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Social Media and the Virality of Risk: The Risk Amplification through Media Spread (RAMS) Model

Abstract: Social media have transformed traditional configurations of how risk signals related to an infectious disease outbreak (IDO) are transmitted from public health authorities to the general public. However, our understanding of how social media might influence risk perceptions during these situations, and the influence of such processes on ensuing societal responses remains limited. This paper draws on key ideas from the Social Amplification of Risk Framework (SARF), Socially Mediated Crisis Communication (SMCC) model and a case study of the US Centers for Disease Control and Prevention's (CDC) social media management of the 2009 H1N1 pandemic to propose a new conceptual model. The Risk Amplification through Media Spread (RAMS) model brings clarity to the new complexities in media management of IDOs by delineating the processes of message diffusion and risk amplification through communication channels that are often highly integrated due to social media. The model offers recommendations for communication priorities during different stages of an IDO. The paper concludes with a discussion of the RAMS model from theoretical and applied perspectives, and sets the direction for future conceptual refinement and empirical testing.

Keywords: emergency; health; outbreak; risk; social media; viral.

1 Background

Infectious disease outbreaks (IDOs), whether ongoing (e.g. HIV/AIDS) or sporadic (e.g. sever acute respiratory [SARS]), can imperil the physical health of millions of

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people, adversely influence the social fabric of affected communities, and burden economies (Morens and Fauci 2013). During 2003–2012, the Emergency Operations Center at the US Centers for Disease Control and Prevention was activated 22 times (more than once a year) on account of IDOs (CDC 2013). In the first 7 months of 2014 alone, the World Health Organization (WHO 2014) tracked three major IDOs: the Middle East Respiratory Syndrome Coronavirus (MERS-CoV), the avian influenza A (H7N9) virus, and most recently the Ebola virus. Efficient and effective communications are critical to the performance of IDO preparedness, response and recovery programs given the sudden occurrence, unpredictable nature of spread and reach, and uncertainty surrounding prevention and treatment of IDOs.

Between the occurrence of an IDO and its ultimate impact on society, the intervening phase is characterized by a series of sociological processes that define, diffuse, and shape perceptions of the risk posed by the outbreak. These processes involve a range of public health stakeholders and a range of communication channels through which messages about the outbreak are diffused or disseminated.

Traditionally, communications about various aspects of an outbreak (e.g. disease burden, symptoms and illness, potential preventive strategies, etc.) were "produced" by public health authorities and disseminated through a top-down approach to the general public via television, radio or newspapers. This enabled the government and public health entities to exercise most of the control over the available health and risk-related information (e.g. how the outbreak was playing out, who was being impacted, expression of risk levels). Monitoring and surveillance activities related to the IDO were the exclusive domains of health agencies, with their public communications similarly lacking a public feedback mechanism (i.e. a method for individuals, such as patients or caretakers to disseminate outbreak-related information).

The past five years have witnessed a seismic shift in this information scenario, one catalyzed by the global proliferation of social media. Social media refers to web and mobile-based technologies and platforms that enable the content creation, collaboration and exchange by participants and members of the public (Cohen 2011). News, opinions, and stories about IDOs can now spread with the touch of a screen, from an individual through online social networks, to millions of others globally. For example, Twitter, the micro-blogging site recorded nearly 2 million tweets on the 2009 H1N1 pandemic from May 1 to December 31, 2009 (Chew and Eysenbach 2010) underlining the volume of IDO information transmitting on social media. More importantly, traditional and mainstream news and information organizations have evolved to the point where they, too, use social media to create multimedia stories and presentations, graphics, interactive websites and applications, and to obtain information for stories.

Because social media offer easy-to-use and low cost tools that can help public health professionals engage with target populations during health emergencies (Merchant et al. 2011), many public health departments have a dedicated and active social media presence, which they use to communicate with the public and among themselves (Thackeray et al. 2012; CDC 2014a,b; Department of Health [Australian Government] 2014).

Concurrently, cutting-edge innovations that enable the general public to use social media for reporting disease-related incidents have emerged. Signaling the advent of mobile-based participatory epidemiology (Freifeld et al. 2010; Vijaykumar et al. 2013) these innovations use nimble crowd-sourcing technologies to gather IDO-related information from the public in real-time. Examples include Outbreaks Near Me (2010) which enabled users to report knowledge and experiences during the 2009 H1N1 pandemic; and Lwin et al.'s (2014) mobile application that enabled users to report geo-tagged pictures of dengue breeding sites to health authorities in real-time in return for hotspot updates and tailored education.

The role of social media in health emergency communication, particularly the 2009 H1N1 pandemic, the first pandemic in the social media era (Chew and Eysenbach 2010), has been extensively studied (Liu and Kim 2011; Signorini et al. 2011; Freberg et al. 2013). However, we lack an understanding of how social media and different types of social media users might influence risk perceptions during these situations, and the influence of such processes on ensuing societal responses. Also, it is important to understand the level of reliance that public health authorities should place on social media conversations and the usefulness of this information for communication interventions. Finally, we need to consider how public health agencies can best utilize social media in order to influence risk information and perceptions that flow from the online to the offline world (e.g. steps that can or should be taken so that level of public concern is aligned with the actual threat posed by an IDO). Understanding these issues is necessary for designing and implementing effective risk communication in a landscape flush with social media.

This paper address gaps in our understanding of the role of social media in IDO risk communication by proposing a new conceptual model called the risk amplification through media spread (RAMS). We begin by reviewing two frameworks of relevance to IDOs: the social amplification of risk framework (SARF) and the socially mediated crisis communication (SMCC) model. A case example that describes the social media strategies and tools used by the CDC during the 2009 H1N1 pandemic is then presented. Drawing upon key concepts from the SARF and SMCC, and evidence from the case example, we propose and elucidate the RAMS model. The paper culminates with a discussion of the model's theoretical and applied implications.

2 Review of Conceptual Frameworks

2.1 The Social Amplification of Risk Framework (SARF)

The first, the SARF (Kasperson et al. 1988; Renn 1991; Renn 1992; Kasperson and Kasperson 1996; Pidgeon et al. 2003) explicated the processes that underlie how a risk event generates an assessment of the risk, which is then amplified or attenuated through its engagement with psychological, social, institutional and cultural processes. The authors proposed a five-stage model that unravels after a risk event has occurred: sources of amplification (utilize) channels of amplification (which transmit signals that are decoded by) social or individual stations of amplification, resulting in behavioral responses to the risk that can further lead to ripple effects at various levels of the social ecosystem.

Amplification, a term adapted from rhetoric theory, "… occurs when the situation of use … is exploited intentionally in order to enrich the interpretation of utterances" (Nerlich and Halliday 2007), with its converse being attenuation. An example of risk amplification or attenuation in an IDO scenario is when its threat perception is severe, leading to anxiety and worry, or not serious enough, leading to apathy. Social and individual amplification stations include scientists who conduct and communicate technical assessments of risk, risk management institutions, news media, opinion leaders, public agencies, and personal networks of peer and reference groups (Kasperson et al. 1988). These stations use metaphors, statistics and other devices to shape expectations and justify actions pertaining to risk events (Nerlich and Halliday 2007).

The SARF has been used, with varying levels of effectiveness, to study the heightening or softening of risk perceptions related to a range of environmental and health crises (Bakir 2005; Lewis and Tyshenko 2009). However, one of the recurring critiques of SARF has centered on the argument that by using the "amplification" metaphor, there is an implicit assumption that there exists a benchmark level of risk against which this phenomenon can be measured – and that might not be the case. While this argument gains traction in the fuzzy, and at times, ephemeral environs of the social contagion of risk, social media technologies provide the ability to objectively document not only communication events (like individual Twitter feeds), but also provide the ability to use scientific methods to analyze these events (e.g. sentiment analysis) and/or to track their diffusion through digital networks. The use of social media-based infoveillance (portmanteau of information and surveillance) techniques (Chew and Eysenbach 2010) can help generate additional measures of risk perceptions and situate them against clinical levels of an outbreak's

risk to the population, rendering the basic purpose of the SARF stronger in the years to come.

Another recurring critique of SARF has focused on its static or linear conception of communication (Petts et al. 2001; Bakir 2005). Our perspective to this argument emerges from a mass communication lens, and suggests that the linearity of the SARF and its model of effects were in some ways, suggestive of the top-down risk communication practices prevalent at the time when the model was conceptualized. Today, however, social media have created a new playing field for various groups of individual and institutional actors, each of whom has the ability to try to exert influence on information and communication related to an outbreak as it plays out across space and time.

We contend that some of these critiques have partly arisen because of the generic nature of the SARF, and the limitations can be addressed if the framework is adapted to specific problem contexts, such as social media communication during IDOs.

2.2 Social-Mediated Crisis Communication (SMCC) Model and Health Crises

In an increasingly complex media environment, the SMCC model was proposed and empirically tested as a framework that could help crisis communicators decide if, when, and how to respond to influential social media, while also acknowledging the influence of traditional media and offline word-of-mouth communication (Liu et al. 2012). The SMCC model describes the relationships between an organization, key publics, social media, traditional media, and offline word-of-mouth communication before, during, and after crises.

The SMCC model identifies three key publics who seek, produce, or share information before, during, and after crises: influential *social media creators, social media followers,* and *social media inactives* (Jin et al. 2014). Influential social media creators develop and post crisis information online; social media followers consume this information from social media creators and also share this information both on and offline; and social media inactives do not participate actively in the social media, but receive this crisis information via other channels – including traditional media and word-of mouth communication – from social media followers, creators, or other inactives.

The SMCC model also represented direct and indirect relationships in the flow of information. For example, social media inactives have an indirect relationship with social media, receiving information indirectly from followers and creators.

It also emphasized a two-way, reciprocal flow of information. For example, social media and traditional media directly inform one another's crisis coverage with traditional media utilizing information from social media in news development and vice versa.

The model highlights three main forms of crisis communication – social media, traditional media, and offline word-of-mouth communication. The organization responding to an issue/crisis and the key publics are situated in the ubiquitous nature of offline word-of-mouth communication among the organization and social media creators, followers, and inactives. Social media, which may include information from influential social media creators or the organization, have a direct relationship with key publics, the organization, and traditional media, while traditional media have a direct relationship with social media, key publics, and the organization.

SMCC can be applied not only to organizational crisis communication but also risk and health communication, as a theoretical framework explaining how media form and message source, along with other characteristics of key parties involved, make a difference in crisis, risk, and health information dissemination and reception. Specifically, SMCC can be used as a theoretical guide to further explore the following questions: (1) How do publics' motivations to use social media in a health crisis vary depending upon the social media type and platform functionality?, (2) How and why are some social media functions more important to users than other functions during health crises? and (3) How do different types of health crises and publics' demographics affect use and motivations for use of social media?

Beyond identifying why publics use (and do not use) social media in health crisis information seeking and sharing, more research is needed to examine what motivates specific individuals to become influential in creating and distributing crisis information (Fraustino et al. 2014). Additional empirical research is needed to develop an understanding of how an individual or groups of individuals become influential and to map the information flow among these influential social media creators and social media followers and inactives, as outlined by the SMCC model. Such mapping also would allow researchers to evaluate which social media message features are most effective in convincing publics to take protective actions prior to, during, and after a health crisis such as an IDO.

A summary of similarities and differences between the two frameworks, and a snapshot of their relevance to socially mediated risk communication during IDOs is presented in Table 1. Having reviewed the two conceptual frameworks of interest, we now describe a real-world example of a major public health institution's use of social media during a pandemic situation, based on one of the co-authors' first-hand experience and observation.

Table 1: Differences and Similarities between the SARF and SMCC Models, and their Potential Relevance to Risk Communication During IDOs.

	SARF	SMCC
Differences	– Focuses on risk events that pose a specific threat – Postulates that risk perceptions are shaped by social, political and cultural factors – Identifies individual and social stations/actors that amplify/attenuate risk perceptions – Considers media as one of the social agencies/stations responsible for amplifying and diffusing risk perceptions – Postulates that risk amplification leads to primary and secondary effects at different levels of the social ecosystem	– Focuses on organizational crises, the role of media and both online and offline communications – Postulates relationships between organization, publics, and media forms in the context of crises – Identifies specific social media actors who play different roles in the crises communication context – Considers media's presence as central, with a specific focus on the role of social media technologies and actors, as well as how they interact with traditional media – Emphasis more on communication processes as opposed to effects, although effects at communication outcome level can be considered
Similarities	– Conceptualization of the diffusion of risk or crisis perceptions as socially mediated processes – Recognition of the role of social contagion in diffusion of risk perceptions or crises-related messages – Recognition that specific actors in the social ecosystem play critical roles as risk perceptions diffuse through society	
Relevance to IDOs	– Helps to understand public anxiety or media coverage of IDOs like Ebola – Helps to identify specific health system stakeholders (including media) responsible for amplification of IDO risks – Helps to delineate process of effects that IDO-related risk perceptions bear on different levels of public health ecosystem	– Helps to understand organizational response to IDOs from a strategic communication standpoint – Relationships between traditional media, social media and word-of-mouth helps to understand diffusion of IDO risk perceptions – Helps to hypothesize roles and contributions of social media actors in online diffusion of risk perceptions

3 Case Analysis: CDC's Use of Social Media in the 2009 H1N1 Pandemic

3.1 Overview of the Case

In mid-April 2009, a new strain of influenza (ultimately termed 2009 H1N1) was identified in a 10-year-old California patient. On April 21, 2009, CDC announced that it had identified the new strain in two patients, including the 10-year-old (CDC 2009). In the hours after this initial press conference, it was learned that health officials in Canada had just determined the strain was responsible for much of the influenza illness that had been occurring in Mexico. On April 26, the US government declared 2009 H1N1 a public health emergency. By June, 18,000 cases of H1N1 had been reported in the US and a total of 74 countries were affected by the pandemic. The WHO declared a pandemic on June 9, 2009. By November 2009, 48 states had reported cases of 2009 H1N1 and limited supplies of vaccine were made available. Ultimately, CDC estimated that 43 million to 89 million people had 2009 H1N1 between April 2009 and April 2010, with between 8870 and 18,300 H1N1-related deaths. Around 80 million people in the US were vaccinated against H1N1 (CDC 2010).

CDC's public communication response began in earnest on April 23 when CDC commenced the first of what would eventually be more than 60 press conferences related to 2009 H1N1. The major goals of CDC's pandemic communications were to 1) provide information and guidance that would help prevent or limit the spread of the disease; 2) to maintain trust and confidence in CDC and public health through constant information provision; 3) quickly identify and address questions and concerns; and 4) foster awareness and adoption of recommendations, including vaccination as vaccine became available. The initially daily press briefings, along with dozens of media interviews each week with top CDC officials and scientists, provided high visibility and reach for CDC's information and guidance as well as served as the foundation for a multi-faceted health and risk communications response. Over the course of the pandemic, CDC's health and risk communication response entailed frequent media briefings and interviews, extensive use of the Health Alert Network to reach clinicians and health care providers, collaboration and coordination with a wide range of partners (e.g. state and local health departments, including public affairs, health care provider organizations), public service announcements, posters and flyers, a dedicated 2009 H1N1 website, frequent updates and online trainings for health care providers, a hotline, and use of social media tools and channels (Kim and Liu 2012; National Collaborating Centre for Methods and Tools 2011; Walton and Seitz 2012; Pistol and Streinu-Cercel 2013).

While news and traditional media were the primary means that CDC used to provide updates, guidance, key messages and resources to an array of partners and audiences, social media were a part of the response from the beginning. It was quickly determined that social media could help CDC in its efforts to provide timely health and risk information to as many people as possible. Social media enabled CDC to rapidly provide information and updates, reach people not typically reached via traditional media channels and outlets (e.g. younger people), tailor messages and materials, give people access to information on demand (e.g. via YouTube), get feedback from members of the public, and foster consistency in messaging and guidance among the many people and organizations that were providing 2009 H1N1-related advice and information, especially influential and interested social media users (Smith 2009).

3.2 Social Media Strategies and Tactics

As with the messages and materials disseminated via traditional media, social media communications and efforts were guided by risk communication principles, including 1) be as a candid as possible and foster transparency of information and efforts; 2) foreshadow possibilities (e.g. with respect to how the pandemic or public health recommendations could play out); 3) share dilemmas (e.g. how to use the initially limited supplies of vaccine); 4) express empathy for those affected; 5) put risks into appropriate perspective and 6) accept and involve the public as a partner in coping with the pandemic.

The specific social media that CDC used to disseminate these messages during the pandemic included:

– *RSS or really simple syndication* – this enabled interested people in the US and around the world to subscribe to the main CDC website or any of its components, such as the Division of Media Relations page. Tens of thousands of people used RSS to get updated pandemic flu information from CDC and it was estimated that RSS feeds fostered over 37 million views of CDC H1N1 information.

– *Content syndication* – this enabled health departments, hospitals and any entity with a website to subscribe (for free) to CDC webpages with 2009 H1N1 information and to display that information on their website. The benefit of content syndication was that when CDC updated a page, the information was automatically updated on subscribers' pages without the need for human involvement. Content syndication provided a streamlined process for disseminating risk and health information on thousands of websites. It was estimated that content syndication resulted in over 400,000 views of CDC information by December 2009 (Smith 2009).

- *On-line video sharing, primarily via YouTube* – In the course of the pandemic, CDC produced and posted 32 videos covering 2009 H1N1-related topics, which were viewed more than 3.13 million times. The most popular video, "Symptoms of H1N1" was viewed more than 2 million times and ranked in the top two videos across YouTube in the news and science category (National Collaborating Centre for Methods and Tools 2011).
- *Social Networking sites* – CDC began using Twitter in October 2008 for posting information and updates related to seasonal influenza, but initiated its Facebook page at the beginning of H1N1 flu outbreak (Biswas 2013). The Facebook page was used to share H1N1 and seasonal flu updates, provide social media tools such as badges and widgets for users to download and share, and post blogs from CDC experts. By December 2009, the CDC Facebook page had around 53,000 fans. CDC used three Twitter pages, with two focused on H1N1 situation updates and information on diagnosis, treatments and prevention. By December 2009, CDC had 1.18 million Tweeter followers and over 400,000 clickthroughs of flu-related tweets.
- *Buttons, badges and widgets* – the applications were used to enable partners and interested parties/people to post information on their websites of the steps that could be taken to prevent the spread of 2009 H1N1 and seasonal flu. Eleven flu-related widgets provided interactive resources, including seasonal flu updates, school guidance and an interactive quiz. CDC flu widgets were viewed more than 5.5 million times by December 2009 (Smith 2009).
- *Podcasts* – both audio and video podcasts were produced and available from the CDC website and through the iTunes store. By December 2009, the 2009 H1N1 podcasts were viewed a total of 2.67 million times.
- *eCards* – electronic greeting cards were created and developed so that individuals could send flu-related health messages to family members, friends and co-workers. By December 2009, over 22,000 eCards had been sent resulting in an estimated 103,000 views.

3.3 Impact and Lessons Learned

The above statistics on the online viewing, usage and sharing of CDC's social media tools allude to the impact of CDC's social media efforts on the level of engagement with the general public. While no studies have been conducted yet on the impact of CDC's social media efforts on psychosocial and behavioral outcomes pertaining to the 2009 H1N1 pandemic, most of the H1N1-related messages that CDC disseminated through social media fell into one of five categories: 1) investigation/diagnosis; 2) preventive and safety measures; 3) treatment;

4) situation updates; and 5) promotion of web-based communication services and tools (e.g. video podcasts, widgets, virtual news briefing, press conference transcripts) (Biswas 2013).

Alongside its own initiatives, CDC was monitoring social media content on H1N1 and found that 16.2% of YouTube videos on 2009 H1N1 were misleading with the following themes: anti-vaccination messages, conspiracy theories about "manmade" H1N1 virus, government propaganda, and exaggerated H1N1 risks (Gesser-Edelsburg et al. 2014). Most critically, the social media strategy was successful in strengthening public perception of CDC's trustworthiness. Research showed that CDC's quarterly score in the American Customer Satisfaction Index jumped from 74 to 82, and "people who used social media … rated CDC as more trustworthy than those who did not use CDC's social media tools" (Reynolds 2009).

In terms of lessons learned, it was traditional media that played a far more significant role, especially for CDC. CDC led with traditional media because their scope, reach and influence were far greater than Facebook or Twitter at the time. Large news media organizations and entities have online and social media platforms that are far more effective and powerful than those of individuals who blog, tweet or post on Facebook pages, especially when it comes to IDOs. Most of CDC's key risk communication messages are designed and disseminated via traditional media and partners and then re-purposed for use in social media. Also, the real-time, interactive nature of social networking media make it challenging for government agencies to provide responses in-real time to individuals, as most government messages require review and clearance. Finally, social media that reach and involve experts, such as blogs and the FluWiki Forum can be extremely useful for learning what other experts and interested parties are discussing.

4 New Conceptual Model: Risk Amplification through Media Spread (RAMS)

Drawing key ideas from the SARF and SMCC model, and evidence from the above case analysis, we propose the RAMS model presented in Figure 1. This model disambiguates the communication processes, the pathway of media influences, and the role of social media in influencing risk perceptions among the general public in the event of an infectious disease outbreak. The model's nomenclature is intended to portray the diffusive movement of risk messages and perceptions through media channels. The word "amplification" has been chosen to be consist-
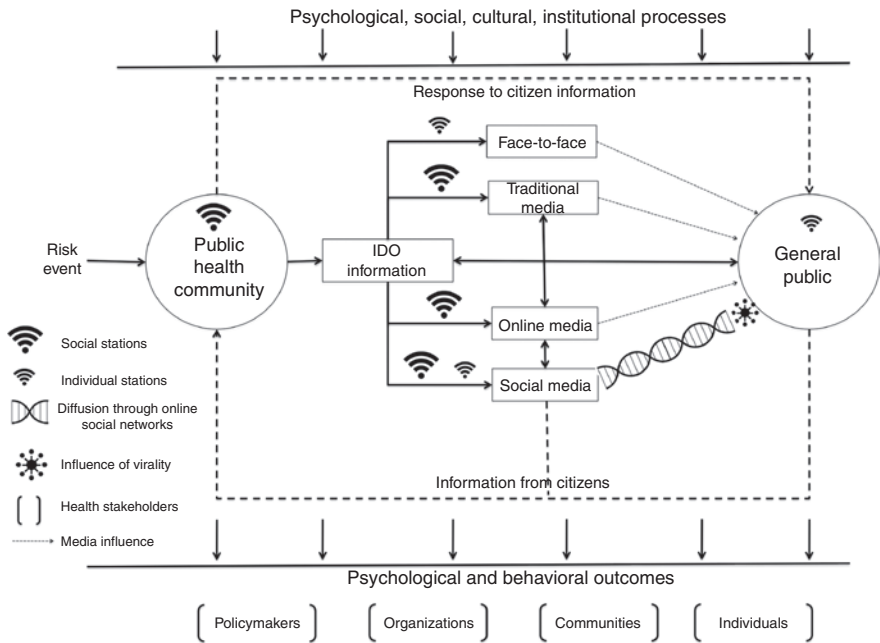
Figure 1: The Risk Amplification through Media Spread (RAMS) Model.

ent with the vast amount of literature on SARF, although the model is designed to include its variants: attenuation/de-amplification and maintenance. Next, we use the generic word "media" instead of the specific "social media" (the focus of this paper) in recognition of the integrated nature of media channels in today's communication environment. Finally, the term "media spread" does not refer to structural penetration of media channels but rather, the spread of risk perceptions through media in a manner, amplified or otherwise. Before elucidating the model, we present an operational definition of its key components:

4.1 Definitions

Risk event: We define a risk event as any instance of an infectious disease case or outbreak (IDO) that the public health community has confirmed through laboratory testing, and one that has the potential to spread through a social system, thereby posing a real or perceived threat to the health of the general public.

   Public health community (PHC): The public health community includes all actors who are involved in governmental and non-governmental public health

institutions and organizations (primarily health departments but also including community-based organizations), and the scientific community consisting of researchers who directly or indirectly examine or comment on issues related to public health.

Infectious disease outbreak (IDO) information: IDO information includes factual or opinion messages related to any scientific, social, physical or mental aspect of infectious diseases.

Traditional media: We define print and broadcast media as the physical forms of print and broadcast media, not connected to the Internet, such as newspapers, magazines, television and radio.

Online media: Online media refers to Internet-based media channels such as websites that are "static" (i.e. not allowing for nor providing tailored information), and not interactive in the sense that users can input information and get customized guidance or advice.

Social media: Social media refers to web and mobile-based technologies and platforms that enable content creation, collaboration and exchange by participants and members of the public (Cohen 2011). We include traditional media that have websites and utilize social media to promote stories, disseminate stories or solicit input for stories.

The RAMS model considers a typical IDO scenario where one or more public health agencies, in collaboration with clinical experts, confirm a case or cases of a potentially harmful transmissible disease. From a public communications standpoint, the public health authorities devise a risk communication strategy commensurate with the type and level of current and potential threat the infectious disease poses to 1) people who may have been exposed (e.g. by being in close recent contact with an infected individual or individuals); 2) the local population or community; and 3) the broader public (e.g. recent air travel by infected or infectious people can have implications for cities beyond those that have confirmed cases). We postulate that the PHC usually disseminates their messages by engaging any or all of four main communication channels: face-to-face (F2F, such as community awareness workshops or town hall sessions), print and broadcast media, online media (organizational websites providing in-depth non-interactive information) and social media (including social networking sites and others). The variety and types of messages are not explicitly stated in the model as they would likely include a range or combination of themes from basic information about the modes of transmission, the global and local burden of the disease, preventive actions to be undertaken by the potentially exposed individuals and the public, to updates about the outbreak situation. Apart from factual information, messaging could also potentially include opinion-based communication such as commentaries by experts in the academic community.

4.2 Process of Media Spread and Flow of Influence

From this stage, the model seeks to explain the process of media influence on risk perceptions among the general public. First, we postulate that face-to-face messaging (e.g. a community meeting in the aftermath of a confirmed case of viral meningitis) or the initial stories in print and broadcast media outlets (e.g. about a person infected with a novel influenza virus) would influence risk perceptions among the general public either directly (e.g. those individuals who attended the community sessions or viewed/read/heard initial news reports) or indirectly (through a process of social contagion).

Second, we suggest that traditional media often further diffuse messages (comprising official information from the PHC as well as their own news reports) through offline, online and/or social media channels. For example, a print news organization can diffuse information and messages through the printed newspapers, their website(s), social media widgets on their website, or share links to the news articles on social networking sites (as many journalists do). Communications through each of these avenues influences knowledge and risk perceptions among members of the public either directly (through direct exposure to the messages) or indirectly through social contagion.

Third, we postulate that IDO information is disseminated through static websites ranging from websites of public health authorities directly involved to other public health authorities (e.g. state and local health departments not yet directly affected) to university and academic journals. This information typically includes statements and press releases about the infectious disease and its transmission. These communications can influence risk perceptions among members of the public either directly (for instance, individuals who actively seek this information on the WHO's websites) or indirectly (through social contagion).

Fourth, and most importantly from the perspective of this paper the PHC community disseminates IDO risk information directly through social media channels. In terms of public communication, the distinguishing aspect of social media as opposed to other forms of media is that it enables instantaneous sharing of messages through online social networks, referred to in common parlance as a "message going viral." This phenomenon merits further explanation.

4.3 Understanding Virality

Virality, now commonly used in the context of online content, was derived from infectious disease terminology that refers to the spread of a biological virus (Goel et al. 2013). From an online information transmission standpoint, the traditional

approach was to focus on virality in terms of access, electronic word of-mouth (eWOM), or engagement. Taking a user-centered behavioral approach to define virality, Alhabash and colleagues (2013) defined virality by identifying features of user interactivity with a persuasive message associated with "affective evaluation (likes), viral reach (comments), and message deliberation (shares and views)" (Alhabash and McAlister 2014). Encompassing the above perspectives, virality, in our context, refers specifically to the potential for a message to spread across online social networks through a process of online social contagion (person-to-person sharing) by contact between individuals who have the message and those who do not. Goel and colleagues further deconstruct the metaphorical components of "virality" by explaining that an infectious agent (an idea or a message) is spread from the "infectives" (those who have it) to "susceptibles" (those do not) (pp. 1–2), much akin to the case of an IDO. The double helix in the model represents the non-linear (and at times, exponential) diffusion of risk information through online social networks while the node with the spokes indicates the virality of messages.

Different messages achieve different rates of virality based on a range of message characteristics, such as valence and the ability of the content to evoke positive or negative arousal (Berger and Milkman 2012). The SMCC model adds another dimension by identifying three key segments of publics – influential social media (content) creators, social media followers, and social media inactives – based on the extent of influence and engagement they exert in the social media sphere. We incorporate this aspect to suggest that social media user types influence rates of virality of IDO information (and thus risk-related communications). For instance, we can hypothesize that key social media influencers might catalyze the highest rate of message virality, followed by social media followers and social media inactives, in that order. Along with directly influencing risk perceptions among members of the general public, message virality can indirectly affect social conversations and in the process, shape risk beliefs and perceptions. In addition, given the features of social media and the recent definition of information virality via social media, social media (content) sharers might be a fourth key public group, who might not necessarily create content but actively share content via social media to social media followers and via traditional media to social media inactives, thus gaining influence.

4.4 Communication Priorities during the Stages of an IDO

Based on literature and insights from IDO communication experience, the RAMS model provides a set of recommendations for communication priorities during the stages of an IDO (see Table 2). The key components of this table of recommen-

Table 2: Recommendations for Communication Priorities during the Stages of an Infectious Disease Outbreak.

Communication Channel Priorities	General Stages of an Infectious Disease Outbreak				
	Preparedness	Initial Case or Cases	Increasing Number of Cases	"Outbreak" – Many Cases in Many Places	"Recovery" – Significant Decrease in Number of Cases
Online media	– Make available information on likely or potential disease threats – Utilize RSS to build and foster information sharing network – Build awareness, visibility and use of online media (e.g. your website)	– Be transparent; provide accurate information as soon as possible – Use risk communication principles to guide expectations – Add information, including FAQs	– Use to foster transparency and to provide more frequent updates – Provide more guidance information to website – add links to others – Offer content syndication – Use analytics to inform messages	– Provide frequent updates on who is affected and recommended preventive actions – Provided tailored information for specific groups and regions – Add resources for responders – Use analytics to inform activities, messages	– Provide updates on a less frequent basis (e.g. weekly) – Provide information that helps people – Provide information on effectiveness of actions taken
Print and broadcast media	– Develop and assess response templates and materials (e.g. press releases, key messages) – Create B-roll and visuals/graphics that would foster response – Establish and maintain list of key media	– Provide background information and materials on disease and its transmission – Use media briefings to help guide expectations – Provide on-camera access to experts	– Increase engagement, including access to experts – Provide media with other experts who can provide perspective – Consider background briefings – Increase/use availability of B-roll, visuals	– Make effective media access and engagement a high priority – Identify key experts and spokespeople who can be available on a daily basis – Develop and provide materials that can increase understanding	– Continue to make effective media access and engagement a priority – Prepare for, and address, skepticism and doubt regarding decline – Provide information that puts outbreak into context

Table 2 (continued)

Communication Channel Priorities	General Stages of an Infectious Disease Outbreak				
	Preparedness	Initial Case or Cases	Increasing Number of Cases	"Outbreak" – Many Cases in Many Places	"Recovery" – Significant Decrease in Number of Cases
Word-of-mouth	– Identify likely opinion leaders and key influential – Cultivate trust – Consider background briefings for key external sources	– Provide likely opinion leaders, key influential with background resources – Share key messages externally	– Share key messages externally (e.g. post on website, send to partners) – Provide real-time access to press briefings	– Share key messages externally – Provide real-time access to press briefings – Engage directly with health care providers, key partners, affected communities	– Continue to provide updates and information – Use surveys and other research to assess effectiveness of communication efforts and engagement
Social media leaders and creators	– Identify likely leaders/creators – Establish relationships – Cultivate awareness and trust	– Provide with background resources – Create materials for social media sharing	– Listen: monitor social media to identify presence, needs, misperceptions – Share key messages and provide real-time access to experts	– Listen and Learn: monitor social media to identify presence, needs, misperceptions – Engage with social media leaders and creators	– Learn: monitor social media to identify presence, needs, misperceptions – Access value and effectiveness of social media activities
Social media followers	– Cultivate awareness and trust – Use social media and create social media presence – Use to identify social media leaders and influential social media creators	– Use social media channels to provide current and helpful background information – Build awareness -promote your use of social media as a source of information on the topic/disease	– Use social media channels to provide current and helpful background information – Continue to build awareness -promote your use of social media as a source of information on the topic/disease	– Directly address - take steps to increase social media engagement and visibility (e.g. Twitter chats) – Listen and Learn: Increase monitoring of social media to identify concerns, questions, misperceptions	– Learn: monitor to identify understanding and to identify current or lingering issues and concerns – Continue to use to provide information and updates

Table 2 (continued)

Communication Channel Priorities	General Stages of an Infectious Disease Outbreak				
	Preparedness	Initial Case or Cases	Increasing Number of Cases	"Outbreak" – Many Cases in Many Places	"Recovery" – Significant Decrease in Number of Cases
Social media inactives	– Cultivate awareness and trust – Use social media and work to create social media presence	– Build awareness – promote your use of social media as a source of information on the topic/disease – Use social media channels to provide current and helpful background information	– Listen: monitor social media to identify reach, presence, needs, concerns, misperceptions – Continue to build awareness – promote your use of social media as a source of information on the topic/disease – Use social media to promote online resources – Listen: monitor social media to identify reach, presence, needs, concerns, misperceptions	– Highlight social media use and availability – Directly address – take steps to increase social media engagement and visibility (e.g. Twitter chats) – Use social media to promote online resources – Listen and Learn: Increase monitoring of social media to identify concerns, questions, misperceptions – Highlight social media use and availability	– Learn: monitor to identify understanding and to identify current or lingering issues and concerns – Continue to use to provide information and updates

dations are based on the main pillars of SARF and SMCC model, which also serve the founding blocks of the RAMS model.

On the one hand, RAMS recommends tailored communication activities according to different stages of an IDO, from preparedness, initial case(s), increasing number of cases, "outbreak" (many cases in many places), to "recovery" (significant decrease in number of cases). On the other hand, RAMS recognizes that depending on different IDO stages, different communication channels (e.g. online vs. offline), media forms (e.g. print and broadcast media), and key social media publics (e.g. social media creators and followers) play different roles in IDO information spread. Public health information officers and communication practitioners need to understand the nature of each communication channel and media form, be prepared with tools that can timely be implemented at each stage, and synergize the strength of each interface of media spread in order for the accurate IDO information to be clearly and timely communicated to affected individuals and communities.

4.5 Theoretical Implications

The RAMS model accounts for future developments in the infectious disease emergency management domain by depicting two potentially influential pathways. First, we account for emerging investigations into the co-creation of health educational content (individuals contributing to message design) by depicting a direct pathway from the general public to the IDO Information box. This echoes the paradigm shift in strategic communication called for by Botan and Taylor (2004), moving from functional approaches to more co-creational approaches, with genuine interest and concrete emphasis on how publics create and share meaningful messages on issues. This audience-oriented co-creational approach to health and risk communication recognizes and emphasizes how social media has changed the way organizations and publics communicate to each other and among themselves, and more importantly, how organizations and publics co-create meaning through the social-mediated health and risk information they share and manifest online and offline. Second, we depict the emerging domain of technology-driven participatory epidemiology (described in the literature review) through the dashed pathway showing disease-related information flowing from the public to the PHC, and a feedback loop of response from the PHC to the public.

From the classical SARF, the RAMS model incorporates three aspects. First, we depict how psychological, social, cultural and institutional processes influence the entire diffusion process of IDO information through multiple channels to the intended audiences. Second, the RAMS model identifies a dynamic flow of

information between two types of amplification stations: the social amplification stations consisting of the PHC and print and broadcast media, and individual amplification stations that comprise of members of the general public. The model identifies social media as both a social *and* individual station of amplification, as social media have the potential to host collectives of users (groups, communities) as well as individual users. Lastly, we adapt the SARF's model of ripple effects and impacts to focus on two specific and related outcomes of the risk amplification process: psychological and behavioral. Also, we adapt SARF's multi-level model of effects to public health by suggesting that these outcomes affect four specific levels of the public health ecology: individuals, communities, institutions and policymakers.

From the SMCC model, we adapted the concept of transitions of modern communication processes between face-to-face interactions, print and broadcast, online and social media. Although our primary focus remains on the role of social media during an IDO, our model, similar to SMCC, describes the role of social media in the fully integrated context of online and offline communications as well as the interconnected networks comprised of different forms of media and different sources of content creation and sharing. Therefore, the RAMS model recognizes the presence of a complex, highly integrated, media scenario offering multiple affordances to the user at once. Inheriting the publics-oriented approach from SMCC, the RAMS model identifies primary information sources during the IDO information spread: public health community and the publics, among whom influential social media creators and followers are actively engaged in risk communication activities, supplying, receiving, and processing information both ways.

5 Summary and Future of RAMS Research

Recent IDOs have revealed fundamental challenges to the management of communication efforts in the 21st century's hyper-connected age, where social media cannot be ignored. The RAMS model, proposed in this paper, is the first step in bringing clarity to our understanding of the transmission of risk perceptions in a complex, often integrated media world. We discuss this model in terms of its value to the two frameworks that have informed its conceptualization and its practical utility to public health emergency efforts during an IDO.

In putting forth this model, we extended the domains of the SARF and SMCC model, and in the process, opened new lines of theoretical inquiry. The original and revised versions of SARF were developed when the Internet was either a

publicly inaccessible tool, or was in its nascent stage (the web 1.0). The RAMS model depicts how the presence of social media can alter the prevailing pathways of risk signals (i.e. IDO messages) through its multimodal and "viral" capabilities, and thereby influence the amplification, attenuation or maintenance of risk perceptions. We demonstrate how distinctions between social and individual stations of amplification might be blurring with the emergence of social media. Most importantly, we addressed one of the main limitations in the SARF model, that of the linear depiction of the risk amplification process. By accounting for integration between different media systems, future technological developments enabling the emergence of circuitous communication channels, and the viral structure of information diffusion, we demonstrate that the risk amplification process in the current media landscape is dynamic and complex rather than linear.

The RAMS model also expands the SMCC and addresses some of its limitations. For instance, SMCC in its current form presents how one organization communicates about crisis information with key publics in a social-mediated context. The RAMS model introduces the concept of "social station" of publics, such as the PHC, which is especially critical in examining an IDO communication situation where multiple organizations are involved in information dissemination and public health crisis management. Within each "station," whether being in the public station or in the public health community station, the group segments might create alliances, form coalitions, or create competition or even escalate conflict among themselves, depending on the situation. Thus, the expansion of the actors or key players in the new framework advances the scope and depth of the current SMCC.

Further, the RAMS model focuses on the creation, process and impact of IDO information virality, taking both computer interfaces and mobile technologies into consideration. This augments the explication of the concept of "influence" on social-mediated health and risk communication and identifies a key focal point to study unique risk and risk perception amplifications of IDO information that social media bring to the health media cluster. These aspects of RAMS provide additional perspectives on why and why not organizations and publics use social media in different IDO situations.

From an applied perspective, the RAMS model serves as a new roadmap for the PHC to synergize the affordances of different media forms and communication channels when designing, implementing, and evaluating communication efforts. For preparedness, practitioners can evaluate the comparative effectiveness of risk messaging across channels in related to their impact on risk perception, attitudes and beliefs, and adherence to emergency directives. During an outbreak where misconceptions and social anxiety can proliferate, knowledge of

social and individual amplification stations can be used to identify and detect those social entities that are catalyzing these reactions. This can inform interventions designed to quell rumors and social anxiety. An understanding of key social media influencers can help to strategically channelize messages through them, and potentially even recruit these influencers in the process of participatory message design.

As a new conceptual model, RAMS has its limitations and much room for further refinement through empirical testing. Pathways and testable propositions on how specific RAMS components might predict IDO communication outcomes need to be further tested from multiple disciplinary lenses, including but not limited to, health policy, health communication, traditional media effects theories, risk governance and social networks. For instance, future research can empirically test this new model by 1) conducting interviews with public health communicators on how they use social media and traditional media to communicate public health risks; 2) media content analyses of both traditional and social media in full life cycles of IDO cases to capture how the virality of certain IDO information was developed and amplified via the synergized media spread process; 3) surveys of publics, based on their level of influence and social media engagement, to gauge the risk perception among social media creators, follower and inactives as well as what motivate publics (or not) when it comes to risk information seeking and sharing, as well as following instructions recommended by public health communities; and 4) experimental designs using representative samples to examine the cause-effect of key IDO communication factors, including the effects of message strategy, media form combination, disease type, and individual differences on IDO communication outcomes.

In conclusion, social media have catalyzed a paradigmatic shift in health risk communication by bringing a new dimension to how risk signals transmit through social systems. The RAMS model brings clarity to the new complexities in media management of IDOs by delineating the process of message diffusion and risk amplification through communication channels that are integrated largely due to social media. Although the model has been constructed in an IDO backdrop, it can be applied to a broader suite of issues that impact public health such as foodborne illnesses, natural disasters and bioterrorist attacks. Further development of the RAMS model will depend on harnessing its potential to generate amplification measures, using big data analytics to track amplification routes and processes in the online world, and contributing to its conceptual refinement through continued empirical testing in a range of public health contexts.

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