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GLOBAL RISK MANAGEMENT

THE ROLE OF COLLECTIVE COGNITION IN RESPONSE TO COVID-19

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ROUTLEDGE

1 Collective Cognition in Complex Systems

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The Challenge: Building sustainable resilience to emergent threats

In an increasingly interdependent world, the number, frequency, type, and cost of large-scale disasters have escalated rapidly since the turn of the 21st century. Cascades of damaging events have rippled across cities, regions, nations, and continents, affecting the health, economies, and well-being of the world's population. The size, scale, and severity of these extreme events create a compelling need to design innovative means of risk detection, communication, and action to enable communities to recognize risk and act to reduce threats on a global scale. Increasing capacity to build sustainable resilience to emergent hazards both within and among nations is imperative in this dynamic, interconnected environment (Comfort, Boin, & Demchak 2010; Rivera & Kapucu 2015). This capacity is challenged by a sudden, severe threat to human health.

In the highly uncertain environment that characterized the emergence of the global threat of SARSCoV2, the stealthy, rapid transmission of the novel coronavirus challenged nations in unexpected ways, revealing variance in cognition of risk among nations. Consequently, variance followed in the systems and patterns of response to the spread of a novel disease, and delay in taking preventive action limited options for control and increased exposure to the unseen virus. Communications technologies influenced the flow of information through societies as evidence of lethality of the virus increased. In some instances, the flow of information built social awareness and collective commitment to action to stop transmission of the virus. In other instances, it led to distortion and distrust of actions that were perceived as unwarranted and unnecessary. These dilemmas played out differently among the affected countries and underscore the dynamics generated by the global pandemic.

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Emergence of a Novel Coronavirus and Slow Recognition of Global Risk

The exact date of the first human illness from the novel coronavirus has not yet been verified. The initial observations of a strange new type of pneumonia were reported in Wuhan, China, in early December 2019 (WHO 2020a). The first cases were dismissed as variations of seasonal influenza or pneumonia; only when patients failed to recover with known treatments and required hospitalization, or the illness ended in death, did the physicians in China recognize this illness as a novel coronavirus, different in its degree of lethality and patterns of rapid transmission. There was confusion and disagreement among the physicians and health care workers in Wuhan about the nature of the disease, and the doctor who initially reported it as a novel virus was forced to recant his diagnosis by those who did not recognize its unusual markers. Tragically, this same doctor later contracted the novel virus from patients he was treating, fell seriously ill, and died in Wuhan in January 2020.

The actual notification of the novel coronavirus occurred with a casual discovery. On December 31, 2019, staff at the Country Office of the World Health Organization (WHO) in Beijing, China, read a report posted on the website of the Wuhan Municipal Health Commission of a viral pneumonia in Wuhan. The Country Office notified the International Health Regulations (IHR) officer in the WHO Western Pacific Regional Office and provided a translation of the report. The WHO’s Epidemic Intelligence from Open Sources Office identified the same report from the Wuhan Municipal Health Commission, and the combined intelligence activated the WHO’s Incident Management Support Team on January 1, 2020 to initiate an investigation of a public health outbreak in China. The investigators confirmed a novel coronavirus with an unexpected lethality and named it COVID-19, to distinguish it from the similar coronavirus that caused SARS, SARSCoV1 (WHO 2020b).

While the WHO activated its international response team to investigate the virus, consistent with its mission to protect global health for all UN member nations (United Nations 2020, Health Mission), other factors limited the effort to move toward prompt, effective management of risk from the virus. The novelty of the virus meant that there was no previous playbook. Physicians were discovering critical characteristics of the virus, including its modes of transmission, effects on different types of people, and rates of spread under varying conditions in real time. The deep uncertainty surrounding transmission pathways of the virus, with little explanation for widely varying outcomes and late discovery of asymptomatic carriers, stymied decision makers.

The full complexity of the modes of global transmission of the virus became apparent only in retrospect and in fragmented stages, as recipient countries gradually recognized cases of infection and began to respond with different levels of knowledge, experience, and effectiveness (see daily reports from the Johns Hopkins University Coronavirus Resource Center 2020). This fragmented approach further exacerbated the spread of the infection, as actions taken – or not taken – at one site affected the potential for infection at other sites.

The staggered rate of transmission of the virus, with disparate actions taken in response at different timescales across the globe, created a complex set of interacting conditions that proved extremely difficult to manage in any one location, let alone on a global scale. The larger risk was a complexity crisis in which interdependent systems failed, as constraints imposed by one system interacted with a second, and both affected the performance of still a third system in a cascading series of crises that strained the performance of the whole complex system of systems (Krakauer 2020).

Collective Cognition in Crisis

As the virus spread from city to city within countries and from country to country across the world, it demonstrated a classic collective action problem occurring on a global scale. With no known vaccine or treatment to halt transmission, the only known strategy that proved effective was following basic public health measures of wearing masks, physical distancing, and careful sanitation of immediate surroundings. These simple measures have been deployed in many contexts, but they require basic recognition of the threat to self and others to secure broad public acceptance of risk and voluntary adaptation of behavior to reduce it.

The critical issue is translating cognition to action, a challenge at the individual level, but even more demanding at a collective level (Simon 1962). Cognition is defined as the sudden comprehension of risk that leads to action (Comfort 2007; Comfort et al. 2020b). It is the flash of understanding that structures action and enables an individual to overcome uncertainty and act in a particular context. Guided by a clear goal, cognition is informed by both social and cultural conditions and includes the concept of empathy that recognizes the impact of actions taken – or not taken – on others. Cognition builds the social coherence needed for collective action (Fligstein & McAdam 2012).

In uncertain, dynamic contexts, cognition begins the process of solving complex problems by structuring information to shape action and leads to shared recognition of risk within a community or society. It initiates a collective learning process that enables widespread adaptation to changing conditions in a community at risk. This concept differs from the process of sensemaking that focuses on individual awareness of risk (Weick 1995; Weick & Sutcliffe 2007; Boin et al. 2016) and acknowledges the multiscale complexity of building coherent social action to counter an unseen, but lethal, threat.

Collective cognition emerged as an urgent challenge for collective action, acknowledging that the dimensions of time, scope, and scale vary with the uncertainty of the novel coronavirus. COVID-19 offers a striking case for analyzing the capacity of nations to recognize and respond to a deadly threat. The virus had not been observed in humans before. There is no medical history of the disease, no previous understanding of its mechanisms or means of transmission. Prior to the discovery of a vaccine, the only known means of reducing transmission of the virus was through simple behavioral actions: physical distancing, wearing masks, washing hands, deep cleaning of the immediate environment – practices that have been known and used for centuries (Vicentini et al. 2020). These actions do not require expensive investment, but rather a clear, collective understanding of the risk to self and others and sustained action to slow transmission and isolate and treat cases when they are found.

Collective Cognition in Theory and Practice

Cognition provides a critical link between an individual's comprehension of risk and active engagement in steps to reduce risk (Comfort 2007). In large-scale, dynamic, multi-organizational systems, cognition necessarily shifts from the individual to the social scale to counter shared risk – that is, risk that affects all residents in the community. In the rapid transmission of the SARSCoV2 virus through networks of international travel, cognition of risk from this highly contagious virus is critical to mobilizing effective public action. Recognizing the novel virus as a public threat was especially difficult, as transmission is silent, with no visible manifestations until symptoms appear in an infected person, when the infection has likely already contaminated whomever and whatever objects are in reasonable proximity.

Given the rapidity with which the infection spread, any delay in action to stop transmission escalated the risk. Timing meant the difference between possible control and rampant infection. As cognition is the first – but often contested – step toward controlling the virus, this study focuses on the first six months of the pandemic, January through June 2020. During these early months, knowledge of the virus and its modes of transmission was limited, as nation after nation struggled with the initial task of recognizing when and how the virus had entered the country. The emerging shift from limited acknowledgment to collective cognition of the risk, followed by public communication of responsible actions and mobilization of coordinated programs to reduce the risk, occurred at different rates in different countries. This six-month period defined the early trajectory of crisis operations for most countries in coping with COVID-19 and warrants critical study to reveal signs of success or failure.

Theoretical Concepts Underlying Collective Cognition

Collective cognition is the first step in a broad process of societal learning that includes communication of specific risks and signaling of desired behavior while setting the boundaries of undesirable behavior (Holland 2012). The concept of collective cognition builds on the initial framework of a "knowledge commons" articulated by Elinor Ostrom (1990, 2005), which proposes a shared platform for the search for, and exchange and updating of, information that community members both create and use to solve practical problems.

In action environments, knowledge and the capacity for action are distributed among the many residents, groups, and organizations that make up a community and access information from different sources (Hutchins 1995). Mobilizing diverse actors to address shared risk requires building a collective comprehension of that risk through interactive information exchange and learning that align, based on shared standards of evidence, timeliness, and commitment to a guiding goal.

The Gap between Theory and Practice

The gap between cognition and action has posed a long-standing dilemma in public affairs. Officials inform people regarding risk and provide detailed instructions regarding the reduction of risk; individuals listen, understand intellectually what actions would reduce risk, but fail to act in the context of obvious risk. This lack of action despite public warning is repeated again and again in reference to known hazards – for example, earthquakes, hurricanes, and floods. The gap is even more apparent in reference to an unseen threat such as a deadly coronavirus.

Cognition differs from sense-making in which an actor selects clues from a vague, ambiguous situation to create meaning, reflecting on present or past events (Weick 1995; Weick & Sutcliffe 2007; Boin et al. 2016). Cognition, rather, assesses the situation in terms of who and what are needed to solve a problem and support action in future strategies to cope with an uncertain context. The distinguishing feature of cognition is the capacity to extend knowledge of the risk to others, building collective cognition, or shared comprehension of risk, among many actors to act together to achieve a common goal.

Importantly, collective cognition emerges within a society, not from external orders, but from wide acknowledgment of risk among constituents that demonstrates shared understanding and willing acceptance of changes in behavior to achieve a desired goal. It includes the empathy essential to understand the impact of actions taken – or not taken – on others that is essential to the emergence of social coherence needed for collective action (Fligstein & McAdam 2012). This shared understanding underlies the shift to collective action where individuals voluntarily initiate new behaviors or accept constraints on their usual patterns of action to achieve a larger goal for the benefit of the whole society. Collective cognition extends to broader groups within the society through multiple means of communication and is followed by coordination among different types of activities across different scales of organizations and jurisdictions to achieve control over a threatening situation.

Measurement

To shift from theory to practice, it is essential to document and measure the phenomena that we are seeking to enact. Collective cognition in practice captures a mental shift in the acknowledgment of risk, followed by actions that mark a change from previous behavior. It is measured indirectly by actions taken by broad numbers of people in a society and indicates their shared understanding of risk. For example, collective cognition can be measured by the general adherence to social distancing rules in supermarkets, the drop in purchase of airline tickets as people stopped traveling, and the precipitous fall in hotel bookings and restaurant indoor dining reservations as people followed the general guidance to stay home as the most effective means of stopping the spread of the virus; alternatively, it can be measured by direct surveys, as reported in Chapters 7–9. Not all of these measures were uniform; some were taken in accordance with policies adopted by sub-national and local authorities, but, overall, such actions were taken voluntarily and demonstrated broad understanding of the need for collective action to protect not only oneself, but also others, in a shared effort to reduce risk of COVID-19. Other indicators include the increase in numbers of people searching for information on public websites quickly established to provide valid information regarding the risks of the virus and sources of assistance. Such websites – for example, www.covid19.ca.gov, established by the Governor's Office in California to provide a wide range of information and assistance to residents seeking information – record the number of times the site is accessed and the number of downloads for specific types of assistance to guide action. These are indirect measures of search, exchange, and feedback to agencies that indicate signs of adaptation and widespread learning to support daily operations in a changing, dynamic environment. These indicators are particularly acute in situations of high uncertainty and risk.

The empathetic, emotional content of collective cognition can be documented by identifying the symbols of shared understanding that represent a social goal benefiting the community. In the context of COVID-19, the symbols might include wearing masks to protect self and others from an unknown virus, or spontaneous clapping for first responders every night at 7:00 pm, or baking cookies for the firefighters. Such symbols signal acceptance and support of the shared goal, desired behavior needed to reach the shared goal, and limits to undesirable behavior that threaten the goal for all members of the community.

In summary, collective cognition is composed of three principal components: (1) social comprehension of risk; (2) empathy for others; and (3) use of multiple communications technologies for the continual search, exchange, and updating of information. All three components indicate the human capacity for learning exercised in public space and build the social coherence that is essential for collective action. Collective cognition creates a baseline of shared knowledge regarding risk and shared responsibility for actions to mitigate that risk for the benefit of the community. A fourth potential component of collective cognition is public trust, but that component builds over time as the first three components are exercised in collective action. As collective action produces observable benefits for the whole community, public trust increases and strengthens both collective cognition and action.

Linking Collective Cognition to Risk Conditions

The distribution of capacities, knowledge, authority, and practical experience of both decision makers and ordinary people in a complex system will likely lead to different degrees of collective cognition. Specifically, these differences reflect variance in the capacity of multiple actors to understand the same risk, revealing varying degrees of ability to frame viable courses of action for the same set of changing conditions. Harnessing divergent views and reframing them to enable people to act collectively are essential to achieving effective coordination and control.

Collective Cognition on a Global Scale

Collective cognition is challenging in small groups, in organizations, or in communities, but initiating it on a global scale represents a massive learning process involving myriad actors across the world. Yet, it is precisely this global scale of social learning that is needed to counter novel threats such as COVID-19 for which, during the first six months of 2020, there was no means of stopping transmission other than basic public health measures that require consistent, sustained change in social behavior.

Drawing from a theoretical framework of complex adaptive systems (Holland 1995; Rhodes et al. 2011), this volume examines four basic factors that affect the generation of collective cognition in large-scale, dynamic, multi-organizational, multi-jurisdictional systems: time, space, scale, and energy (Comfort 2019). Importantly, in a global learning process, learning proceeds across space and scale through different perceptions of time, which leads to varying degrees of adaptation in different locations. These factors interact to affect the global learning process.

Complex time

In complex adaptive systems, time may be perceived differently in different contexts, creating syncopation in a global learning process. Actors in different physical locations may acknowledge the same threat simultaneously but perceive the threat with different levels of urgency. Accordingly, they respond in their respective contexts by adapting actions to the same threat based on different perceptions of time and urgency (Krakauer 2018). The result is different patterns of action and performance among the social units, each aligned with their own interpretation of time, but misaligned on the macro scale with the societal goal of shared risk reduction (see Figure 1.1).

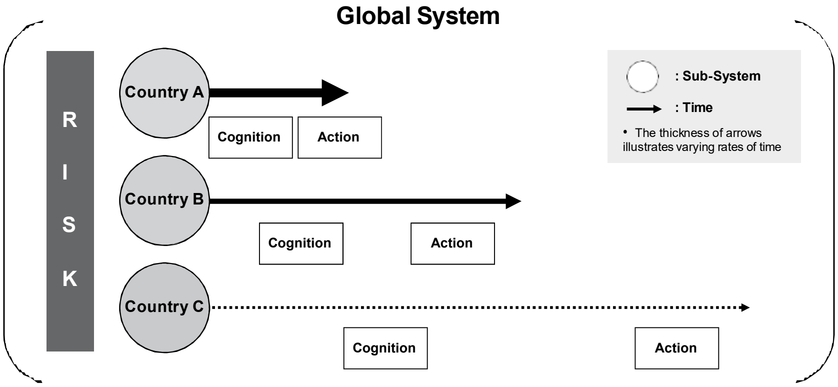

Figure 1.1 Varying perceptions of the same risk in complex time. Diagram by Sae Mi Chang.

For example, South Korea, Japan, and the United States discovered early cases of the threat of the novel virus, SARSCoV2, at approximately the same time, just after the WHO (2020c) announced the discovery of the virus on January 1, 2020. Within days of the WHO's announcement, early cases of infected persons were identified in all three countries, but response to the reported discovery differed. In South Korea, public health experts at the National Center for Disease Control rapidly recognized the risk of widespread infection from a novel virus from their prior experience with SARS-CoV1 and immediately implemented strict measures for testing, tracing, and isolating infected cases (see Chapter 5).

In Japan, the first infected case was considered essentially an isolated instance and was referred to a district health center for local treatment, but it did not merit national concern until weeks later when the number of cases began to escalate (see Chapter 6). In the United States, the discovery of the first case was met with initial wariness and a travel ban for travelers to, and from, China. This action was followed by presidential assertions that the virus would disappear and limited national response, as waves of infection spread across the 50 states (see Chapter 10). These observed, documented accounts illustrate the concept of complex time, where different nations responded to the same risk with very different operations, based on the rate of cognition of the risk by the local political and public health leadership and differing perceptions of time available for action. Given the syncopated cognition of risk from the novel virus in other affected countries, the time lost in instituting measures to control the virus in each country contributed to the spread of the virus throughout the global system, spurring the advance of the COVID-19 pandemic.

Complex time differs from the classic concept of time as a unidirectional, asymmetrical 'arrow' that moves only forward, never back (Layzer 1975). Although activities in different locations proceed ever forward and cannot go back, complex time recognizes many 'arrows' of time that move at varying rates in different locations and scales of decision-making authority. Learning does occur, but the degree of coherence in behavioral change depends upon the processes of communication through which information flows within and among the social units or sub-systems of society. That is, if each country aligned its perception of time available for action to the others' practice in stopping transmission, the countries, as sub-systems of a larger, global public health system, would adjust their actions to one another in a shared effort to minimize the risk of transmission of the virus throughout the global system.

The concept of complex time enables analysts to identify a set of events as interconnected via a common, underlying dimension of information flow that undergirds the shared goal (Glass et al. 2011). This recognition anticipates that successive events in a system under strain are likely to generate either further disruption of existing response actions or activation of new patterns of adaptation within the larger macro system. To the extent that disparate activities relate to the same shared goal, complex time allows the identification and analysis of concurrent processes of learning within the macro system that evolve toward coherent behavior. To the extent that disparate activities reflect different goals, the processes of communication and learning in the sub-systems fracture and strain the overall performance of the macro system. Under strain, the weakened macro system is vulnerable to cascading crises.

Space

In a global learning process, space provides a measure of the distribution of actors across a wide geographical area, the physical distance between them, and the density of actors within specific regions. Space and similarity affect the degree of interaction and learning among actors. Small, homogeneous communities tend to reach collective cognition more easily, as information flows more readily over shorter distances with fewer areas of resistance and in less time. Large, heterogeneous communities tend to fracture into clusters of different perspectives and to move more slowly to accept a common goal (Watts 2003). Mapping the physical space of communities provides insight into the level of daily interaction, but, in large-scale, dynamic systems, physical distance can be overcome by jet travel and electronic means of information exchange. Mapping also provides a visual measure of the extent to which threats, such as a virus, or newly accepted norms of practice have spread. Space, in conjunction with other factors, may either constrain or extend exposure to the deadly virus.

Scale

In complex adaptive systems, the learning process is affected by the scale of operations for which decisions are being made. As the number of levels of decision making increases, the number of interactions among the actors increases, and the possible points of difference among the actors also increase, generating likely variance in the decision process (Simon 1962, 1997). Scale is defined as the structure of decision authority that a society has designed to manage its affairs. In practice, it refers to the size of the unit for which decisions are being made, as well as the quantity of resources required to implement and maintain operations for the population of the area. As scale increases, the complexity of the decision process also increases, and variance in potential strategies further increases.

Communicating the global goal or desired outcome to an increasingly large number of participants to build shared comprehension of a common threat is a critical task in the social learning process. Whether this explanation goes through a complex federal system with states or provinces, counties or districts, and municipalities, each with their own authority to amplify or diminish the content, as in Canada and the US, or is transmitted via a single, unified message by a central authority, as in China and Turkey, the structure of decision making affects the outcome. It is possible to build a unified explanation of a threat through multiple decision levels, but that requires a clear understanding of the problem, credible sources of authority, and valid communication at each level, building a cumulative understanding of both threat and action required to reduce it.

Energy

The fourth, and most vital, factor in initiating and sustaining collective cognition is energy. In social systems, *information* activates cognition and leads to action (Smith 2008; Smith & Morowitz 2018). As information flows through social networks, it represents the energy that activates and sustains a learning process across individuals, groups, organizations, and, eventually, the whole society. Gaps and delays in information flow impede the learning process; false or inaccurate information flowing through the same channels distorts the learning process, creating obstacles and misjudgments that must be overcome. These obstacles and misjudgments lead to further delays or, worse, erroneous decisions that cost lives and livelihoods.

A major task in any learning process is identifying the channels through which information flows as well as the feedback loops that validate, correct, or distort the process. Importantly, the flow of information can produce either positive or negative results. If incomplete, inaccurate, or distorted, information can activate destructive actions that harm the whole community. If corrected and updated, the flow of information becomes the driving force of learning – the energy – of complex adaptive systems. In the complex adaptive systems of systems (CASoS) framework (described in detail below), the feedback loops used by social organizations and technical systems to monitor their respective performances offer a continual process for the detection and correction of error and updating shared knowledge with new information and innovative techniques to support learning.

Generating Collective Cognition

Reflecting on the four factors named above, we argue that this interrelated set of factors – complex time, space, scale, and energy – affects the generation of collective cognition. There is no certain outcome. Each factor has both positive and negative directions. Human choice shapes the outcome in a continual learning process. Guiding that learning process without knowing the future outcome requires articulation of a clear, strong goal that all groups in the society can understand. Acting to achieve that goal without certainty relies on the continual flow of information and the capacity to update and correct outdated, obsolete, or inaccurate judgments about conditions in which we live and to search for new information to reduce the uncertainty of the future. The responsibility for choices made rests not solely with individuals, but also with the context of information generation, circulation, analysis, and feedback that the society creates. The human capacity to learn provides hope. The human propensity for error warrants humility.

Research Design

The CASoS framework developed by the interdisciplinary research group at Sandia National Laboratory (Glass et al. 2011) outlined a series of basic steps that could be applied to any hazard, acknowledging that inquiry is an iterative learning process. The steps include: (1) define the problem under study using empirical indicators; (2) develop a computational model of the problem to determine the logic of interactions among the components (and sub-components) of the system; (3) implement a model of the system in an actual environment to test the logical analysis; and (4) evaluate the observed results, review, refine, and redesign the model in an iterative process of learning. This process has been used by the Sandia research group in the study of the 2009 H1N1 epidemic (Perlroth et al. 2010) and in hazards research for the study of early tsunami detection (Comfort & Dunn 2022).

Ironically, there is a challenge in applying the CASoS model at different scales of response operations simultaneously. For example, actions taken to reduce the transmission of COVID-19 may constrain known practices for coping with other hazards, such as wildfires or hurricanes, deepening the overall complexity for response agencies trying to manage both. Further, different degrees of risk cognition likely reflect the diversity in population, leadership styles, and types of knowledge and experience among professional personnel coping with multiple threats. These differences constrain the flow of information among actors, leading to different patterns of response operations from national to local levels, but illustrating the complexity of the social learning process in large-scale, dynamic systems.

The research undertaken for this book begins with the definition of collective cognition within complex adaptive systems of disaster response. The contributing authors examine this problem in each of their countries using the definition of collective cognition described above and a general framework for complex adaptive systems designed to facilitate the exploration of any complex adaptive system without predefining the computational model that might best suit (Rhodes & MacKechnie 2003; Rhodes & Murray 2007; Rhodes et al. 2011). The general framework consists of: (1) actors, (2) interactions, (3) environmental context, (4) emergent outcomes, and (5) a continuing loop of feedback processes among and between actors and the environment (see Figure 1.2).

This set of interacting components constitutes a system for any socio-technical system operating in a specific environmental context that is subject to changing dynamics. It provides a set of conceptual categories for the case studies presented in this book, enabling comparative analysis of collective cognition across case studies but allowing sufficient flexibility for co-authors to explore different aspects deemed relevant in their respective country contexts.

The concept of collective cognition provides specific guidance for examining the interactions among actors and the successive steps of communication, coordination, and control that lead to the different country experiences in coping with the unknown and emerging risk over time. The variables of complex time, space, scale, and energy are reported at the country level in the international response system described in Chapter 2 and are summarized in the cross-country comparison in Chapter 13. As noted earlier, the creation and exchange of information are central components of the 'complex energy' process; hence, information and communications technologies (ICT) are accorded particular attention.

Measurement and Modeling

Understanding the concept and process of collective cognition is the first step toward designing measures to translate this concept into practice and to model

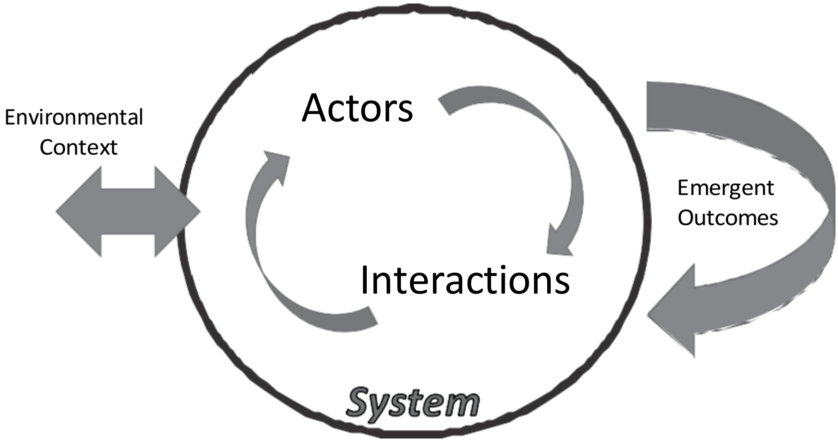

Figure 1.2 General CAS modeling framework. Diagram by Mary Lee Rhodes.

alternative strategies for developing it in actual contexts. Measurement allows analysts to capture the core elements of the collective learning process and to demonstrate change over time and the interrelationships among these elements. In the dynamic social world in which learning moves at different rates in different settings, modeling explores the potential outcomes from different strategies, visualizing possible choices under varying conditions.

Recognizing that collective cognition is extended through multiple means of communication allows the identification of empirical indicators for measuring these phenomena. Communication is followed by coordination of different types of activities across successive scales of jurisdictions and organizations to achieve control over a threatening situation. Empirical indicators include the types of communication used among key actors, the mechanisms of coordination to align actions from different groups to achieve a shared goal, and the feedback, adaptation, and control processes invoked to continue operations in a changing, dynamic environment. Framing the indicators in a logical model to explain the emergence of collective cognition clarifies the process and provides a guide for testing the logic computationally and evaluating the model for implementation in practice.

Multiple Models

The search for a model to provide the clearest explanation of the process of emerging collective cognition quickly leads to the realization that any complex risk situation is likely to be characterized by multiple models over time (Page 2018). Yet, the development of each model follows the same rational process: (1) identify the structure through which the participants/organizations/jurisdictions interact; (2) outline the logic of their interactions; and (3) determine the function that the modeled unit performs in the overall context of the macro system. This rational process of measurement enables analysts to collect empirical evidence of changing behavior in the overall system and to detect emerging trends or clusters of performance that reveal shared comprehension and collective action taken to reduce risk in the wider society. Developing models assists researchers in thinking through complex problems and offers a rigorous means of exploring complex adaptive systems (Page 2018; Glass et al. 2011).

Modeling in a Global Context

Models of collective cognition may differ among countries, given differences in geography, historical experience, structure of decision processes, rate of change, size, economic resources, and cultural values. Models may change within countries as they go through different stages of learning about the risks of COVID-19 and encounter or overcome different sets of obstacles. Not all countries will demonstrate fully specified models of collective cognition, but all countries will likely develop some mode of social learning that leads to some form of collective action. Echoing Scott Page's (2018) description of models observed in social contexts undergoing change, we briefly consider seven types of models or analytical components that may be combined into more complex models to characterize the emergence and evolution of collective cognition in response to the novel threat of COVID-19.

Networks

Social networks are a foundational element of human life, and network models capture the formation and evolution of ties that connect people together and motivate change. The first step in modeling networks is to identify the primary actors engaged in a shared set of activities and document their interactions with one another and with external actors in reference to the achievement of a specific goal. These data allow the analyst to determine the structure of the network, what it does and does not achieve, and, especially, what keeps the network operating. Networks have long been analyzed in disaster response operations (Hu, Khosa, & Kapucu 2016; Comfort, Yeo, & Scheinert 2019; Comfort & Zhang 2020) and represent building blocks for other methods of research.

System Dynamics

Once the basic components of a system have been identified, often through techniques of network analysis, modelers can develop a view of how the overall system operates and the feedback loops and interdependencies within the system. System dynamics modeling offers an overall perspective of the whole system, showing the interdependencies among the operating components. Derived essentially from perspectives developed in economics and business administration, system dynamics models are framed in the language of sources, sinks, stocks, and flows (Page 2018). Framed in these terms, analysts use system dynamics models to guide action in changing conditions. Extending network analysis, modelers first identify the source of change in the system they are studying; they then identify the key components of the system – stocks – and describe the relationships among those components – flows. By including just enough detail from the real system to provide an overview of its operation, analysts discover where it may fail if conditions change and, importantly, where to strengthen the system so it will not fail under greater pressure.

Signaling

Since learning to manage risk involves both social and technical systems, identifying appropriate bridges between the two types of systems is essential to managing change. Given human capacity for choice in any circumstance, guiding that choice in constructive ways, especially to reduce risk, is fundamental in dynamic conditions (Holland 2012). Modeling the process of signaling identifies the choice of signals, the intent that is being communicated, and the audience to whom the intended message is directed. Signals become key instruments for indirect communication of values and willingness to act on those values.

Thresholds of Change

In complex adaptive systems, change may occur gradually, or pressure may build cumulatively over time, and, when the system reaches a threshold point, it may change dramatically into an entirely different state (Solé 2011). These thresholds of change, termed *phase transitions* (Solé 2011), mark inflection points where the system shifts the trajectory of its operations into a different direction or mode. Understanding the development of thresholds as a process of systemic change aids decision makers in anticipating points at which system operations require markedly different strategies of action to achieve its basic goal (Page 2018, Ch. 19). Thresholds of change mark analytical shifts in social action and can be incorporated into more complex models of the larger process of social change.

Collective Action

Building a coherent basis for sustained collective action in practicing standard public health measures is the only viable strategy to slow the transmission of COVID-19 without access to a vaccine (Armitage 2020). Collective action models are especially relevant when the risk is shared, and all members of a community are susceptible to harm, whether they contribute to the action needed to reduce it or not. There is a cost imposed by those who benefit from others' actions to reduce harm when they do not contribute, with potential damage to the whole system (Hardin 1968).

Managing collective action dilemmas has been the subject of decades of research (Ostrom 1990, 2005; Hess & Ostrom 2011) and constitutes a central issue in developing a coherent strategy to reduce widespread risk of a deadly disease. Such models involve developing estimates of the cost of public action if all people contribute, if most people contribute with a relatively minor contingent of free riders, or if increasing costs of non-contributors tip the system into nonviability. In modeling collective action, the relationship between size of the system, its estimated number of participants, structure for participation, and cost of not participating in risk reduction that affects the whole shapes the calculus for this strategy. In complex adaptive systems, the social learning process necessarily focuses on ways to enable participants to discover that their own interests align with the general goal for the whole community.

Learning Systems

Developing systematic models of desired behavior in contexts of social change is a classic means of showing people how to navigate uncertain, difficult situations with the resources and knowledge available. Learning models acknowledge that learning occurs in a social context, so that creating opportunities for people to learn together, reinforcing newly acquired skills and practices, and setting norms of constructive performance contribute to a broad program of social learning. Creating a technical infrastructure to provide easy access to current information, enabling the search for alternative strategies and opportunities, is central to initiating and sustaining an inclusive program to engage the population at risk in developing the skills and mindset needed to reduce risk.

Fitness Landscapes

Fitness landscapes or 'NK' models (Kauffman 1993) have been proposed by scholars in economics, business, policy, and public management as having significant advantages over existing theories in explaining how systems behave in a landscape of infinite possibilities and complex interactions (Nelson & Winter 1982; Levinthal 1997; Rhodes & Dowling 2018). NK models recognize and incorporate evolutionary features and dynamics of adaptation and interaction with the system's environment, which enables complex, nonlinear, multilevel outcomes to be understood and explained.

Fitness landscapes consist of three basic components: (1) independent, heterogeneous organizational agents that seek to maximize individual outcomes by moving around a landscape; (2) a landscape made up of a range of decisions and environmental factors (N) that are interdependent to some degree (K) and that affect the level to which agent outcomes may be achieved; and (3) measures of outcomes that have both individual and systemic relevance. Specifying these three elements enables the creation of sophisticated, dynamic computational models that provide insight into both incremental and radical changes over time and also help to explain how systems get 'stuck' in specific locations on the landscape of possibilities, despite not achieving the maximum possible outcomes desired.

Adaptation and Learning on a Global Scale

The threat of COVID-19 has created a challenge for global adaptation and learning under time constraints that the nations of the world are only beginning to recognize. There is, first, the obvious need for systematic inquiry to push the limits of what is known about a novel disease. Second, there are new tools and concepts in science, such as the rapid decoding of the genome for the coronavirus (Gannett 2019), that make inquiry into the characteristics of infectious diseases more promising in terms of identifying modes of treatment and discovering and testing vaccines that can safely ward off the disease. Third, there are evolving means of building collaborative networks of actors who can both teach others and learn from their experience in coping with this unknown, novel threat. Finally, there is the massive challenge of building a global infrastructure – technical, organizational, and cultural – supported by shared resources of the world's nations to solve practical problems, such as threats to global health.

Three basic questions drive this inquiry. First, what symbols and signals of collective cognition of risk emerged in the ten selected countries regarding COVID-19, and how did the signals differ among countries? Cognition includes communication through indirect signaling of meaning and intent, often more powerful than a direct exchange of words or written orders.

Second, what linked the symbols of collective cognition to practical actions taken collectively among key actors to reduce the threat of exposure to the novel coronavirus? Signals become an essential means of communication when large numbers of people learn to act collectively to reduce risk.

Third, what factors inhibited or enabled the transition from cognition to collective action, coordination, and control in each country? Were there gaps in the information flow, distortions in the transmittal of information, misrepresentation of evidence, or delays in reporting the number of infections or deaths that signal loss of control? In practice, each of these actions interacts with others, worsening the mismatches and threatening system collapse. The question is whether a process of collective cognition emerges in each country, and, if so, to what extent it marks the transition to collective action that could bring the threat under control without vaccines.

Modeling as a Learning Process in Uncertain Conditions

Clearly, all countries experienced the COVID-19 pandemic and responded in varying ways, depending on the degree of collective cognition achieved in their respective societies. We examine these processes of response to explore different modes of learning, coping, avoiding, failing, and adapting to the same threat of the pandemic in actual operations undertaken in ten selected countries and to assess whether clear models emerge to aid in understanding this global event. The intent is to learn from this event to build greater capacity for resilience to other major global policy issues.

To enable comparisons as well as to examine the nature and dynamics of collective cognition in more detail, Chapters 2–12 will examine the different countries' responses to the onset of COVID-19 and their operations over the first six months of 2020, following the integrated framework as shown in Figure 1.3. This framework was developed collectively by the co-authors between April and July 2020 to enable case comparisons that engage with the key concepts described above, while allowing for inter-case variability in identification of models and model elements.

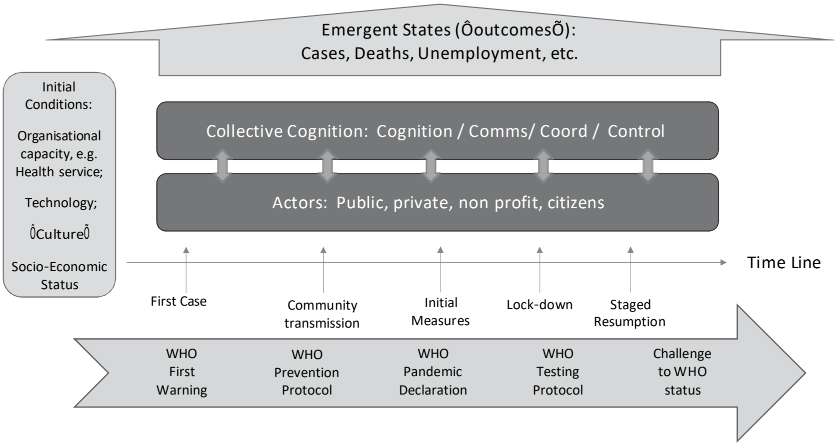

Figure 1.3 Structure of Case Studies. Diagram by Mary Lee Rhodes.

The next chapter, Chapter 2, examines the global system of crisis response as represented by actions and published statements of the WHO and other global crisis response organizations. This chapter focuses mainly on the timeline at the bottom of Figure 1.3 to establish the baseline for other country responses. The following chapters, Chapters 3–12, report the progress of the virus through ten countries on three continents, using the case study framework shown in Figure 1.3. Chapter 13 presents the key findings relating to collective cognition in each country and examines the barriers and enablers that led to collective action and emergent outcomes over the first six months of 2020. These comparative findings will identify key components of resilience to unknown threats through a process of collective cognition, continual learning, and adaptation to changing conditions. Chapter 14 concludes the study by presenting implications of these findings for policy, practice, collective learning, and continuing research in a dynamic, global world.

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