Cell Broadcast Alerts as Tools for Community Outreach in Ebola Virus Disease Outbreaks in Central and Western Africa

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Accessibility
Cell Broadcast Alerts as Tools for Community Outreach in Ebola Virus Disease
Outbreaks in Central and Western Africa

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A Thesis in the Field of Biology
for the Degree of Master of Liberal Arts in Extension Studies

Harvard University
May 2019
Abstract

Ebola Virus Disease outbreaks have been a deadly and ongoing problem since the initial outbreaks of *Zaire ebolavirus* and *Sudan ebolavirus* in 1976. To date, 28 distinct outbreaks have been identified (CDC, 2017), with the deadliest outbreak occurring between 2014 and 2016, and 4 additional outbreaks since, including one which is still ongoing as of January 2019 (WHO, 2019). Analysis of self-scored, standardized emergency response evaluations called JEETs revealed that national governments in affected areas encounter a variety of difficulties in responding to these outbreaks, often lacking severely in areas such as funding, organizational cooperation, and access to critical supplies. The goal of this research was to identify an effective, low-cost strategy for EVD outbreak response communications. By analyzing mobile usage statistics, as well as comparing existing mobile network infrastructure to recent EVD outbreaks, it was determined that emergency cellular alerts would be a feasible and effective method of emergency outreach. Existing cellular communication networks are present in the most heavily-affected countries, and mobile communication penetrations in these countries are high and rapidly increasing, providing an already-established method of rapid, direct communication with hundreds of millions of potential targets. Previous studies on EVD outbreak tracking using mobile communications have yielded positive results (Feng, Grepin & Chunara, 2018; Njoku, 2014; Tracey et al., 2015). By investigating the roles of engagement with local communities and importance of building trust and respecting local customs, as well as previous examples of EVD outreach communications, several guidelines for emergency messages to EVD-affected areas were created, which, if implemented, could quickly and effectively aid in outbreak control in affected areas.
Acknowledgments

I would like to sincerely thank Mr. Stephen Taylor and Dr. Marcia Castro, my thesis directors, for their support and guidance throughout my thesis process. Without their suggestions, ideas and support, I would not have been able to produce this work. Mr. Taylor and Dr. Castro have accepted my ideas and encouraged the flow of developing this work throughout this entire project.

I would also like to thank Dr. James Morris for his guidance and reassurance through the entire proposal and thesis processes. Despite developing both my proposal and thesis hundreds of miles away from the Harvard campus, I was able to successfully submit a thesis proposal and connect with both a local and a Harvard thesis director. Thank you very much for your efforts in helping me complete this process.

I would like to thank my family for supporting me through the entire process of obtaining my MLA degree over the years, and I would like to highlight the incalculable amount of support and faith in me given by my wife Becca. Without them by my side, none of this would have been possible.

Finally, I would like to thank my cat for his able performance as a paperweight and keyboard warmer throughout the thesis process. Good job, buddy.
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Chapter I

Introduction

History of Ebola Outbreaks

Ebola virus disease (EVD) is a devastating disease that has caused numerous outbreaks across Africa since its first recorded emergence in 1976. The disease is highly fatal, highly communicable, and tends to appear without warning. Infection spreads rapidly and can devastate entire towns and villages. Although EVD is not transmitted by air, transmission can occur through contact with bodily fluids of an infected host, or with items in contact with infected bodily fluids, such as bedding or clothing. EVD infection results in high mortality rates: historical large-scale outbreaks have led to fatality rates between 25% and as high as 90% (WHO, 2017). EVD has an incubation period of between 2 and 21 days, during which time the disease is asymptomatic, and there is no evidence of disease communicability. Once symptoms begin, the disease becomes highly communicable via contact with infected bodily fluids. Initial symptoms are similar to common influenza, including fatigue and weakness, fever, and muscle/joint pain. Even during this initial phase of relatively mild symptoms, the disease is still communicable. In fact, lack of or misdiagnosis of EVD during this mildly symptomatic phase can be a major contributor to early outbreak proliferation (Bausch & Schwarz, 2014). More severe symptoms begin several days after initial symptoms, and can continue to mimic more
common illnesses, presenting as vomiting and diarrhea, chest pains and rashes. The most severe symptom is internal and external bleeding: significant decreases in blood clotting ability lead to bleeding into the skin, the whites of the eyes, and mucous membranes. Death typically occurs due to fluid loss from bleeding and vomiting. Survivors typically report ongoing minor symptoms such as fatigue and pain for weeks to months after recovery (Qureshi et al., 2015). Table 1 shows a list of EVD outbreaks in Africa since the initial emergence of the virus in 1976.

<table>
<thead>
<tr>
<th>Country</th>
<th>Town</th>
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<th>Deaths</th>
<th>Species</th>
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<td>284</td>
<td>151</td>
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*Numbers reflect laboratory-confirmed cases only.

Table 1. Ebola Virus Disease outbreaks in Africa (CDC, 2018).
A variety of factors contribute to the rapid spread of EVD. The primary focus of containment and prevention has been human-to-human transmission. In earlier, smaller outbreaks in Central Africa, even the worst examples, such as the initial 1976 outbreak in the DRC (280 deaths across 318 cases, a mortality rate of 88%), or the 1995 outbreak, also in the DRC (254 fatalities across 315 cases, a mortality rate of 81%) were contained relatively quickly (Alexander et al., 2015), and infection did not spread beyond localized villages. However, the most recent outbreaks in West Africa spread throughout almost the entirety of the affected countries of Liberia, Sierra Leone and Guinea, and lasted for nearly 2 years before being finally contained. Additionally, the latest EVD outbreak in the DRC is still ongoing as of January 2019, and now threatens to spread into Uganda (Molteni, 2018).

A primary concern in the 2014-2016 EVD outbreak in Liberia/Guinea/Sierra Leone was the mobility and social dynamics of the local populations. West African populations are known for being heavily migratory, as well as preserving familial relationships across long distances:

“Large-scale population movements in the region, both within and between countries, have been driven by decades of conflict and the search for improved socioeconomic conditions and opportunities…as such, present-day population
mobility in West Africa has been an important contributing factor to the explosive nature of the West African Ebola outbreak” (Alexander et al., 2015, p.14).

This increase in transmission across geographical regions is exacerbated by the relatively long incubation period of EVD, as well as the early-onset symptoms resembling many other common, less severe diseases. In addition to heavy population migration, another major factor in the size and spread of the West African EVD outbreaks was the heavy urbanization occurring in recent years. Between 1960/1961 and 2012/2013, Guinea, Liberia and Sierra Leone experienced population density increases of 223%, 275% and 178% respectively, leading to heavy urbanization (Alexander et al., 2015). This significantly increased population density was certainly a major contributor to the size of the 2014-2016 EVD outbreaks, due to the increased likelihood of contact with infected individuals. The rapid movement of potentially infected individuals led to small outbreaks across the region, a problem that was compounded by a lack of properly equipped treatment centers, as well as multiple cases appearing in areas very far from treatment centers (Dixon & Schafer, 2014).

Local hospitals at the onset of the outbreak were unequipped and uneducated in dealing with EVD, which contributed heavily to the spread of the disease. Various factors such as lack of preparedness, insufficient quarantine facilities, improper barrier precautions and even use of non-sterile instruments and syringes (Weber & Rutala, 2001) contributed to turn local hospitals into hotbeds of nosocomial infection. Another major issue was the reluctance of infected patients to seek proper medical attention, frequently due to mistrust and fear of modern healthcare interventions. (Weber & Rutala, 2001). The reasoning behind this reluctance and mistrust of health care authorities was a primary
focus of this study, and methods of overcoming these setbacks were a critical aspect of designing community outreach guidelines for EVD prevention and treatment. Rejection of medical treatment can severely amplify an EVD outbreak. Infected patients are frequently treated at home, or nearby by a traditional healer or untrained doctor. They are often kept in completely non-sterile conditions, with no regard to exposure barriers by the patients’ family, or others in the community. Often a single infected individual can spread the disease to dozens of others in their vicinity, simply due to the communal nature of various aspects of life such as washing clothes or sleeping conditions.

EVD vaccines have been demonstrated, with a recent vaccine for a specific EVD strain known as rVSV-EBOV demonstrating 100% efficacy in a pilot trial in Guinea and Sierra Leone (Henao-Restrepo et al., 2017). However, vaccinations are a proactive solution, and the challenges of vaccination programs, even with widely-available common vaccines, is a massive public health burden even for much more well-known diseases such as influenza. Vaccine programs in EVD outbreaks have been limited, and limited data on their efficacy exists. The ongoing EVD outbreak in the DRC has been a field test for EVD vaccinations. While a formal assessment of the vaccine’s efficacy during this outbreak has not been assessed, WHO officials are claiming that the vaccine is having a major impact on fighting the outbreak (Cohen 2018). However, funding for production of the vaccine is expected to run out in January of 2019, and as of that date the outbreak is still ongoing, with signs of potentially spreading into other countries (Molteni 2018). Should the outbreak continue past January, vaccine stores may run out and vaccines will no longer be a reliable method of outbreak control.
Fighting Ebola in the Community

One of the most critical elements of controlling EVD transmission is the ability to engage with local populations on a community level. Data from previous outbreaks has shown that improper community engagement and responses can severely hamper outbreak control efforts. Calain & Poncin (2015) examined the role of practical ethical principles in EVD outbreak control. At the initial onset of the 2014-2016 outbreak, Guinea, Liberia, Sierra Leone and Nigeria began issuing compulsory declarations in order to attempt to control the spread of the virus. These declarations included curfews, quarantine, mandatory screenings, mandatory treatments, and sanitary burials. Many of these efforts backfired, increasing mistrust and hostility towards both governmental and healthcare personnel. Many of these efforts were not based on any specific epidemic control doctrines, and were merely reflexive responses by panicked governments.

The 2014-2016 outbreak, as well as the ongoing outbreak in the DRC, has provided a wealth of information regarding positive enforcement and engagement with local communities. These efforts have yielded significant, positive results (Abramowitz et al., 2015; Gray et al., 2015; Kucharski et al., 2015). Community leaders, traditional healers, and other trusted individuals have been recognized as key elements of spreading useful, factual information on EVD control and treatment. Multiple studies have been performed to evaluate the perception of EVD control efforts in affected communities (Anoko, 2014; Marais et al., 2015; Oosterhoff & Wilkinson, 2015). By working together
with community leaders, health care workers have made great strides in EVD control. This study explored the strategies employed to engage with local communities, as well as efforts to build trust between healthcare personnel and affected communities, in order to effectively design public health guidelines and messages in the context of emergency alerts, broadcast on a localized basis to affected areas.

Digital Communications in EVD Outreach

Digital communications are an important part of controlling EVD outbreaks. Previous and current outbreaks have seen the use of television, radio and printed news for dissemination of information, but digital information has been inconsistent. With the rapidly increasing prevalence of mobile phones and Internet access comes a flood of misinformation, rumors, and conspiracies regarding Ebola. This misinformation can be greatly compounded by local customs (Oosterhoff & Wilkinson, 2015) or political tensions (Anoko, 2014). Although community engagement efforts have helped to correct misinformation and spread factual information, the use of official, coordinated digital media outreach to combat EVD outbreaks has been limited. Pilot programs using digital communications have been studied, most notably the 117 emergency EVD reporting hotline in Sierra Leone (Alpren et al., 2017), as well as U-Report, a UNICEF-backed, SMS-based application that mimics a basic social media environment, in order to allow healthcare organizations to both disseminate information and respond to community concerns on a local basis.
This study analyzed these methods of outreach, but focused on using Cell Broadcast alerts as a proposed method of community outreach. Cell Broadcast is a well-established, codified method of transmitting geographically-based, specific alerts to all subscribers on a mobile network. Cell Broadcast systems form the basis of emergency alert systems worldwide, including in the United States and the European Union.

Research Goals & Specific Aims

The primary goals of this thesis were to demonstrate the necessity and potential effectiveness of Cell Broadcast alerts during EVD outbreaks, and to propose a series of guidelines for producing effective, positive engagement-based emergency alerts for these broadcasts. While a variety of EVD outbreak management strategies exist, recent and ongoing outbreaks have demonstrated that every possible tool is needed to help combat the spread of EVD. Previous research has shown that in order to be effective, community engagement and information dissemination must be approached with a significant level of care towards local traditions and customs, as well as current sociopolitical situations in affected areas. In order to effectively present the proposed guidelines, four specific aims were followed.

The first specific aim was to demonstrate the necessity for additional methods of EVD outbreak control. Self-scored national evaluations of core emergency healthcare capacities were analyzed and presented. This data showed that even with recent advancements and lessons learned from previous outbreaks, both EVD-affected countries
and other countries in the region at risk for potential EVD outbreaks are severely lacking in proper EVD response protocols on a number of levels.

The second specific aim was to demonstrate that existing cellular networks in affected countries are present and relatively robust. Cellular network data was presented and analyzed in the context of recent EVD outbreaks. This data showed that while high-speed mobile networks are still sporadic and developing, a majority of recent EVD outbreaks occurred with significant overlap of low-speed mobile networks. Additionally, the presence of widespread low-speed mobile networks in affected countries demonstrated that emergency alerts disseminated via SMS or other cellular technologies would be received by a significant proportion of the potentially-affected population.

The third specific aim was to further demonstrate the potential efficacy of mobile alert systems. Several pilot studies of mobile-based EVD response strategies were presented, as well as information regarding social media-based EVD responses. The results of these analyzed studies further demonstrated that mobile communications were, and will be, effective methods of spreading emergency information.

The fourth specific aim was to analyze prior studies regarding community engagement, in order to effectively design guidelines for future emergency alert content. Several studies of community engagement efforts in recent EVD outbreaks were presented, and the data from these studies were used to formulate a series of guidelines for effective, localized information dissemination, with the goal of reducing false information and mistrust of healthcare officials, and increasing safe practices when dealing with individuals infected or killed by EVD.
Chapter II

Materials and Methods

Joint External Evaluation Tool

In order to evaluate the necessity of additional methods of EVD outreach and detection, as well as demonstrate the importance of technology and social media as underused methods of community outreach and engagement, data from the WHO’s Joint External Evaluation Tool (JEET) were collected and analyzed. The JEET is a self-evaluation tool based on the 2005 International Health Regulations (IHR). The IHR contains a series of requirements related to core public health capacities, such as the capacities to detect and respond to public health emergencies. State Parties to the WHO are required to report annually to the World Health Assembly on the state of IHR implementation. The JEET was developed in order to allow countries to self-evaluate their public health capabilities, and create a roadmap to improving deficient areas. All JEET reports are voluntary and self-initiated, and report data are published publically.

The JEET consists of a series of scored measurements of a country’s capacity for a variety of public health emergency response factors. These factors are divided into four categories: Prevent, Detect, Respond, and IHR-Related Hazards and Points of Entry. Categories are further divided into IHR capacities, such as National Legislation, Policy
and Financing in the Prevent category, and Reporting in the Detect category. These capacities each consist of a series of scored indicators. For example, under the Prevent category, National Legislation, Policy and Financing capacity, the following scored indicators are present:

P.1.1 – The State has assessed, adjusted, and aligned its domestic legislation, policies and administrative arrangements in all relevant sectors, to enable compliance with the IHR

P.1.2 – Financing is available for the implementation of IHR capacities

P.1.3 – A financing mechanism and funds are available for timely response to public health emergencies

Each indicator is scored on a scale of 1-5, and color-coded appropriately (Figure 1). In addition to the scored indicator system, each category contains a series of contextual questions, related to region-specific considerations or circumstances which may affect the self-evaluation responses, as well as a series of technical questions directly related to quantifiable indicators, in order to help a country’s self-evaluation.

The JEET represents a significant source of information regarding the need for additional outbreak monitoring and control methods. As each JEET is fully reviewed by a WHO JEE team, consisting of an international assembly of experts in the subject matter, it provides both a country’s own perception, as well as a peer-reviewed evaluation, of critical shortcomings in a country’s public health response systems. While the JEET covers a wide range of capacities, I focused specifically on capacities related to outbreak prevention and response, with regard to information dissemination and community outreach.
In the Prevent category, the capacity for zoonotic disease prevention, the capacity for antimicrobial resistance (specifically the indicator for healthcare-associated infection prevention and control programs), and the capacity for biosafety and biosecurity were emphasized.

In the Detect category, the capacity for effective modern point-of-care and laboratory-based diagnostics, the capacity for real-time surveillance (including surveillance systems and analysis), and the capacity for reporting network and protocols in-country were the points of focus.
In the Respond category, almost the entire category was relevant to the subject, including capacities for public communication, dynamic listening and rumor management, linking of public health and security authorities, systems for sending and receiving medical countermeasures, etc.

In addition to the scored indicators, each category of capacities includes a series of State-specific individual capabilities, recommendations for further action, and detailed strengths/weaknesses for each indicator, tailored to the individual country participating. Relevant recommendations and capabilities were used to help assess the feasibility and necessity of the proposed outreach mechanisms.

Communications Penetration and Outbreak Overlap

In order to demonstrate the potential level of successful outreach via social media, several sets of data comparing mobile phone network access with recent outbreak patterns were collected and analyzed, using a series of websites and applications designed to monitor and provide mobile network statistics.

Various sources of communication penetration in the region were analyzed, including several communications statistics monitoring websites, as well as reports from technology firms on the penetration rates of mobile networks.

OpenSignal is an international company which focuses on measuring cell phone network performance. Using their OpenSignal mobile apps, users automatically provide
cellular service information, captured automatically from their mobile devices. These
data are collected and aggregated, and are reported in the form of a coverage map. These
maps are displayed in real-time on the app. The app also provides the ability to filter
individual service providers, as well as displaying only 2G/3G networks, or only 4G
networks. Due to the fact that OpenSignal’s software is only available on mobile
platforms (Android/iOS), I used the Android Developers Studio to emulate an Android
phone on a PC platform. Emulating a phone allows for Android applications to be run on
a desktop PC. This was done simply to aid in capturing map data for analysis purposes.

In addition to OpenSignal, two websites were used to provide coverage data for
analysis. nPerf is an internet/mobile connection testing website that offers coverage maps
similar to OpenSignal. nPerf also offers the option to distinguish between 2G, 3G and 4G
network coverage individually in certain locations. MobileWorldLive offers network
provider-level information, including official coverage maps submitted by network
providers, as well as individual mobile network capabilities, including bandwidth,
roaming partners (which can increase available coverage), and updated service status,
including upcoming planned networks.

The distinction between 2G, 3G and 4G networks is critical and was analyzed and
discussed. Older networks are capable of extremely limited internet-based
communications, and instead function mostly for telephone and SMS capabilities.
Understanding the network structure in target countries is critical for determining the
nature of digital outreach – for example, social media use generally requires at least a 3G
network, as data rates are simply too low to support loading full-media web pages on 2G
networks, whereas SMS-based correspondence is available on virtually any mobile network.

Outbreak map data was collected from WHO publications. Outbreak map data and mobile coverage maps were compared, using Adobe Photoshop to overlay network coverage data onto outbreak maps.

Digital communications in EVD Detection and Response to Date

Another measure of potential effectiveness is the demonstrated use of mobile technology and/or social media in recent EVD outbreaks. Several recent studies were analyzed, including pilot studies of SMS-based correspondence and outbreak tracking, in order to demonstrate the potential of mobile technology in disseminating EVD-related information, as well as to gain a deeper understanding of the crucial aspect of information content, including presentation, consistency, simplicity, etc.

Cultural and Societal Barriers to Effective Outreach

Once the target communication methods and demographics were analyzed, the final component was defining and discussing the content of the proposed outreach content. In order to understand the ideal information to be presented during outreach, particular attention was paid to the cultural and societal difficulties encountered in EVD
outreach programs during recent outbreaks. Understanding the challenges and obstacles inherent in outreach to developing countries is critical in ensuring that information is presented in a safe, consistent manner, by trusted individuals and conflicting with as few cultural practices as possible. In order to demonstrate this importance, it was necessary to analyze and discuss previous EVD outreach programs in the affected areas, paying specific attention to the community-level details in order to maximize the trust given to information provided. As demonstrated, lack of respect for local cultural traditions, as well as conflicting information, can cause more harm than good, contributing to improper safety precautions, increased mistrust of healthcare personnel, and even violent conflict (Gray et al., 2015).
Chapter III

Results

JEET Scores

Relevant response scores from the JEET are summarized in Table 2. Every country in Western/Central Africa that has to date completed a JEET is represented, as well as the scores from two sample developed countries, the United States of America and Belgium. While not all countries are represented due to an absence of JEET responses, the four countries most severely affected in recent EVD outbreaks – Sierra Leone, Guinea, Liberia and the DRC – have completed JEET responses and are represented in the data.

Scores relating to antimicrobial resistance were uniformly undeveloped. The four countries with major EVD outbreaks, as well as nearly the entire region, have no protocols at a national level to educate, prepare or respond to resistant bacterial infections.
| R.1.1 Multi-hazard NPHEPR plan is developed and implemented | Liberia | Guinea | Sierra L | DRC | Senegal | Maurit. | Gambia | Benin | Ivory C | Nigeria | Mali | Camro | Burkina | Togo | Belg. | USA |
|------------------------------------------------------------|---------|--------|----------|-----|---------|--------|--------|-------|--------|---------|-----|-------|--------|-------|------|
| R.1.2 Priority public health risks and resources are mapped and utilized | 2       | 2      | 2        | 2   | 2       | 2      | 2      | 2     | 2      | 2       | 2   | 2     | 2      | 2     | 2    |
| R.1.3 Capacity to activate emergency operations | 3       | 2      | 4        | 3   | 3       | 3      | 2      | 3     | 2      | 2       | 3   | 3     | 3      | 3     | 3    |
| R.1.4 Emergency operations program | 4       | 4      | 3        | 3   | 2       | 3      | 2      | 3     | 2      | 2       | 2   | 1     | 2      | 2     | 2    |
| R.2.1 Case management procedures are implemented for IHR relevant hazards | 2       | 2      | 2        | 2   | 2       | 2      | 2      | 2     | 2      | 2       | 2   | 2     | 2      | 2     | 2    |
| R.2.2 Public health and security authorities are linked during a suspected or confirmed biological event | 4       | 4      | 1        | 2   | 2       | 2      | 2      | 2     | 2      | 2       | 2   | 2     | 2      | 2     | 2    |
| R.3.1 Public health and security authorities are linked during a suspected or confirmed biological event | 4       | 4      | 1        | 2   | 2       | 2      | 2      | 2     | 2      | 2       | 2   | 2     | 2      | 2     | 2    |
| R.3.2 System in place for sending and receiving medical countermeasures during a public health emergency | 4       | 4      | 1        | 2   | 2       | 2      | 2      | 2     | 2      | 2       | 2   | 2     | 2      | 2     | 2    |
| R.3.3 System in place for sending and receiving health personnel during a public health emergency | 4       | 4      | 1        | 2   | 2       | 2      | 2      | 2     | 2      | 2       | 2   | 2     | 2      | 2     | 2    |
| R.3.4 Risk communication systems | 3       | 3      | 3        | 3   | 3       | 3      | 3      | 3     | 3      | 3       | 3   | 3     | 3      | 3     | 3    |
| R.4.1 System is in place for sending and receiving medical countermeasures during a public health emergency | 4       | 4      | 1        | 2   | 2       | 2      | 2      | 2     | 2      | 2       | 2   | 2     | 2      | 2     | 2    |
| R.4.2 System is in place for sending and receiving health personnel during a public health emergency | 4       | 4      | 1        | 2   | 2       | 2      | 2      | 2     | 2      | 2       | 2   | 2     | 2      | 2     | 2    |
| R.4.3 Mechanisms for responding to zoonoses and potential zoonoses are established and functional | 2       | 2      | 2        | 2   | 2       | 2      | 2      | 2     | 2      | 2       | 2   | 2     | 2      | 2     | 2    |
| R.5.1 Whole-of-government biosafety and biosecurity system is in place for human, animal and agricultural facilities | 2       | 2      | 2        | 2   | 2       | 2      | 2      | 2     | 2      | 2       | 2   | 2     | 2      | 2     | 2    |
| R.5.2 Biosafety and biosecurity training and practices | 2       | 2      | 2        | 2   | 2       | 2      | 2      | 2     | 2      | 2       | 2   | 2     | 2      | 2     | 2    |
| R.5.3 Public Communication | 4       | 4      | 1        | 2   | 2       | 2      | 2      | 2     | 2      | 2       | 2   | 2     | 2      | 2     | 2    |
| R.5.4 Communication engagement with affected communities | 2       | 2      | 2        | 2   | 2       | 2      | 2      | 2     | 2      | 2       | 2   | 2     | 2      | 2     | 2    |
| R.5.5 Dynamic listening and rumor management | 3       | 3      | 2        | 2   | 2       | 2      | 2      | 2     | 2      | 2       | 2   | 2     | 2      | 2     | 2    |

Table 2. JEET scores for selected capacities.
Capacities for surveillance and response to zoonotic diseases was varied across the region, with some countries demonstrating currently-developing systems to manage zoonotic detection and response. For example, the DRC has developed and is in the early stages of implementing an integrated zoonotic disease surveillance plan, with cooperation between several organizations (health and wildlife ministries) and dedicated field investigation teams. However, the three countries most severely affected by the 2014-2016 EVD outbreak are severely lacking in these capacities – Sierra Leone has no zoonotic surveillance systems whatsoever, and both Liberia and Guinea are capable of only basic monitoring of potential zoonotic transmission events, with fragmented communication and information-sharing between animal and human health services.

Testing laboratory capacities are developing at a steady pace, with Liberia, Sierra Leone and Guinea all demonstrating at least limited capacity for lab-based EVD detection on a national level. In particular, both Liberia and Sierra Leone have demonstrated significant progress in EVD detection, and both countries no longer rely on foreign personnel and equipment for local EVD testing.

Real-time surveillance scores are promising across the countries most heavily affected by EVD outbreaks, and in fact almost the entire West African region demonstrates at least limited or developing capacities for real-time surveillance. Liberia, Sierra Leone, Guinea and the DRC all demonstrate well-developed disease surveillance capacities. In Sierra Leone, for example, a proficient laboratory network is well-equipped to both diagnose EVD locally, as well as safely transport specimens to national-level laboratories for further analysis. Liberia has implemented community event-based surveillance in 11 out of 15 of the counties that make up the country.
One capacity which was significantly lacking across the entire region was in-country reporting networks and protocols. However, the four countries majorly affected by EVD outbreaks all demonstrated developing capacities for both in-country coordination in the event of emergency situations, as well as reporting protocols to the WHO in these situations.

While the JEET scores for implementing multi-hazard national public health emergency protocols are marked as non-existent (score of 1) in the countries of highest concern, the reports do specifically note the existence and development of EVD-specific protocols.

Emergency operation protocol capacities were mixed among the four EVD-prone countries. Liberia and Sierra Leone both scored high, demonstrating sustainable capacities for responding to emergency situations. Both countries have emergency operations centers spread throughout all counties/districts, and both countries have had their local-level rapid response teams trained and tested during the recent EVD outbreak that affected both countries. Guinea and the DRC, on the other hand, are severely lacking in nationwide emergency response plans, with funding and local government organization coordination and cooperation as particular issues.

A similar divide exists in the linking of public health and security authorities in the event of a public health emergency. Both Liberia and Sierra Leone have demonstrated sustainable capacities to integrate their security and public health responses, providing a coordinated front, ensuring that health care workers and officials are properly secured and supplied at the front lines of outbreak control. Additionally, both countries have demonstrated the ability to sufficiently supply the front lines of emergency response with
sufficient medical supplies and personnel. While Guinea’s response to the recent EVD outbreak was well-coordinated between security and healthcare authorities, the lessons appear to have been wasted to an extent, as the country currently has no formal multi-sector framework for emergency event response. The DRC is similarly poorly-equipped to coordinate responses to emergency events. Political instability and civil unrest have contributed significantly to a lack of ability to properly send both secure healthcare personnel as well as medical supplies to affected areas.

Risk communication capacities were well-represented in Liberia and Sierra Leone, with Guinea and the DRC again falling behind. As with several other capacities, the JEET reports specifically underscored the lessons learned from the 2014-2016 EVD outbreaks, with the result that both Liberia and Sierra Leone have comprehensive, national-level risk communication plans, including dedicated personnel, coordinated media responses, and consistent public communication via media platforms. Guinea, while significantly lagging behind Sierra Leone and Liberia, has demonstrated basic risk communication, but lacks a multi-sector framework for risk communications, and relies heavily on external organizations to assist in communications and community outreach. The DRC also lacks in coordinated risk communication capacities. Information exchange is not codified, community engagement practices are sporadic and underfunded, and communication and information technologies such as SMS alerts or radio/television reporting are limited in scope.
Mobile Coverage and EVD Outbreak Data

Mobile coverage maps were overlaid onto outbreak maps. Figure 2 shows 2G network coverage overlaid onto the most recent map of EVD cases during the 2014-2016 outbreak, using the final WHO Situation Report map. Figure 3 shows 2G network coverage overlaid onto the 2018 EVD outbreak in northwestern DRC. Figure 4 shows 2G network coverage overlaid onto the ongoing EVD outbreak in eastern DRC.

Mobile coverage maps for Liberia, Guinea and Sierra Leone, the three countries most heavily affected by recent EVD outbreaks, are displayed in Figures 10-18. Figures 10-13 show provider-submitted coverage maps for Orange Liberia and Lonestar, for both their 2G and 3G networks. Figures 14 and 15 show coverage maps for Orange Sierra Leone’s 2G and 3G networks, and Figure 16 shows 2G coverage for Africell in that country. Figures 17 and 18 show 2G coverage maps for Areeba and Cellcom in Guinea. Additionally, coverage information for the 2 most recent EVD outbreaks in the DRC is shown in Figures 3 and 4. These areas have 2G coverage from Vodacom.
Figure 2. 2G network coverage (pink) overlaid on 2014-2016 EVD outbreak map.
Figure 3. 2G network coverage (pink) overlaid on 2018 EVD outbreak map.
Figure 4. 2G network coverage (pink) overlaid on 2018-2019 EVD outbreak map.
User-submitted data from OpenSignal was somewhat limited in the analyzed countries. Figures 19-21 show overall maps of submitted data points. Unfortunately, due to the limited entries, specific data regarding 2G vs 3G coverage was unavailable. User-submitted data from nPerf for Sierra Leone, Guinea, Liberia and the DRC were unavailable. Maps for several other countries in the region were available, and demonstrated the tendency for mobile networks to follow major transportation routes (Figures 22-24).

WHO Situation Reports provided outbreak maps for the ongoing DRC outbreak, the 2018 DRC outbreak, and the 2014-2016 outbreak in Liberia/Sierra Leone/Guinea (Figures 25-27).

Recent EVD Communication Methods

Househ (2017) analyzed data from Twitter and Google News in a one-month period between September-October 2014, during the onset of the 2014-2016 EVD outbreak, and found that Twitter activity related to the term “Ebola” increased significantly at the early stages of the outbreak. However, although a portion of Twitter messages regarding Ebola came from affected areas such as Liberia, the majority of messages came from the United States, and significant peaks in Twitter trends related primarily to Google News articles from the United States, such as then-President Obama authorizing National Guard reserves to combat Ebola, or the potential of infection in the city of Dallas, Texas. Rodriguez-Morales et al. (2015) also analyzed Twitter messages in
a similar period, identifying an 11-fold increase in messages related to Ebola in the 24 hours immediately following news reports of an Ebola-infected individual who had travelled from Liberia to the United States. Fung et al. (2015) similarly reported on the prevalence of social media traffic in the United States regarding Ebola.

In a comprehensive review, Fung et al. (2016) discussed a series of 12 different studies relating to social media usage and Ebola. However, most of the studies analyzed were, similar to Househ (2017) and Rodriguez-Morales et al. (2015), related to global Twitter activity, rather than outbreak-localized social media responses. The review also discussed image and video social media sites such as Youtube or Instagram, which generally depend on a high-speed internet connection, and are thus significantly less popular in West Africa.

Feng, Grepin & Chunara (2018) performed an SMS-based EVD survey in Liberia and highlighted a number of potential benefits of using mobile phone-based communication. While the study primarily focused on SMS-based survey responses, rather than one-way information distribution, the results emphasized the usefulness of mobile communications in dealing with EVD outbreaks.

Alpren et al. (2017) analyzed the 117 call alert system, a national-level phone hotline for reporting potential EVD cases and deaths. Data from this study showed promising results, with nearly 350,000 calls made to the hotline. Calls to the hotline increased significantly during the peak of the EVD outbreak in 2014, and calls continued even after the outbreak had subsided (Figure 5).
Tracey et al. (2015) described an SMS-based EVD monitoring system called EbolaTracks, used in Western Australia to monitor individuals returning to that region from EVD-affected countries. The system uses SMS to open a dialogue between monitored individuals, allowing them to report symptoms, which are followed up on by dedicated health care officials. Although the number of participants in the system was low (n=22), the program successfully maintained contact with all enrolled participants throughout the entirety of the monitoring period.

**Figure 5.** 117 alert system calls vs. confirmed new EVD cases (Alpren et al., 2017).

In 2014, UNICEF launched an SMS-based platform called U-Report in Nigeria. This platform allowed positive EVD-prevention and avoidance messages through a
cascading message system, allowing a single user to spread these messages to other users, who in turn spread the messages further. Results from the use of U-Report were promising. Within 24 hours of the first reported EVD case in Nigeria, subscribers to U-report doubled from 19,000 to 38,000, and in the ensuing month, subscribers rose to 63,000. In addition, common questions and responses, as well as EVD facts, were shared from U-report onto social media such as Facebook and Twitter, in order to further increase outreach (Njoku, 2014).
Chapter IV

Discussion

Significance of JEET Scores

The JEET scores analyzed demonstrate the numerous healthcare shortcomings inherent in the region, providing a clearer picture of the necessity for outbreak response tactics that are efficient, low-cost and easy to implement.

The lack of antimicrobial resistance (AMR) preparedness has both theoretical and practical relevance in EVD outbreak control. While EVD itself does not demonstrate newly-emergent resistance to traditional treatments, Symptomatic EVD patients suffer from highly compromised immune responses, and AMR diseases create significant complications in treatment and management of EVD cases. Additionally, the JEET category for AMR protocols specifically distinguishes health care-associated infection (HCAI) prevention as a core capacity. HCAI is a significant source of EVD spread, through a variety of factors, including lack of patient isolation and poor infection-prevention protocols (Rajakaruna et al., 2017). The JEET documents for both Liberia and Sierra Leone specifically describe a complete lack of either current action or future planning for HCAI reduction and prevention:
“There is no mention of antimicrobial resistant pathogens in the National Health Laboratory Strategic Plan 2016–2020. No national plan for surveillance of infections caused by antimicrobial resistant pathogens exists” (WHO Sierra Leone, 2017, p.10).

“The country has not developed any capabilities to address AMR. There is no planned activity to develop a national action plan to combat AMR, and there is inadequate knowledge about the Global Action Plan on AMR. There are no AMR detection, surveillance and stewardship programmes in place” (WHO Liberia, 2017, p.9).

In addition to the demonstrable effects of HCAIs during previous EVD outbreaks, the lack of preparedness and response capacities in the health care system also indicates an even more severe lack of proper infection control knowledge among the general population. Electronic dissemination of even the most basic acquired-infection control procedures, such as proper handwashing or disposal of contaminated materials, would be an effective method of educating both the general population, as well as health care workers.

While multi-hazard emergency event protocols are scored as essentially non-existent in EVD-affected countries, individual reports do note the presence of EVD-focused response plans. This is likely due to these countries’ experience and responses to recent EVD outbreaks, and demonstrates the prioritization of EVD outbreaks over other public health emergencies. Unfortunately, this prioritization may have unintended consequences in other public health emergency situations, but in the context of EVD
response, these results show that affected countries are ready and willing to engage in coordinated EVD outbreak responses.

The capacities to activate and implement emergency operations in the event of an EVD outbreak are well-developed in Liberia and Sierra Leone. The JEET reports specifically single out the recent EVD outbreaks as a significant factor in the development and improvement of these capacities, providing further evidence that national-level policies and procedures are aligned with proposed community outreach plans. However, both the DRC and Guinea have not developed proper emergency response protocols. While Guinea is specifically mentioned as having learned a great deal from the recent EVD outbreak, leading to advances in outbreak response, DRC emergency responses have been severely hampered by political instability, unrest and violence. The currently-ongoing EVD outbreak in North Kivu Province in the northeast DRC has been severely affected by sustained attacks by local militias in the area, significantly affecting emergency response efforts by both local health care workers and UN/WHO authorities (UNOCHA, 2018). However, communications infrastructure is generally unaffected, with personnel and civilians as the primary targets (UN Secretary General, 2018). In these cases, mobile network-based information is of particular importance, as these militia attacks prevent physical EVD outbreak interventions, and the affected communities are therefore particularly vulnerable to infection.

While Liberia and Sierra Leone have comprehensive plans to link security and healthcare sectors in emergency health events, Guinea and the DRC are poorly-equipped to respond. Guinea does not have a formalized coordination plan, but has demonstrated on-the-spot coordination during the 2014-2016 EVD outbreak. In the DRC, similar issues
to the lack of emergency response plans in the country arise. Rampant political instability has caused significant disarray in ensuring health care workers are properly protected when entering affected areas.

Guinea and the DRC, as in several other capacities, are severely limited in community engagement, information dissemination, and rumor management. While both Liberia and Sierra Leone have demonstrated active community engagement and information spreading, Guinea and the DRC’s responses are fragmented and uncoordinated.

Guinea, Sierra Leone, Liberia and the DRC, geographically and demographically similar countries, demonstrate widely varying abilities to effectively respond to emergency events. However, this disparity does not necessarily mean that emergency mobile alerts would be affected in similar ways. Liberia and Sierra Leone have demonstrated effective and efficient emergency responses, and emergency mobile alerts would be an effective additional tool in their response protocols. On the other hand, in Guinea and the DRC, where emergency responses may be limited in scope and coordination, emergency mobile alerts would still be an effective method of information dissemination, especially in politically volatile areas that may hamper on-the-ground responses. In villages cut off by violence, mobile communications would play an important part in initial response, outbreak tracking, and continued outbreak control strategies.
Modern mobile networks are generally classified as 2\textsuperscript{nd}, 3\textsuperscript{rd} or 4\textsuperscript{th}-generation (2G, 3G or 4G), with 5\textsuperscript{th}-generation (5G) mobile networks currently in the early stages of adoption. A variety of network types exist within each generation. While each network has its own characteristics, in the context of this study, mobile data capabilities are the major relevant factor. The primary reason for this criterion is due to the nature of wireless emergency alert systems and social media penetration. 2G networks are capable of a relatively low maximum data transfer rate, and are generally sufficient only for basic voice and SMS capabilities. Mobile web browsing, including social media, is generally restricted to 3G/4G networks. Most mobile service providers in developed countries have either completed or are in the process of decommissioning their 2G networks. For example, in the United States, Verizon Wireless and AT&T comprise more than 50\% of current wireless subscriptions: Verizon plans to shut down their 2G network at the end of 2019 (Dano, 2016), and AT&T’s 2G network was shut down in January of 2017. However, in developing countries, 2G networks are still dominant, and although 3G/4G networks are developing, 2G networks continue to operate, and in fact, many 2G networks are in planning phases alongside equivalent 3G networks.

In the context of these network differences and potential limitations, it is important to recognize the capabilities and limitations of SMS-based emergency alerts and social media. While social media by nature invites community engagement, and
allows for detailed messages including multimedia components, SMS-based emergency alerts have the potential to reach a larger targeted audience. This is especially important in rural and other isolated locations, where even 2G wireless coverage may be located miles away from the nearest village.

Figures 10-13 demonstrate the significant differences between 2G and 3G coverage. In Liberia, both Orange Liberia and Lonestar offer coverage of most metropolitan areas and major highways in 2G (Figures 10 and 11), while both providers have only sporadic, isolated 3G coverage throughout the country (Figures 12 and 13). The same is true for Sierra Leone (Figures 14 and 15), and 3G coverage maps for Guinea are currently unavailable, with sporadic 2G coverage (Figures 17 and 18). Additionally, the currently-ongoing EVD outbreak in the DRC has significant overlap with established 2G network coverage in that area (Figures 3 and 4).

Mobile network coverage has shown an increasingly rapid trend across both Sub-Saharan Africa (Figure 28) and Western Africa (Figure 29). However, the question of actual mobile usage is slightly more complex. As shown in Figures 28 and 29, separate figures are given for unique mobile subscribers, and for SIM (Subscriber Identity Module) connections. A variety of factors can affect these reported figures, including categorizing phone users versus phone owners, mobile phone subscriptions versus actual usage (e.g., a single phone/SIM shared among a large family), and the concept of potential mobile access versus actual mobile access (James & Versteeg, 2007).

The data published in Figures 28 and 29 are collected by the GSM Association, a collective group of mobile-related companies that publishes mobile data forecasts on a regular basis. The criteria for their descriptions of unique mobile subscribers vs. SIM
connections are designed to address several factors similar to the critical analysis done by James & Versteeg (2007), but is concisely summarized in a GSMA publication regarding this exact issue:

There is an important difference between the number of mobile connections – the metric traditionally used by the industry to measure market size and penetration – and what we term unique mobile subscribers. The latter refers to a single individual that has subscribed to a mobile service and that person can hold multiple mobile connections (i.e. SIM cards) (Gillet, 2014).

The difference between a unique mobile subscriber and a SIM connection is generally important when discussing mobile penetration. In the context of disaster alerts, the number of SIM connections is of less importance. A single individual possessing multiple SIM cards, for example, would ideally receive the same emergency alert regardless of which SIM card/mobile network was currently in use. In addition, since operating a mobile network requires usage of physical network towers, different service providers will often use the same towers, leading to similar areas of network coverage between providers/SIM connections: Figures 10 and 11 show how two network providers offer similar 2G coverage networks in Liberia. Despite the differences in coverage zone size, the overall distribution of the networks is nearly identical. Generally, individuals using multiple SIM cards are doing so to take advantage of varying mobile access rates, as local providers compete with each other to entice consumers with lower-priced access rates.

As demonstrated in Figures 2-4, there is significant overlap between areas of high EVD outbreak activity and mobile network coverage. It stands to reason that outbreak rates would be higher in urban areas with much higher population densities, and that
mobile network coverage would prioritize these high-population areas. However, this does not diminish the importance of mobile network outreach; in fact, densely populated urban centers tend to be the area where EVD outbreaks quickly spiral into unmanageable proportions. Infected individuals from rural areas tend to approach urban areas, frequently in search of more advanced medical treatment than is available locally (Fallah, Skrip & Enders, 2018).

In addition to concentrations in urban centers, mobile network availability tends to spread across established methods of travel, notably road and highway infrastructure. Mobile user-submitted data on wireless network availability in Senegal (Figure 22), Cameroon (Figure 23), and Ivory Coast (Figure 24) show that even in areas with low mobile penetration, major travel routes tend to have at least basic mobile coverage. This is of particular importance in the context of EVD alerting and reporting, as infected individuals from rural areas must travel these routes, and would therefore be entering into mobile coverage areas, even if their home village is outside of a coverage area.

Reported figures for EVD-affected countries is high enough to justify exploring mobile communications as a useful tool in rapid information dissemination during EVD outbreaks. As of 2017, Liberia had 1.7 million unique subscribers, Guinea had 5.9 million, and Sierra Leone had 2.8 (The Mobile Economy Sub-Saharan Africa, 2017). The ability to instantly reach almost 10 million mobile users with localized, specific information would greatly enhance EVD response capacities in affected areas. In an analysis of mobile and media audiences in Sierra Leone, Wittels & Maybanks (2016) found that while only 53% of the population in Sierra Leone actually owns a mobile phone, 83% of the population has access to a mobile phone through a direct connection
such as a family member. Additionally, mobile phone access is actually higher in rural areas than in urban areas (Figure 6).

![Figure 6. Mobile phone access and ownership in Sierra Leone (Wittels & Maybanks, 2016).](image)

**Cell Broadcast Messaging**

A protocol for emergency cellular alerts exists and has been defined by the European Telecommunications Standards Institute (ETSI), known as Cell Broadcast messaging. Cell Broadcast alerts work in a similar fashion to traditional SMS, with several advantages. Figure 7 shows a comparison between traditional SMS and Cell Broadcast.

![Figure 7. Comparison between traditional SMS and Cell Broadcast.](image)
Cell Broadcast offers several important features in the context of EVD outbreak communication. As described earlier, a common situation in African countries occurs
when a single individual possesses multiple SIM cards from different service providers. As Cell Broadcast is mobile number-independent and message broadcasts can be confirmed to have been sent, the greatest possible number of individual mobile users can be reached. Cell Broadcasts are enabled by default on most mobile handsets, and do not require registration or an opt-in process, meaning that a majority of users are equipped to receive these alerts with no extra steps needed on the part of the user. Cell Broadcast has the ability to send messages by geographical location, based on the actual location of network towers and their areas of coverage. This allows not only for specifically targeted messages based on the appropriate local cultural traditions or social/political situations, but also for region-specific instructions for treatment locations, rather than nationwide announcements. Cell Broadcast messages display on a phone with no interaction necessary from users, and play a distinct warning tone when they appear on the phone, decreasing the likelihood of being dismissed or ignored.

Several developed countries already use Cell Broadcast alerts in their nationwide emergency alert systems, including the United States, Canada, Japan, the European Union, South Korea and New Zealand. Figure 8 shows a test message of the Emergency Cell Broadcast System used in the Philippines.
Figure 8. Test message of a Cell Broadcast alert system used in the Philippines (Telcos test emergency alert systems, 2017).

These Cell Broadcast systems range from disaster-specific alerts, such as the Earthquake and Tsunami Warning System in Japan, to highly localized event-specific alerts such as the Wireless Emergency Alerts system in the United States, which, among other alerts, sends out Amber Alerts – highly location-specific messages related to child abductions, which often include details such as suspected car model, color and license plate, and last-seen information. Figure 9 shows an Amber Alert emergency message being displayed on a non-smartphone device.
Figure 9. Amber Alert information displayed via Cell Broadcast technology (Lee, 2017).

Cell Broadcast messages are built-in as features on most existing mobile networks (Mobile Network Public Warning, 2013), and thus the cost of implementation is extremely low. However, Cell Broadcast systems must be enabled by individual network providers. A key factor of successful implementation of Cell Broadcast systems is regulation on a national level (Mobile Network Public Warning, 2013). In the United States, the Wireless Emergency Alert system is regulated by the Federal Communications Commission. While participation is voluntary, strict guidelines exist and virtually all
network providers in the United States participate (FCC, 2018). National regulation of Cell Broadcast systems could be particularly problematic in West African nations. As per the JEET scores discussed, EVD-affected countries lack in many important capacities in emergency outbreak management. For example, while the JEET for Sierra Leone identifies an existing call-in emergency alert system, the 117 call alert system, this is the only mention of a targeted mobile-based emergency alert system across the entire affected region. A dedicated emergency alert system should be a critical component of any emergency preparedness plan, and the JEET documents demonstrate a distinct lack of such systems.

Previous EVD Tracking and Response

Data on social media response to EVD outbreaks was found to be quite limited, and primarily focused on global trends, rather than localized data from EVD-affected countries (Fung et al., 2015; Fung et al., 2016; Househ, 2017; Rodriguez-Morales et al., 2015). A primary reason for this lack of social media analysis is likely the general lack of social media statistics in affected countries. While mobile phone usage is high (The Mobile Economy Sub-Saharan Africa, 2017), internet and social media usage still lags significantly behind: of Liberia’s 4.8 million population, while 1.7 million individuals are considered unique mobile subscribers, less than 400,000 people have access to the internet, and thus social media (InternetWorldStats, 2018). The trend of low internet usage continues in Guinea (1.6 million internet users across a population of 13 million).
and Sierra Leone (900,000 internet users in a country of 7.7 million). While social media is potentially a valuable source of EVD information, in the context of reaching the largest possible demographic in the shortest possible timeframe, cellular-based messaging covers a significantly larger demographic, and as discussed earlier, does not require any sort of subscription (such as a Twitter or Facebook account), does not require any specific app to be opened to view the alerts, and does not require a broadband (3G/4G) network to function properly.

Although a variety of EVD tracking systems have been described and analyzed (Feng et al., 2018; Alpren et al., 2017; Tracey et al., 2015), to date, no definition of a dedicated, outbound emergency alert system in EVD-affected countries exists. EbolaTracks was implemented in Western Australia, with only 22 individuals being monitored for EVD symptoms. Feng et al. (2018) used SMS-based polls to collect data in directly EVD-affected areas concurrent to an EVD outbreak. However, the data collected primarily related to health care practices in general, rather than specific symptom monitoring or EVD prevention information. These studies, while different than the goal of this study, serve as important proofs-of-concept in terms of the feasibility of mobile phones as an emergency information channel. EbolaTracks, the SMS-based monitoring protocol used in Western Australia, was found to be a low-cost solution, costing €17,000 to develop and implement over a 3-week period (Tracey et al., 2015). As discussed earlier, Cell Broadcast systems are already built-in to most mobile network software, and therefore a significant cost of development and implementation can be avoided.

The most promising evidence of the potential of emergency alert systems was found in an analysis of the 117 call alert system in Sierra Leone. The 117 system was
used to great effect during the 2014-2016 outbreak, and demonstrates the potential for community engagement with emergency outreach services in order to curtail EVD outbreak spread. Unlike the proposed Cell Broadcast alerts, the 117 system is an active hotline that affected individuals can call to report suspected EVD cases and deaths. The crucial aspect of this system is the relative speed and low cost of implementation. Despite being a fully staffed hotline with actual human responders to each call, a maximum of only 198 responders was required at peak call volume during the outbreak (>16,000 calls weekly), and stabilized at only 52 call responders throughout the entirety of 2016 (Alpren et al., 2017). Estimates of the cost of operating the 117 hotline were US$200,000/month at peak call volume, and approximately US$47,000/month at stable call levels. It is important to note that a significant factor in these costs was training and salary for call center staff, rather than infrastructure implementation or other non-personnel costs (Alpren et al., 2017).

In addition to the high level of call volume received during the 2014-2016 outbreak, the 117 system also implemented a callback system for received reports, in order to ensure that calls to the hotline were properly acted upon. In January of 2015, 60% of live alert calls and 70% of death alert calls were successfully reached through the callback system. (Alpren et al., 2017). The high proportion of successful callbacks demonstrates the level of engagement that can be reached with the community via mobile strategies, as a successful callback demonstrates active community engagement with EVD information responses.

U-Report is another SMS-based information dissemination tool already in use. U-Report is a UNICEF-created service, and allows for communities to rapidly gather
information on currently-discussed topics. U-Report allows for both information exchange via cascading messages transmitted by U-Report users, as well as direct community interaction. U-Report information and trends are reported back to UNICEF and their local partners, allowing for targeted information responses based on the currently pressing issues being discussed via the tool. The tool can be used for a variety of purposes: a three-country poll in Africa received 34,000 responses regarding political corruption, with 94% of respondents calling for meaningful anti-corruption steps. These results were shared with the African Union Commission to help formulate future responses to widespread political corruption (African Union, 2018). Another case study demonstrated the use of U-Report in disseminating information after a mudslide in Sierra Leone killed hundreds of people. U-Report allowed UNICEF to immediately provide situation updates, clean water access instructions, and methods of tracking down missing family members. U-Report users were able to spread this information locally, reducing the risks of drinking contaminated water, and ensuring the public avoided still-dangerous areas (Powell & O’Connor, 2017).

Notably, U-Report was deployed in Nigeria in 2014, specifically to fight the nascent EVD outbreak in that region. The deployment was successful, not only enabling UNICEF to provide EVD safety recommendations, but also to directly engage with communities in rumor management and combatting false information. In Nigeria, a popular source of misinformation holds that bathing in and drinking salt water cures Ebola. Using U-Report, the community was able to effectively communicate that this was false information. Additionally, the tool allowed for common myths regarding EVD to be dispelled, by nature of allowing the community to pose questions which were then
answered by U-Report members, such as whether or not EVD could be transmitted by mosquito bites, or if traditional medicine was effective against EVD (Njoku, 2014).

In 2014, UNICEF launched an SMS-based platform called U-Report in Nigeria. This platform allowed positive EVD-prevention and avoidance messages through a cascading message system, allowing a single user to spread these messages to other users, who in turn spread the messages further. Results from the use of U-Report were promising. Within 24 hours of the first reported EVD case in Nigeria, subscribers to U-report doubled from 19,000 to 38,000, and in the ensuing month, subscribers rose to 63,000. In addition, common questions and responses, as well as EVD facts, were shared from U-report onto social media such as Facebook and Twitter, in order to further increase outreach (Njoku, 2014). The successful deployment and use of U-Report in an EVD outbreak-specific context demonstrates the potential of SMS and other mobile-based systems in effectively communicating EVD outbreak response information.

A critical component of information dissemination is education, namely accepting positive information and rejecting negative or false information. Abramowitz et al. (2017) analyzed social learning during the 2014-2016 EVD outbreak in Liberia. They found that local communities rapidly internalized provided information, while abandoning negative or incorrect messages. Through focus groups and direct interviews, it was found that negative rumors such as government conspiracies, and ineffective EVD control strategies such as protection from insect bites, steadily decreased in acceptance as information was internalized and spread through the community. Conversely, as the epidemic gained in severity, an increase in effective healthcare strategies being accepted was noted. For example, an increase in acceptance of the necessity to report suspected
EVD illness and death was noted, as well as an increase in basic EVD control practices such as avoidance of direct contact with potentially infected individuals.

While the discussed EVD-related strategies demonstrate the potential for successful mobile outreach programs, a critical aspect of proper information dissemination is missing: the tailoring of emergency information based on appropriate cultural and societal norms. Understanding the intricacies of local customs, community priorities, distrust of outsiders and outside information, and other aspects of local engagement in EVD outbreak response, is an essential step in ensuring emergency information is properly received, understood and acted on.

Local Engagement Strategies

Arguably the most critical aspect of community/social outreach during recent EVD outbreaks has been the level of local engagement between HCOs and local communities. Standardized outbreak response protocols have repeatedly demonstrated to be often ineffective, and on several occasions even exacerbated EVD outbreak spread (Oosterhoff & Wilkinson, 2015). Initial EVD response communications tended toward alarming and sometimes even borderline threatening behavior:

On the orders of [Sierra Leone’s] president, the Western Area Surge included house-to-house visits and the following ‘fact-based messaging’, designed to ‘shock’:
‘How bad does it need to get before you take notice and start to fight this disease? You have wasted seven months, let’s make the next one count.

‘Do you really want to die? Do you want to kill your family? Don’t conduct secret burials.’ For good measure, this was supplemented with a warning, ‘those that conduct secret burials are spreading this disease. It is their fault that your friends and relatives are dying. They are destroying our nation and I (the President) will see that they are punished for their illegal, selfish, behavior.’ (Oosterhoff & Wilkinson, 2015).

These harsh messages demonstrate a number of major issues with emergency communication. Additionally, the messages were combined with culture-insensitive, impersonal control methods, maintained by use of force when necessary. These methods included curfews, mass burials/cremations, and quarantines – all justified as necessary by the government of Sierra Leone. The first issue demonstrated by these messages is the political aspect of the messages. The messages directly invoke political/governmental organizations, as well as blaming individuals for nation-wide crises. Suspicion of government conspiracies and ulterior motives is common in West African nations (Abramowitz et al., 2017; Anoko, 2014). By invoking nationalist or political tendencies, emergency messages risk inflaming anti-government sentiment, on either a local or national scale. These messages, if not ignored outright, could even be used as “proof” of government conspiracy.

Another issue with the President’s messages is the shifting of blame directly onto victims of the outbreak. Not only does such victim-blaming increase suspicion of the message-bearing group, similar to invoking political ideas, but it helps to stigmatize EVD
victims as scapegoated villains rather than victims in need of help (Oosterhoff & Wilkinson, 2015). Shifting blame onto victims also minimizes the actual concerns and needs of the victims. While affected individuals may be seeking treatment or preventative measures to avoid spreading the disease, this information is much harder to come by when the primary message content paints such measures as selfish and wasteful.

In addition to victim-blaming, the President’s messages also emphasized negative connotations of community interaction. Although isolation of affected individuals can be an effective strategy in controlling local outbreaks (Abramowitz et al., 2015), isolation procedures must be carried out in a community-positive manner. Without proper guidance and positive reinforcement, isolation and quarantine procedures are generally viewed simply as convenient ways to isolate and dispose of EVD victims. Ideally, quarantine procedures should involve the entire community, with the mutual understanding that isolated victims will not be ignored and left to die, and that isolation of sick individuals will have a positive net effect on the health and well-being of the community, while prioritizing safe treatment of the victims whenever possible.

Finally, the President’s messages touched on a cultural tradition common to many cultures in affected areas, namely the practice of burial traditions. Safe burial practices are a critical component of community-managed infection control. In West Africa, traditional burial rituals involve large amounts of contact with a deceased individual by family and community members. In their study of social learning in EVD-affected communities in Liberia, Abramowitz et al. (2015) noted that while a variety of Ebola-related messages were accepted more or less based on community experience and gained knowledge, avoidance of direct contact with dead bodies was a message that did not
experience increased community acceptance. Nielsen et al. (2015) noted that in initial assessments of safe burial practices in Sierra Leone, guidelines and recommendations to avoid contact with EVD-infected corpses and arrange for health care officials to assist in conducting safe burials were not well-accepted by the community. Affected communities would hide dead bodies when safe burial teams approached (Marais et al., 2015). In interviews with local families, a critical concern was that safe burial practices were incompatible with highly-respected traditional burial practices. For example, health care workers performed burials in unmarked graves, frequently with multiple bodies in a single grave. In response to this information, the government of Sierra Leone launched a “Safe Burials Save Lives” campaign, which disseminated information on standard procedures performed by health care workers for safe burials. This information was presented in a way that indicated respect for local burial traditions, and the procedures were amended over time to allow for cultural burial practices to be performed whenever safety permits. Some examples of these cultural allowances included allowing families to provide ceremonial burial clothing or shrouds to health care workers in order to safely dress the body before burial, and inviting family and community members to witness the burial procedure and pray from a safe distance (Nielsen et al., 2015).

A common point of acceptance in community engagement is that local cultural practices are an important aspect of successful outreach. Non-specific EVD control guidelines have historically focused on correcting behaviors based on the concept that local customs and traditions are a barrier to effective outbreak control:

A principle underpinning these efforts is to change risky “behaviour” related to “traditional” practices and “misinformation”. Populations at risk of
contracting Ebola virus disease have been exhorted to “put aside tradition, culture and whatever family rites they have and do the right thing” (Chandler et al., 2015).

This lack of engagement with local traditions is a primary source of community mistrust. In order to properly encourage community engagement in EVD outbreak safety protocols, emergency information must be compatible with local practices.

Effectively Customizing Emergency Communications

The key advantage of using Cell Broadcast is the ability to easily customize emergency communications for local communities, tailoring specific messages based on prevalent cultural or social traditions to maximize their efficiency. Current standardized emergency messages are rolled out on a national scale, prioritizing speed and scale of deployment over engaging, adaptable messages (Chandler et al., 2015). Based on lessons learned in community engagement during EVD outbreaks, the following guidelines should be followed in any correspondence with the general public during an EVD event.

Messages should be apolitical. As discussed earlier, political connotations can not only add a threatening overtone to emergency messages, but can also promote outright rejection of the message content due to distrust of government officials (Oosterhoff & Wilkinson, 2015; Anoko, 2014).
Messages should appeal to the greater community good, in a positive manner. In the previous example of the President’s message in Sierra Leone, appeals to the greater good were made in a negative light that depicted infected individuals as intentionally infecting and killing their friends and family. Instead, a more effective message would involve community safety as a positive outcome. For example, instead of “it is the infected people’s fault that your friends and family are dying,” “following these easy instructions highly increases the chances of you, your friends and your family staying healthy” promotes a positive motivation to follow emergency guidelines for the good of all.

Messages should be overall positive, or at least neutral in tone, rather than conveying ominous warnings. Obviously an EVD outbreak is not a positive event, but the message context should emphasize positive results whenever possible. For example, the message “If you show signs, you MUST go to a treatment center” and the message “If you show signs, there is hope – treatment centers are ready and willing to help you” both convey the urgency of getting to a treatment center, but the second message conveys the potential of a positive outcome, while the first message is simply a direct command with no incentive.

Messages should be sensitive to local traditions and customs, and should emphase preventative measures while supporting local customs whenever possible, and respectful to the importance of these customs when proper preventative measures conflict with local customs. As discussed earlier, these local customs are essential parts of many peoples’ lives, and ignoring or directing against them carries a significant risk of the overall message being ignored entirely.
Message content should be respectful of existing knowledge. After years of outbreaks and worldwide attention, the idea that Ebola exists, and is contagious and deadly, is well-established. In a 15-county focus group Monrovia and Montserrado County in Liberia, over 350 community leaders were interviewed regarding their knowledge, questions and concerns about Ebola (Abramowitz et al., 2015). Through these interviews, it was determined that community leaders understood the basic facts about Ebola. Instead, information was sought out on applying generalized public health messages on a number of fronts. According to one individual in the study, “we have heard the messages, but most people do not know how to practicalize them” (Abramowitz et al., 2015). Avoiding basic messages such as “Ebola exists” and focusing on more advanced concepts such as proper corpse isolation or proper disinfection of homes and surfaces, would help to convey effective guidelines without needing to “dumb down” the messages.

When available, messages should include relevant contact information for alerting health care authorities to EVD incidents. As discussed earlier, while their levels of development and capability vary, most West African countries possess at least local-level response protocols (even though they may be uncoordinated, underfunded or improperly monitored and regulated), and emergency contact information could be critical in an early and rapid response to potential outbreaks. Contact information could also be provided not just for emergency response personnel, such as the 117 hotline in Sierra Leone, or the U-Report system initially deployed in Nigeria. These contact sources could be extremely helpful in confirming facts and dismissing rumor, as well as connecting disparate locations under common protocols.
Finally, messages should be location-specific on a number of levels. Due to the ability to deploy Cell Broadcast alerts to geographically localized areas, localization can be achieved on a level not possible with nationwide alerts. Localizing efforts should include three primary areas.

Local languages and dialects should be used whenever possible, in addition to nationally-recognized languages. As Cell Broadcast alerts allow for multiple “pages” of messages, it is possible to broadcast emergency alerts in multiple languages, and this feature should be taken advantage of whenever possible. In addition to reaching the maximum number of individuals, embracing multilingual alerts would show a willingness on the part of health care officials to engage affected communities on a localized, compassionate level.

As discussed earlier, as respecting local customs and practices are essential parts of community engagement, local customs and practices should be considered when creating emergency alerts. For example, in regions primarily occupied by Muslims, initial burial practice alerts could include the fact that burial teams are able to respect Muslim burial traditions while still assisting in safe burials. This messaging guideline is possibly the most critical of all, as previous studies have demonstrated how crucial respecting local customs can be to EVD prevention and control efforts (Marais et al., 2015; Abramowitz et al., 2015).

None of these message guidelines are complicated or unfeasible to consider when presenting emergency information during EVD outbreaks. By following these simple practices, emergency outreach efforts to local communities can be greatly enhanced, while also building important trust between healthcare workers and affected populations.
Limitations of Mobile Communication

While network coverage and mobile access are relatively high in some countries, significant gaps exist and would prevent populations in these mobile dead zones from receiving emergency alerts via any type of mobile communication route. Despite the fact that mobile networks are rapidly developing throughout West and Central Africa (The Mobile Economy Sub-Saharan Africa, 2017; The Mobile Economy West Africa, 2017), there is no guarantee that coverage will ever extend across the entirety of affected countries, and therefore it must be assumed that mobile broadcasts will not reach everyone. However, there are some potential solutions.

While mobile coverage may not extend throughout a country, radio is a hugely popular, well-established technology used throughout Africa. Data from 2008 indicates that radio was by a wide margin the most ubiquitous media technology in West Africa (Myers, 2008). As shown in Figure 10, radio ownership in multiple West African countries is extremely high.

![Figure 10. Equipment ownership in West Africa (Myers, 2008).](image)
This ubiquity of radio broadcasts is obviously advantageous in countries where mobile coverage is particularly lacking. For example, as shown in figures 19, 20 and 21, mobile coverage in Guinea is significantly less widespread than in other countries in the area. However, radio coverage is widespread throughout the country and is the dominant form of information access, with over 40 public and private stations broadcasting in the country (Guinea Media and Telecoms Guide, 2012). Figure 11 shows a map of radio station coverage across the three countries affected by the 2014-2016 EVD outbreak.

Figure 11. Radio station coverage in Liberia (MapAction 2014).

Radio information spread should always be taken advantage of during EVD outbreaks, and generally already exists during these events. While the guidelines described above
for emergency messages are most useful for specific and locally-tailored outreach, they would also apply to most other forms of outreach. Radio broadcasts should follow positive-thinking messages, and especially in national broadcasts, should avoid political affiliation or implications.

Some countries may have uneven mobile reception, but still have overall high levels of penetration. For example, while large parts of Liberia are outside of mobile coverage areas (Figures 13 and 14), mobile penetration is actually quite high, at 75% (Liberia – Telecommunications, 2017). During an EVD outbreak, it would be advantageous to expand mobile network coverage in affected areas that may normally be outside of coverage. In these cases, a number of relatively inexpensive, rapidly-deployable emergency network solutions exist.

![Cell On Wheels portable network tower](image)

*Figure 12. Cell On Wheels portable network tower (Kramer, 2017).*
Figure 12 is an example of rapidly-deployable cellular towers that allow for instantaneous creation of a zone of mobile coverage. In areas where mobile ownership is high but mobile reception is poor, these mobile towers could be helpful in spreading the message during EVD outbreak events. In addition, there have been more exotic concepts of expanding mobile coverage in emergency situations: a project called Loon uses stratospheric balloons to broadcast mobile coverage over an extremely wide area. This technology was used in the aftermath of Hurricane Maria to provide emergency mobile communications to over 200,000 people in Puerto Rico (Loon, 2018).

Unfortunately, there are areas where electronic communications are virtually absent in any form. Even if deploying emergency mobile coverage is feasible, this does not mean that individuals in the affected areas will necessarily own mobile devices to access these emergency networks. A notable example is the DRC. As shown in Figure 3, only the major city of Mbandaka was in an area of cell coverage, while nearly all of the health zones of Bikoro and Iboko had no cell coverage at all. Additionally, in Figure 4, it can be seen that a large swath of the western areas of the currently-ongoing outbreak do not have mobile coverage. The problem of communicating with these areas is further compounded by the fact that radio coverage in the DRC is also highly sporadic (DRC Media and Telecoms Guide, 2012). In these cases, physical outreach by on-the-ground healthcare forces may be the only way to spread information to affected communities.

While the guidelines for emergency messaging discussed above would be applicable to the information conveyed by healthcare workers, the guidelines are of slightly less importance in this context, as emergency healthcare workers are, by necessity, generally already well-trained in outbreak control methods and positive community interaction.
Conclusion

The goal of this research paper was to define a simple, effective method of emergency outreach during EVD outbreaks in West and Central Africa. Data from self-scored emergency health capacity evaluations was presented and demonstrated the need for additional EVD control options, while mobile communications data was analyzed to assess the potential effectiveness of using mobile alerts to provide emergency information. Cell Broadcast alerts were identified as a feasible, low-cost/low-maintenance method of conveying emergency information across a maximum of mobile networks, and existing mobile-based alert systems were examined for evidence of efficacy. Finally, using data acquired and lessons learned from previous EVD outbreaks, a series of positive, community-oriented guidelines for emergency alerts were created. Altogether, a basic plan of implementation and customization of Cell Broadcast-based emergency alerts was formed. While actual implementation of these alerts is beyond the scope of this thesis, the data presented could, in future efforts, form the basis of simple, effective and widespread outreach to EVD-affected communities.
Appendix

Figure 13. 2G network coverage from Orange Liberia (GSM Coverage Maps, n.d.)
Figure 14. 2G network coverage from Lonestar (GSM Coverage Maps, n.d.)
Figure 15. 3G network coverage from Orange Liberia (GSM Coverage Maps, n.d.)
Figure 16. 3G network coverage from Lonestar (GSM Coverage Maps, n.d.)
Figure 17. 2G network coverage from Orange Sierra Leone (GSM Coverage Maps, n.d.)
Figure 18. 3G network coverage from Orange Sierra Leone (GSM Coverage Maps, n.d.)
Figure 19. 2G network coverage from Africell (GSM Coverage Maps, n.d.)
Figure 20. 2G network coverage from Areeba Guinee (GSM Coverage Maps, n.d.)
Figure 21. 2G network coverage from Cellcom (GSM Coverage Maps, n.d.)
Figure 22. OpenSignal user-submitted network information for Guinea.
Figure 23. OpenSignal User-submitted network information for Sierra Leone.
Figure 24. OpenSignal user-submitted network information for Liberia.
Figure 25. User-submitted coverage information for Senegal (nPerf 2018).
Figure 26. User-submitted coverage information for Cameroon (nPerf 2018).
Figure 27. User-submitted coverage information for the Ivory Coast (nPerf 2018).
Figure 28. Final EVD case counts for the 2014-2016 EVD outbreak (WHO 2017).
Figure 29. EVD Outbreak in Western DRC, 2018 (CDC 2018).
Figure 30. EVD Outbreak in Eastern DRC, currently ongoing (CDC 2019).
Figure 31. Infographic on mobile demographics in Sub-Saharan Africa (Mobile Economy Sub-Saharan Africa, 2018).
Figure 32. Infographic on mobile demographics in West Africa (Mobile Economy West Africa, 2018).
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