aspects of risks such as they appear with localized pollution and contained technological failures that are by now well understood by risk analysts and managers. There are suitable and effective risk management and governance instruments available to prevent, reduce, or mitigate these risks. That does not mean that these instruments are used and implemented worldwide, but they are available in principle and haven been proven to be effective. The systemic aspects of risks, however, are more difficult to assess due to their complex nature and interactions with multiple other risks and socioeconomic activities. We still lack a clear understanding of how to address, manage, and govern these risks mainly because they transcend the sectoral policy tradition and there is a lack of management knowledge about the effectiveness, efficiency, resilience, and fairness of the consequences associated with potential policy interventions and we still face problems communicating both the nature and the urgency of these systemic risks to policymakers and the public.

3. PERCEPTIONS OF SYSTEMIC RISKS

People's response to a risk will depend considerably on their perception of the risk. One factor that influences people's perceptions is their capacity and capability for risk mitigation or adaptation. Risk perceptions can be amplified or attenuated due to a variety of factors such as perceived dreadfulness, familiarity, or lack of controllability (Breakwell, 2014; Renn et al., 1992; Siegrist & Arvai, 2020; Slovic, 1987). These qualitative risk factors, that is, attributes that people associate with risks, may lead in combination with intuitive heuristics and biases to a disconnect between people's concern about risks and their potential impact measured by statistical or experimental analysis (Raue & Scholl, 2018; Ropeik, 2010; Siegrist & Arvai, 2020). People tend to overrate risks that are readily available in their memory (availability bias), that are associated with positive or negative emotions (affect heuristics), that confirm what the already believe (confirmation bias), that lend themselves to blame others for its occurrence (blame), and that are associated with immediate dreadful consequences (dread) (Siegrist & Arvai, 2020; Slovic, Finucane, Peters, & MacGregor, 2004).

Conventional risks are sometimes socially amplified, sometimes attenuated depending on the perceived qualitative risk characteristics but systemic risks tend to be systematically attenuated in risk perception. One reason is that individuals draw on cultural memories of hazards and perils encountered by previous generations, such as openly visible markers for previous flood levels or landmarks reminding people of historical disasters. Stories of these perils are passed on and are readily available in our memories. Many of the factors that impact judgments about conventional risks are linked to risk characteristics that people have learned in the course of becoming familiar with the causes of risk, such as fire, explosion, floods, or technical failures (Ewald, 1999).

Systemic risks, however, refer to potential events in the future. People might experience the impacts of these risks only after passing a tipping point; even then, the experience itself is likely to be primarily about the impacts rather than the systemic connections that brought them about. Before a tipping point the risks will appear more distant and less dangerous to the individual person (optimism bias) than many conventional risks. In particular, they are less easily understood and, due to their complexity and nonlinearity, less present in the mental representation of most people (Nahari, Glicksohn, & Nachson, 2010). Some of the key features of systemic risks, such as complexity as well as nonlinearity and stochasticity give rise to a feeling of lacking agency (Smith & Mayer, 2018) or being trapped in the dilemma of the commons (Renn, 2011).

Even though systemic risks can threaten the functionality of society's vital systems, individuals are likely to perceive less urgency to change their own behavior or to accept more stringent regulatory actions. Fatalist perceptions appear to be more common than in other risk areas (Mayer & Smith, 2019). At the societal and policy level, perceptual complexity and the diversity that people show in framing systemic risks, as well as their diversity in levels of concern, will create incoherence that might reduce further any urgency toward control efforts.

In the remainder of this section the ways in which public perceptions and behaviors are affected by the characteristics of systemic risks will be explored. In this section an expanded social amplification of risk framework will be used to seek a better understanding of how policy formation is affected both by system complexity directly and by its indirect effects on perceptions and behavior.

3.1. Counterintuitive Causal Connections

Individuals intuitively associate causality strongly with proximity in time and space (Michotte, 1963). This makes sense from an evolutionary point of view. Cause and effect are temporally and spatially related in the case of most conventional risks. Causality is immediate and for this reason less challenging to ascertain with occupational hazards, car accidents, and natural hazards. Risk perception is therefore primed on proximity or relatedness (Renn, 2019, p. 47). The systemic risks caused by interdependencies in complex coupled systems are more difficult to fathom. In this case, causality is obfuscated by the multitude of intermediary factors and a lack of predictability in their relationships. Causes and effects are disconnected in space and time (Markowitz & Shariff, 2012, p. 244). It is hard for most individuals to relate their personal experience and behavior to systemic risks. For instance, CO_2 emissions caused by private transportation in Germany may increase the risk of extreme weather events in places that are far away from the original source, such as Bangladesh. In combination with sea-level rise these events will eventually displace millions of people (Seneviratne et al., 2012). However, these effects are temporally and spatially unrelated to personal experience. How can people feel responsible for events that will happen far away in the (probably not so distant) future? These complex relationships lack plausibility and tangibility. Populists and other climate change sceptics take advantage of the seemingly implausibility of complex relationships. They offer simple explanations based on common sense reasoning and/or refer to powerful actors behind the scenes (McIntyre, 2018, p. 127f.). Conspiracy theories can seem more straight forward and plausible compared with scientific evidence that points toward a multitude of interconnected climate change triggers.

3.2. Nonlinearity and Stochasticity

The second reason for attenuation is due to the nature of complex and stochastic relationships. Deterministic relationships that follow the pattern "If A then B (and nothing else)," thus establishing clear causal connections between drivers and consequences, are rare to find in the context of systemic risks. Probability distributions of outcomes may be modeled to represent the potential effects of drivers. However, stochastic relationships are difficult to communicate to the public appropriately, and the challenge is even greater when potential outcomes are delayed or when systems may change drastically due to tipping points (Dutt & Gonzales, 2010; Leiserowitz, 2005). The challenge is to communicate the innate uncertainties associated with stochastic and dynamic effects without giving the impression that truth claims are arbitrary or due to partisan interests. The negative effect might occur that individuals interpret uncertainties associated with stochasticity as ignorance and fall back on their intuition (Breakwell, 2014, p. 86ff.). This tendency is encouraged by the political instrumentalization of constructivist approaches to science by populist and fringe movements (Gardner, 2009; Urbinati, 2019). Constructivism claims that knowledge and truth claims, in as far as they refer to knowledge, are the product of social learning via interaction and communication. In its most pronounced variation, the paradigm postulates that knowledge formation does not require external stimuli from the natural environment, rather that social interaction is the sole input for knowledge formation. This claim can be twisted and instrumentalized to cause irritation about due scientific practice so that science seems susceptible to be influenced by partisan interests (McIntyre, 2018, p. 128ff.). However, communication must find ways for communicating the essence of stochasticity, that is, that scientific truth claims are neither arbitrary nor representations of wishful thinking; rather their lack of certainty in predictions demonstrates the complexity of the phenomena under investigation (Fischhoff & Davis, 2014).

Furthermore, stochastic modeling can impact perceptions of the seriousness of risk in different ways. In the face of uncertainty, some individuals may take an optimistic view and turn a blind eye toward adverse effects that may happen; others, more pessimistic, may fear the worst. It is a claim often made against climate change mitigation that scientific proof is lacking for the anthropogenic causes of climate change, despite strong evidence supporting the argument (Rosa, Diekmann, Dietz, & Jaeger, 2010). This may also lead to the conviction that in those cases in which scientific uncertainty is communicated, people believe that this is a sign of ignorance or sloppy science. Faced with uncertainty, many respondents may conclude that scientists are just guessing. For example, a national U.S. survey found that 47% of the American public believed that "it seems like almost everything causes cancer" and 71% agreed that "there are so many recommendations about preventing cancer, it's hard to know which ones to follow" (Jensen et al., 2011; Niederdeppe, 2008, p. 488). These perceptions are based on the impression of arbitrariness of knowledge claims about risks leading to devaluation of scientific assessment or paralysis due to a lack of confidence in scientific assessments (Maxim, Mansier, & Grabar, 2013). Absolute certainty is an unattainable and inappropriate ideal when faced with stochasticity. Although this insight is simple, it is challenging to communicate to people who have been educated to associate scientific evidence with proof confirmed by deterministic natural laws.

3.3. Trust in Institutions

Public trust in authorities and institutions has been identified as a significant precondition for effective risk governance (Earle & Cvetkovich, 2013; Löfstedt, 2005; Poortinga & Pidgeon, 2003; Siegrist, 2021; Siegrist & Cvetkovich, 2000). Many adverse effects caused by technology or industrialization, such as the destruction of the ozone layer by chlorofluorocarbons, the effect of greenhouse gas emissions on climate, or health risks caused by pesticides cannot be perceived by our senses. Where individuals cannot rely on personal experience, they need to fall back on mediated information. In this situation, trust in the information source and intermediaries is crucial.

Three general strategies can be identified that individuals adopt when personal experience is lacking. The first strategy is to trust a reference group (Renn, 2005). If people opt for this strategy, they will believe the truth claims made by this reference group, largely irrespective of content. "If people trust the industry or the governmental agencies responsible for regulating a hazard, they may perceive the technology more positively and as more acceptable compared with situations where they lack trust" (Siegrist, 2021, p. 482). However, statistical evidence suggests that loyalty to established reference groups, in particular mainstream political parties or associations is decreasing (Lavezzolo & Ramiro, 2017; Mair, 2013; Pharr, Putnam, & Dalton, 2000). The traditional loyalty to established groups and parties seems to become more and more replaced by alliance to polarized communities that are often supported by internet platforms (Flaxman, Goel, & Rao, 2016). This development can also be observed for voting behavior in Europe and abroad. Established parties have lost a significant number of core voters and are now coveting swing voters (Jun & Bukow, 2020). Although trust in science has been steadfast for many years, this trend also takes in this domain. Trust in science has become a politized issue, in particular in the United States. Republicans have been far more skeptical about trustworthiness of science over the last decade than democrats. Notably, the gap between political partisans expanded sharply between 2016 and 2018, growing from a five-point gap to an

11-point gap (Krause, Brossard, Scheufele, Xenos, & Franke, 2019, p. 819). The impression of general confidence in science has been replaced in large parts of the population by cautious skepticism, suspicion, or outright distrust with respect to the possibility that scientific institutions deliberately or unwillingly misinform or misguide public opinions (Hendriks, Kienhues, & Bromme, 2016). Such suspicions persist but are less prominent when it comes to research activities performed by universities; but they are more pronounced when it comes to industry-related research (van der Meer, 2017).

Under the condition of being worried about the impartiality of information concerning risks, individuals may resort to the second strategy, which is general refusal and opting for a zero-risk strategy no matter the risk or potential countervailing risks (Millstone & van Zwanenberg, 2000; Renn, 2006). As all statements are allegedly biased by partisan interests, no one and no institution can be trusted. Consequentially, people tend toward denial and inaction rather than acting on scientific evidence.

The third strategy involves shifting trust over time depending on the attractiveness of communication sources (Fjaeran & Aven, 2021). This strategy has been termed reliance on vagabond trust (Renn, 2005; 2019). According to this strategy, individuals rely on peripheral cues as postulated by the elaboration-likelihood model of persuasion when trying to make fast and simple judgments (O'Keefe, 2008, Petty & Cacioppo, 1986). Since they are unable to evaluate the validity of arguments, they look for other clues that can help them to judge the credibility of scientific assessments. Those clues include academic titles of experts, elegance of articulation, signs of empathy, or attractive appearance. For instance, talk shows might be used as an anecdotal illustration for this effect. Many political talk shows on Western TV follow an established pattern. They feature a moderator and usually four invited guests. An industry representative in favor of innovation and technology; their opponent, who is often an NGO spokesperson; the representative of a regulatory body or agency; and a celebrity representing the public. Studies indicate that most of the audience cannot remember the arguments that had been brought forth in the discussion, even if they watch these shows for information rather than entertainment (Mattheiß et al., 2013). Although they cannot recall the content, they make inferences about whom they think trustworthy and whose arguments are believable. The judgement about what might be true or false is also driven by the subjective impression that viewers associate with each participant.

3.4. Cognitive Dissonance

Vagabond trust is fickle. Individuals may change their minds often and attribute trustworthiness to different persons or groups over a short period of time. This process may cause cognitive dissonance (originally in Festinger, 1962; Harmon-Jones & Mills, 2019). Cognitive dissonance occurs when individuals experience psychological stress because they hold contradictory beliefs. Cognitive dissonance gives rise to frustration, anxiety, and increasing insecurity. Insecurity leads to heightened risk perception. Individuals are torn between competing cues that affect risk ratings. Individuals deal with cognitive dissonance either by downplaying the conflict and ignoring the risk or the opposite, paying a lot of attention to those risks where they perceive conflicts among the peers to which they relate (for example tobacco risk perception by smokers and nonsmokers, see McMaster & Lee, 1991). This may lead to under- or overestimating the extent of damage and/or probability occurrence of risks depending on personal experience and perceived familiarity. This effect can be observed concerning refugees. Concerns about refugees and xenophobia tend to increase in cases in which refugee arrivals are massive but also transient (Lucas & Renn, 2020). The lack of meaningful interactions with refugees sparks hostility (Hangartner, Dinas, Marbach, Matakos, & Xefteris, 2019). The mechanisms of vagabond trust cause situations of heightened anxiety and may cause a preoccupation with some highly imaginable but rare conventional risks and an attenuation of serious but less visible or definable systemic risks.

3.5. New Communication Media

People's perceptions of risk are often generated and altered by communication. Modes of communicating about risks have changed significantly over the past few decades due to digital technology (Balog-Way, McComas, & Besley, 2020). Digital communication, especially in the social media, differs both from face-to-face interaction and communication via conventional media in many ways. One difference is especially significant for systemic risks. Communication in virtual space makes it easier to avoid the possibility of experiencing cognitive dissonance than conventional modes of communication (Donsbach, 2009). Information can be selected based almost exclusively on one's own preferences. The algorithms employed by search engines and social media generate a flood of suggestions that match user preferences and support making knowledge claims without concern for contrary evidence (McIntyre, 2018, p. 89ff.). Echo chambers offer affirmation and confirmation of existing beliefs so that users may avoid information that might cause cognitive dissonance (Farrell, 2015). Conventional media, such as newspapers, and face-to-face interactions, although far from being unbiased, are less streamlined to support existing beliefs and thus will confront individuals with opinions, values, and beliefs that differ from their own. Individuals relying on social media, therefore, have less incentive to reconsider their positions. Constructive social learning thrives on the respectful exchange and debate of diverging ideas. Under conditions that hinder social learning, diverging beliefs are considered a threat instead of an opportunity, leading to increased polarization (Yarchi, Baden, & Kligler-Vilenchik, 2020). With the selective use of information sources and polarization, groups of people communicate primarily within separate bubbles while there is only limited communication between bubbles. The formation of bubbles can be exploited by individuals and groups who deliberately provide misinformation to further other purposes.

The dilemma of systemic risks is that coping with complexity and diverse interests requires effective negotiation and constructive social learning. However, that same complexity also provides opportunities and incentives to emphasize particular aspects of systemic risks. Yet different aspects will be of interest to people with different concerns. The inertia in the climate change debate is an example. Acceptance or denial of anthropogenic climate change has become a matter of almost religious belief in countries where polarization has taken root (Poortinga, Whitmarsh, Steg, Böhm, & Fisher, 2019). A similar effect can be observed in the wake of the COVID-19 pandemic where a variety of conspiracy theories have gained ground (Collins, Florin, & Renn, 2020).

4. PROCESSES OF SOCIAL AMPLIFICATION AND ATTENUATION

The original motivation for developing the SARF came from empirical observations. In many contexts there can be large divergence between expert and public perceptions of the nature and/or seriousness of a risk, and, significantly, such divergence can impact the risk context by amplifying or attenuating drivers or promoters of risk (Kasperson et al., 1988; Pidgeon et al, 2003). Both risk amplification, that is, the magnitude or probability of a risk is either inflated or particularly emphasized, and attenuation, that is, the magnitude or probability of risk is either downplayed or deemphasized in the public debate, can be observed in actual risk debates (Pidgeon et al., 2003). The framework was not intended to be an explanatory theory. Instead, it is a conceptual map that can be used to organize information about these phenomena to gain a better understanding. The framework was also advocated as a heuristic tool for developing research designs, including hypotheses and variable selection (Renn, 1991).

In its simplest expression, SARF draws attention to three aspects of risk dynamics: perceptions of risk, how communication (as well as communication strategies and communication channels) affects perceptions and responses, and how perceptions and communication affect risk management and shape the potential nature and likelihood of consequences (see Fig. 1). The consequences may relate directly to the risk or to its potential secondary or tertiary effects.

Already in its original formulation SARF anticipated two key aspects of systemic risks: (1) the possibility of feedbacks—that risk management could be affected by changes in perception influenced by earlier management activities; and (2) multiple connections giving rise to secondary and tertiary risks. Subsequent work has revealed another systemic aspect, the complexity and multiple linkages attendant on communication (Sword-Daniels et al., 2018).

These aspects are important, yet they do not provide the full story for relating SARF to systemic risks. Two general questions arise: How can SARF be helpful in the analysis of systemic risks? And how can the characterization of systemic risks inform and help guide the further development of the SARF? Answering the second question is essential to answering the first. The formulations of SARF to date have focused on what happens after an initial event that might serve as a signal. However, the complexities in systems imply that it is not realistic to consider initial events in isolation. The connections with other parts of the system and what is happening in these other parts will strongly influence the subsequent social process. Context matters! Guidance for expanding the focus can be found by looking more closely at the two analogies that inspired the original SARF: the picture of spreading ripples in a pond from an

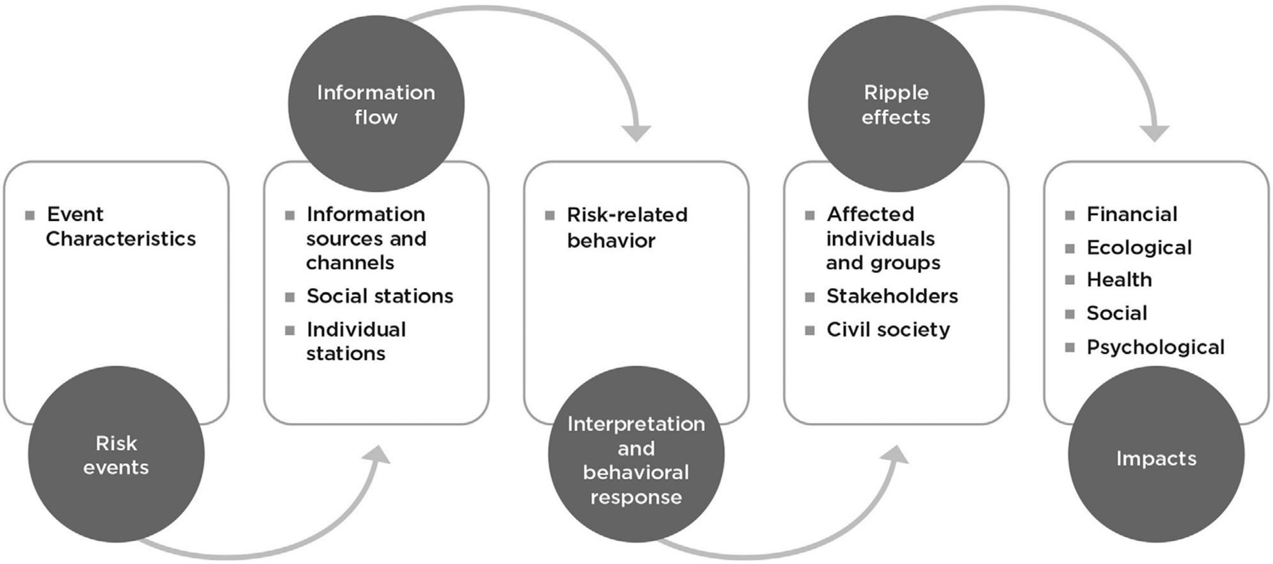

Fig 1. Social amplification and attenuation of risk framework (simplified version based on Kasperson & Kasperson, 1996; Kasperson et al., 1988)

initial event (a dropped stone in the analogy) and an electronic amplifier of a sound system processing an audio signal.

In the original version of the ripple analogy and in much of the follow up the picture was of signals expanding outward (Kasperson et al., 1988). An event could serve as a signal like a rock dropping into a pool. There was also an implicit context to the picture: the image evoked was a still pond (perhaps at dawn or dusk). All was quiet until the event and then we looked for the outward spreading ripples causing direct effects and, as a consequence of these effects, secondary and tertiary impacts. A similar expanding outward outlook was attached to the electronic amplifier analogy. An initial signal was filtered and modulated; it then was distributed as various outputs that were then listened to, interpreted, and, possibly, acted upon. The challenge for the risk community posed by these two analogies was to learn how such signals get filtered and modulated, transmitted, and interpreted under different conditions in different settings (Renn, 1991).

Once we think more comprehensively about systems, however, we need to take account of feedback mechanisms and activity in other parts of the system. The ripples do not just spread outward, they encounter barriers and reflected ripples return. In a complex system, there can be many barriers with differing reflective effects (Cairney, 2012). One can imagine instead of a pristine pool with neat borders, a swampy pond with tree stumps and fallen branches and some rocks and muddy islands. Ripples will travel complex paths. We can extend this image further: the pond is very rarely still; breezes or winds will produce waves; a frog or a fish might jump and cause a splash; there might even be rain; we must not expect to deal only with single events and their ripple pathways; other events, creating other ripple patterns, will occur in the swamp at roughly the same time; the ripples that we will see will be from the interacting patterns of ripples from many sources shaped by the many irregularities in the swamp. In such settings, there are the further challenges of characterizing the background in which signals might appear, characterizing the interactions which will alter signals, and considering how the altered signals will be interpreted when they appear amidst numerous other signals. In the next section we consider tools to aid in doing so.

What guidance does a systemic risk perspective offer for further development of SARF? As suggested by our reimagining the pond and electronic amplifier analogies, the primary contribution will be to support a conceptual shift that will pay close attention to the systemic context in which social amplification and attenuation occurs and to the diversity of framings of risk that can ensue. As we discuss in the next section, analytic tools from systemic risk analysis (especially the decision landscapes from the human side of systemic risk) will be helpful in supporting this change in focus. The first step is to develop capabilities for characterizing the systems, the information processing nodes, the communications links, and the relationships of different actors with and influences on each other.

Another step will be developing capabilities for assessing ongoing patterns of communication, and in what parts of the system do what kinds of information get reinforced, suppressed, ignored, or distorted. The COVID-19 pandemic is a good example where even fairly simple messages about social or physical distancing were either taken extremely seriously, traded off against other risks such as economic losses, repelled as not credible, repressed as not relevant, simply ignored or transposed into one of the popular conspiracy theories (Cori, Bianchi, Cadum, & Anthonj, 2020). In this respect, the role of algorithms in communication platforms in shaping patterns of communication merits more study. More attention to the system context would also be useful to develop a better understanding of how group processes shape individual perceptions and how people balance their use of multiple modes of communication (Krause, Freiling, Beets, & Brossard, 2020). Diversity matters: different people and different groups behave differently, and communicate through different channels, so there will be differing kinds of patterns and balances. Dynamics also matter: all configurations and responses will likely change over time (Horlick-Jones, Sime, & Pidgeon, 2003).

How will an enlarged SARF improve our understanding of systemic risks? From the beginning SARF was conceived as an approach to integrating social science insights about human perceptions, communication, and responses with technological information about risks. The links between the entities that comprise systems of concern are, more often than not, communication links. And the behavior of the entities over time and their responsiveness is shaped by individual and organizational characteristics, knowledge but also perceptions, purposes, and values. The SARF offers an integrative approach to these characteristics. Furthermore, the SARF encourages attention to the role of information and misinformation in system dynamics (see study on social media amplification by Ng, Yang, & Vishwanath, 2018). Hazards are threats to humans and, notably, things they value. Traditionally hazards have been associated with events that release energy or materials. These releases, perhaps modified as they travel, and contingent on the exposure of people or their assets, can directly cause harms of various sorts; there can be further knock-on harms arising from the original damage (Kates, Hohenemser, & Kasperson, 1985). However, early on it has been recognized (see for instance Graham & Kasperson, 1985) that releases (or suppression) of information could also cause harm. Harm could come directly from trauma or other mental pain or from stigma; it could come indirectly from causing individuals or institutions to act in harmful ways or to fail to take necessary actions. The SARF applies to releases (and suppression), transmission and transformation, and exposure to, interpretation, and use of information. It is concerned with direct and indirectly caused harm and with secondary and tertiary consequences. Among the consequences can be effects from actions (or failures to act) that lead to exposure to energy or materials. A famous example from the 1930s and 1940s was flood control efforts in the Midwest of the United States. The information that massive efforts at flood control had successfully controlled normal floods sparked migration into flood plains, and total flood losses (that came from abnormally large floods) rose (Burton, Kates, & White, 1968).

There are obstacles to including social amplification in assessments. One obstacle is analytical difficulty. We have already noted that systemic risks are challenging. Indeed, they are impossible to assess fully. Social amplification/attenuation only adds to the challenge. We thus need new analytic tools to guide assessments (McMillan & Overall, 2016). The second obstacle is institutional. There is little demand for assessments of complex systems with wide-ranging ramifications and there is a natural resistance to the kind of institutional self-reflection that will be needed for assessing social amplification impacts (Goble, Bier, & Renn, 2018). Despite these obstacles there are good reasons to incorporate social amplification in risk assessment, provided the needed capabilities for understanding amplification processes, for assessing them, and for creating management tools to influence the processes are developed. Human and organizational behavior is at the root of most systemic risks and human and organizational behavior is shaped by social amplification/attenuation.

5. THE WAY FORWARD: TOOLS AND APPROACHES

The human dimension of systemic risks consists of many different actors (organizations or individuals) pursuing a variety of activities and interacting with each other. The actors differ in their purposes, their capabilities, their knowledge, and their concerns. The nature of their interactions also has great variety. There are communication links and, sometimes, material ones; there may be strong or weak influences; some connections are formal and legally defined; others are informal. Such complexity is a bar to predictive analysis. Conventional risk assessments may be useful, but only in describing pieces of the system. A similar limitation applies to the use of conventional risk management approaches.

From that perspective, an approach to assessment, management, and governance should have two aspects: (1) capabilities for identifying when and how to use effectively conventional risk assessment and management approaches; (2) capabilities for responding to system complexities where conventional approaches will be inadequate (Renn et al., 2020). New tools will be needed to support both aspects. Such tools should incorporate and further develop insights from the SARF. Assessment tools are needed to help actors better understand the potential impacts from their position in the larger system, to determine when conventional approaches are appropriate and when they are not, and to identify when and where opportunities might be found to gain help and reduce harm from activities in other parts of the system. Because of predictive intractability, the focus should be primarily on risk characterization in support of adaptive approaches to management. Adaptive approaches in turn will require management to have sufficient flexibility to make their efforts adaptable (Klinke & Renn, 2012). When broader system activities are in play, actors must learn to marshal their capabilities for influencing other parts of the system to help. Effective governance will require capabilities for taking broad views of system interactions and the nature of influences.

In this context three descriptive tools promise to improve assessment of systemic risks. In all three, there is both the opportunity and the need to consider social amplification/attenuation phenomena, namely, altered perceptions of risk, the multiplicity of communication channels and distortions in communications, and effects on responses. The tools are still in development; they have been considered mostly for use by experts, that is, the analysts who perform assessments, but, as shall be mentioned in the next section, they have potential for use also in participatory processes in support of governance efforts.

The first of the tools is "decision landscapes" (Blowers, 2007; Webler, Tuler, Goble, & Schweizer, 2015). The idea is to create a picture showing the various actors and their direct connections (influences) as a network. Such pictures should be considered fluid, subject to change as information is acquired or discarded and shaped to the situation of concern. While the first sketch of a landscape might map stakeholders and their interactions, the tool is intended to collect and organize more information. Like a geoinformation system assemblage of layers, the landscape will contain additional information about the actors and their mutual influences such as their capabilities for actions or effects, their goals and incentives, their use of communication channels and the nature of those channels, their knowledge, vulnerabilities, and values. The objective is not to model but, in support of risk characterization, to provide a map, a guide, to help identify opportunities for managing particular risks and to identify for whom and how assessments could be useful. Thus, analysis of actor networks in interconnected complex systems is a key objective for systemic risk analysis (Helbing, 2013). A further objective is to identify the system vulnerabilities and opportunities for coordination and/or collaboration that lie in the realm of risk governance. Critical information pertaining to social amplification will be included within the layered categories (1) by including perceptions as an important aspect of knowledge; (2) by observing communication as a type of influence and communication channels as patterns of linkage; (3) by noting that having triggers for deciding to respond (or not to respond) is among the capabilities for action. With such information available, it should be possible in particular cases to identify situations in which social amplification phenomena are likely to have significant influence and to make some assessment of the nature of the influence.

The second tool is boundary analysis, the systematic examination of the choices (explicit and implicit) made in an analysis (Mattor et al., 2014). Choices are inevitable; when everything is connected to everything else, the system is too complicated to describe, let alone analyze. One set of choices is which actors and which links between them to include. Further choices will be what properties are mapped in various layers. A risk analysis may limit the choices even more by characterizing some potential contributions to risk as too insignificant to consider or by making exclusions based on other reasons (for instance, the risk contribution is too difficult to estimate, or is not acceptable to talk about). A boundary analysis will not provide a guarantee against including too much or too little for the desired assessment. But acknowledging the importance of care in boundary definition, recognizing that many choices are made implicitly, and making a formal effort to examine the choices can substantially improve choices. The boundary analytic task is to make explicit what is included, what is not, and why. We can also consider "soft" boundaries. These can be tentative exclusions for which a limited analysis might give conditions for revisiting the exclusion. There can be different reasons for an analyst's choices for what to exclude from an analysis. Some possibilities are, "didn't think about it," "don't know enough," "considered it unimportant," "considered it not responsive to someone's concerns," or "considered it important, but chose to address it separately." Boundary analysis can provide a framework for explicitly considering the inclusion or exclusion of social amplification ramifications in a risk analysis and for assessing the implications of the choice in terms of the types of risks considered and how much of the system gets considered.

The third tool is identifying and characterizing conceptual gateways or entry points. A gateway (entry point) focuses attention on the space between conceptual realms that are usually considered in isolation (for a generic discussion about gateways to empirical studies see Blaikie & Priest, 2019). While there can be a variety of reasons for isolation, the most common reason is specialization, that is, scientific disciplines claiming particular topics or methodologies as their area of expertise. Medicine and public health are riddled with such specialization and thus offer many opportunities for identifying gateways. In a particular risk characterization process, sources of information and modes of evaluation will be identified, and these can be further characterized based on the extent that they inhabit isolated silos. The characterization of specialized silos and, especially, the gaps between them is pertinent for systemic risks because they reflect vulnerabilities in the assessment process. Risks that do not fit well in a particular silo may be neglected or considered in an unbalanced way. Silo-induced vulnerability is increased with systemic risks. Consequentially, different aspects of risk will be deemed to lie in different conceptual spaces and the likelihood of imbalance in assessment is that much greater. An important example is the delayed attention given to so-called "natech risks," risks associated with the combined effects of natural hazards and releases from industrial facilities (Cruz & Okada, 2008; Cruz, Kajitani, & Tatano, 2015). The gaps between silos also play a direct role in systemic risks through social amplification/attenuation processes. Messages from different silos are likely to be incoherent or even contradictory. Trust will be diminished, and factionalism is likely.

6. GOVERNANCE

What can scientists and science institutions do to contribute to the addressing of systemic risks when confronted by a multitude of conflicting public perceptions and inadequate management strategies? Systemic risks require integrative governance approaches that merge the efforts of many disciplines, organizations, and agencies. Thus, governance of systemic risks needs to be interdisciplinary and cross-sectional (Binot et al., 2015). In addition, it needs to be inclusive (Renn & Schweizer, 2009). It should address the differing concerns, interests, perceptions, and values of many different actors. To help, scientists must be able to participate effectively in suitable governance processes. They have roles to play both in developing information and insights that speak to the wide range of people's concerns and perceptions, and in the design and implementation of constructive participatory arrangements.

One contribution would be the effective creation as well as cocreation of scenarios and simulations as tools for anticipating potential harm before it occurs (Breckwoldt, Gruber, & Wittmann, 2014). Our usual learning mode of trial and error is totally inapt to deal with nonlinear cause–effect chains with tipping points. However, trial and error as a heuristic is deeply engrained in social learning processes (Mathew & Perreault, 2015). So, it would be useful to create simulations in a virtual environment where participants can learn by trial and error. In these virtual surroundings, dynamic systems behavior including tipping points can be simulated and people can experience what it means to trespass these tipping points. These experiences can sensitize people not to wait for negative feedback before changing behavior and lifestyles. Yet this method of virtual preparation for relying on anticipation rather than trial and error will be effective only when the simulations are framed in a form of a plausible, easy-to-grasp, and credible narrative, are accompanied by options and suggestions for personal actions (agency), and/or collective initiatives of how to avoid disaster and provide opportunities for users to include their own preferences and values (Chabay, Koch, Martinez, & Scholz, 2019). The simulations need to be not only scientifically well designed, but also well visualized. Adding to the challenge is that the system behavior is influenced by public perceptions and communication. Thus, creating sensitivity to social amplification and its effects is part of the exercise to anticipate potential impacts before negative feedback is experienced. The task is not trivial and requires a joint effort of modelers, natural scientists, social scientists, communication specialists, and psychologists. It may even be conductive to include professional writers and science fiction authors. Decision landscapes and thoughtful boundary analyses can help guide the effort and can facilitate communication between the participants. For instance, we have used participatory simulation efforts in several studies of our own (Brukmajster, Hampel, & Renn, 2007; Squires & Renn, 2011). To reform fishing rules and regulations for the European Union, we installed a Round Table with major stakeholders, including representatives from the fishing, the fish processing, and tourism industry as well as environmental NGOs to develop options for regulations and measures to improve the sustainability of the fishing industry. These options were handed over to two major research groups specialized in ocean life simulations. They included the regulatory options such as temporary no-fishing zones, early retirement of elder fishermen and women, increasing net-size, and many others in their simulations and reported the results back to the Round Table. Based on these results, the stakeholders had time to reflect on the likely impacts of their preferred policy options. They did question the assumptions behind the simulations but once they understood the fabrics of the simulation methods, they felt empowered to use them constructively in the discourse. In the end, they all agreed on a set of measures that were in line with their basic values but also clearly effective in terms of the impacts revealed by the simulations that were presented to them.

Another example of such a successful participatory simulation effort is the construction of energy scenarios for Switzerland (Brukmajster et al., 2007). In this simulation, various stakeholder groups but also groups of randomly selected citizens were given the opportunity to change parameters of simulation tools for designing their own preferred energy scenario. The simulation tool enabled them to acknowledge and consider the functional and causal relationships between their preferred interventions and the likely impacts on crucial variables such as energy security, ecological impacts, and cost for energy services. This method of empowering stakeholders and citizens to use simulations tools for experiencing the likely impacts of different policies and articulating their own preferences has been further developed into so-called "decision theaters" in which participants design future scenarios aided by prestructured simulations and Artificial Intelligence applications (Boukherroub, D'amours, & Rönnqvist, 2018; Global Climate Forum, 2018; Roach, 1986).

The experiences with participatory modeling and simulations emphasize the need for inclusive and active participation in collective decision making. Once people are engaged in making decisions collectively for their community, they are much more willing and determined to learn about the complexities in which they operate (Renn & Schweizer, 2009; 2020). If people are invited to join a Round Table with other citizens, they become aware that their opinion and their judgment will have an impact on the wellbeing of the community in which they live and they feel accountable for all the preferences that they have articulated (Landwehr, 2021). Evidence suggests that people in situation of collective decision making are (1) more willing to look into more complex relationships and deal prudently with uncertainties and ambiguities (Breckon, Hopkins, & Rickey, 2019), and (2) willing to resolve conflict by looking into the tradeoffs between different options and consider not only the consequences for themselves but also for others who ideally are all represented in the discussion (Niemeyer, 2011). For this to happen we need good opportunities and open spaces that provide such a catalytic service to the communities. Social scientists can help in exploring opportunities for and designing the appropriate institutional structures and processes in which people are encouraged to develop these civic virtues of evidence-informed and value-based production of collective decision making (International Risk Governance Council, 2018). Social scientists can employ decision landscapes effectively in this effort; they must be sensitive to social amplifying, attenuating, and distorting impacts on perceptions and responses. Thus, social sciences must be considered an equal partner among other scientific disciplines in risk analysis and risk management (Kuzma, Grieger, Brown, & Cummings, 2020).

Collective decision making to address systemic risks effectively will require collaboration among members of the public, scientists, and other decisionmakers. Scientists are required to mention and characterize uncertainty, explicitly stress the stochastic nature of what we know, and point out the various ambiguities in the interpretation of complex relationships (Spiegelhalter, 2017). They have the dual task of communicating what can be known about the system and also communicating the justification as well as the limitations for that description, to make the boundaries more visible and pronounced in public discourse (Williams & Noyes, 2007). However, participating scientists must also recognize and acknowledge the limitations of their role as well as in their knowledge claims. Complexity and uncertainty mean that not all scientific questions can be fully answered. Moreover, many critical aspects lie outside the domain of science. People's values matter for any decision. Thus, experiential or tacit knowledge, entangled with people's values must also be respected (Renn, 2010). Societal values and concerns are essential parameters for decision making. Hence, transdisciplinary approaches toward systemic risk research are needed (cf. Hirsch Hadorn et al., 2008; Lang et al., 2012).

7. CONCLUSIONS

Systemic risks pose more difficult challenges in risk management and risk governance than do conventional risks. The challenges come partly from attenuated, misguided, and differing perceptions of risk by the public; they also reflect the very nature of systemic risks in terms of their complexity, uncertainty, and ambiguity. These challenges are sufficiently severe that they are unlikely to be met in a comprehensive manner. There are, however, prospects for substantial progress with significant benefits. Achieving progress will require, among other demands, sustained commitment and effort by scientists and scientific institutions. We want to emphasize several insights expressed in our article. One major obstacle for bridging the gap between the acknowledgment of systemic risk as a serious challenge and the lack of effective actions that are required to deal with these risks effectively is the likelihood of risk attenuation in the public discourse. This phenomenon can be explained by specific heuristics and biases of how most people perceive these risks. In this article, we identified several factors that can lead toward attenuation.

First, most complex systemic risks run counter to our intuition that serious dangers are caused by factors close in space and time. Anything that appears "far-fetched" is also seen as less plausible and obvious than risks where we can immediately recognize the driver in time and space.

Second, science cannot provide deterministic and nonambiguous models for systemic risks. People tend to find information that is associated with uncertainty and ambiguity not very credible, even when the information is based on sound scientific analysis.

Third, effective governance measures require trust in scientific assessments even if they are not obvious to people or reconfirmed by their personal experience. To rely on information that only scientists can provide and that individuals outside of science cannot test by their own means causes a lot of tension. Distrust in science is still not widespread but depending on the issue can increase substantially (examples in Kabat, 2017). Furthermore, as most people are unable to prove the correctness of scientific arguments in a public debate, they tend to use cues for assigning trustworthiness or credibility. Since these cues change over time and are often contradictory, people can feel irritated and frustrated and then prefer inaction rather than risking doing the wrong or the inappropriate thing.

Fourth, misrepresentation of systemic risk is easily reinforced by digital communication tools which bolster echo chambers in public discourse. Consequently, knowledge camps become polarized and differentiated approaches that are crucial for dealing with systemic risks become marginalized.

It is difficult for scientists to work and communicate effectively in settings where these triggers of risk perception prevail. But that is the challenge scientists must meet. There are two types of tasks. One is helping to design and implement suitable collective decision-making processes and institutions which can encourage joint problem analysis. The other is combining analysis with communication, characterizing systemic risks collaboratively so that attenuated perceptions are not triggered, and so that decisionmakers and the public can understand, reflect, and make prudent choices about actions.

The three tools described in Section 5 can help scientists perform these tasks. Decision landscapes coupled with boundary analyses will help in identifying the communities, entities, and interests that should be represented in decision-making processes. Decision landscapes with attention to boundaries and gateways will provide structure to facilitate systemic risk characterization. They can also be used as communication aids in collaborative discussion.

Systemic risks can cause devastating impacts. When attenuated risk perceptions of the public are a barrier to effective action, the risk itself is amplified. Considerable risk reduction is feasible, but it will require acknowledging the barriers created by attenuated and distorted perceptions, assessing their impact, and then making the substantial efforts to cope with those barriers.

ACKNOWLEDGMENT

The authors gratefully acknowledge Roger Kasperson, Michael Siegrist, and the anonymous reviewers for their helpful comments.

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