Anatomy of digital contact tracing: role of age, transmission setting, adoption and case detection

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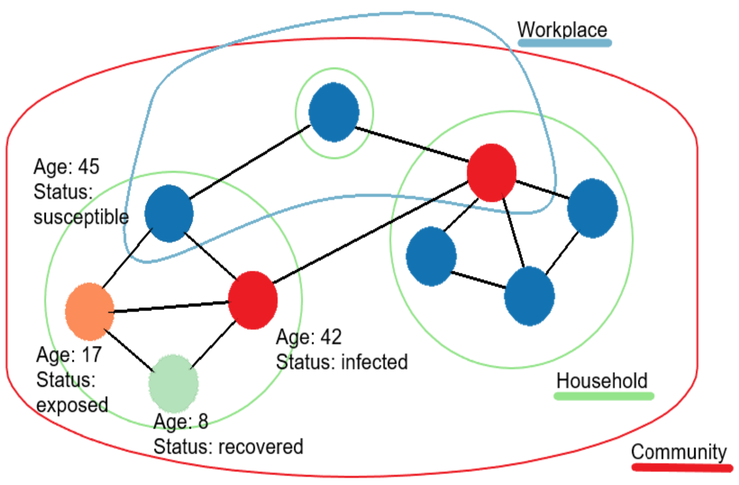
Abstract

The efficacy of digital contact tracing against coronavirus disease 2019 epidemic is debated: Smartphone penetration is limited in many countries, with low coverage among the elderly, the most vulnerable to COVID-19. We developed an agent-based model to precise the impact of digital contact tracing and household isolation on COVID-19 transmission. The model, calibrated on French population, integrates demographic, contact and epidemiological information to describe exposure and transmission of COVID-19. We explored realistic levels of case detection, app adoption, population immunity, and transmissibility. Assuming a reproductive ratio R = 2.6 and 50% detection of clinical cases, a ~20% app adoption reduces peak incidence by ~35%. With R = 1.7, >30% app adoption lowers the epidemic to manageable levels. Higher coverage among adults, playing a central role in COVID-19 transmission, yields an indirect benefit for elderly. These results may inform the inclusion of digital contact tracing within a COVID-19 response plan.

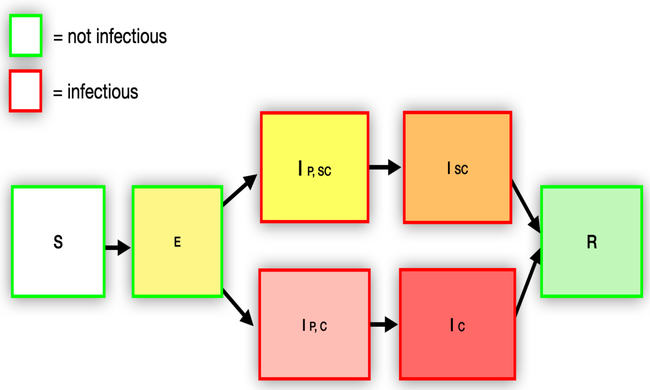
The Model

The Network: dynamic and multilayered



- The network is built following some **key statistics** such as the French age pyramid, the size of households distributions, the smartphone penetration or the frequency and setting of contacts by age.
- **Dynamical**: contacts vary every day depending on an activation rate.
- **Multilayered:** contacts may occur in five different settings (households, work, schools, community and transport).

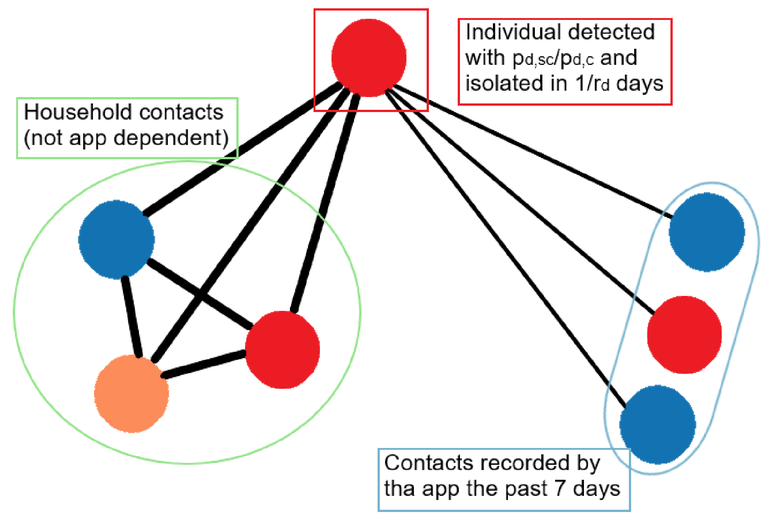
Transmission model



- The severity of symptoms is age dependent.
- The probability Λ_i of a susceptible node (i) of being infected by its infectious (I) neighbors (j) depends on age $\sigma_{A,I}$, the layer ω_L, the infectious stage β_I and a overall force of infection β.

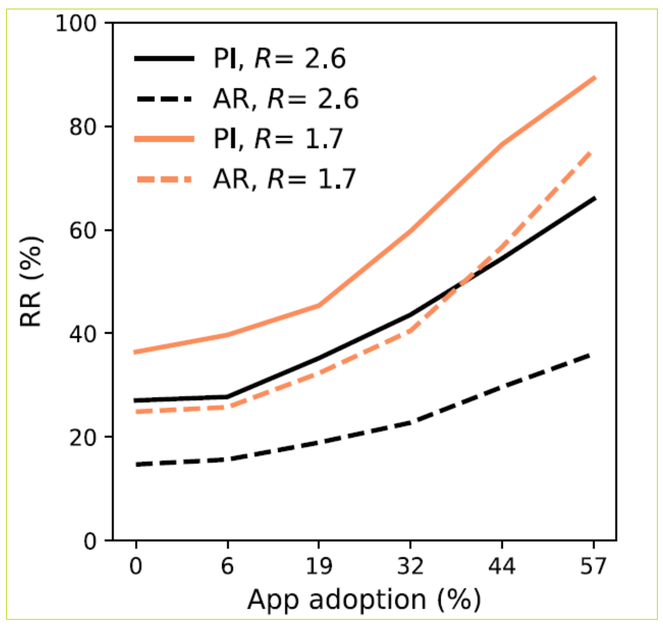
$$\Lambda_i = 1 - \left(\prod_L \prod_{j \in \nu_L} (1 - \sigma_{A,i} \beta \beta_{I,j} \omega_L \delta_j(I) \delta_j(L,I)) \right)$$

Contact Tracing



- Theprobability of being detected depends on the severity of the symptoms (clinical or sub-clinical).
- Each household contacts is isolated with a probability of compliance $p_{c,hh}$. Each app contact is isolated with probability p_c.
- There is a certain probability for people to drop-out the isolation program.

Results



Impact of digital contact tracing and household isolation on the epidemic: A - Relative reduction versus no intervention scenario (RR) in attack rate (AR) and peak incidence (PI) as a function of the app adoption. The attack rate is computed as cumulative incidence discounting initial immunity (10%). **B,C -** Peak incidence and attack rate according to reproduction ratio R and app adoption. Incidence threshold level corresponding to ICU saturation is showed as a red line in panel B.

Discussion

- Under realistic hypotheses, the intervention would not be able alone to bring the epidemic under control in a scenario where transmission is high, mainly due to the strong role of asymptomatic transmission in fuelling the epidemic.
- We found that a reduction of the epidemic to a manageable level would be possible with a moderate R (e.g. R =1.7 explored here).
- App adoption remains the key factor determining the efficacy of digital contact tracing.
- When exploring non-uniform app adoption by ages (elderly people may be less inclined to use the app even when they own a smartphone) we show that the impact of digital tracing provides indirect protection in the elderly population.

[1] Anatomy of digital contact tracing: Role of age, transmission setting, adoption and case detection
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