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Recommendations for the role of social science research in One Health

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ABSTRACT

The social environment has changed rapidly as technology has facilitated communication among individuals and groups in ways not imagined 20 years ago. Communication technology increasingly plays a role in decision-making about health and environmental behaviors and is being leveraged to influence that process. But at its root is the fundamental need to understand human cognition, communication, and behavior. The concept of 'One Health' has emerged as a framework for interdisciplinary work that cuts across human, animal, and ecosystem health in recognition of their interdependence and the value of an integrated perspective. Yet, the science of communication, information studies, social psychology, and other social sciences have remained marginalized in this emergence. Based on an interdisciplinary collaboration, this paper reports on a nascent conceptual framework for the role of social science in 'One Health' issues and identifies a series of recommendations for research directions that bear additional scrutiny and development.

1. Introduction

Evolution in communication technologies has made the possibilities for information-exchange, networking, and data integration limitless. Using new and emerging communication technologies to promote health behavior change and facilitate decision making is fast becoming the norm among health practitioners. Grassroots communication efforts have stimulated technological innovations that are facilitating social change (e.g., Crisis Commons and Ushahidi), capturing epidemiological trends (e.g., Google Flu; Bernardo et al., 2013), driving the development of the so-called 'quantified self' (c.f., Topol, 2012) and transforming the nature of human and animal health systems (e.g., Patients Like Me, I-Cow). In the science of communication and information, however, there remain many unanswered questions about how and whether new communication technologies can be useful for influencing outcomes such as facilitated decision-making, innovation diffusion, and behavioral adaptation. Researchers are examining the characteristics of the users of new communication media to inform health communication practice (e.g., Chou et al., 2009) and are striving to determine the ways in which the nature of the content and sources of information work with the features of the technology to drive behavior change and adoption patterns. At the root of all communication technologies, however, is human action and interaction. Our understanding of how and why humans make decisions and take action is fundamental to questions of the ways in which communication technologies function in societies.

The current paper has been inspired by the work of Hesse et al. (2010) in their article *Social Participation in Health 2.0* and Topol's (2013) *The Creative Destruction of Medicine*, which set the stage for research on the role of communication technologies in the human health domain. Our focus is the integration of human, animal, and ecosystem health as a context for thinking about innovative research on communication technology and human behavior from a range of perspectives. Given the fast pace of change in technological innovation and research, as well as the complex nature of One Health issues, addressing these questions demands the attention of integrated teams of scholars in diverse fields to determine where research efforts should be focused. The concept of One Health provides a context for formulating a research agenda because it is inclusive across a broad range of disciplines as well as timely; for example, United States Centers for Disease Control and Prevention (CDCP), World Health Organization, World Bank, Food and Agricultural Organization of the United Nations (FAO), World Organization for Animal Health (OIE) and others have begun to

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shape policy and practice in this area (CDCP, 2013; World Bank, 2010, 2012).

At its' simplest form, One Health is the idea that human, animal, and ecosystem health are interdependent. Although the concept of One Health is not novel, there is a pressing need for renewed focus on interdisciplinary efforts in this arena in order to improve health. Despite the recognition that human communication processes and behaviors are critical in this realm, social scientists have not played a central role in the One Health conversation (Choffnes et al., 2012). Recommendations from previous One Health meetings, held by the CDC (Centers for Disease Control and Prevention, 2013), National Academies of Sciences (Choffnes et al., 2012), and others (see, Hueston et al., 2013), recognized that communication, in particular using new technologies and the knowledge base about human behavior change and decision-making, is critical to achieving 'One Health' goals. Yet, there is a paucity of research regarding efficacious approaches. Further, in order for One Health approaches to be adopted, it must be clear that there are added benefits to pursuing an intervention integrated across human animal and ecosystem health. Adoption of One Health approaches will not (and should not) be adopted without a clear sign of added value (Zinsstag et al., 2012a). As such, this paper reports on a nascent effort to craft several broad directions for social science research in the One Health realm.

2. Communication technology, human behavior, and the value of social science

Communication technology continues to change the nature of human interaction in key ways; yet fundamentally, human behavior is at the root of all technology questions. As such, social science, in all its forms, contributes to understanding how technologies form and function in society. We recognize the breadth and tremendous diversity of disciplines and perspectives encompassed by the term *social science* and do not claim to represent its breadth here. We use this term simply to mean researchers who study humans. With this said, understanding how communication technology changes human experience (and the experience of other animals and ecologies) drives much of our thinking. Recognizing the concept of the 'digital divide,' our premise is that the ideas presented here regarding communication technologies (existing and emergent) and human behavior are globally focused; revolutions in the ways in which communication technologies are leveraged are occurring all over the world. There are several aspects of communication technologies that we highlight here as an overarching framing for the paper: the concept of constant connection, enabling access to large-scale information and human connections, and the potential for contextualized decision-making and behavior.

Many people across the globe now have the ability to be constantly connected: across time, space, and place (Vorderer and Kohring, 2013), and this ability serves as a disrupting and facilitating force in people's lives (Misra and Stokols, 2012). This means that there is potential for almost limitless access to information about everything from market prices of goods being sold in a faraway city (e.g. Abraham, 2006; Fafchamps and Minten, 2012) to pandemic disease outbreak maps; from what one's mother (who lives 1000 miles away) thinks about what you ate for dinner last night to how many steps you walked yesterday. One can connect with another person at any time and almost any place. This information and connectivity cuts across contexts; it can influence the way people live their lives including the breadth and depth of interpersonal connections with others (Ellison et al., 2011) and the nature of people–environment relations (Misra and Stokols, 2012).

Along with facilitating interpersonal communication among single individuals, emerging communication technologies have enabled communication among groups of people; revolutionizing how people engage in decision-making, team work, and collaboration. This has the potential to change the ways in which individuals, groups, communities, and societies function. Forte and Lampe (2013), for example, have discussed the concept of open collaboration and technology-enabled innovation spaces (e.g., Wikipedia, the most widely known) enabling things such as disaster response, open mapping, aggregation of news and information, and crowd-sourcing of democratic processes. It also has the potential to change the ways in which we think about others as influential in our lives; making the study of group dynamics and group processes more important and more complicated than ever.

The potential for ubiquitous connection to individuals and groups, along with the access to large-scale and innovative forms of information (about the self as well as about other entities) allows for contextualized decision-making in a form never seen in the history of human-kind. That is, for any one decision, a person or group may access massive amounts of information ranging from system-level factors to individual opinions. This elevates the need to understand issues such as critical evaluation of information and information processing, the role of group norms and networks, and information/data visualization, integration, and management; points we will return to below. Social scientists, both those who's focus has been in information science and those who have not, contribute to our understanding of these issues through their research on decision-making and communication related to health and the environment, the ways in which innovations disrupt the social environment and promote change (Misra and Stokols, 2012), and how interventions like those seen in the realm of health behavior can influence behavioral decisions and ultimately human, animal, and ecological health outcomes. Communication technology and the information and connections it affords increasingly plays a role in decision-making about health and environmental behaviors and is being leveraged to influence that process.

Working under the assumption that a diversity of viewpoints can facilitate solving the challenges faced by the application of technology to questions of decision-making and behavior change in the context of One Health, this paper brings together the perspectives of a broad cadre of social science researchers with scientists in human, animal, and ecosystem health to determine key research questions for using new and emerging communication technologies for understanding and facilitating behaviors that might impact One Health challenges. With support from the National Institutes of Health, this group (Appendix; Link to Figure) has convened in a series of meetings at Michigan State University over the last two years to begin to form collaborative teams and forge a research agenda in this space. For this paper, our goal is modest; to identify several broad issues that can generate additional thinking about the role of social science in One Health questions. As such, we focus the scope of this inquiry to places we see as value-added by the possibility of social scientific research to answer broad questions in order to move science and practice forward. Ultimately, our agenda is more ambitious: to craft an integrated framework for interdisciplinary research that allows for testing of basic research questions in various social, biological and physical science disciplines; gaining insight into practical application of the research findings, and true integration of research projects across traditional disciplinary boundaries. Ideally, it is hoped that integrated research projects that are of substantive interest for researchers in the biological, physical and social sciences can be developed as a result of these efforts and produce real impact on One Health-related challenges.

3. Defining 'One Health': examining existing frameworks

The concept of One Health has appeal as an overarching theme for thinking about large-scale, interdisciplinary or transdisciplinary research problems. In this manuscript, we use the definition of interdisciplinary research as set forth by the US National Academies of Science: "Interdisciplinary research is a mode of research by teams or individuals that integrates information, data, techniques, tools, perspectives, concepts, and/or theories from two or more disciplines or bodies of specialized knowledge to advance fundamental understanding or to solve problems whose solutions are beyond the scope of a single discipline or area of research practice." (p. 2, Committee on Facilitating Interdisciplinary Research, Committee on Science, Engineering, and Public Policy, National Academies, 2004).

Interrogation of the concept of One Health is overwhelming in its scope: it is challenging to think of examples of issues that might not be classified as One Health challenges. Ironically, despite its potential scope, research in the realm of One Health has focused frequently on the classic case of zoonotic and vector-borne diseases (e.g., malaria, dengue fever, bovine tuberculosis, avian influenza, West Nile Virus, foodborne illnesses). Also in health services delivery that integrates human and animal health (Schelling et al., 2007) or surveillance of human and animal health (Jean-Richard et al., 2014) to increase coverage and reduce costs. More ironic, perhaps, given the broad potential scope of the One Health concept is the fact that social science, despite the role of human behavior at the center of many One Health challenges, is noticeably absent from scientific research on One Health. Even in the classic case of zoonotic diseases, where significant human behavior issues lie at the root of propagation, prevention, and transmission, social science research is rarely engaged in this realm. Examples of such work that to fill this gap are models that specifically address the ways in which social science method and theory can be brought to bear in the case of zoonotic disease (e.g., Clarke, 2009; Leach and Scoones, 2013; Triezenberg et al., 2014).

In addition to the limited engagement of social science research in the classic One Health example of zoonoses, there is a need to define One Health, at least within the framework of this manuscript's goals. One Health is thought to be an ancient concept (Zinsstag et al., 2011) although more recently it is rapidly evolving in its scope as evidence of the interdependence of the health of humans, animals and the ecosystem, are further elucidated. Extensively reviewed by Zinsstag et al. (2011); One Health originated from 'One Medicine', developed by Schwabe (1984) as a general medicine that was shared by animals and humans. One Health was seen as an expansion of 'One Medicine' in recognition that the interdependence between animals, humans and their ecosystem extends beyond medical intervention for clinical disease. One Health integrates eco-health (Zinsstag et al., 2012b) and supports the concept the health and well-being of animals, humans and the environment are interdependent (Zinsstag et al., 2011). Conceptually, One Health is further extended by inclusion of social-ecological systems (SES) and Zinsstag et al. (2011) suggests a model of health in social ecological systems (HSES). Rock et al. (2009) calls for application of the syndemic concept for prevention, which focuses on "…connections among health-related problems, considers those connections when developing health policies, and aligns with forces for social change" as a mechanism for engagement of social scientists in One Health (p. 991). This highlights the explicit call to interdisciplinary teams to include social science expertise along with the science, technology, engineering and medicine (STEM) fields to address societal challenges.

A tension exists within the One Health framework in regard to scope. The risk that a global overview may be so large in scope as to be meaningless, while simultaneously recognizing the limitations of reductionist approaches has been noted as a challenge (Zinsstag et al., 2011). Yet, despite the breadth of scope for inclusion, most One Health initiatives have focused on infectious diseases of humans and animals (Hueston et al., 2013). A recent review of One Health initiatives by Hueston and colleagues, conducted for the purpose of evaluating global adoption highlights limitations of existing initiatives: an absence of a consistent definition of One Health, challenges in identifying the scope of activities that benefit from One Health approaches, an absence of evidence of the benefits of a One Health approach, minimal acknowledgment of ecosystem health and an absence of engagement of private sector organizations in One Health initiatives (Hueston et al., 2013).

For the purpose of the current interrogation, One Health is conceptualized as the idea that the health of humans, other animals and ecosystems are interdependent. Health is broadly defined; for instance, human health encompasses not only physical health (e.g. infectious and non-infectious diseases of both acute and chronic duration), but also encompasses more broad indicators of the health of people and societies such as psychological, emotional, spiritual and economic well-being and socio-political stability. The health of animals includes not only physical health, but also concepts of optimal productivity, animal welfare and ethical considerations of animal use. Ecosystem health is not only mitigation of environmental toxicants, but also captures plant health, biodiversity, sustainability and resilience of ecosystems. This approach to One Health is a recognition and extension of Zinnstag's (2011) inclusion of health within social ecological systems (HSES), and the requirement that One Health approaches provide an added-value over solutions that are implemented without consideration of this interdependence (Zinnstag et al., 2012a). We acknowledge that, as an emergent concept, this definition of One Health may be challenged, but the interdependence of the health of these systems is without doubt.

Contextualizing research under the One Health umbrella yields a number of key areas that merit scientific inquiry by integrated research teams. One Health provides an appropriate framework for this effort; in part, because it is integrative by definition: making biological, physical and social science disciplinary boundaries less relevant, and setting the stage for interdisciplinarity that can motivate integrative thinking across social-scientific disciplines. Second, human behavior is at the root of many One Health challenges and holds the promise for addressing those challenges. One example is, the role of the mosquito as a vector for a number of diseases of humans and other animals including some zoonoses. It is human movement of goods around the globe through human-built transportation systems (Tatem et al., 2006; Reiter, 2010; de La Rocque et al., 2011), and potentially human-induced climate change that may alter the ecology and epidemiology of vector-borne diseases (reviewed by Altizer et al., 2013), causing emergence of animal and human disease in novel geographic regions (and perhaps reducing its impacts in existing endemic regions). Ultimately, it will be human action that can modify the antecedents described above to prevent degradation to human, animal, and ecosystem health in this context. Still, at the most basic level, questions remain about the utility of One Health as a context for thinking about basic research on human behavior. The answer to this question is crucial because it limits the potential heuristic value of any initial work done in this framework.

4. Broad recommendations for the role of social science in One Health challenges

Social science contributions to 'One Health' can be thought about at a number of different levels of One Health challenges.

Human behavior functions causally in One Health questions: that is, in creating and perpetuation of the basic conditions that lead to One Health challenges. Put differently, human actions lead to changes in the intersected systems that define One Health: the ecological, human, and animal systems. Social scientists can aid in understanding these behaviors, their motivations, and the role technology plays in this process. For example, human practices, such as clearing of forest land and intensification of agriculture put humans and domestic animals in contact with otherwise foreign wild animals and foment disease transmission between animals and humans (Plowright et al., 2008). There are significant social questions about why this behavioral practice exists, how to engage communities regarding the risks associated with this practice, whether or not it makes sense to persuade people to cease this behavior to adopt different behavioral strategies, and how best to do this. Some of these questions can incorporate fundamental social science questions about culture and social systems, public engagement, behavior change communication, and decision-making.

Changes in human behavior that result in changes to the One Health system and how this feeds back into the system form another broad area of inquiry. Social science can contribute to our understanding of how combined changes in environmental, animal, and human health effect human psycho-social outcomes and of the cyclical relationship between humans and their environment. For example, it is becoming clear that climate change will result in temperature and water availability changes all over the world. This will influence the movement and health of wild animals and will also influence the ways in which humans care for domestic animals (Moore et al., 2012). It will yield changes to human migration and well-being including food security (Wheeler and von Braun, 2013) and the frequency of human conflicts (Hsiang et al., 2013). Understanding the ecological effects of climate change, how to communicate the nature of these complex changes, how humans will be impacted and how human behaviors in response to climate change will impact ecosystem health, all provide fertile ground for significant social science research endeavors and fit squarely in the One Health paradigm. Understanding the policies and practices that will mitigate detrimental effects and coming to consensus about what the effects and responses might be is an additional engagement point for social researchers.

In the following section we describe three recommended conceptual areas that can form a basis for understanding how social science might contribute in meaningful ways to One Health challenges. These are issues that have emerged in discussions among our team and are designed to stimulate additional thought and discussion in this realm.

4.1. Recommendation #1: understand how humans contextualize their own health within animal and ecosystem health

Fundamental to social science research about One Health issues is a better understanding of the ways in which humans conceptualize their own personal health in relation to social, animal and ecosystem health and whether addressing the intersection of these issues is profitable for facilitating human decision-making and ultimately, human action. In the most basic sense, this is a question of how people come to understand complex systems and how this understanding influences the decisions they make about their own individual action with in larger systems (social, organizational, etc.). The identification of this fundamental issue is rooted in our assumption that humans, and their actions, are at the base of most One Health-related challenges as the cause and/or solution (through of adaptation or prevention). It is the sum of many individual-level decisions that result in collective action scenarios which can ultimately have profitable large-scale ecosystem, human and animal health outcomes. Understanding how people see the interplay between and among these three systems becomes important because of existing science on how people make decisions (and the role of information and informational complexity in that process; a point to which we will return below).

By profitable, we mean decisions that will yield optimal benefits for human, animal and ecosystem health; a view of the benefits of action that expands the traditional and anthropocentric scope of thinking about why humans act. Historically, concerns about human health have been used to legitimize questions about ecosystem and animal health. For example, efforts to improve ecosystem health are typically contextualized in the human benefits to that action (e.g., Why should a community install a sewer system? So members of the community can have access to drinking water that is not polluted by human waste.). This approach appears to have merit because research is clear that when people make a direct connection between their own behavior and its direct health benefits, it makes behavioral action more probable (e.g., Bandura, 1986, 2004; Janz and Becker, 1984). The literature on health risks is robust in its indication that identification of the direct benefits to the self can motivate action when it comes to personal health behaviors (Carpenter, 2010) and that perceptions of these benefits are contextualized in the broader social normative system (e.g. Lapinski and Rimal, 2005). It is less robust in terms of the findings regarding indirect or depersonalized benefits as motivational. The question then becomes: can ecosystem and animal health benefits of behaviors be connected with human health benefits in order to motivate action that will result in human decisions that optimize benefits across the three contexts? Ultimately how people come to understand the costs and benefits of behavioral action are only a piece of what influences decisions to act. There are existing theoretical frameworks for complex approaches to understanding decisions and actions that are useful for identifying other future research directions in this realm.

Social ecological models of human behavior have a prominent place in the literature on health and environmental-related behaviors (see Stokols, 1996 for a review); similarly, work on coupled human-natural systems (e.g., Liu et al., 2007) provide a comprehensive, interdisciplinary basis for research on One Health. Ecological models of health describe a systematic range of factors that influence health-related outcomes; from macro-level factors such as access to services to social-psychological factors that influence action. As a general class of models (e.g., Airhihenbuwa, 1995; Stokols, 1996; Street, 2003), these approaches take a macro-perspective on human action and have their basis in systems theory; they identify all of the classes of factors that can influence human action and have been applied in the context of human−technology interaction (Montero and Stokols, 2003). These models can include specific psychological drivers (e.g., perceptions of the benefits and risks of taking action) to the more general social (e.g., normative barriers) and contextual (e.g., access to an environment that facilitates behavior) factors.

At the level of the individual, it is clear that both logical/rational and intuitive/emotional systems factor into behaviors and behavioral decision-making (Slovic et al., 2007). People act (either with or without consciousness about actions) based on a variety of psychosocial factors such as habitual tendencies, attitudes and values (Rokeach, 1968), perceptions of the benefits and risks of engaging in a certain act (e.g., Decker et al., 2010), the nature of social relations, including perceptions regarding what other around them do or think they should do (Kallgren et al., 2000; Ellaway and Macintyre, 2007; Lapinski et al., 2007), and aspects of self-concept and identity (Hogg and Reid, 2006). Contextual factors such as access to services or information, cultural predilections, media context, political and

legal context, and the natural and built environment (Masuda et al., 2012) are all believed to have the potential to indirectly or directly influence human behaviors and outcomes as does the relationship among actors and the information that is exchanged verbally and non-verbally among and between these actors.

Work on coupled human and natural systems examines the complexity of interactions between the human and natural world and provides an additional conceptual bases for thinking about One Health questions if animal health (both wild and domestic) can be added to the equation. Liu et al. (2007) summarized a number of projects around the globe that adopted this perspective and identified the common features of these projects as having a number of key characteristics including: 1) explicitly addressing the relationships among the social and ecological realms; 2) involvement of an interdisciplinary team of researchers from social and natural sciences; 3) use of methodologies and approaches from multiple disciplines; and 4) longitudinal and contextualized research.

These approaches, borne largely out of environmental psychology and environmental sociology, can be expanded to address additional hypotheses about the ways in which information from ecological, human and animal health systems can influence behavioral outcomes. Inclusion of human and animal health outcomes is particularly relevant when thinking about this issue in the context of One Health. Yet there remains a need to specify testable hypotheses about how and why the information gleaned from those ecological systems might prove influential in behavioral decision-making and how it interacts with psycho-social systems. Hypotheses can be formed about how humans integrate information gleaned from the ecology with their own cognitions and the messages that they exchange with others in the social system.

The simplest examples to consider this point further are those in which an individual or group relies heavily on aspects of the ecology for their own direct monetary and non-monetary benefits. For example, consider a nomadic herder with a large herd of animals, which she grazes on a collectively held parcel of land. What information does she draw from the ecology as she makes decisions about her daily actions and how does that information connect with the information she receives from members of her social networks? Is the motivating force behind her actions consideration of her own well-being (broadly construed: economically, mental health, social position), the health of her animals (productivity, infectious disease, and welfare), ecosystem conservation (preservation of the grasslands), or a combination of those things? If she instead is the mother of a child with severe asthma living in an urban center, do her observations of the quality of the air drive decisions about the activities in which she personally engages, and does she connect those decisions with her own actions that may lead to degradation of air quality (e.g., driving her car to work, using large amounts of electricity)? It may be the case that identifying clear linkages between human, animal, and ecosystem health and communicating that information in strategic ways can have the power to significantly influence the ways in which people consider their own behaviors such that they optimize benefits across these systems. As such, there are basic social science research questions that might be addressed to determine the profitability of the One

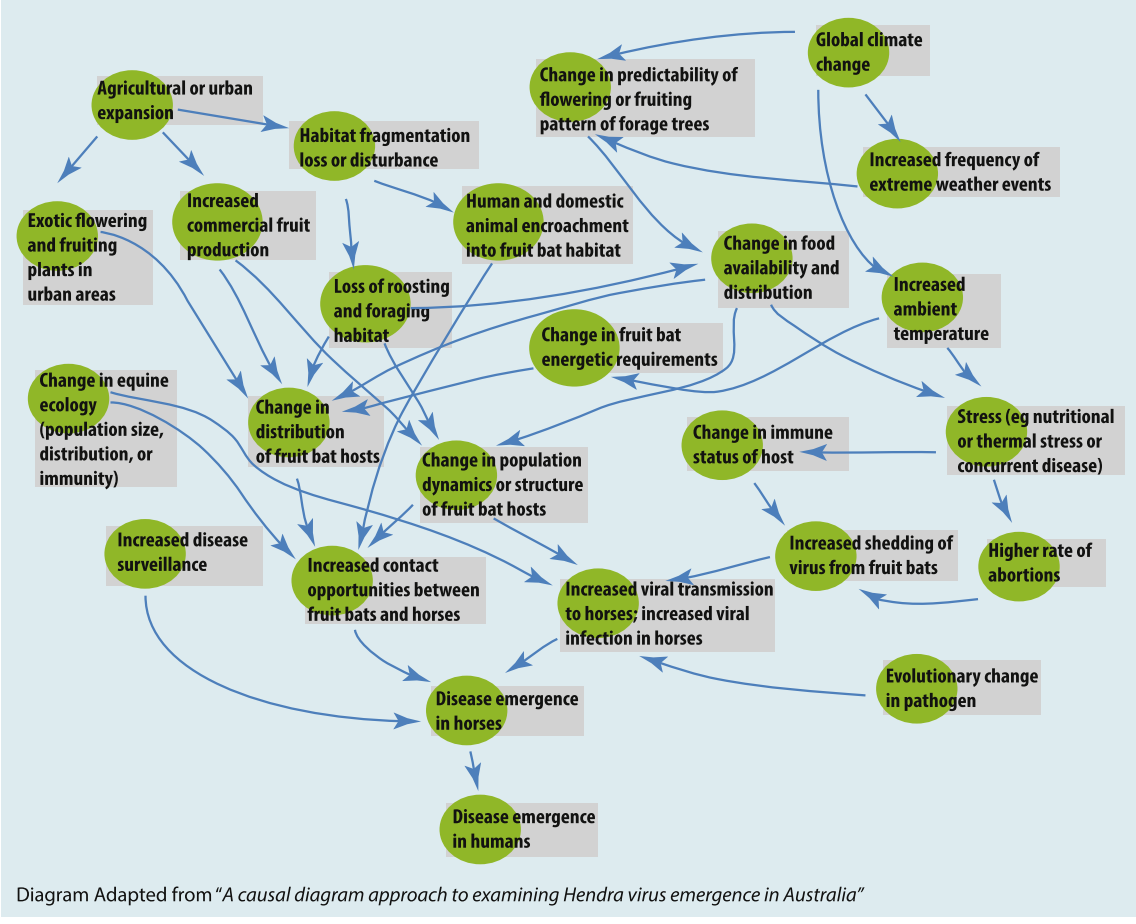

Fig. 1. Proposed causal pathway for the emergence of Hendra Virus in Australia.

Health approach for promoting particular behaviors that have collective benefit.

An additional example (Fig. 1) of an emerging disease that fully integrates the One Health paradigm is the emergence of Hendra Virus in Australia (Murray et al., 1995). Despite a long association of the virus with the fruit bat hosts, the disease has emerged in human and equine populations. Using a causal web model (Plowright et al., 2008), many different potential factors are identified: destruction of habitat, agricultural consolidation, urbanization, habitat encroachment changes in equine population geographic distributions, and global climate change impacts on bat food sources as potential contributors to this disease emergence. Many of these changes are a result of human activities. However, this is a very complex causal pathway. How would people conceptualize their health secondary to agricultural development and activities that impact climate change while understanding the consequences of such practices for emergence of novel viral infections (i.e., Nipah and Hendra virus)? Would behavior change be likely when the risks are explained in a complex system framework? What direct benefits to the self are possible to identify to encourage change in behavior? How would people conceptualize the economic and food security benefits of agricultural production vs. impact on wildlife habitats and subsequent risk to human and animal health resultant to emergent viral diseases? This example highlights the role of human behavior at many points in the causal pathway occurring at the individual, social and organizational levels. Likewise, the virus may have a significant impact on human, animal and ecosystem health. Understanding the basic underlying social-ecological systems, with particular reference to human behavior, could contribute significantly to promotion of One Health.

The issues highlighted here address a single basic human perception question associated with One Health and can form the basis for thinking about other fundamental issues including the types of information and messages that are desired or needed to facilitate behavioral decision-making and the ways in which communication technology factors into the process. In short, social science can contribute to the understanding of how these 3 realms are connected in people's cognitions. Methodological approaches to understanding this complexity exist [c.f., the mental models approach; Morgan et al. (2001)]; these can then be linked to the nature of communication and information that is needed to help people better understand, modify or adapt appropriately within these systems.

4.2. Recommendation #2: understand the ways in which information and communication can improve One Health outcomes

If scientists develop a deeper understanding of how people come to understand the integration across human, animal and ecosystem health and the level at which they need to understand this integration to make personal, social, and organizational decisions, we can better identify the nature of the information that people need to make these decisions. Moreover, studying these decision-making processes and the nuances of the information people use and exchange are areas for basic social research in the context of One Health. Research in communication for health prevention and promotion has significant lessons to contribute to such an effort. The process of communication and education intervention design addresses the importance of researching the nature of people's existing perceptions, needs, behaviors, and knowledge as a precursor to development of information like decision making aids, persuasive messages, educational content, etc. (e.g., McGuire, 1987). This approach does not assume information is desired by stakeholders; that information provision will somehow result in modification to behavior, or that humans have the motivation and ability to process information about a particular issue.

There are situations in which people do not desire information about an issue because it does not allow them to maintain good mental health (Brashers et al., 2002). It is clear that having knowledge about an issue is often disassociated from acting in a way to address the issue (Fishbein and Azjen, 1975). Moreover, more information about an issue can overwhelm people's processing capacity and result in biased processing of information and use of heuristics for decision-making (e.g. Gilovich et al., 2002). If information is provided that is too complicated, it might not be useful for behavioral decision-making (Chaiken, 1987). On the contrary, if the complexity of an issue is not acknowledged, certain forms and types of information might be dismissed as overly simplistic or insufficient (c.f., Griffin et al., 2004). As such, before the development of communication or information dissemination efforts, the understanding of how people understand and conceptualize a One Health issue is necessary. That is, to know the types of information that is preferred, needed, or appropriate for a particular population on any given issue, existing patterns of behavior and the nature of the conceptual system associated with an issue, must be understood.

Understanding how people contextualize their personal health within the context of ecosystem and animal health and the informational needs associated with One Health issues becomes important if there is a point for intervention and opportunity for researchers to study the effects of that intervention. Any possible intervention should begin with understanding human perceptions and the social and ecological systems in which the intervention will be introduced. In this case, we use the term intervention to mean the introduction of a new technology or new ideas to a social system (on par with diffusion of innovations see Rogers (1962); also termed a ‘shock’ in economics) and includes communication and educational interventions. Innovations should not occur absent of an understanding of the social systems into which they will be introduced (see Dearing, 2008). For example, consider an innovation that occurs regularly: a new planting technique is researched and discovered that requires less pesticide, less water, and yields more foods for humans and animals. As the innovation is developed (not after development, when there is no chance for modification based on social information) basic research can help to uncover the dynamics of the social system that will ultimately drive the adoption of the technology. Questions such as the following can be asked: What are the existing behaviors associated with this innovation? How will information help this technology diffuse through a population? What are the perceived benefits of the technology to human, animal, and ecosystem health? How can the benefits of this technology be communicated to members of the social system? Who are the influential people in the system and what are their existing beliefs and behaviors associated with the technology? At the same time, there are questions about crop yields, changes to the water system, as well as food security and nutrition benefits to the community that need to be addressed by biological and physical scientists.

In Fig. 2, we describe a framework for understanding the impact of an intervention [in this case, payment for ecosystem services (PES)] on One Health outcomes. A typical economic model characterizes the effects of conservation payments as promoting conservation behavior and thus improving ecosystem conditions; an alternative model drawn from a recently funded U.S. National Science Foundation (NSF) project (Lapinski et al., 2013) suggests the conservation payments and the resulting actions both influence social norms and in turn are influenced by social norms. Feedback from changes in ecosystem conditions also influences decisions and actions. In the referenced project, this model is being applied to two

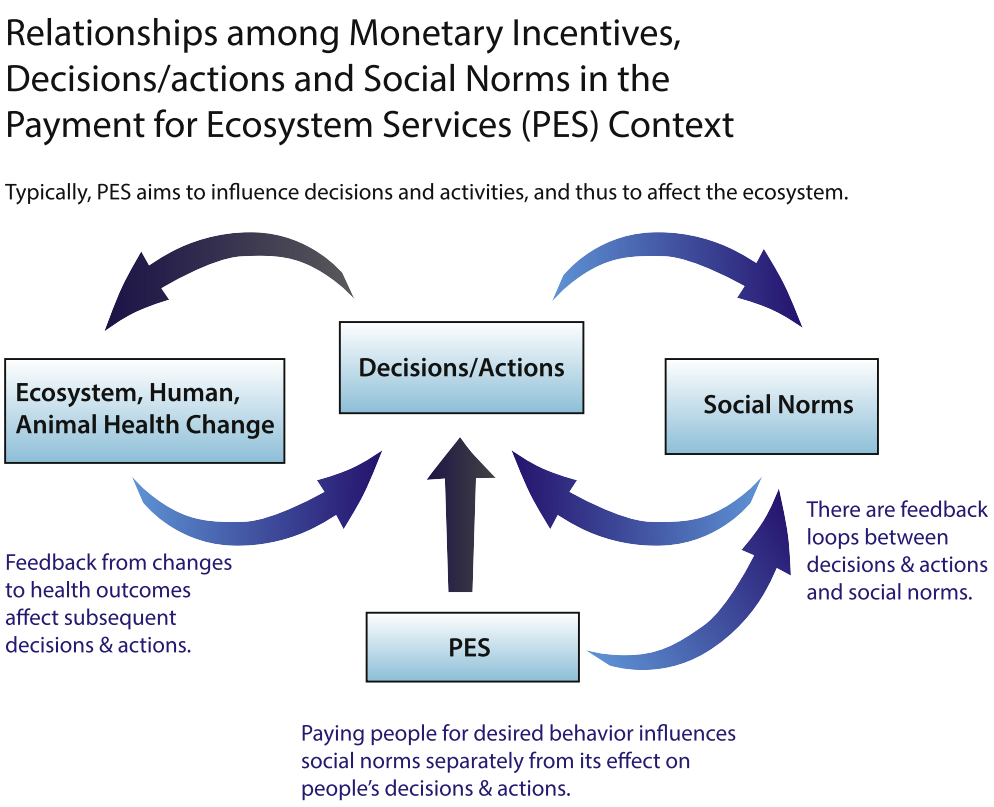

Fig. 2. A proposed framework for understanding the impact of an intervention [payment for ecosystem services (PES)] on One Health outcomes. Artist: J. Kerr in Lapinski et al., 2013.

behaviors (domesticated animal herding and patrolling to reduce poaching of large mammals like the endangered snow leopard) and can address ecological outcomes (e.g., grassland and watershed health or biodiversity), animal outcomes (e.g., health of domesticated and wild animals) and human outcomes (e.g., economic well-being and access to adequate nutrition).

As with the first recommendation, there are frameworks and theories for better understanding how people seek out and respond to information (e.g., Afifi, 2009; Kahlor et al., 2006; Rimal and Turner, 2009) that have utility for One Health challenges. Further, there are large scientific literatures on message and informational design (c.f., Dillard and Pfau, 2002) and informational tools for decision support (e.g., Arvai et al., 2001; DeSanctis et al., 2008). Although there is significant research that has been done in this realm, there remain questions that are unaddressed; One Health issues serves as a forum for expanding this research. (Fig. 2)

4.3. Recommendation #3: identification of the key characteristics of new and emerging communication technologies including how and when are they can be used globally for information-seeking and sharing about One Health issues

Until now, the focus of the discussion has been on the dynamics of the human social and ecological systems in which One Health issues occur. As discussed above, fundamental to human systems are the devices and technology that pervade the human experience. These take the form of communication technologies themselves and/or the products and outcomes of communication technology that are used by humans as they make decisions. Communication technology is ubiquitous and fundamental to human experience across many contexts (Misra and Stokols, 2012; Vorderer and Kohring, 2013); we are living in a constantly connected world where *customized information consumption* and *crowdsourced collaboration* are the norm (c.f. Topol, 2013).

Many of the decisions humans make about their own well-being, that of the ecosystem, and of wild and domestic animals will be seeded by information exchanged through communication technology in various forms. Communication technologies might not only be changing the content of human experience but also the ways in which we think. There is evidence that media-multitasking and gaming may be changing how we process and respond to information (e.g. Ophir et al., 2009) to the point that it changes brain functioning. As Reeves and Nass (1996) in *The Media Equation* pointed out: mediated experiences are equal to human experiences. That is, all people respond to mediated communication much like they do human interaction (that is, responses to media are both "social" and "natural") making communication technologies more than just "tools" in the social world (p. 251). As such, any effort to understand human outcomes and response to One Health challenges must seriously consider the role of communication technology (emerging, emergent, and emerged) as an integral part of that experience.

Importantly, communication technologies, like all technologies, evolve faster than the positive and negative social implications of the technologies can be understood and anticipated. The tendency to adopt, to be tempted by the 'possibility' of communication technologies, is strong. That is, it is often the case that what *can* be accomplished with communication technologies relative to what *should* be done with communication technologies are out of step. Put differently, in the rush to adopt, basic questions about whether or not communication technologies might be useful for desired outcomes or the moral implications of adoption go unaddressed. Take for example, the use of mobile applications to facilitate health behavior change and improving disease management. A meta-analysis by Free et al. (2013) on the use of mobile apps for health

promotion based on the analysis of 75 studies concludes that text-based (SMS) interventions can have utility for influencing certain health behaviors, but that there is a dearth of solid, statistically high-powered trials to know when they work and why, that the design of most mobile apps are not based on theory, and that most have been tested in developed countries only. The use of wireless sensor networks to track animal and human health and to provide opportunities for feedback [e.g. Fitbit®, JAWBONE UP®, WhistleGPS (for dogs)] are another example. Innovations in this realm allow both for real-time monitoring and feedback on health behaviors as well as large amounts of data that can be available to scientists and individuals regarding behaviors and conditions (i.e., *taming data* , see Epstein et al., 2014) . Social science research in information science and technology mediated interaction, philosophy, and other fields are at the cutting edge of this research and can inform both theory and practice as these innovations evolve. These tools provide platforms for research questions that leverage integrated data systems on One Health questions and contribute to detection, prevention, and surveillance efforts.

Attention might be directed toward studying the characteristics of communication technologies that make them more/less useful in various contexts and identification of the One Health issues (e.g., diseases, problems, risks) for which communication technology can be useful. There are many questions regarding the nature of particular communication technologies (or classes of technologies) that make them effective for use in One Health contexts: Is it the social nature? Is it the potential for massive amounts of data? Is it the connectivity? Is it the expanded reach? These questions can form the basis for social research and subsequent application. Large quantities of data about health (e.g., GoogleFlu) and environmental conditions like climate, water, air quality are being integrated, synthesized, visualized, and shared using communication technologies. The social networks in which this information flows can be observed through mining of the outputs of social communication technology and visualized with the same tools. The unanswered question about the use of these technologies for these purposes is this: Will these innovations be useful to people as they make decisions about their own behavior, the actions of organizations with which they affiliate, etc.?

An example involves the visualization and democratization of disease reporting. HealthMap (http://healthmap.org, Fig. 3) is an internet based biosurveillance technology that uses online sources for disease outbreak monitoring and real-time surveillance for disease events (Brownstein and Freifeld, 2007). Data is aggregated from freely available sites, geolocated and mapped globally. Qualitative assessment of activity associated with outbreaks and crowd-sourced assessment associated with each disease event are also provided. Through an application called “Outbreaks Near Me” subscribers can receive informational updates regarding outbreaks near their location. The site also utilizes crowd-sourcing for posting of disease events. A “Disease Daily” component provides informative articles on current disease outbreaks by medical professionals and scientists. This represents a potentially powerful tool for decision-making and behavior change, and could be used as a component of risk assessment and surveillance activities.

Key questions involve whether information about outbreaks changes human behavior proximally (e.g. I will wear mosquito repellent since there is West Nile Virus detected in my area), if the information provided aids in decision-making, and whether crowd-sourced information influences behavior change. For example, does crowd-sourcing validate or diminish behavior change given the particular disease information (i.e. I am more likely to change my behavior if the crowd-sourced information indicates interest in the outbreak is high relative to information gleaned using other epidemiologic approaches)? Would presentation of the change in disease outbreak patterns locally or globally through a mapping tool (i.e., changes in patterns of vector-borne illness secondary to complex systems forces such as climate-change, socio-political disruption, ecosystem degradation) promote behavior changes such as adaptations in personal energy usage?

Another example is the adoption social media platforms for non-social use. Many public health organizations in the country have a social media presence as a tool for information dissemination and public connectivity. The US Centers for Disease Control and

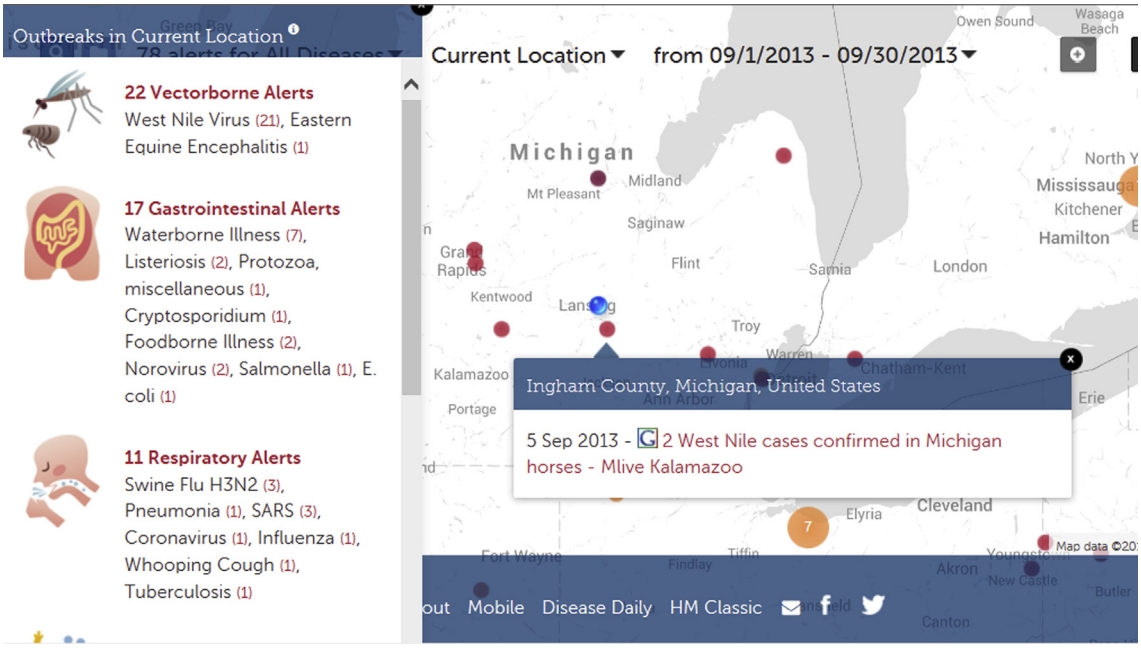

Fig. 3. Example data visualization from HealthMap (http://healthmap.org) an internet based biosurveillance technology that uses online sources for disease outbreak monitoring and real-time surveillance for disease events.

Prevention (CDCP) has a presence on 8 different social media platforms. At the writing of this paper, CDCP had 204,084 people following its Twitter feed (and 1700 following on Pinterest) compared to over 10 million people following CNN on Twitter. Many information science questions remain about the costs and benefits of using social platforms like Twitter as a mechanism for public health outreach, including its effects on source perception and behavioral decision-making. In this case, the merits of using particular types of communication technologies might be studied rigorously (yet rapidly) before adoption to understand their potential utility. In short, technologies can become ubiquitous before the practical, moral, and social implications of those technologies are understood. Alternatively, communication technologies might be resisted or ignored despite having important benefits (e.g., advanced communication systems for early responders as a classic case). In either case, integrated social research can inform practice and practice can inform theory-building in this realm.

The scope and complexity of One Health challenges mean that communication technologies and their ability to synthesize and simplify data is essential in order to make good decisions about how these challenges can be addressed. Communication technologies are already being leveraged in this way. There is a pressing need for research to better understand the key characteristics of communication technologies that can make them more useful in addressing integrated human, animal and ecosystem health challenges.

5. Conclusion

Social science research from a variety of disciplinary perspectives has enormous potential for integrative research projects with researchers from a variety of STEM, human health and other natural science disciplines in the context of One Health. One Health serves as an over-arching framework for interdisciplinary and transdisciplinary thinking about complex systems. Although the focus of social science research is often, by definition, anthropocentric, One Health provides a context for expansion of traditional thinking about basic research questions regarding the intersection of human, animal, and ecological health.

The unique and global abilities of technology accompanied by interdisciplinary collaboration present the opportunity to produce effective interventions for a healthier, more conscious global community, in which One Health is common knowledge and everyday vernacular. Understanding that health, broadly defined, is a shared quality essential to humans, animals and the ecosystem; and creating a shared language for the foundation of One Health can only aid in research and development that will solve One Health challenges.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.socscimed.2014.09.048.

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