A network modelling approach to assess non-pharmaceutical disease controls against SARS-CoV-2 in a worker population

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Modelling response: University of Warwick involvement

Warwick has developed multiple models for understanding COVID-19 in the UK:

- Age-structured deterministic model
  - Estimates current infection levels, R and incidence
  - Longer-term predictions and planning
  - Vaccination analysis
  - Costs & benefits of COVID-19 response
- Local spatial spread
  - Investigate the impact of the spatial scale of lockdowns on outbreaks
- Secondary school model
  - Lateral flow testing and isolation of contact bubbles
- **Network models**
  - Used to study transmission in universities and in **work sectors**

https://tinyurl.com/warwickCOVID19

Talk outline

(1) Introducing the model and contact parameterisation

- Multi-layered network model;
- Contact survey data analysis.

(2) Workplace targeted interventions

- Proportion working from home;
- Worker patterns;
- COVID-secure workplaces.

(3) Adherence to test, trace & isolate guidance

- Assess the general role of adherence to (or effectiveness of) isolation and test and trace measures.

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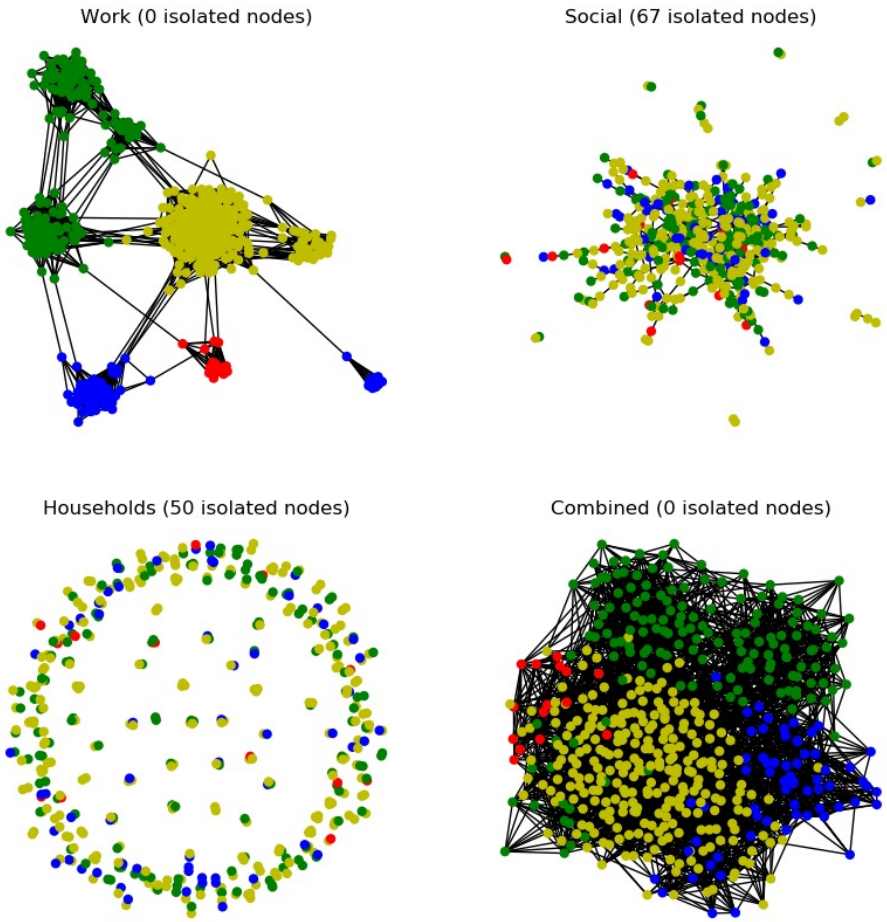
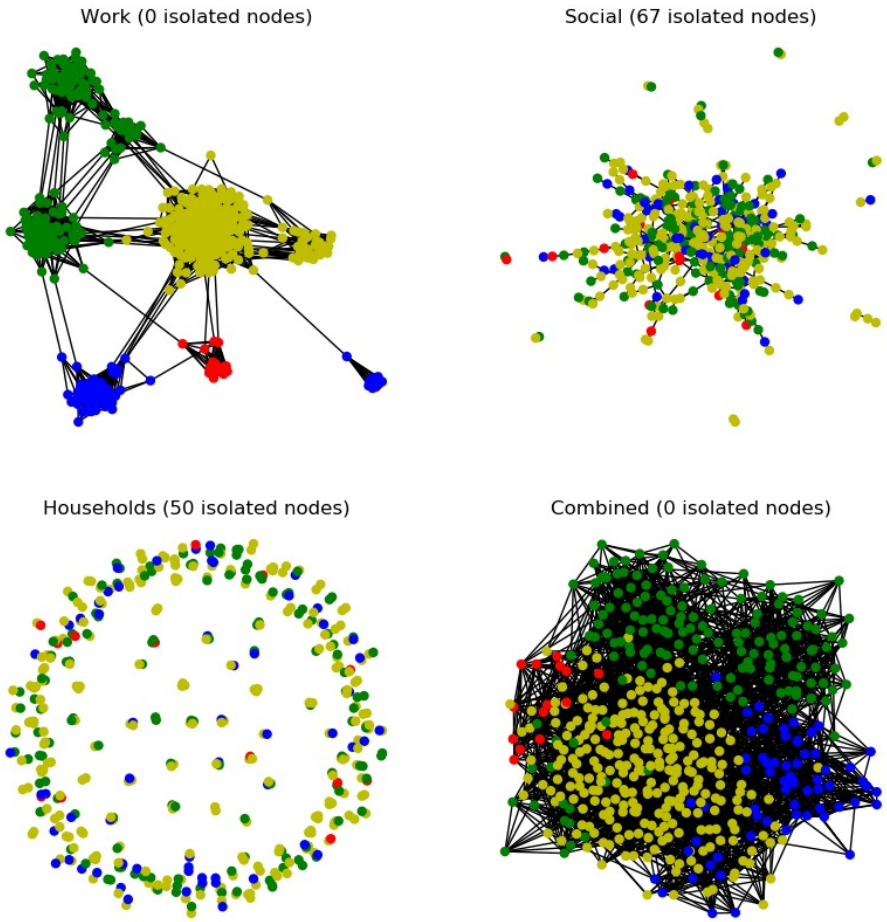
Network model summary

- Nodes represent workers
- Connections represent contacts that can result in disease transmission
- Connections form network layers:
  - Household contacts
  - Workplace contacts
  - Social contacts
  - Dynamic contacts (both workplace and social)



Network model summary

- Infection dynamics
  - Erlang distributed latent period
  - Infectiousness dependent upon time since infection
  - Transmission is scaled according to location and symptomatic status
- Test, trace and isolate:
  - Adherence to tracing and isolation
  - Delays in testing
  - Test sensitivity and specificity
  - Ability to remember dynamic contacts decreases with time



Workplace contact distributions

Table: Listing of the 41 industrial sectors workplaces were grouped into.

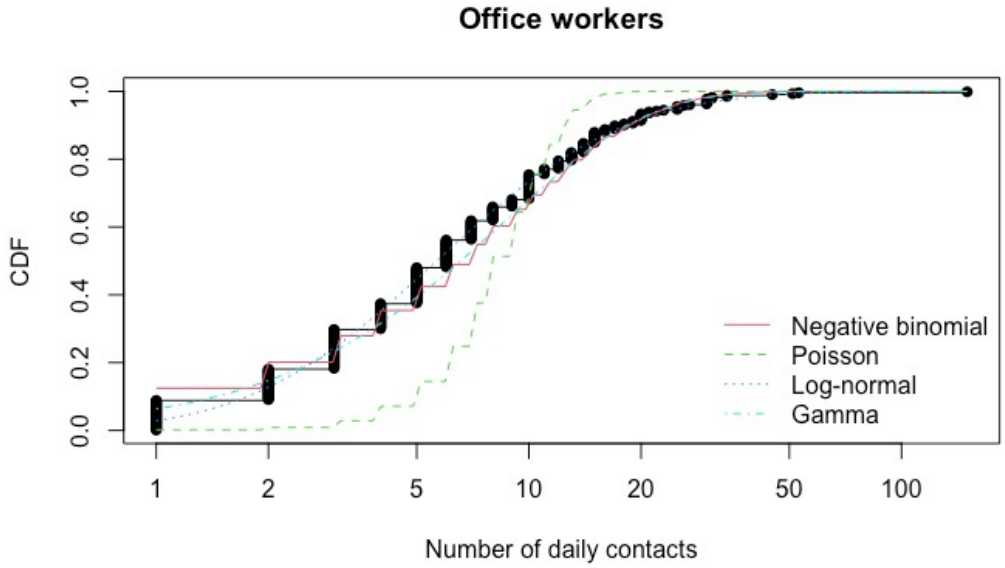
1. Agriculture	12. Postal	23. Employment and HR	34. Betting
2. Mining	13. Accommodation	24. Travel Agency	35. Sport
3. Manufacturing (food & beverages)	14. Restaurant and Bar	25. Security	36. Theme Parks
4. Manufacturing (other)	15. Broadcasting and Communications	26. Cleaning	37. Religious and Political Organisations
5. Utilities and Waste	16. Information Technology	27. Office (other)	38. Repair
6. Construction	17. News	28. Public Administration and Defence	39. Hairdressers
7. Motor Trade	18. Banking/Accounting	29. Education	40. Funeral
8. Wholesale	19. Real Estate	30. Hospital/Doctor/Dental	41. Personal Services
9. Retail	20. Professional/Science/Tech	31. Care Homes	
10. Transport	21. Veterinary	32. Social Work	
11. Transport Support	22. Rental Companies	33. Arts	

- Contact distributions and risk parameterised using Warwick contact survey.
- Model split contacts both within a worker's workplace (most common) and to other workplaces in the same industrial sector (less common, assumed 5%).
- We generated static contacts using a 'configuration model' style algorithm, allowing the specification of a desired degree distribution for each sector.

Reference:
Danon L, Read JM, Keeling MJ, House TA, Vernon MC. Social contact study. [Dataset] (2009). URL https://wrap.warwick.ac.uk/54273/

Workplace contact distributions

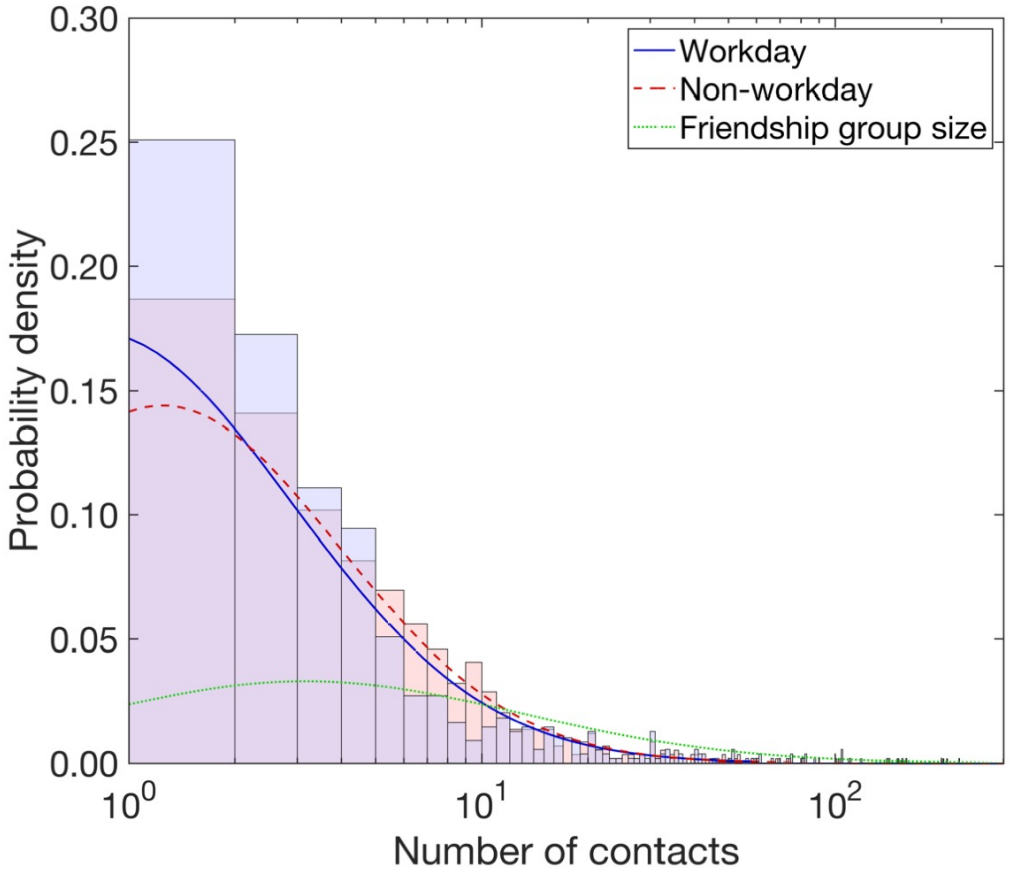
Figure: Parametric distribution fits to empirical data on daily number of work contacts by office workers.



- Daily number of workplace contacts (static and dynamic) displayed a heavy tail.
- Lognormal distributions consistently provided stronger correspondence to the data, across different occupations, than alternative choices of distribution.

Social contact distributions

Figure: Density functions of the best fit lognormal distributions with respect to number of social contacts each workday, non-workday and friendship group size.



Friendship group size	Lognormal(3.14,1.141)
Social contacts (workday)	Lognormal(1.40,1.27)
Social contacts (non-workday)	Lognormal(1.54,1.15)

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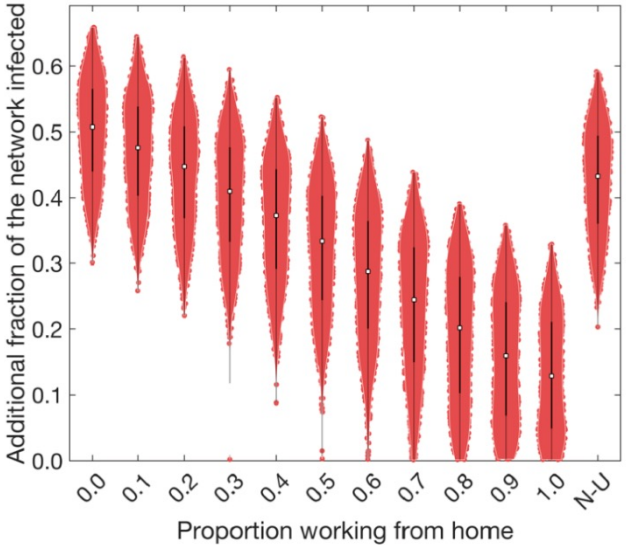
Simulation overview

- **Population & time horizon:** 10,000 workers, 365 days.
- **Simulation count:** 1000 runs (20 runs per network realisation, 50 distinct network realisations)
- **Initial disease state conditions:** Ten individuals began the simulations in an infectious state. All other individuals began in a susceptible state.
- **Default worker pattern:** Applied a simplifying assumption that all workers had the same working pattern of five days at the workplace (Monday-Friday) and two days off (Saturday and Sunday).
- **Intervention implementation:** Assumed that all NPIs, including isolation and test-and-trace (default assumption of 70% adherent), were implemented from day 15.

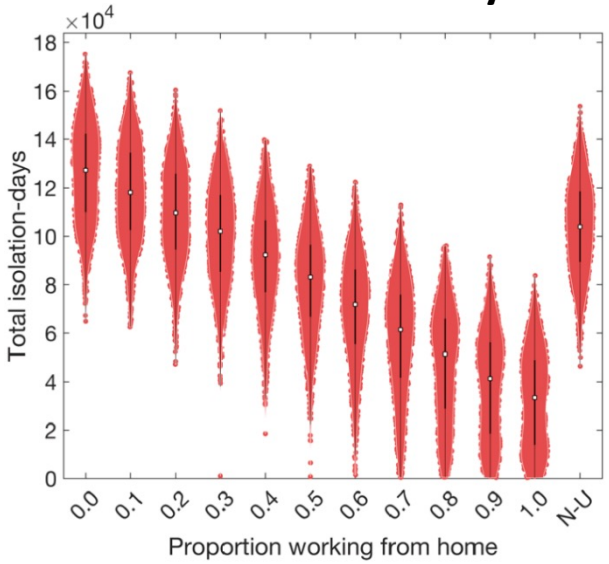
Proportion working from home

Figure: Case and isolation summary statistics under differing fractions of workers working from home.

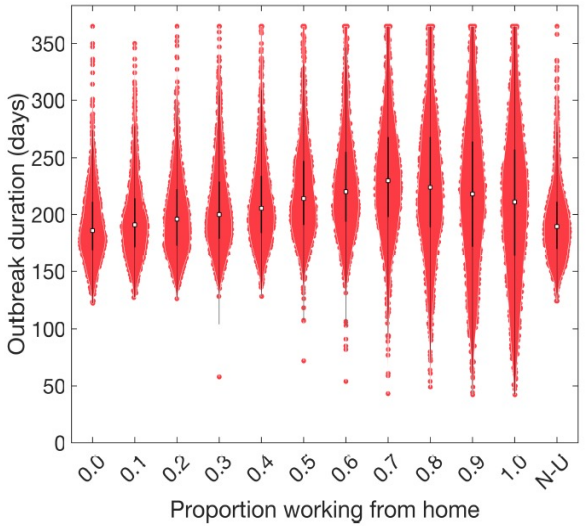
Additional proportion infected (day 15 onwards)



Total isolation-days



Outbreak duration

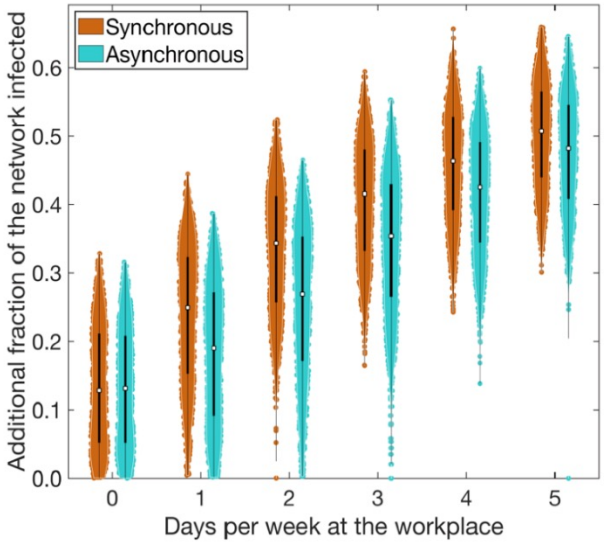


- Progress of an outbreak can be stunted by a large proportion of the workforce working from home.

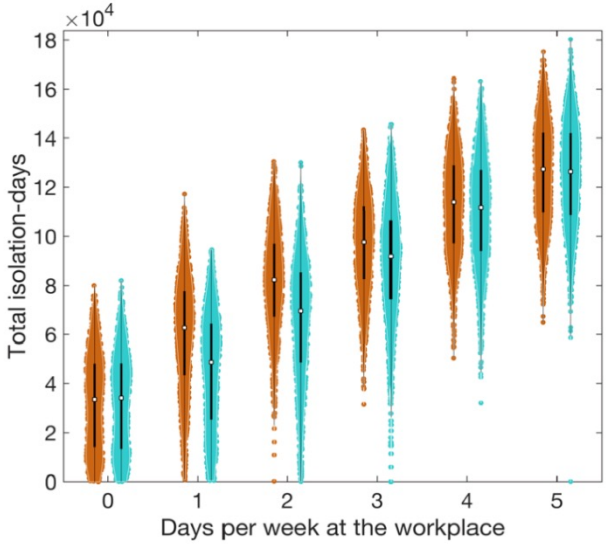
Worker patterns

Figure: Case and isolation summary statistics under synchronous and asynchronous worker patterns.

Additional proportion infected (day 15 onwards)



Total isolation-days



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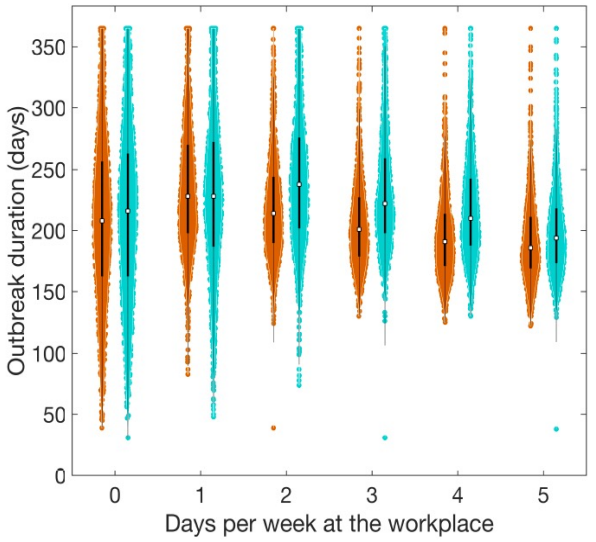


- Asynchronous work patterns reduces infections compared with scenarios where all workers work on the same days, particularly for longer working weeks.

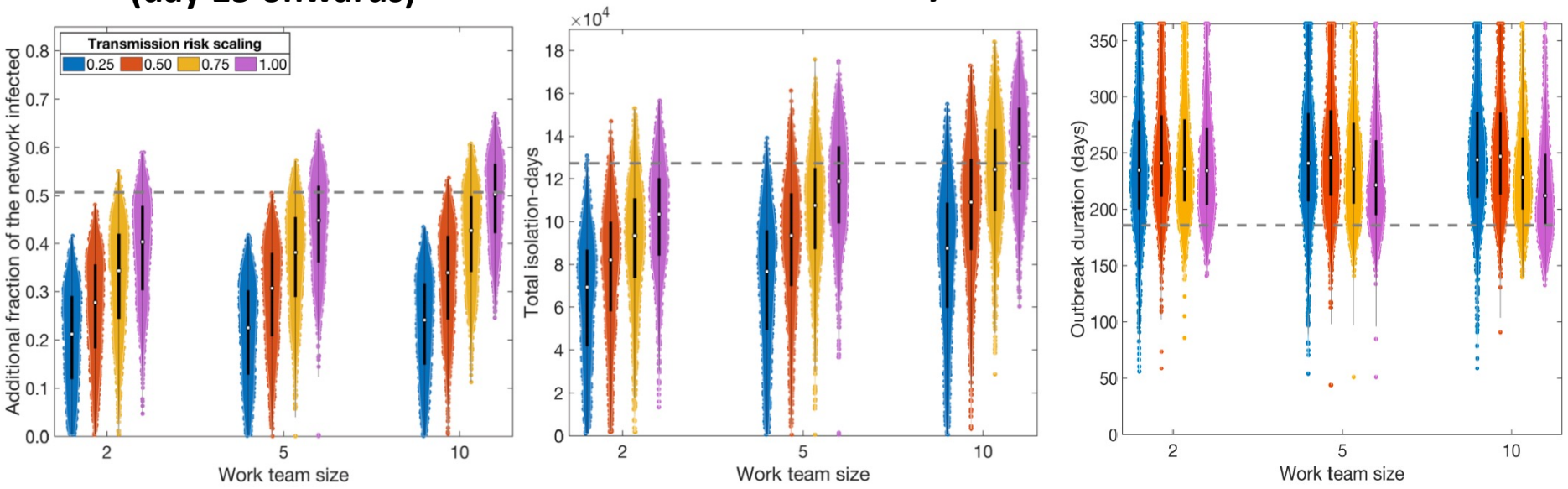
COVID-secure workplaces

Figure: Case and isolation summary statistics under COVID-secure workplace measures, altering work team size and workplace transmission risk.

Additional proportion infected (day 15 onwards)

Total isolation-days

Outbreak duration



- Smaller work teams and a greater reduction in transmission risk reduced the probability of large, prolonged outbreaks.

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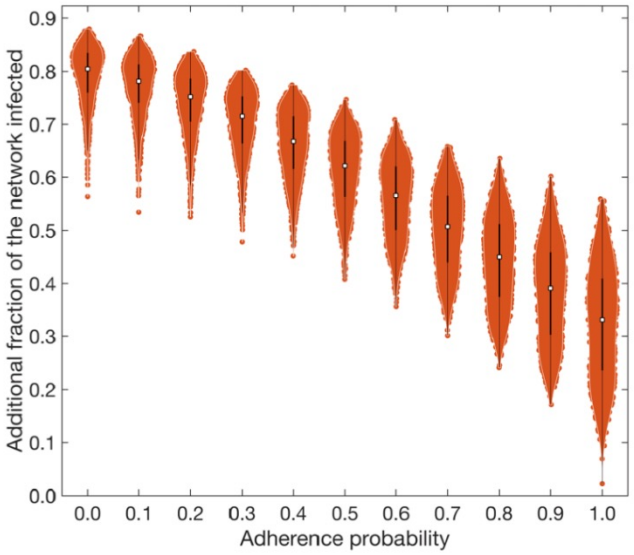
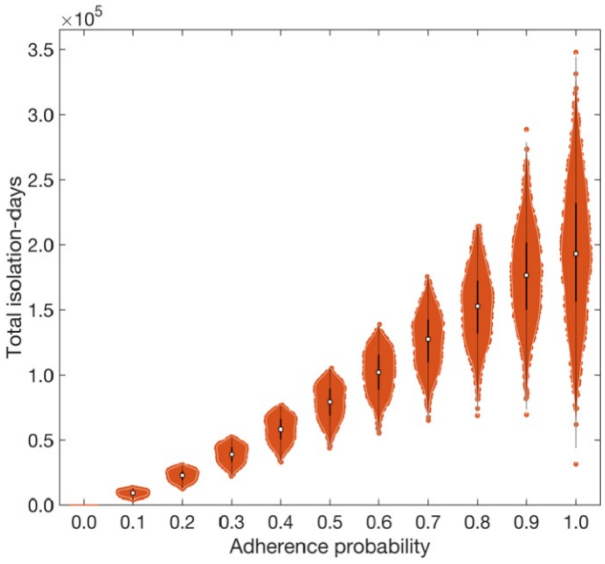
Adherence to test, trace and isolate

Figure: Case and isolation summary statistics under differing levels of adherence to test, trace and isolate measures.

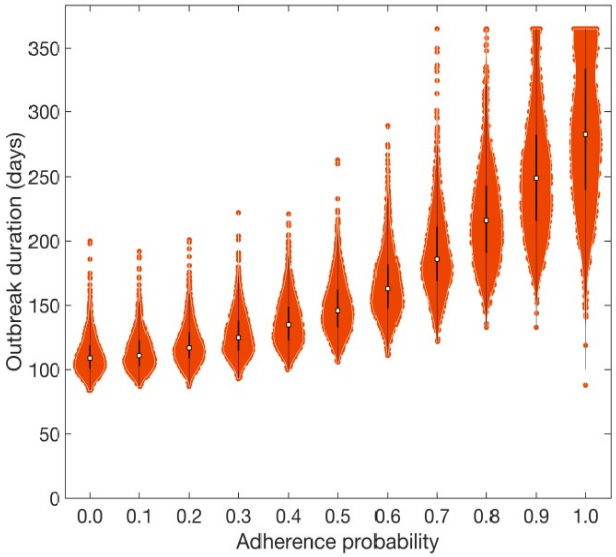
Additional proportion infected (day 15 onwards)



Total isolation-days



Outbreak duration

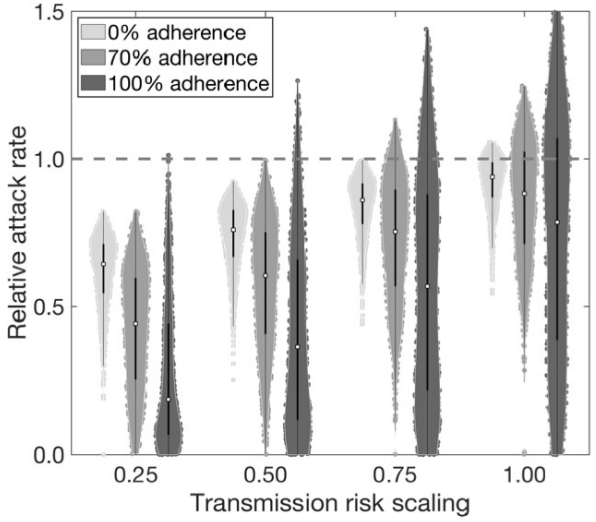


- An absence of sufficient adherence to non-pharmaceutical interventions increases the likelihood of SARS-CoV-2 spreading widely in the population.

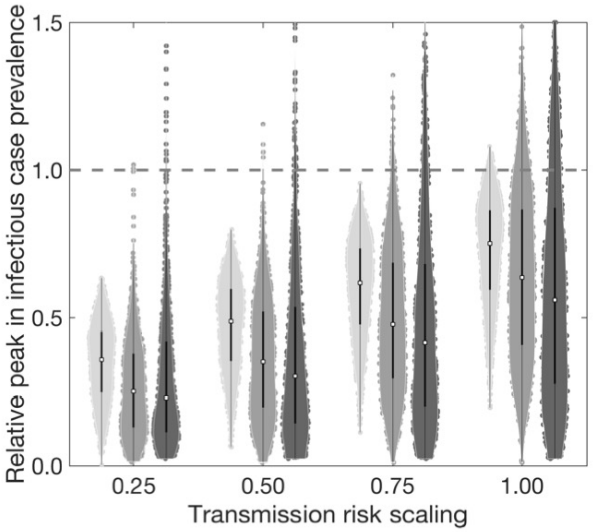
Adherence to test, trace and isolate

Figure: COVID-secure workplace measures and sensitivity of epidemiological quantities to adherence of test, trace and isolate measures.

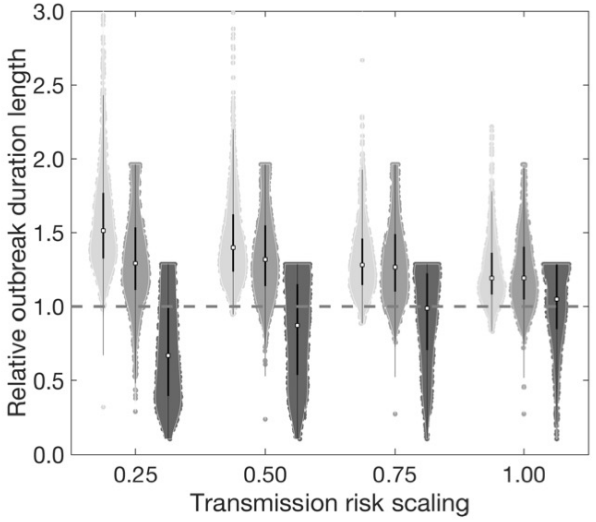
Additional proportion infected (day 15 onwards)



Peak infectious prevalence



Outbreak duration



- Stronger control with high adherence to test, trace and isolate measures in combination with workplace-targeted measures.

Limitations and further work

- Our system contained active workers only, with children and the elderly not present.
- Contact distributions were informed from a single data source, specific to UK.
- Findings may be sensitive to alternative epidemiological model structures and intervention assumptions.
- Other possible model extensions:
  - clustering of individuals within an individual workplace
  - part time workers

Summary

(1) Introducing the model and contact parameterisation

- Presented a multi-layered network model to model SARS-CoV-2 transmission in a population of workers.
- Used data from a contact survey to paramterise work and social contact distributions.

(2) Workplace targeted interventions

- Outbreaks can be hindered through the majority of the workforce working from home, asynchronous work patterns and smaller work teams.

(3) Adherence to test, trace & isolate guidance

- Following isolation guidance and engaging with contact tracing without other measures is an effective tool to curb transmission

Acknowledgements

Related research undertaken by the Zeeman Institute: SBIDER group.
https://tinyurl.com/warwickCOVID19
@WarwickSBIDER

Publication:
A network modelling approach to assess non-pharmaceutical disease controls in a worker population: An application to SARS-CoV-2
Hill *et al.* (2021) *PLoS Comp Bio.*
doi:10.1371/journal.pcbi.1009058

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