SUPPLEMENTAL INFORMATION

Scoping Review of Artificial Intelligence via Mobile Technology and Social Media for Health in Africa

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Table SI 1: A summary of included study aims, methods, performance measures and key findings

Author & year	Aim	Methodology	Measures of Performance	Key Findings	Study Limitations
Schaible, B. J. *et al.* (2019)[1]	To explore the use of Twitter data as a tool for public health communication regarding polio.	A 40% random sample of Twitter data with #polio (79,333 tweets) was used for descriptive analyses. Sub-corpora were created for specific countries using co-occurring hashtags. Latent Dirichlet Allocation (LDA) identified topics, and a Mantel-Haenszel test was used to compare themes in Twitter data with English-language media articles related to polio.	Chi-square for association	Themes of Twitter contents varied by countries in which eradication efforts were popular. Social media demonstrated a more positive and supportive stance toward polio initiatives when compared to traditional media.	Only tweets in English were analyzed. Limited number of news articles used for comparison which may not be representative of the entire English language media environment.
Odlum, M. & Yoon, S. (2018)[2]	To assess health information needs about Ebola through longitudinal tracking of Twitter data.	Tweets related to the Ebola outbreak were collected at three time points. Natural Language Processing (NLP) and Content Analysis techniques were employed. The collected tweets were analyzed for content, including topics discussed, sentiments expressed, and dissemination patterns.	None reported	The number of tweets posted and disseminated to Twitter followers increased over time. Top tweets were analyzed to provide insight into public sentiment. Concerns included the readiness of hospitals, fear of volunteering, frustration with government policies, and lawsuits against hospitals. These tweets reflected ongoing information needs and public fears.	Only Tweets in English and Spanish were analyzed. Data was obtained via Streaming API, which has limitations in capturing all tweets due to its rate limits.

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Parham G.P. *et al.* (2023)[3]	To evaluate two approaches for cervical cancer detection; HPV genotyping and AI-assisted visual evaluation (AVE).	The AVE algorithm underwent pre-training using images from NCI to categorize cancer severity into three classes: "likely precancer/cancer," "indeterminate," or "normal" appearance. Subsequently, a set of images from Zambia was progressively integrated into the NCI images for retraining.	Kappa Coefficient Accuracy	Applying the AVE trained using images from NCI to images from Zambia was unsuccessful. Most of the models retrained using transfer learning performed well.	Algorithm was not run on a smartphone camera itself. Analysis was restricted to a convenience sample that included women with complete data.
Movahedi Nia, Z. *et al.* (2023)[4]	To use Twitter data to investigate reasons for the utilization use of Ivermectin in select countries despite the WHO having deemed it inappropriate for COVID-19 prevention and treatment.	Methods included LDA and RoBERTa for tweet analysis, emotional models - Pysentimiento and CardiffNLP, and a transformer-based approach for gender detection.	Accuracy Recall F1-Score Precision	Tweets from both nations studied predominantly supported ivermectin, fueling debates on vaccines versus ivermectin. Pro-ivermectin users often opposed vaccines, and vice versa.	Compared to other social media platforms, only a limited number of people used Twitter to share their views Only Tweets in English were analyzed.
Maturana, C.R. *et al.* (2023)[5]	To create a dataset of labelled thick blood smear images and use it to train a low -cost algorithm for malaria diagnosis.	Blood smear samples from Spain and Sierra Leone were annotated in Spain using Convolutional Neural Networks (CNNs). The models classified images into leukocytes, mature trophozoites, and early trophozoites.	Precision Recall F-Score mAP0.5	The YOLOv5x algorithm excelled on a test set, demonstrating strong metrics for leukocyte and *Plasmodium* trophozoite detection. Integrated into a smartphone-computer app, the models automate *Plasmodium* infection diagnostics in Giemsa-stained blood smears, accessible through the iMAGING app.	Preparation of the Giemsa stain required specialized personnel. The stain was unable to distinguish between *Plasmodium* species. Potential difficulties in implementing the iMAGING prototype.

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Kabukye, J.K. *et al.* (2023)[6]	To collect stakeholder's perspectives about the usability and effectiveness of a telemedicine system for cervical cancer diagnosis.	Through focus group discussions, stakeholders' perceptions on benefits, concerns and fears of the telemedicine system were recorded and transcribed. Focus group discussions were supplemented with an evaluation survey of health workers and field observation of authors.	Sensitivity Specificity Accuracy AUC*	Patients and health workers appreciated the system for benefits such as improved cervical visualization and enhanced communication. However, some health workers found it time-consuming initially, and patients expressed concerns about image capture and sharing.	The intervention aimed to facilitate remote consultation, yet was unable to fully achieve this. The project relied on grant funding, and was not fully institutionalized, making impact and sustainability uncertain.
Turon, G. *et al.* (2022)[7]	To develop a streamlined process for drug discovery for the treatment of malaria and tuberculosis that applies ML and AI methods to chemical compounds.	The methods replicated the assays used in the drug discovery pipeline. Five AutoML methods were independently developed. Each model used a different ML/AI or statistical technique and focused on a specific feature.	AUC* Hit Enrichment Potential	The system successfully yielded 15 production ready models. It allowed for the automated discovery of new anti-disease agents.	The binary classification tasks were limited to a single output. One of the methods relied on embeddings and descriptors from pre-trained models, which may not be optimal for all tasks and may limit the tool's applicability.
Fredriksson, A. *et al.* (2022)[8]	To predict the likelihood that a pregnant woman would deliver at a health facility based on demographic characteristics, current pregnancy characteristics and self-reported data.	The study used data from women in Zanzibar's Safer Deliveries programme to create a predictive model for facility delivery. Employing logistic regression, LASSO, random forest, and a neural network, the model incorporated enrollment visit data with techniques to handle imbalanced data.	Accuracy Sensitivity Specificity AUC*	A majority of women delivered at health facilities, while predictive models achieved moderate accuracy in identifying home deliveries. When integrated into a cellphone app, the model helped alert community health workers to high-risk home deliveries, facilitating timely support for improved health outcomes.	Missing data. While KNN was employed to address missingness, it introduced randomness and diminished the quality of imputation.
Ogbuokiri, B. *et al.* (2022)[9]	To analyze public sentiments toward COVID-19 vaccines in	The study collected Twitter posts and analyzed sentiments using VADER, followed by machine learning	Accuracy Precision Recall	Identified prevalent sentiments toward COVID-19 vaccines in the studied cities, highlighting varying	Only Tweets in English were analyzed. Twitter users included in the study

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	major South African cities using Twitter data.	classification to validate sentiment analysis results.	F1-Score ROC AUC*	levels of support and skepticism.	were not representative of the general population.
Dacal, E. *et al.* (2021)[10]	To develop a mobile microscopy and telemedicine platform, assisted by deep learning, for the quantification of *Trichuris trichiura* infection.	Use of a mobile app and a 3D-printed microscope adapter for digitization of samples, followed by AI-powered analysis on a telemedicine platform.	Precision Recall F-Score	High precision and recall in identifying *Trichuris* spp. eggs, demonstrating the potential of AI in enhancing the diagnosis of soil-transmitted helminths infections.	Study included limited number of subjects and the variety of soil-transmitted helminths species, suggesting a need for further validation with a larger and more diverse dataset.
Gbashi, S. *et al.* (2021)[11]	To systematically scrutinize media communications (Google News headlines or snippets and Twitter posts) to understand the prevailing sentiments regarding COVID-19 vaccines in Africa.	A total of 569 texts from Google News and 637 Twitter posts meeting the study's criteria were collected. Computational linguistic models (TextBlob, Variance Aware Dictionary and Sentiment Reasoner, and Word2Vec) were employed for analysis.	Accuracy	The researchers found that Google News headlines or snippets and Twitter posts within the stated period were generally passive or positive toward COVID-19 vaccines in Africa.	Some text from Google News or Twitter may have been spam or irony, but it is very difficult for ML/AI to detect such language. Sentiment analysis models used were mostly built in English limiting its applicability to other languages.
Bruzelius, E. *et al.* (2019)[12]	The study aimed to explore the viability of employing ML analyses on satellite imagery for mapping remote communities, with a primary focus on enhancing service delivery and planning for healthcare interventions in community	The study used two datasets: a rural satellite image dataset and the SpaceNet Corpus. Employing TensorBox, a deep learning approach, the model identified buildings in rural images using the SpaceNet-trained algorithm. The study compared algorithm-generated community results with manually collected data, and identified false positives and false	Positive Predictive Value Sensitivity F1-Score	A deep learning-based approach using satellite imagery was effective in building and community detection, providing a cost-efficient and scalable solution for mapping remote communities to aid in healthcare service planning.	Difficulty in distinguishing between occupied and unoccupied buildings Measurement errors and missing imagery. Neural network methods used in this study may not perform well in other remote or non-rural settings.

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	health systems.	negatives through visual inspection of satellite imagery.			
Kraemer, M.U.G. *et al*.(2019) [13]	To estimate and predict the future distribution of *Aedes aegypti* and *Aedes albopictus*.	The study employed a combination of environmental modeling, statistical analysis and simulation approaches to estimate the predicted future distribution and spread of *Aedes aegypti* and *Aedes albopictus* mosquitoes. The study utilized a database of geo positioned occurrence records of the mosquitoes species.	AUC* Accuracy	The best fits from the models showed that the detection of *Ae.aegypti* increased relative to *Ae.albopictus*. The inclusion of changes in surveillance data quality over time reduced the model predictive performance for both species, changes may not necessarily improve the accuracy of the models.	Surveillance constraints linked with limitations in representativeness of reported distributions. Movement data was only available for one African country.
Rosado, L., Da Costa, J.M.C., Elias, D. & Cardoso, J.S. (2017)[14]	To develop an image processing methodology using supervised classification to analyze microscopic images of malaria-infected thin blood smears.	ML techniques were employed to automatically identify malaria parasite species and life cycle stages in thin smear images captured on mobile devices. Image features, categorized into geometry, colour, and texture, were extracted based on relevant literature for malaria parasite detection on thin smears.	Sensitivity Specificity Accuracy F1-Score	A segmentation approach was developed to detect malaria parasites in microscopic images of malaria-infected thin blood smears. The results demonstrate the potential of the developed methodology as an effective alternative to conventional microscopy-based diagnosis of malaria.	Limited quantity of images were used to train the classifier. Increasing the number of annotations, particularly for less represented species-stage combinations, could improve the robustness and generalizability of the methodology.

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Fast, S. *et al.* (2017)[15]	To develop and validate a near real-time warning system for predicting social responses to infectious disease outbreaks around the world.	Disease outbreak news articles from the HealthMap database were collected, and an exponentially weighted moving average (EWMA) identified periods of unusually severe social response using anomaly scores from a Bayesian network. Two models, employing Random Forests, were trained and evaluated.	Accuracy Specificity Sensitivity Precision	The models performed well for country-disease pairs with substantial media coverage and moderately for less-covered pairs. Higher media attention improved the prediction of social response onset, highlighting the effective use of Internet-based news for forecasting social responses to infectious disease outbreaks. Valuable insights were provided for decision-makers and bio-surveillance experts, particularly for diseases receiving significant media attention.	Limited applicability of the model to all infectious disease outbreaks worldwide.
Oyebode, O. & Orji, R. (2019)[16]	To use text mining and machine learning techniques to analyze health-related posts from Nairaland, a social media platform popular in Nigeria, specifically focusing on topics related to diabetes.	Using web scraping, the study extracted 371,996 posts from 74,224 topics within the Health Forum of Nairaland. Posts related to diabetes were filtered using keywords, resulting in a dataset of 3,051 diabetes-related posts. The study utilized a systematic approach combining data collection, preprocessing, classification, and analysis to uncover insights into diabetes prevalence and potential intervention strategies in Nigeria.	Accuracy Precision Recall F1-Score Sensitivity Kappa Coefficient Specificity	Analysis revealed that weight, food, and diet were the primary factors contributing to diabetes prevalence in Nigeria. Additionally, other factors such as pregnancy, age, and sleep were identified, although to a lesser extent. The study provided insights into the significant contributors to diabetes in Nigeria, highlighting the importance of lifestyle factors (such as dietary habits and physical activity levels).	Data were collected solely on Nairaland, which might not represent the broader Nigerian population. Filters applied may exclude relevant posts that discuss diabetes. Study did not use longitudinal data, which may provide insight into the perspective of diabetes over time.

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Zhao, O.S. *et al.* (2020)[17]	To develop a streamlined and sequential approach for automating the diagnosis of malaria in low-resource settings, specifically focusing on the process from inputting blood smear images to outputting the number of infected and uninfected red blood cells.	Two datasets were used - the NIH malaria dataset and the Broad Institute malaria dataset. The NIH dataset contained labelled images of infected and uninfected red blood cells, while the Broad Institute dataset consisted of images with bounding boxes, thus indicating infected cells. The methodology involved training and optimizing deep learning models for object detection, image classification, and resolution upscaling, followed by integration into a mobile phone application for automated malaria diagnosis in resource-limited settings.	Accuracy Sensitivity Specificity AUC* F1-Score Matthews Correlation Coefficient Precision Recall	The SSD300 object detection model achieved high average precision (but relatively lower average recall when detecting red blood cells, indicating high precision but missed detections. Second, the developed Android application successfully integrated the trained models, allowing for on-device malaria diagnosis without the need for internet connectivity. The app processed images of blood smears and provided diagnostic results.	Model was not trained with samples from indigenous African populations. Encountered difficulties in creating corresponding cell segmentation model due to a lack of comprehensive dataset.
Oladeji, O. *et al. (*2021)[18]	To assess how internet search data related to diet and exercise could be used for monitoring information-seeking patterns and obesity prevalence in 52 African countries.	Search data for 108 terms related to chronic diseases, risk factors, diet, and physical activity were collected from Google API. Support Vector Machine (SVM), Random Forest (RF), gradient boosting, and Bayes Generalized Linear Model (GLM) were employed to identify search patterns associated with changes in obesity and overweight prevalence across African countries.	Coefficient of Determination Root Mean Squared Error	Information-seeking patterns related to obesity and overweight, as captured through internet search data, showed significant correlations with actual obesity prevalence across African countries. Several search terms related to weight loss, exercise, diet, and nutrition were found to be correlated with obesity prevalence.	Only Google search data in English were analyzed. Health data may inaccurately reflect current obesity and overweight rates.

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Yang, A. *et al.* (2019)[19]	To develop and evaluate a point-of-care diagnostic tool for soil-transmitted helminths (STH) in rural Madagascar. Specifically, it aimed to address two key obstacles to STH diagnosis in rural areas: the lack of portable and inexpensive microscopy and the limited capacity and expertise to interpret microscope images.	Employed a prospective design to evaluate diagnostic methods for soil-transmitted helminths (STH) in two rural villages in Madagascar using traditional laboratory techniques and advanced technological methods to evaluate and improve the diagnosis of STH in resource-limited settings.	Kappa Coefficient Specificity Sensitivity	Parasitologist interpretation of UVC (ultraviolet C) imaging of SSTT (salt solution flotation and sedimentation) slides were comparable to standard microscopy of KK (Kato-Katz) for detection.	Insufficient image quality of the USB video class used hindered accurate imaging of *T. trichiura* and hookworm. Kankanet model was based on a dataset limited to two imaging modalities. Dataset only included images from samples prepared under Kato-Katz conditions, limiting the assessment of the system's efficacy to those specific conditions.
Mejía, K., Viboud, C. & Santillana, M. (2019)[20]	To extend the AutoRegression model with Google search data (ARGO) to track influenza viral activity in near real-time in four African countries: Algeria, Ghana, Morocco, and South Africa.	Used a combination of influenza surveillance data, Google search data, and predictive modeling techniques to achieve its objectives. Three benchmark models were implemented for comparison: a)Autoregressive (AR) model: used only historical influenza activity data. b) GT model: used only influenza-related Google search frequencies. c) Google Flu Trends (GFT): historical predictions from GFT, available only for South Africa.	Root Mean Squared Error Mean Absolute Error Pearson Correlation	AutoRegression model with Google search data (ARGO), when adapted to monitor influenza activity in African countries, showed promising results in predicting influenza activity in near real-time.	Low sample size in search data and influenza data. ARGO method failed to perform well for countries that do not have seasonal influenza epidemics.

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Aiken, E. L. *et al.* (2020)[21]	To evaluate the performance of digital epidemiological methods in nowcasting five contemporary disease outbreaks in low-income settings, namely yellow fever in Angola (2016), Zika in Colombia (2015-2016), Ebola in the Democratic Republic of the Congo (2018-present), pneumonic plague in Madagascar (2017), and cholera in Yemen (2016-2017)	Used daily or weekly national case counts from epidemiological situation reports for outbreaks of yellow fever in Angola, Zika in Colombia, Ebola in the Democratic Republic of the Congo (DRC), pneumonic plague in Madagascar, and cholera in Yemen. Additionally, country-specific time-series of Google query volumes were downloaded from the Google Trends API for the same time periods.	Pearson Correlation Coefficient Root Mean Squared Error Relative Root Mean Squared Error Absolute Error Percentage Error	Digital epidemiological methods, particularly those combining real-time disease-related Google search activity with epidemiological information, showed promise in providing real-time insights into the trajectory of disease outbreaks in low-income settings.	Google search data may be susceptible to bias especially during disease outbreaks. Media coverage may complicate the interpretation of models used.
Nsoesie, E. O., Oladeji, O., Abah, A. S. A. & Ndeffo-Mbah, M. L. (2021)[22]	To model and forecast influenza-like illness (ILI) in Cameroon using data from a surveillance system for influenza and ILI implemented by the Ministry of Health (MOH) in Cameroon.	Weekly ILI (influenza-like illness) data spanning January 2012 to December 2018 were obtained from the Cameroon sentinel surveillance system. This system monitors ILI cases across 22 health facilities in Cameroon. Additionally, weekly Google search volume data for 65 terms related to ILI symptoms, home remedies, and prevalent infectious diseases in Cameroon were collected from the Google API.	Root Mean Squared Error R-Squared	The study demonstrated that health information seeking trends on the internet, particularly Google search data, can serve as accurate predictors of disease trends in sub-Saharan African countries like Cameroon. Search terms related to ILI symptoms, home remedies, and prevalent infectious diseases were found to be useful for tracking ILI trends.	Methods performed best in the short-term. Consistent data collection procedures are necessary for reliable ILI surveillance. Forecasting ILI trends in subtropical and tropical areas are challenging due to less defined seasonality.

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Abebe, R. *et al.* (2019)[23]	To identify and measure people's everyday health information needs, concerns, and misconceptions regarding infectious diseases such as HIV/AIDS, malaria, and tuberculosis.	Used a comprehensive approach combining data collection, natural language processing (NLP), and statistical analysis to investigate health information seeking behavior in sub-Saharan Africa.	Pearson Correlation Coefficient	There were significant differences in search behavior based on demographics (such as gender and age). For instance, topics related to pregnancy and breastfeeding were more popular among women, while news on cures was more sought after by men.	Bing users might not be representative of the entire African population. Imprecise language in search queries may have led to the exclusion of relevant searches and potentially introduced bias.
Olukanmi, S. O., Nelwamondo, F.V. & Nwulu, N. I. (2021)[24]	To investigate the predictive utility of Google search data for influenza-like illness (ILI) surveillance in South Africa. Specifically, the study aims to develop forecasting models using various algorithms.	Weekly data on ILI cases and Google search volumes for flu-related queries were collected and various forecasting algorithms were assessed, including Seasonal Autoregressive Integrated Moving Average (SARIMA), Multiple Linear Regression (MLR), Elastic Net (EN), Support Vector Machine (SVM), Feedforward Neural Network (FNN), and Long Short-Term Memory (LSTM).	Root Mean Squared Error Mean Absolute Error Pearson Correlation Coefficient	Google search data can serve as a reliable proxy for monitoring influenza (flu) spread in South Africa. Study demonstrated that various forecasting models, including deep learning (LSTM and FNN), machine learning (MLR, EN, and SVM), and Seasonal Autoregressive Integrated Moving Average (SARIMA) algorithms, performed well when using Google search data alone or in combination with historical ILI data.	Google users may not representative of the entire population.
Tudor, C. & Sova, R. (2022)[25]	To assess the impact of the COVID-19 pandemic on the occurrence of headaches worldwide using Google search data as a proxy.	The study employed a comprehensive approach combining model selection, data splitting, model estimation, evaluation, and testing to provide robust estimates of excess headache occurrences during	Mean Absolute Error Root Mean Squared Error Mean Absolute Percentage Error	The study underscores the significant impact of the COVID-19 pandemic on public health and highlights the importance of considering indirect health effects when assessing the full scope of the	Searches for headache does not necessarily indicate experience of the condition. Headache can be caused by a number of conditions.

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		the COVID-19 pandemic.	Theil's U Statistic Lag 1 Autocorrelation of Error	pandemic's consequences. Moreover, the study identified specific countries most affected by excess headaches during the pandemic, including the Philippines, Kenya, and South Africa.	
Adamu, H. *et al.* (2021)[26]	To address the lack of research on public sentiment regarding the distribution of COVID-19 relief aid and palliatives by the Nigerian government	Employed a methodology based on the Cross-Industry Standard Platform for Data Mining (CRISP-DM) framework, which provides a structured approach to data mining projects. It also constructs a sentiment analysis dataset in Nigerian Pidgin English, applying machine learning algorithms to classify emotions, and evaluate the effectiveness of these algorithms for predicting public sentiment.	Accuracy Precision Recall F1-Score	The study showed it was possible to classify citizens' emotions regarding the distribution of COVID-19 relief aid and palliatives by the Nigerian government with Twitter data in Nigerian Pidgin English.	Only Tweets in Nigerian Pidgin English were analyzed though the majority of the Nigerian population express their sentiments using their native languages.
Majam, M. *et al.* (2023)[27]	To evaluate the accuracy of a machine learning-based risk assessment tool in predicting the susceptibility of adults to HIV infection using data collected from a digital survey	Employed a mixed-method approach involving cross-sectional and longitudinal designs to assess HIV risk factors and develop predictive models. Descriptive statistics, hypothesis testing, and machine learning techniques were used. Predictive modeling included logistic regression, decision trees, and gradient boosted decision trees.	AUC* Sensitivity Specificity Negative Predictive value	Machine learning (ML) models can identify individuals at high risk of contracting HIV using data collected from digital surveys administered directly to potential patients. This approach proved viable particularly in low- and middle-income countries (LMICs) like South Africa.	Combining two separate datasets posed a risk of misclassifying responses and increased susceptibility to biases. Potential introduction of bias due to random sampling strategies.

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Maffioli, E. M. & Gonzalez, R. (2022)[28]	To investigate the characteristics of individuals who were misinformed about the origin of the Ebola outbreak during the 2014 epidemic in Liberia	The survey collected data on various socio-demographic and economic characteristics, access to information, political outcomes, Ebola-related exposure, individual perceptions about the epidemic's origin, and attitudes. Additionally, proprietary data from the Liberia Telecommunications Authority (LTA) and the Liberia Institute of Statistics and Geo-Information Services (LISGIS) were used, providing information on cell phone coverage, GPS coordinates, and census data.	None reported	Distrust in the government played a crucial role in predicting who was more likely to believe misinformation about the origin of the Ebola outbreak in Liberia. Furthermore, being a Muslim was a significant predictor of attributing a supernatural origin to the Ebola outbreak. However, religion did not significantly predict beliefs about political or ethnic origins.	Limited generalizability of findings to other countries Data was collected through self-reported mobile phone survey, which may introduce recall bias. Potential issues regarding confounding variables.
Potgieter, A. *et al.* (2021)[29]	To investigate and compare different sources of spatial mobility data in the context of understanding the spread of COVID-19 in South Africa	The study used various methods to construct and compare spatial weight matrices, aiming to understand spatial associations and their implications, particularly in the context of infectious disease spread such as COVID-19. The effectiveness of the different methods was evaluated based on its ability to capture spatial associations and provide insights into mobility patterns during the COVID-19 pandemic.	Sensitivity Accuracy Specificity	Hierarchical clustering applied to group data points based on similarity, effectively identified clusters of spatial units with similar characteristics, aiding in interpreting spatial relationships.	Mobility data from some sources was only available at higher geographic levels Mobile data can be costly and not always available to researchers

Notes

AUC* - Area Under the Curve

SI 1: SUPPLEMENTARY REFERENCES

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