Critical Limitations of Digital Epidemiology: Why COVID-19 Apps Are Useless

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Network of European Data Scientists (NeEDS)
Workshop on Data and Decisions in the COVID19 times (online)
July 1, 2020

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Introduction

- The German Academy of Natural Scientists (Leopoldina (2020)) suggested the use of:
  1. nationwide surveys via a smartphone app to provide data on the population's current state of health,
  2. apps for voluntary reporting of symptoms and information on the course of the illness,
  3. data recorded by activity trackers and other wearables on the wearer's resting pulse and sleep rhythm to indicate signs of fever and the emergence of flu-like symptoms, and
  4. use of voluntarily provided personal data such as movement profiles (GPS data) in combination with contact tracing.
- In contrast to this recommendations, we consider the methods of digital epidemiology as proposed unsuitable for use as pandemic surveillance tools.

Digital Epidemiology

- Digital epidemiology uses "data that was not generated with the primary purpose of doing epidemiology" (Salathé 2018: 2).
- Digital epidemiology
  - is not based on a statistical research design,
  - therefore, the data generating mechanisms are unknown.
  - Population coverage is not complete or unknown,
  - so no valid inferences by design-based approaches are possible.
- Correspondingly, widely-known flagship demonstrations (search engines for prevalence estimation, see Butler (2013), Cervellin et al. (2017), and Lippi/Cervellin (2019)) are still unproven and debated.

The Total Survey Error Model for evaluating Digital Epidemiology

- Methods of digital epidemiology require access to devices and motivation to participate.
- Availability must be given in all population subgroups, or the relationship between availability and the variable of interest must be known.
- Neither Smartphones nor fitness trackers are uniformly distributed in a population, nor is the functional relationship between their use and health status known.
- Population studies based on this kind of devices will have coverage and nonresponse problems, which in general are studied in Survey Methodology (Biemer/Lyberg 2003).
- We use the bias model of Bethlehem/Biffignandi (2012), initially developed to explain bias in non-probability surveys, as theoretical framework for our argumentation.
- Subgroups owning and using a smartphone or fitness tracker are considered as non-probability samples.

Bias in Non-probability Samples

- The model allows the estimation of the expected difference between the population mean $\bar{Y}$ and the mean of a non-probability sample $\bar{Y}_{ns}$:

$$\bar{Y} - \bar{Y}_{ns} = \frac{R_{\rho Y} S_\rho S_Y}{\bar{\rho}}.$$

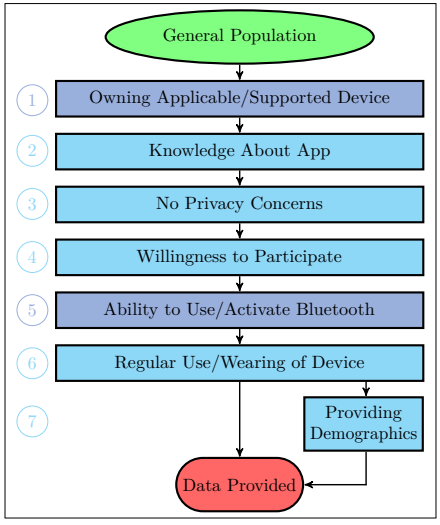
- The model assumes that every person has a response propensity ρ.
- The response propensity has an overall mean $\bar{\rho}$ and standard deviation S_ρ.
- $R_{\rho Y}$ is the correlation between Y and ρ, and S_Y is the standard deviation of Y.
- The bias $\bar{Y} - \bar{Y}_{ns}$ depends on three quantities:
  1. the correlation between the response propensity and the variable to be estimated,
  2. the variance of the response propensity,
  3. and the variance of the variable of interest.
- Therefore, the bias will be small if
  1. the participation rate in the non-probability sample is high or
  2. $R_{\rho Y}$ is small or
  3. S_Y is small.

Limitations of Digital Epidemiology using Smartphones or Wearables

- The official estimate for smartphone penetration in Germany is 82% (Statistisches Bundesamt 2020).
- Smartphone ownership is related to age and socioeconomic status (Generali Deutschland AG 2017).
- 21% of the German general population is older than 65 years.
- Younger children do not own smartphones:
  - 54% at the age of 6–7
  - 82% at the age of 11 (Berg 2020).
- About 29% of the population use fitness trackers and 36% smartwatches (Deloitte and Bitkom 2020).
- 59% of people 60+ are not interested in such devices, and 6% of the respondents own but do not use such a device (Statista 2019).
- There is a lack of validation studies and only sparse empirical evidence on the use of digital health apps.
- However, usage of digital health apps seems to be associated with age, health, and SES (Müller et al. 2020).

Selection Processes in Digital Epidemiology Using Smart Devices

- Steps 1–7 might introduce selection bias by excluding specific subgroups of the general population.
- Step 1 and step 5 exclude non-owners of specific smart devices (coverage problem).
- The remaining steps are similar in their causes and effects to survey nonresponse, where step 7 is identical to item-nonresponse.
- Therefore data will be provided by younger people, those with higher socioeconomic status, better health, more physically activity and higher interest in new technologies.



The RKI Data-donation App

- German CDC considers the identification of regional infection clusters down to postcode levels (about 8,200 in Germany) as possible using data donation apps (Robert Koch-Institut 2020).
- About 515,000 installations are reported (2.6.2020), about 0.6% of the population; the proportion varies between 0.2%–1.2% depending on the administrative unit.[1]
- If a change of a prevalence of 1% (from 1% to 2%) has to be detected, the required sample size for each postcode area exceeds 1,853 persons ($\text{power} = 0.8$, $\alpha = 0.05$), resulting in an overall sample of more than 15 million persons.
- Data-donation app suffers from unproven sensitivity and specificity, sample selection bias, and insufficient statistical power.
- From a statistical point of view, it is hard to see any epidemiological use of this app.

[1] 509,000 devices (5.5.2020), an increase of only 6,000 devices within one month.

COVID-19 Apps for Automatic Contact Tracing

- The most widely proposed kind of COVID-19 app uses Bluetooth signals to track encounters with people who are later diagnosed as infected.
- The accuracy of such automatic contact tracing apps suffers from Bluetooth-based measurement errors (signal strength, signal direction, impact of physical environment features).
- Therefore, false-positive alarms and false-negative alarms are likely (Schneier 2020).
- No data has been published on precision and recall of devices in proximity. SAP has admitted a 20% error-rate (26.6.2020).
- The deliberately misuse might generate false-positives or false-negatives (due to social desirability) (Soltani et al. 2020).
- Especially subpopulations with a higher prevalence of undetected infections will have lower coverage rates by the apps: Older people, children and persons without smartphones due to lower-income.
- To be useful beyond individual cases of preventing infections, a high rate of adaption within a population is required.

COVID-19 Apps for Automatic Contact Tracing

- Germany released the app on 16.06.2020, so far about 14 million downloads (30.06.2020, about 17% of the population).
- As currently observed in Iceland, the app is not of any epidemiological use with a covering rate of 40% in the general population (Johnson 2020).
- To get a higher adaption rate than Iceland (41%), at least 34 Mio. people have to download and use the app in Germany.
- The Australian tracing app identified just one person being infected after one month of usage (Taylor 2020).
- In Singapore, the tracing app did not allow monitoring, contact chains were not traceable, and the number of infections increased again despite the app (Fahrion 2020).
- Such apps might prevent some individual infections.
- They are neither a panacea nor an epidemiological research tool.

Alternatives for COVID-19 Population Research in Germany I: Health Insurance Data

- Heller (2020) suggested using health care insurance data to monitor and analyze the pandemic.
- Health insurances receive data on inpatient treatment of patients with COVID-19 within a few days.
- Data contains required covariates, therefore statistical analysis of outcomes are possible with data already available.
- This gives a fast indicator system, no additional data collection is required and the data can be analyzed within existing legal regulations.

Alternatives for COVID-19 Population Research in Germany II: Municipal Health Data

- Instead of mapping data of a COVID-19 app, data resulting from infections reported to municipal health departments should be mapped.
- The number of inhabitants is known for all 100×100m-areas in Germany.
- Local density estimates can be published using a tool freely available to administrations using the infections reported to the municipal health department or the data of the health insurances (infas 360 2020).
- Automatically aggregation allows to meet GDPR, each municipality can have its own desired level of aggregation.
- This tool would allow the identification of regional infections clusters.

Alternatives for COVID-19 Population Research in Germany III: Random Samples

Schnell/Smid (2020) recommended:

1. There is no alternative to selecting a true random sample of persons ($n > 30,000$) in many PSUs ($k > 120$) and test them for antibodies using blood probes. In addition, they suggested a booster sample of persons ($m = 3000$) living in institutions ($l = 300$) for the elderly.
2. A longitudinal sample is required to study the course of the disease and for the study of symptom-free infected persons.
3. A randomly selected post-mortem sample is needed to estimate the proportion of infected persons among the deceased and determine the cause of death.
4. A small sample should be randomly selected from the population to describe changes in attitudes and reported behavior due to COVID-19.

Only surveys of type 4 are in the field.

Conclusion

- The proposed use of smartphone apps to monitor the spread of COVID-19 have statistical and methodological limitations.
- Use of smart devices suffer from under-coverage and nonresponse, which are rarely addressed by proponents of digital epidemiology.
- Sensitivity and specificity of the suggested apps are unknown and undiscussed.
- So far no promising results from implemented apps anywhere.
- For COVID-19 surveillance, we recommend that instead of digital epidemiology, available administrative data and true random samples should be used.

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