One Health Information and Communication Technologies

How digital humanities contribute to public health

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Abstract **- Zoonoses are infectious diseases that are transmitted either directly or indirectly from animals to human beings. The human and economic costs of zoonoses and antimicrobial resistance can hardly be overestimated. Due to ecological and socioeconomic behavioral changes, new and different zoonoses emerge while antibiotics' effectiveness decreases. Early warning and surveillance systems are part of the public health response. However, a more pre-emptive approach is needed. 'One Health' entails a global strategy to advance interdisciplinary collaboration and communications in all aspects of health care for humans, animals and the environment. As of yet, the importance of social sciences and eHealth technologies for infectious disease research and public health policy is underestimated. The digital humanities provide methods and concepts that can set the One Health approach to work.**

Keywords - One Health; information and communication technology; zoonoses; public health; digital humanities

I. INTRODUCTION

The human and the animal worlds have profound and multifarious interactions that lead to a wide range of psychological, social, medical, economical and agricultural benefits. However, there are some severe drawbacks as well, for instance, with regard to the transmission of infectious diseases from vertebrate animals to human beings (zoonoses). The pathogenic micro-organisms - such as bacteria, viruses, fungi or prions - we share with domesticated or wild animals, have caused some of the most significant disease outbreaks in recent years, including HIV, Ebola, avian influenza, Q-fever, H1N1 flu, SARS and more recently MERS-CoV. Over 200 zoonotic diseases, often species-specific, have been identified. They have a serious and rising impact on global public health [1], and accordingly, receive scientific attention [2].

Outbreaks of zoonoses are typically hard to predict because of the complex and ever changing nature of the risk factors involved. At the same time, antimicrobial resistance is increasing and the dawn of the post-antibiotic era is a matter of global concern [3]. The human and economic costs of zoonoses and antimicrobial resistance are substantial. It is estimated that 60% of all human diseases and 75% of all emerging infectious diseases is caused by zoonotic pathogens over the past six decades [4]. The rate at which these have appeared in people has increased over the past 40 years, with at least 43 newly identified outbreaks since 2004. The immediate costs of zoonotic diseases over the last decade have been estimated to be more than $20 billion, with over $200 billion indirect losses to affected economies as a whole [5].

In the Netherlands, at least 19 people died as a consequence of the Q-fever outbreak (2007-2010), while the societal costs have been estimated between EUR 161-366 million [6]. A decade earlier in the UK the 1996 BSE outbreak caused at least 174 deaths (2010) and led to economic costs of at least EUR 1.1-1.4 billion [6]. But, by far the heaviest burden from human-animal diseases is carried by the poorest people. In 2012, the International Livestock Research Institute published a review study analyzing some 1000 disease-surveys covering ten million people and six million animals [7]. The authors conclude that the thirteen most important zoonoses together cause 2.4 billion cases of human illness and 2.2 million deaths each year, mostly in low- and middle-income nations. Approximately 75% of the economic and health damage impacts on only nineteen countries (e.g., Tanzania, India, Togo, Nigeria, Ethiopia) were the density of people and animals create ripe conditions for zoonotic diseases to arise and spread among populations of poor livestock keepers. In Asia and Africa, at least 55000 people recently died of rabies, according to the World Health Organization [8]. Expenses related to the prevention and control of rabies are estimated at US$ 590 million annually on both two continents. Disability-adjusted life years (DALYs) and monetary losses resulting from diseases such as human and livestock cystic echinococcosis (hydatid disease) have been calculated at the global level - assuming substantial under-reporting. The global human burden of echinococcosis may be as high as one million DALYs - or an annual loss of US$ 764 million. A maximum annual livestock production loss is estimated to amount to some US$ 2.2 billion. More figures and estimations on the health and economic impact of zoonoses can be found at the WHO website on 'neglected' zoonotic diseases [8].

Over the last decades the industrial countries have succeeded to eliminate, reduce or control zoonotic diseases

through substantial investments in public health: preventive measures, health education, feed bans, animal vaccination programmes, sanitation, food controls, culling sick animals etc. Nonetheless, the developed world - especially the US, the UK and Australia - now includes the key hot spots for emerging zoonoses (see Fig. 1). In low resource countries, such investments are not yet feasible in operational, legal, cultural or financial terms. Zoonoses present a threat to both human and animal health. Because of the relationship between development and population health the changing course of zoonotic diseases has led to increased attention in public health policy and research.

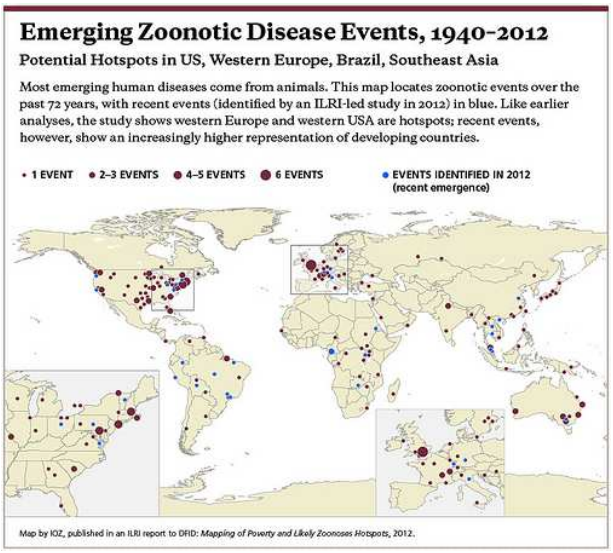

Figure 1. Emerging zoonotic disease events 1940-2012 (source: International Livestock Research Institute, 2012).

It is generally assumed that new and different zoonotic diseases will continue to develop because of

- a worldwide growth of people and animals (population density, cattle density);
- increased international (illicit) traffic of people, animals and products (globalization, eco-tourism);
- cultural changes (urbanization, migration, war, agro-industrial developments, farming new animal species);
- ecological changes (climate, environment, biodiversity).

Quite a few zoonoses are caused by RNA (Ribonucleic acid) viruses, which have high mutation rates and are extremely able to accommodate to changing circumstances. All this has raised global awareness among national, international, intergovernmental bodies and the redirection of resources towards prevention and control of zoonoses. This has led to the establishment of new, international expert networks, and surveillance and early warning systems such as the global network for animal disease research STAR-IDAZ (star-idaz.net), the European Emerging and Major Infectious Diseases of Livestock EMIDA (emida.era.net), the European Network for Diagnostics of 'Imported' Viral Diseases ENIVD (enivd.net/) or Discontools (discontools.eu), a joint initiative of industry and a wide range of stakeholders and several others. In the following sections it is maintained that the 'One Health' strategy to counter the threat of zoonoses can only be effective when the social sciences, the humanities and digital technologies are systematically taken into account.

II. ONE HEALTH

In the course of last century, the age-old shamanist wisdom that human (mental) health, animal health and environmental health are inextricably connected has been revitalized. Long before the well-known 'father' of veterinary epidemiology, the American Calvin W. Schwabe (1927-2006) proposed and promoted the term 'One Medicine' in his textbook "Veterinary Medicine and Human Health" (1984) the German 'founder' of social medicine physician Rudolf Virchow (1821-1902) coined the term 'zoonosis', stating that "... between animal and human medicine there are no dividing lines – nor should there be" [9]. This implies that the scientific foundations between the two do not really differ and that they share the same paradigm. Contemporary insights from human medicine, the natural sciences and veterinary disciplines also indicate that human, plant and animal systems are all part of the shared, planetary eco-system. Biologically speaking, both domesticated animals and wildlife are to be considered as close relatives that possess the same capacities to transfer infectious microorganisms. "We should therefore treat our relationship with other animal species as part of a continuum across which pathogens can emerge and spread, exploiting new niches as we change our interactions, and moving into and out of erstwhile distinct species, regions or communities" [10].

During the last decade, the concept of 'One Medicine One Health' evolved, urged by public concern after the 2003 outbreaks of SARS and Ebola hemorrhagic fever. It strives to advance scientific breakthroughs in an integrative and collaborative way [11]. In 2004 a series of conferences followed, addressing the theme 'One World – One Health' to underscore the health links between people, wildlife and the environment. In 2007/2008 the American Veterinary Medical Association (AVMA) and the American Medical Association (AMA) passed similar 'One Health' policy resolutions and took joint initiatives for action and collaboration. This resulted among others in the One Health commission, in summits and partnerships, targeting "the establishment of closer professional interactions, collaborations, and educational and research opportunities across the health sciences professions, together with their related disciplines, to improve the health of people, animals, plants and our environment" [12].

Today, the integrative, holistic concept of 'One Health' entails a positive, global strategy for expanding interdisciplinary collaborations and communications in all aspects of health care for humans, animals and the environment. It has been disseminated beyond the North Americas. "The synergism achieved will advance health care for the 21st century and beyond by accelerating biomedical research discoveries, enhancing public health efficacy, expeditiously expanding the scientific knowledge base, and improving medical education and clinical care" [13]. The visionary concept inspired many initiatives to improve collaboration between the often-segregated disciplines in policy, education and research. Strengthening the knowledge infrastructure through transdisciplinary cross-fertilization has become an important motivation, e.g., in European public health and policy projects. Since 2008, the EU has promoted the One Health approach, and it has been integrated into certain EU strategy documents [14]. The European Network of Excellence for Zoonoses research (medvetnet.org/) organizes thematic conferences on this subject, international One Health conferences take place (e.g., http://www.onehealthglobal.net/) and many others adopted the concept. One Health is promoted by scientists all over the world and supported by national organizations such as U.S. Centers for Disease Control or the Dutch National Institute for Public Health and the Environment (RIVM) as well as global organizations such as the United Nations (UN), the World Health Organization (WHO), the Food and Agriculture Organization (FAO), the World Organization for Animal Health (OIE), the International Federation for Animal Health and others. WHO, FAO and OIE signed a tripartite collaboration agreement to better coordinate their global activities at the animal-human-ecosystem interfaces [15]. Since 2011 an international open access, peer-reviewed 'One Health Journal' *Infection Ecology & Epidemiology* is published by a Swedish group of scientists to stimulate interdisciplinary collaboration in One Health [16]. In 2012 the World Bank published a report on cost/benefit analyses that accentuate the importance of the One Health approach for prevention and control of infectious diseases and recommended wider implementation [17].

In quite a short time, the concept has drawn massive attention and support. It is "intended to be all-inclusive among the scientific disciplines of human medicine, veterinary medicine and all other related scientific health disciplines" [18]. Therefore, it is remarkable that behavioral sciences, the humanities and technology are most seldomly explicitly mentioned in major documents on 'One Health'.

III. DIGITAL HUMANITIES

'Digital humanities' is a recent term that evolved from an increasing demand to understand and study how digital media interact with human experience and daily life [19]. It denotes an interdisciplinary, academic domain of education, research and practice where digital methods and media are used to study traditional topics in language, history, art, philosophy, communication and cultural studies. Moreover, the 'digital revolution' enabled a range of new behaviors, social contexts and objects, ranging from, e.g., cyber bullying or virtual environments, to web-based recommendations systems or big data, that may be studied from the digital humanities' perspectives. The opportunities of digital media for scholarship, research, education, presentation and cooperation also belong to this area. Like in any new academic field of interest, the subject of defining the scope remains a matter of academic debate. According to the UCLA Center for Digital Humanities "Digital Humanities interprets the cultural and social impact of new media and information technologies - the fundamental components of the new information age - as well as creates and applies these technologies to answer cultural, social, historical, and philological questions, both those traditionally conceived and those only enabled by new technologies" [20]. In line with this definition, we consider the social and behavioral sciences as belonging to the same academic practice and paradigm.

Evidently, the academic exchange between social sciences and computational sciences could benefit all domains of society. Rogers et al. [21] for instance develop methods to study the dynamics of internet censorship through the national web of Iran, or the workings of search engines, query logs and social networks. Others use mapping and advanced visualization techniques to study the role of animals in 19th American century cities [22], plot patterns of intellectual or creative exchange in the early-modern world [23] or operate digital European language repositories [24]. In the biomedical and health sciences the digital humanities gave rise to concepts such as eHealth, Medicine 2.0 or participative healthcare that address the use of information and communication technologies to support and improve health, health care and medical research. The social and participative opportunities enabled by digital media are widely used for the benefit of many [25]. Researchers use the internet as a tool and a source for studying human social behavior. Since 2006, for instance, the use of queries and social media networks have been studied to inform disease surveillance and early warning of infectious diseases [26].

IV. NEW APPROACHES

While the cooperation between the veterinary, botanical, entomological and human domains is now widely encouraged, the involvement of the humanities, i.c., the social and behavioral sciences is conspicuously absent. The ongoing concentration on the pathogen is understandable because of the historical effort - and successes - of the bio-medical professions to curb infectious diseases. It has obviously been the most likely approach. From a contemporary One Health-perspective however, this focus

should be widened as soon as possible. We believe that the humanities and the social sciences could play a decisive role when it comes to operationalizing the high-flown 'One Health' concept on the ground. Especially since they are so happily and prolifically engaged with information and communication technologies in what is sometimes called 'ePublic Health' or 'Public Health 2.0' [27]. At least three reasons illustrate why One Health should be completed with methods and concepts from the digital humanities and the social sciences.

The first is that the threat of (re)emerging zoonoses combined with our limited arsenal to protect public health, simply demand us to combine efforts. Faced with today's challenges we need to better understand what people actually do - not just what microorganisms do. They travel within and between their human hosts who participate in complex social networks. At the end of the day, people's behaviors make the difference when it comes to the transmission of disease-causing microorganisms. People create the conditions for the transmission of novel and re-emerging zoonoses but they also build the conditions that reduce their incidence, and prevent suffering, illness and death. Epidemiological data evidently need a human context to be meaningfully interpreted and put to use. Without the social sciences, the complex interactions of factors and circumstances that determine novel zoonotic disease spill-over get lost because they simply can't be understood. Social behavior is an essential ingredient of R_0, the basic reproduction number of an infectious disease. In Table I the social and behavioral factors associated with all three components of R_0 are summarized, after Janes et al. [28]. This knowledge on the social nature of transmission dynamics and possible modes of transmission informs the design of effective public health interventions and tailored risk communication on zoonoses.

TABLE I. SOCIAL FACTORS AFFECTING ZOONOTIC TRANSMISSION MECHANISMS

		Social and behavioral factors
R_0 basic reproduction number	***Exposure rate***	Social relationships, value system, ethics, rituals, habits, agricultural practice, population density
	Probability of transmission	Poverty, stress, health disparities, level of public health services, density of livestock, housing, sanitation
	Duration of infection	Social inequality, stress, access to care

The second reason to appreciate interdisciplinary collaboration with the humanities and the social sciences is their proven effectiveness in public health practice. Travel vaccination campaigns, personal hygiene, sanitary control, 'test and slaughter', protective clothing, changing life style choices (tobacco, fat, alcohol, sex, drugs), school-based prevention and education are just a few examples of effective social and behavioral measures [29]. Social scientific methodologies could be extended for use in the field of applied infectious disease research. Interesting examples can be found for instance in studies that model the impact of individual behavior on the spread of infectious diseases [30] or in qualitative research on the behavioral defenses and social psychological mechanisms through which people protect themselves against pathogens [31].

Thirdly, the reach and social impact of public health interventions, *when extended and connected with the opportunities offered by information and communication technologies*, is considerably enlarged as compared to biomedical approaches alone [32]. This is demonstrated for instance in the practice of the Antibiotic Stewardship Program of Eursafety Health-net. This cross-border German-Dutch collaboration to prevent and control health care associated infections such as MRSA[1] has been very successful to reach a significant reduction of nosocomial MRSA cases [33]. The use of a web-based tools for both patients and professionals has been important for the protection of patient safety and quality of care. Information and communication technologies [34] potentially empower them to take control over their personal and professional lives. They support for instance adherence to medical guidelines and protocols for hygiene or prudent prescription of antibiotics, which are essential to reduce health care associated infections. Self-management is one of the main promises of Health 2.0 and other innovations in health care [35, 36]. This matches seamlessly with currents attempts to re-define health in terms of peoples' positive capabilities to cope with disease and misfortune [37]. Technology supports this aspiration, which should be extended to the One Health domain. Another example is the design and development of an eHealth intervention to prevent tick bites and Lyme disease infections among green professionals and outdoor people currently undertaken by Beaujean et al. [38]. Although the incidence and prevalence of people presenting to the GP with tick bites or the first signs of Lyme disease has increased substantially, compliance to guidelines for prevention is generally low. A mobile app is developed to address the motivations of people at risk with tailored messages to eventually change this behavior.

The incredible growth in the use, availability, accessibility of these digital technologies - their speed, range and impact - also provides us with new opportunities for disease monitoring, surveillance and research [39]. These allow us

[1] *Methicillin-resistant Staphylococcus aureus* (*MRSA*) is a bacterium resistant against most antibiotics. It belongs globally to the most frequent causes of difficult-to-treat nosocomial infections in humans.

not only to inform a targeted public health response but also to act preemptively. Recently, scholars have called for an investment in fields such as digital humanities and computational social sciences, to using 'big data', the kind of digital information made available by improved data management, advanced mathematical analysis tools and increasing storage capacity [40]. Traditionally social or cultural data were collected via social scientific methods based on data scarcity, demands for formally controlled designs and financial considerations: field studies, user panels, focus groups, interviews, questionnaires and surveys. However today, the social and cultural interactions passing through the internet are considered as fast, valuable and relatively cheap sources of data for social and cultural research [27, 41]. This is obviously of great importance for the early warning, prevention and control of zoonoses. In fact, this new area of study with new methodological issues in risk communication, prevention and big data is the Number One challenge for sustainable and credible One Health solutions.

What is needed to effectively integrate the digital humanities and the social sciences into One Health? A good part of this may simply be translational and relational. Like in art and in music, an open mind is a condition sine qua non for cooperation. Social scientists, natural scientists, and medical practitioners need to be able to confer, to communicate and join forces now the global momentum is there. We hope to co-create one such opportunity at next year's 3rd international One Health Congress in the Netherlands [42].

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