Socioeconomic inequalities in the individual response to the 2014–2015 Ebola epidemic in Guinea: Insights from mobile phone data (SES-EBOLA)

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Scientific Context

Socioeconomic status (SES) plays a critical role in shaping individual responses to epidemics and the adherence to interventions aimed at controlling their spread. Across multiple infectious disease outbreaks—including influenza, malaria, dengue, and Ebola—lower SES has been consistently associated with increased vulnerability, higher infection rates, and reduced access to healthcare resources. During the 1918 and 2009 influenza pandemics, communities with lower SES experienced significantly higher mortality rates. The COVID-19 pandemic further exposed these disparities, with lower-income populations facing greater exposure due to job insecurity, inability to telework, and crowded living conditions[1–3].

Inequalities extend beyond health outcomes to the feasibility of adhering to non-pharmaceutical interventions (NPIs), such as mobility restrictions and social distancing. Despite the substantial evidence highlighting SES as a driver of epidemic outcomes[4], these elements are rarely considered by policy decision-making. As a result, uniform NPIs risk exacerbating existing health disparities by failing to account for the structural barriers faced by vulnerable populations.

SES-EBOLA aims to bridge this gap by leveraging mobile phone data from the 2014–2015 Ebola epidemic in Guinea to uncover the socioeconomic determinants of individual responses to the outbreak. Ebola presents a particularly relevant case: unlike outbreaks in high-income settings, the epidemic unfolded in resource-limited environments, where access to healthcare, information, and protective measures was profoundly unequal. Guinea, one of the countries most affected by the outbreak, offers a critical setting to investigate how structural inequalities shape adherence to NPIs during health crises. Insights from this project will not only improve our understanding of epidemics in low-resource settings but also inform more equitable public health strategies for future outbreaks.

Objectives

1. **Characterize SES-dependent behavioral responses:** Analyze mobility and communication patterns during the Ebola outbreak to identify socioeconomic disparities in adherence to NPIs.
2. **Investigate network segregation by socioeconomic status:** Examine how SES influenced the reorganization of mobility and communication networks during the epidemic and whether these changes bridged or exacerbated socioeconomic divides.

Description of work

Data. We will use anonymized Call Detail Records (CDRs) from Orange, capturing billions of interactions from approximately 9 million users in Guinea during the 2014–2015 Ebola outbreak. Each record includes metadata on calls and SMS exchanges, such as anonymized IDs, timestamps, duration, and cellular tower locations. These data will be combined with spatial SES indicators from the Guinean Government[5], including poverty, education, household composition, and healthcare infrastructure, and high-resolution maps of the Relative Wealth Index[6]. We will also use daily reported Ebola cases and deaths from the Humanitarian Data Exchange platform[7] to characterize the outbreak.

Ethics Statement. The mobile phone data, provided through a collaboration with Orange, will be fully anonymized and processed within secure Orange environments, ensuring strict adherence to privacy and confidentiality standards and GDPR compliance. All other datasets used in the project are aggregated, anonymized, and sourced from publicly available resources.

Task 1: Mobility and Communication Patterns by SES. The first task will characterize individual mobility and communication behaviors across SES groups during the Ebola outbreak. Using Orange CDR data, we will reconstruct individual trajectories and analyze variations in movement patterns by socioeconomic background. Mobility metrics will include distance traveled, trip frequency, and

mobility reduction during interventions. Communication patterns, such as call frequency, duration, and contact diversity, will also be examined. SES proxies based on home location will stratify the analysis. To assess the relationship between SES and mobility reduction, we will apply a Bayesian spatial autoregressive error model, estimating both crude and adjusted correlations[3]. This task will identify whether lower SES groups faced greater challenges in reducing mobility or maintaining social connections, highlighting structural barriers to NPI adherence.

Task 2: Network Segregation and SES Bridging. The second task will examine how mobility and communication networks reorganized along socioeconomic lines during the Ebola outbreak[8]. Time-varying networks will be constructed from the CDR data, where nodes represent individuals and edges reflect communication events or co-location patterns. Assortativity indices will quantify the extent of network segregation by SES, while longitudinal analysis will reveal how these patterns evolved as the epidemic unfolded. Particular attention will be given to identifying whether NPIs led to increased segregation or whether certain communication behaviors facilitated bridging across SES divides.

Impact. The project will provide critical insights into how socioeconomic inequalities shape individual responses to epidemics. By identifying SES determinants of individual response to the Ebola outbreak, it will generate empirical evidence to inform equitable public health policies and tailored interventions for vulnerable populations. Dissemination through publications, open data, conferences, and collaboration with local stakeholders, including Prof. Abdoulaye Toure, will ensure the project impact extends beyond academia to inform real-world public health strategies.

Positioning with Respect to the SOUND Call and 'Inégalités' Axis. This proposal aligns with the objectives of the SOUND program, particularly the 'Inégalités' axis under the 'Sociétés en Mutation' theme. Through an interdisciplinary approach combining epidemiology, social sciences, data science, and public health, the project addresses the call focus on understanding and mitigating inequalities by examining how socioeconomic factors shaped individual responses to the Ebola epidemic in Guinea. The use of digital trace data further reflects the SOUND program emphasis on innovative methodologies for studying social disparities, fostering insights applicable to future health crises.

Supervision and collaborations. The PhD project will be supervised by Dr. Vittoria Colizza, an internationally recognized expert in infectious disease modeling, network epidemiology, and the integration of human behavior into epidemic frameworks. As Director of Research (DR1) at INSERM and the Founding Director of the Surveillance and Modeling Outbreaks Center (SUMOC) at Sorbonne Université, Dr. Colizza brings over 20 years of interdisciplinary research experience, including the successful coordination of major projects such as an ERC Starting Grant, ANR and ANRS-MIE projects, and Horizon Europe initiatives. Her expertise in translating scientific insights into public health strategies will be instrumental in guiding the project. The project will also benefit from a collaboration with Prof. Abdoulaye Touré, Director General of the National Institute of Public Health in Guinea, and Director of the Centre de Recherche et Formation en Infectiologie of the country. His expertise will provide critical insights into the local context of the Ebola epidemic in Guinea and ensure that the research aligns with public health priorities in the region. Furthermore, the project will leverage the collaboration with Dr. Stefania Rubrichi from the SENSE (Sociology and Economics of Networks and Services) lab at Orange for the mobile phone data analysis.

References

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