Supporting COVID-19 quarantine decisions with a statistical risk assessment model

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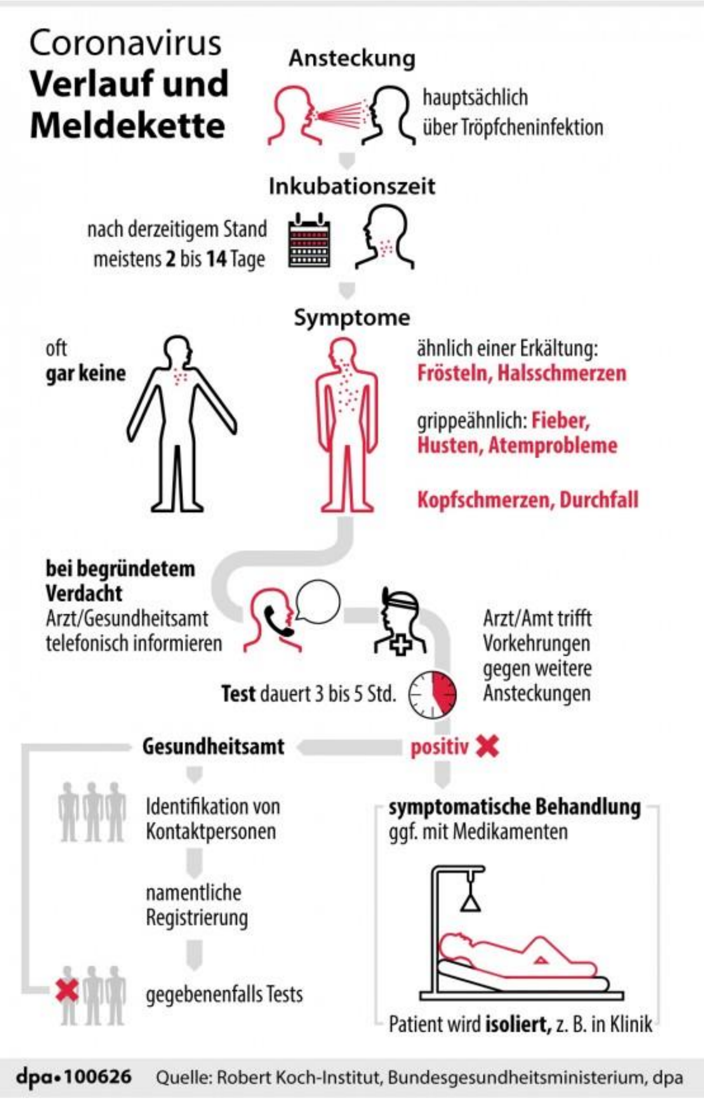
German health offices

- Have to monitor all infected persons and have to report the COVID-19 cases to the Robert-Koch Insitute (RKI)
- Have to find all contact persons of COVID-19 and has to decide about quarantines



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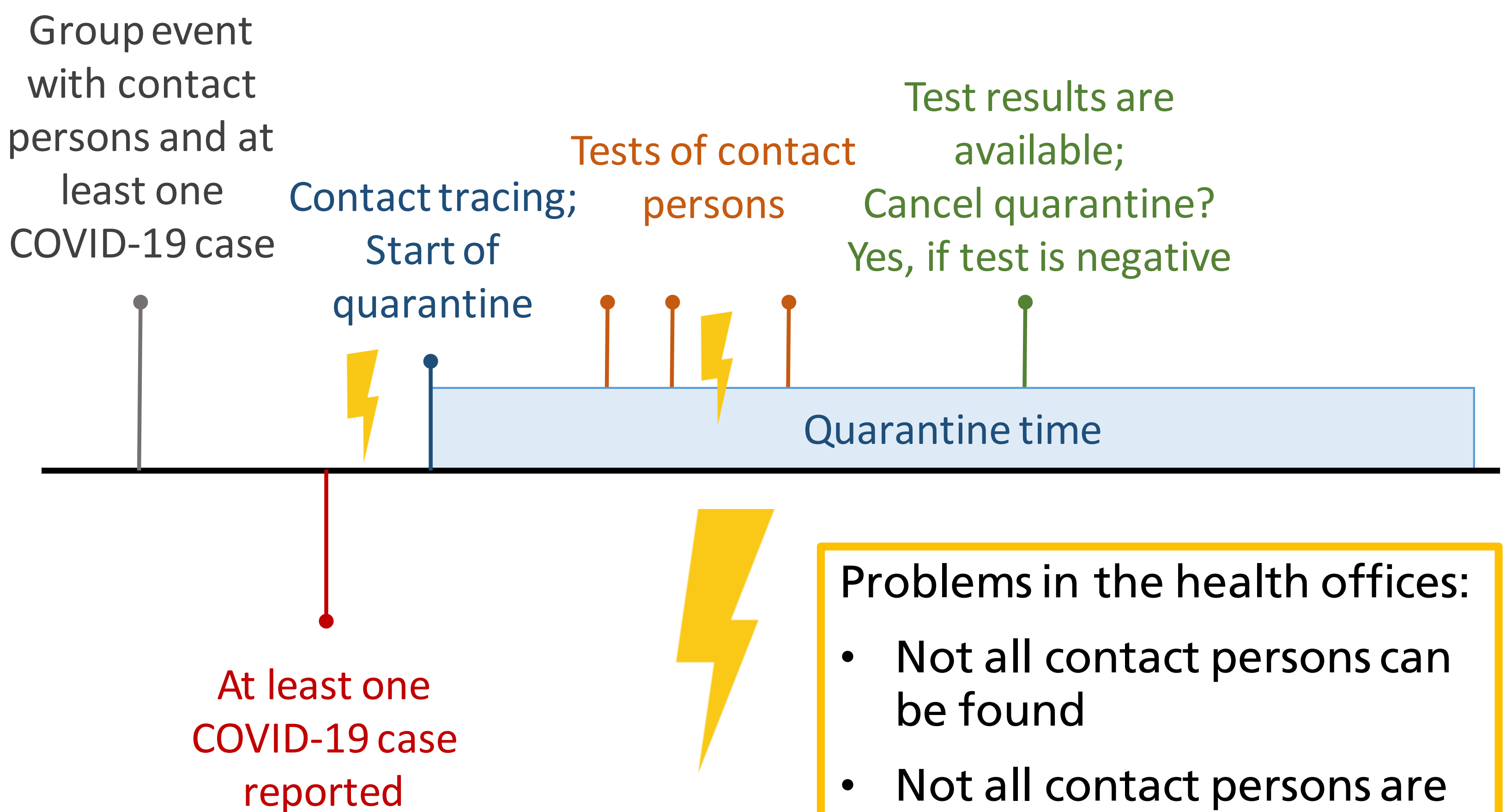
Timeline of monitoring contact persons



Problems in the health offices:

- Not all contact persons can be found
- Not all contact persons are doing a test

Risk assessment for quarantine decisions

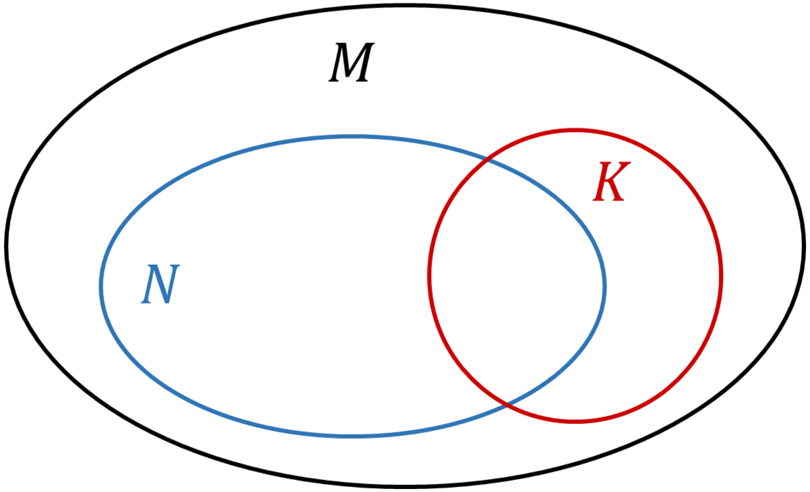
- *"Under which conditions can a group quarantine be released (earlier) such that the probability of overlooking an infection is low?"*

- Restriction: All made test of contact persons are negative.

- Question: "*How likely is it that there occurred no further infections?"*

Statistical model

- Mathematical use case:
  - M Persons were in contact with one infected person
  - $N, N \leq M$ Persons were tested negative
  - $K \leq M$ Number of unknown infected persons



- How likely is it that there occurred no further infections ($K = 0$), given that N out of M persons are tested negative?

Statistical model

- Probability calculation via Bayesian formula → posterior distribution

$$p_0 := P(K = 0 | N \text{ out of } M \text{ tested negative})$$
$$= \frac{P(N \text{ out of } M \text{ tested negative} | K = 0) \cdot P(K = 0)}{P(N \text{ out of } M \text{ tested negative})}$$

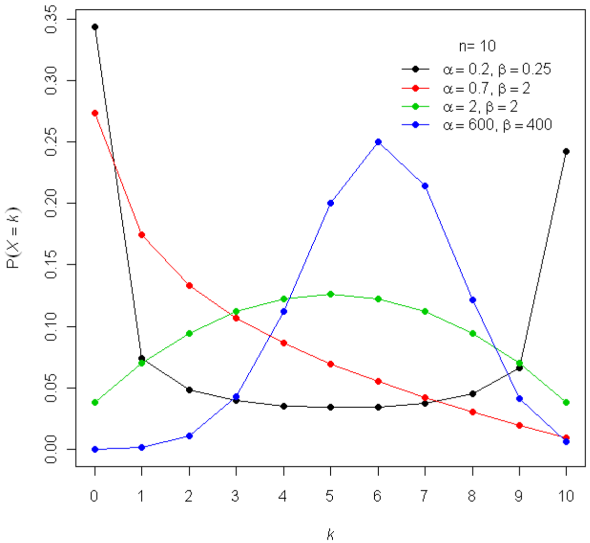
- What do we need?
  - Prior distribution $P(K)$, which describes the probability of an infection
  - Likelihood $P(N$ out of M tested negative$|K)$, which describes the probability of the negative test results under the condition that K persons were infected

Scenario-dependent prior distribution

- Modeling of a beta-binomial distribution for a specific setting

$$K|\alpha, \beta, M \sim \mathrm{BB}(M, \alpha, \beta)$$

- Informations are needed, such as
  - Probability for an infection: $P(K > 0)$
  - Conditional mean: $E(K|K > 0)$

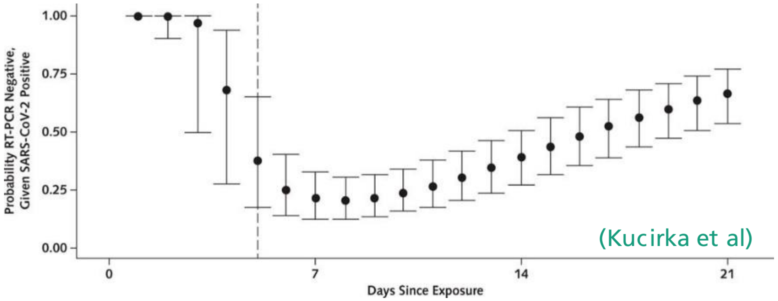


(en.wikipedia.org/wiki/Beta-binomial_distribution)

- Determination of Beta-binomial distribution via optimization, e.g. L-FBGS (Byrd et al)

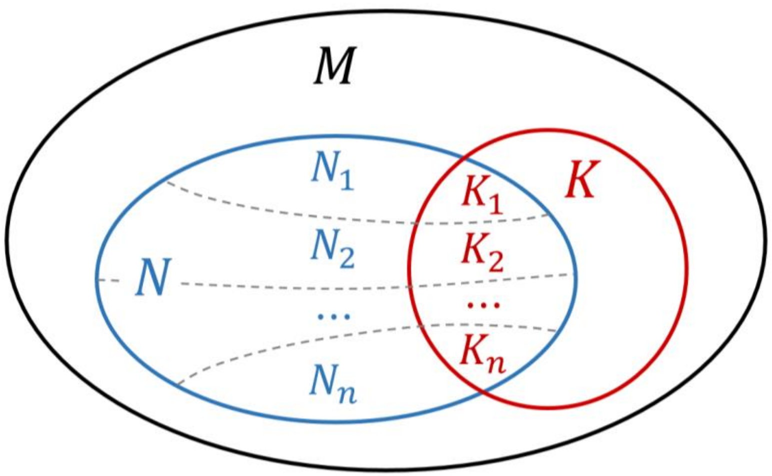
Likelihood

- Day specific test sensitivity is considered for negative testing probability



- Division of N into n day specific groups:

  N_d persons are tested on d-th day with K_d infected persons ($d = 1, \ldots, n$)



- Consideration as an urn model, where K persons are randomly drawn:

  Multivariate hyper-geometric distribution

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Example: school classes

- Literature research:

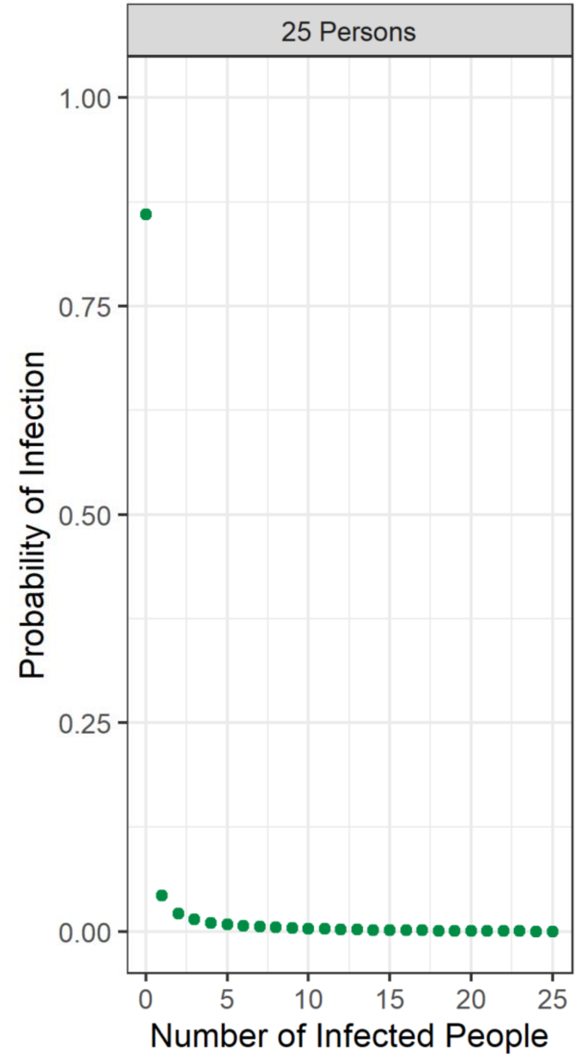
  → 2 studies about infection probability (Heavey et al, Macartney et al)

  → RKI report about average infection numbers in outbreaks

- Prior modelling:

$$P(K > 0) = \frac{3}{21} \approx 0.14,$$

$$E(K|K > 0) = 4.8$$



A school class dataset (Berlin-Reinickendorf health office)

Case number	Date of last contact	PCR test date	PCR test result
1	August 10, 2020	---	---
2	August 10, 2020	---	---
3	August 10, 2020	---	---
4	August 10, 2020	August 18, 2020	negative
5	August 10, 2020	August 19, 2020	negative
6	August 10, 2020	August 19, 2020	negative
7	August 10, 2020	August 19, 2020	negative
8	August 10, 2020	August 20, 2020	negative
9	August 10, 2020	August 19, 2020	negative
10	August 10, 2020	August 19, 2020	negative
11	August 10, 2020	August 19, 2020	negative
12	August 10, 2020	August 19, 2020	negative
13	August 10, 2020	August 19, 2020	negative
14	August 10, 2020	August 19, 2020	negative
15	August 10, 2020	August 19, 2020	negative

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A school class dataset (Berlin-Reinickendorf health office)

- 15 persons divided into 3 test groups:

$$D_1 = \text{August } 18^{\text{th}}, N_1 = 1$$
$$D_2 = \text{August } 19^{\text{th}}, N_2 = 10$$
$$D_3 = \text{August } 20^{\text{th}}, N_3 = 1$$
$$N_0 = 3$$

- Calculated probability that no transmission occured: $p_0 = 98\%$

- With rule $p_0 > 0.9$: **Quarantine cancellation**

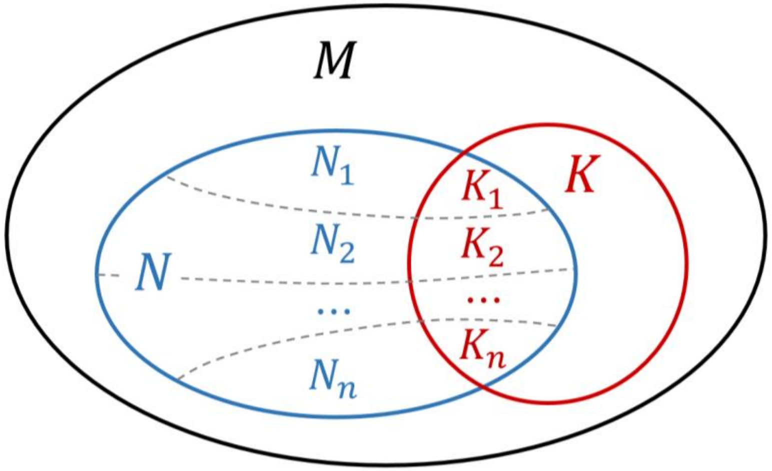
- Feedback of the health office: **No further infections were reported**

Summary & Discussion

- A first statistical model as risk assessment for quarantine decisions

  → Can be specified for any group event situation

  → Has the potential to facilitate the daily work in health offices



- Future work:

  Evaluation of using the statistical model for quarantine decisions

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