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Modelling the epidemiological implications for SARS-CoV-2 of Christmas household bubbles in England in December 2020

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UK Research and Innovation

JUNIPER

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Structure of the COVID science to policy path

List of participants of SAGE and related sub-groups:

How SPI-M-O worked

SPI-M-O provided:

- Multiple independent groups
- Rapid responses to commissions and rapid peer review
- R values / Medium term projections / Reasonable worst-case scenarios
- Consensus statements
- A route for non-commissioned insights

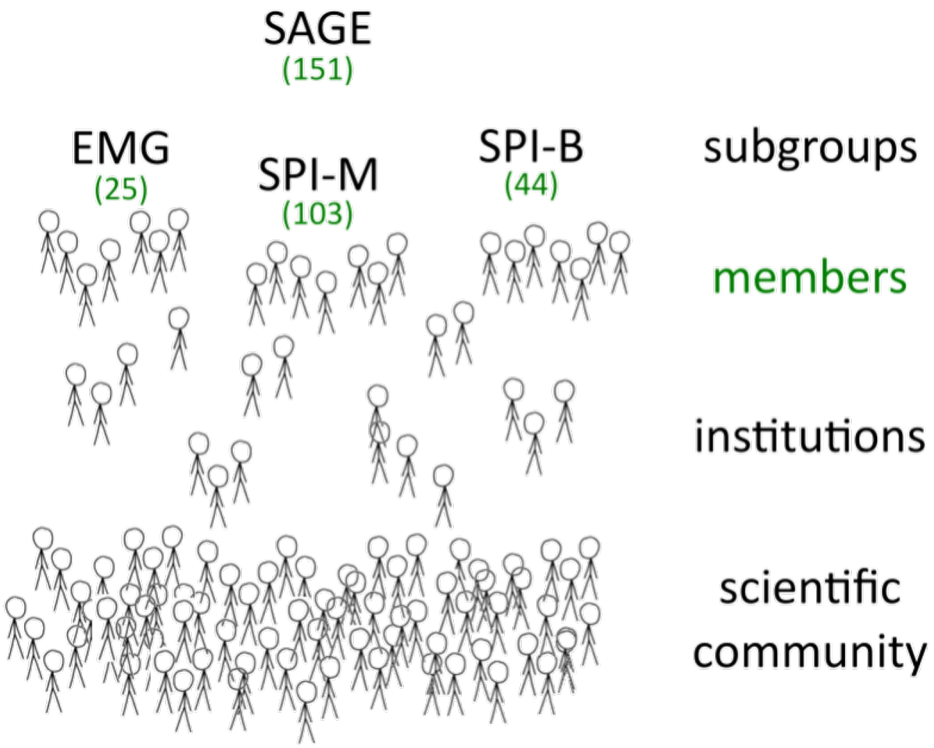
How SPI-M-O worked

Supported by:

- An incredible secretariat
- Data provision through UKHSA (PHE) and DSTL

Structure of the COVID science to policy path

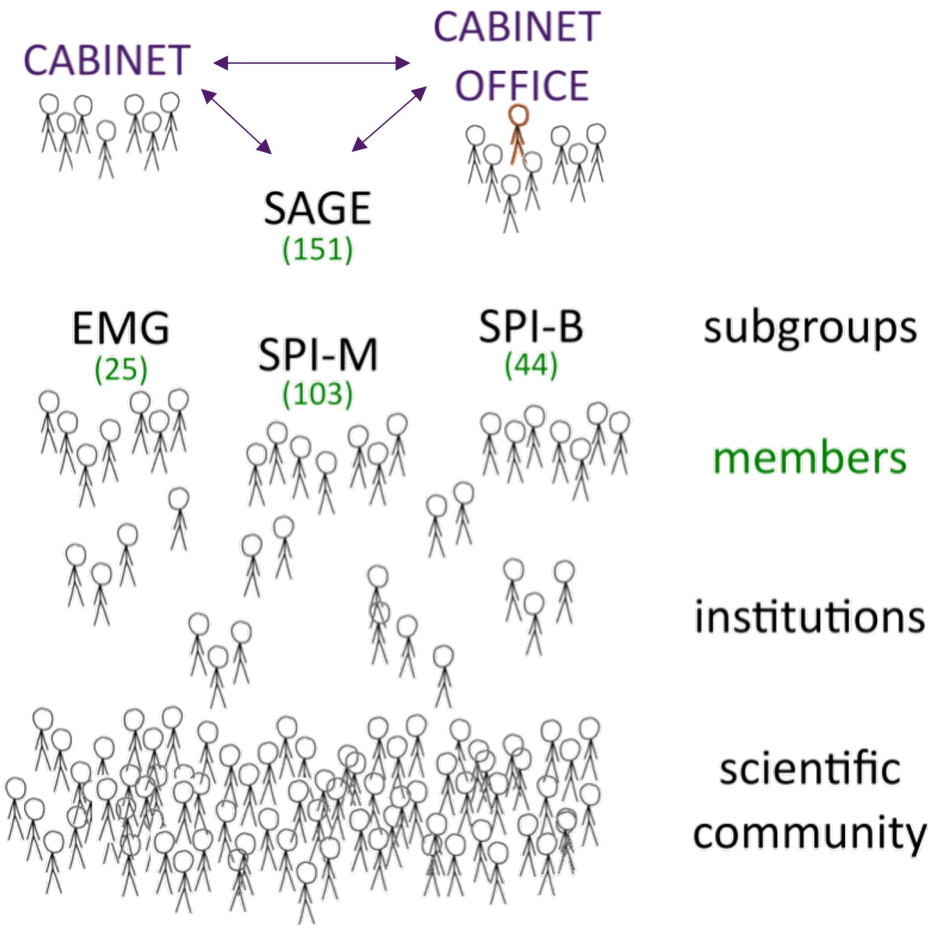
A massive team effort!



Structure of the COVID science to policy path

Feeding into policy

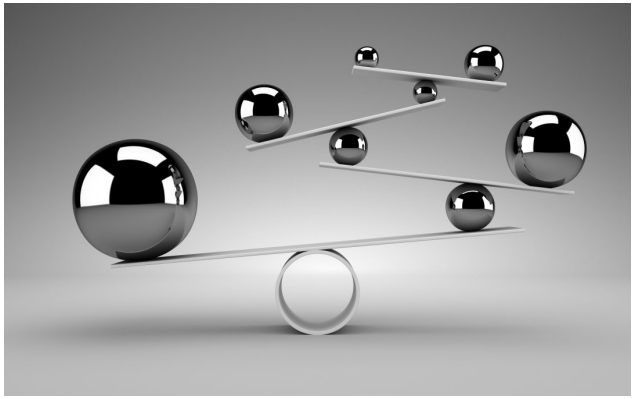
- Chief Medical Officer (Chris Whitty) & Chief Scientific Advisor (Patrick Vallance)
- Secretariat
- Observers
  - UKHSA (also some participants)
  - Cabinet office
  - Treasury
  - No. 10
  - Devolved administrations



Potential tensions

There are inherent tensions in the system **to be balanced**:

- Short deadlines vs careful science
- Privacy concerns vs data requirements
- Open science vs information control
- Rapid communication vs clarity and accuracy



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How may short-term changes to household bubbles influence infectious disease dynamics?

Methods

1. Household model
2. Epidemiological model
3. Testing and isolation
4. Christmas bubble scenarios
5. Simulation overview

Methods: (1) Household model

- Considered a population containing **100,000 households.**
- Approximate overall population of **310,000,** with a three-class age structure: 0–19 yrs, 20–64 yrs, 65+ yrs.
- Household sizes and the proportion of households with a given age composition from 2011 census data for England and Wales.

CT0820_2011 Census - household type, household size and age of usual residents (people) - England and Wales

Methods: (2) Epidemiological model

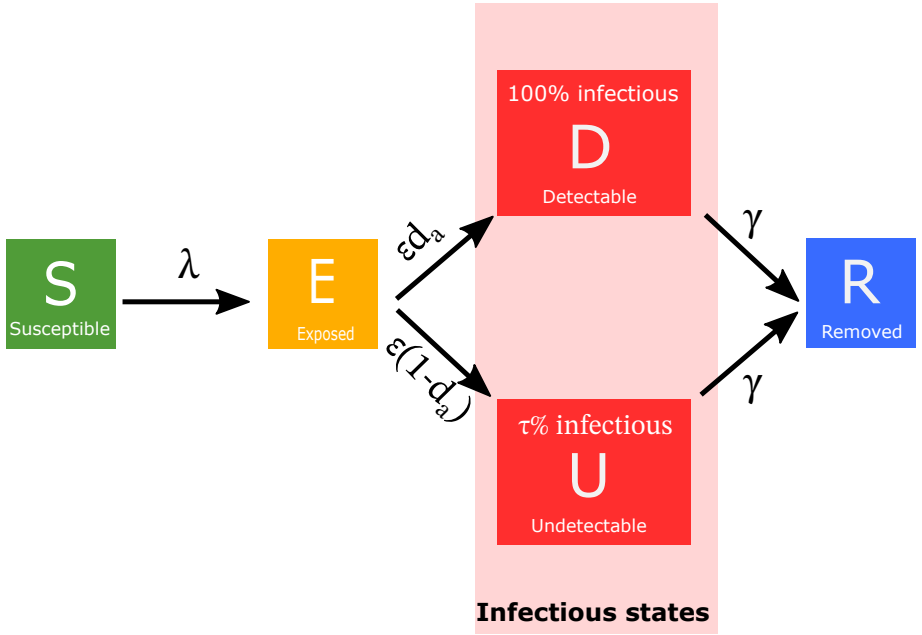

Table 1
Description of epidemiological parameters. The stated distributions are as reported in the cited sources, with additional context provided in the associated subsections of the main text.

Description	Distribution	Source
Incubation period	Erlang(6, 0.88)	Lauer et al. (2020)
Infectiousness profile	Infectivity profile over 14 days: [0.0369, 0.0491, 0.0835, 0.1190, 0.1439, 0.1497, 0.1354, 0.1076, 0.0757, 0.0476, 0.0269, 0.0138, 0.0064, 0.0044]	He et al. (2020) and Ashcroft et al. (2020)
Proportion of cases asymptomatic (0–19 yrs)	Uniform(0.20, 0.35)	Buitrago-Garcia et al. (2020)
Proportion of cases asymptomatic (20+yrs)	Uniform(0.05, 0.20)	Buitrago-Garcia et al. (2020)
Relative infectiousness of an asymptomatic	Uniform(0.30, 0.70)	Buitrago-Garcia et al. (2020) and McEvoy et al. (2020)
Relative susceptibility of 0–19 yrs age class	Uniform(0.40, 0.60)	Davies et al. (2020a)

Methods: (2) Epidemiological model

For an infectious individual *j* on day *t* of their infectious state, the probability of transmission to each susceptible contact *k* in household bubble *h*:

$$p_{j,k,h}(t) = r_h a_j s_k i_j(t)$$

- Sampled household attack rate in household *h*

Household attack rates	Size 2: Normal(0.48,0.06) Size 3: Normal(0.40,0.06) Size 4: Normal(0.33,0.05) Size ≥5: Normal(0.22,0.05)	Bernal et al. (2022)

- Relative infectiousness of individual *j*
- Relative susceptibility of individual *k*
- Value of the infectiousness temporal profile on day *t* for individual *j*

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Methods: (2) Epidemiological model

- **Initial conditions:** Intentionally had **no symptomatically infected individuals** at the start of the simulated time horizon, meaning no households began in isolation.

Table 3
Percentage of each age group initialised in each infection status.

	Age (years)		
	0–19	20–64	65+
Susceptible	73%	74%	84.5%
Latent infected	1%	0.5%	0.25%
Asymptomatic infected	0.3%	0.1%	0.05%
Presymptomatic infected	0.7%	0.4%	0.2%
Recovered	25%	25%	15%

Methods: (3) Testing and isolation

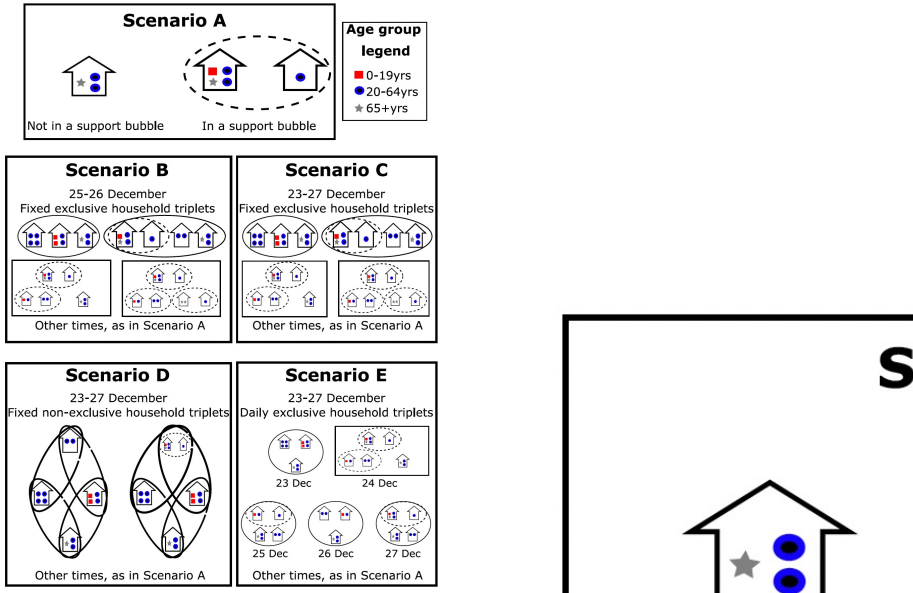
Table 2
Description of testing and isolation related parameters.

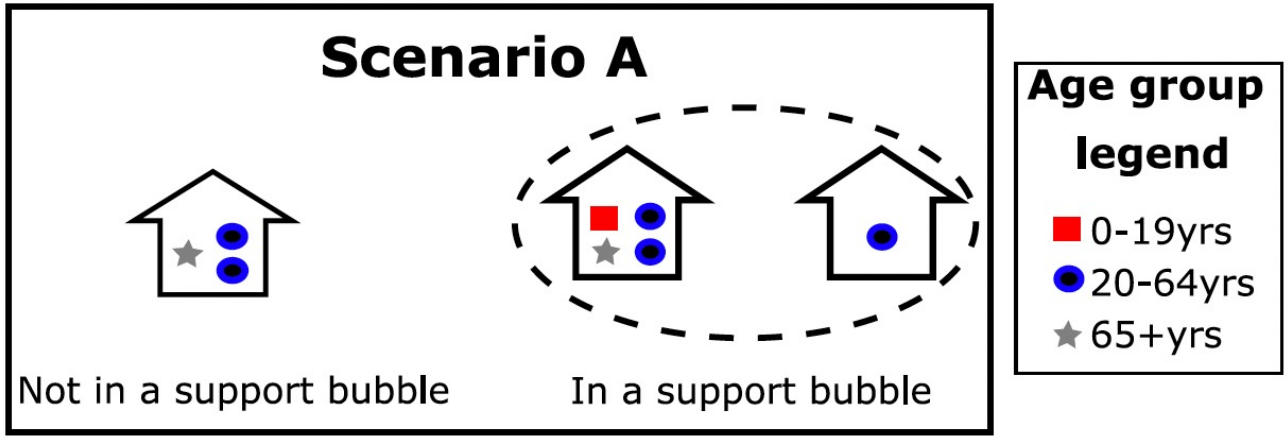
Description	Value	Source
Adherence	70% (30% in adherence sensitivity analysis)	Office for National Statistics (2020a)
Test specificity	100%	Office for National Statistics (2020b)
Test sensitivity	87%	Holborow et al. (2020)
Duration of self-isolation if symptomatic	10 days	UK government guidance in November 2020 (Public Health England, 2020b)
Household isolation period	14 days	UK government guidance in November 2020 (Public Health England, 2020b)
Duration of isolation if contact traced	14 days (beginning from the day the index case first displays symptoms)	UK government guidance in November 2020 (Department of Health and Social Care, 2020)

- Assumed all individuals within a household (or extended household/support bubble) had the **same adherence status**.
- Those that adhered would both follow **isolation guidance** and engage with **test and trace**.
- Assumed an adherent individual household member took a **PCR test** if they displayed symptoms, with **same day** return of result.

Methods: (4) Bubbling scenarios

Figure: Illustrative examples of the five bubbling scenarios.





- Sampled the propensity to form a support bubble from a Uniform(0.5,0.75) distribution.

Methods: (4) Bubbling scenarios

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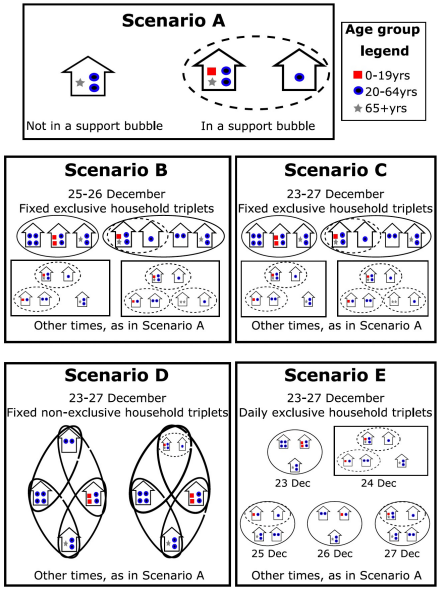

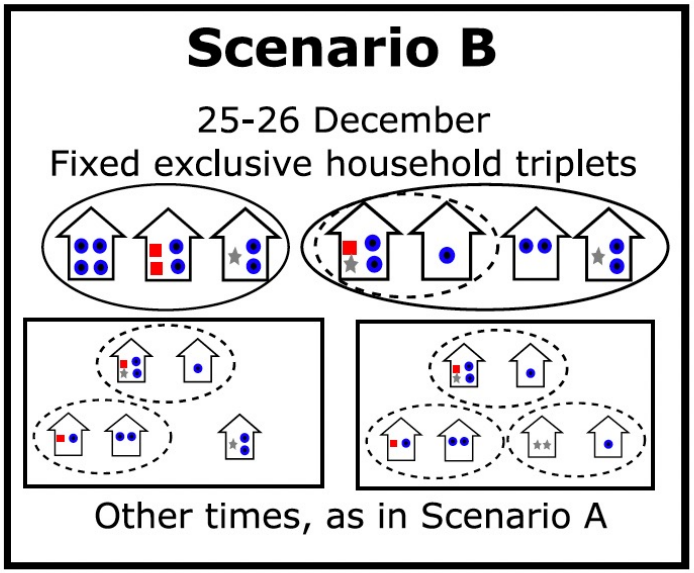

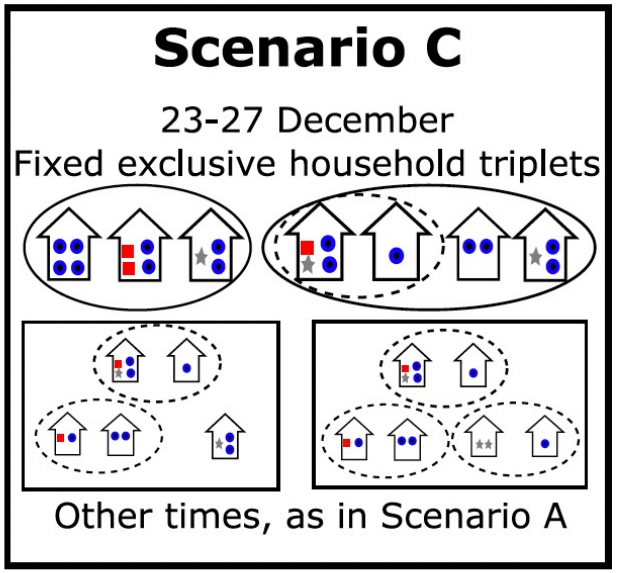

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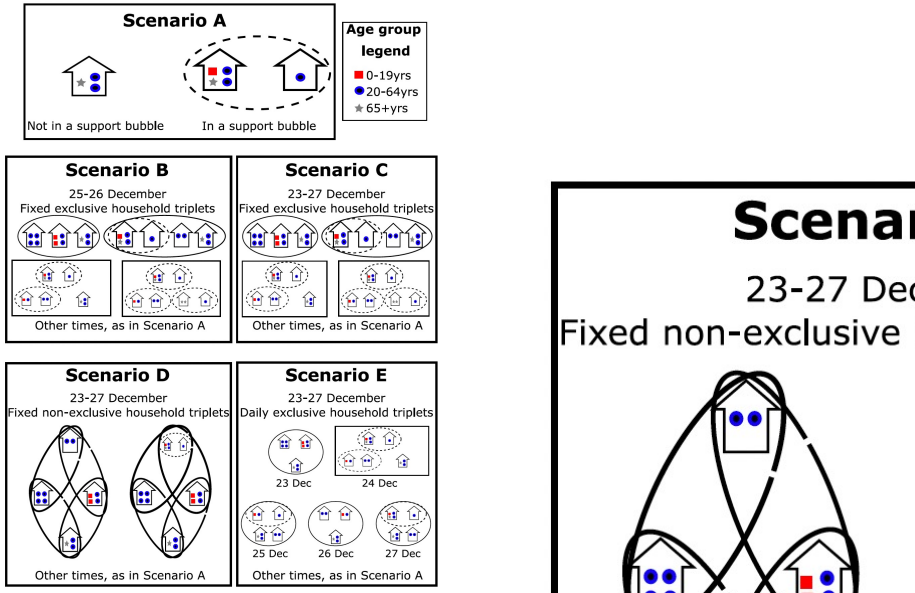
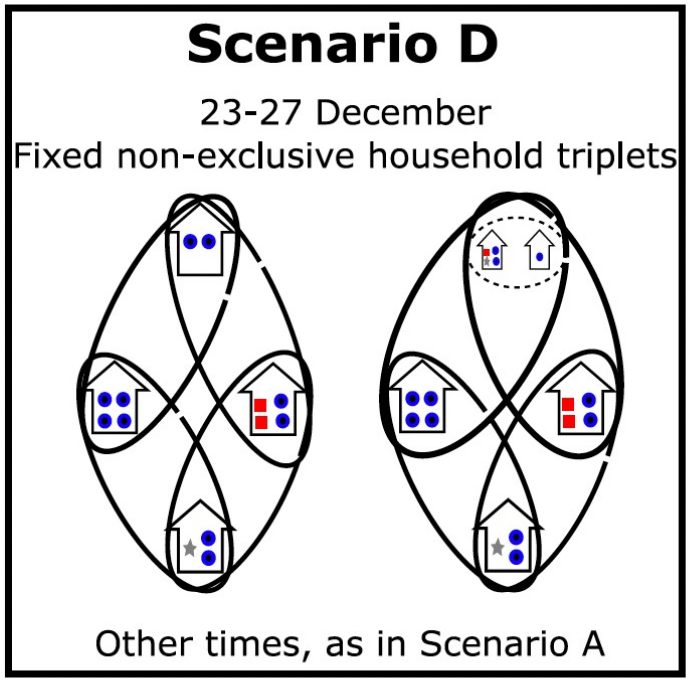
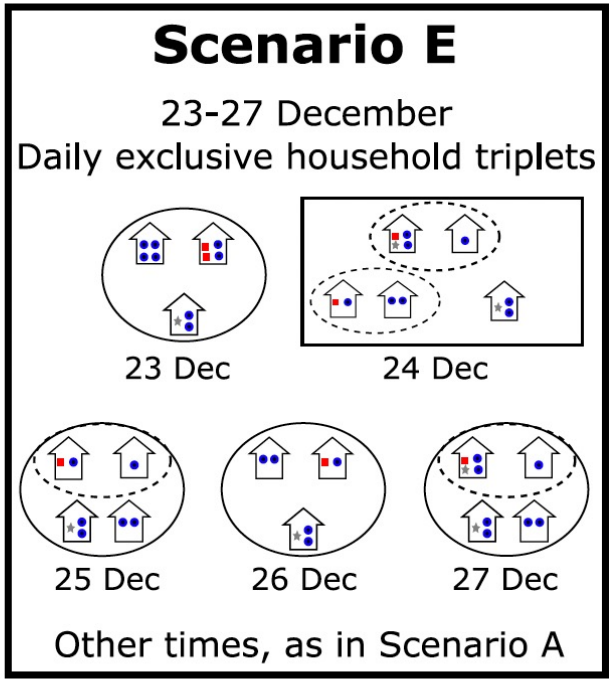




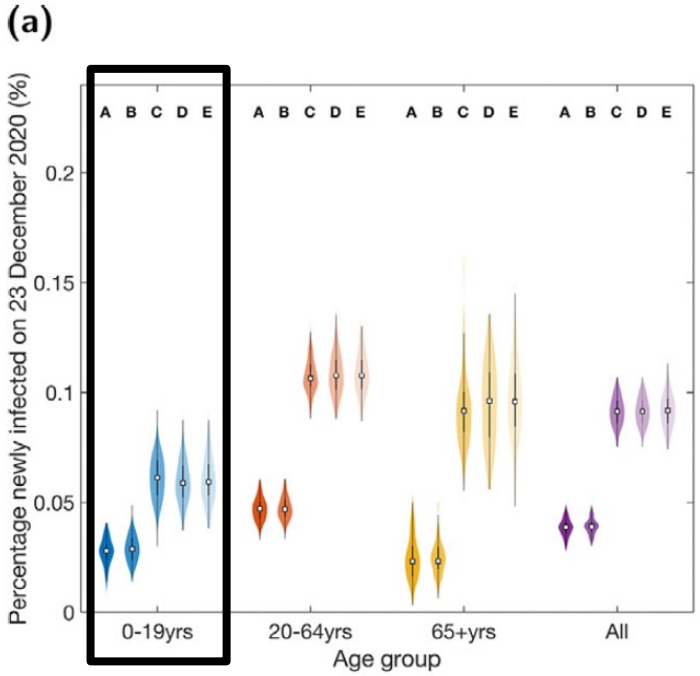


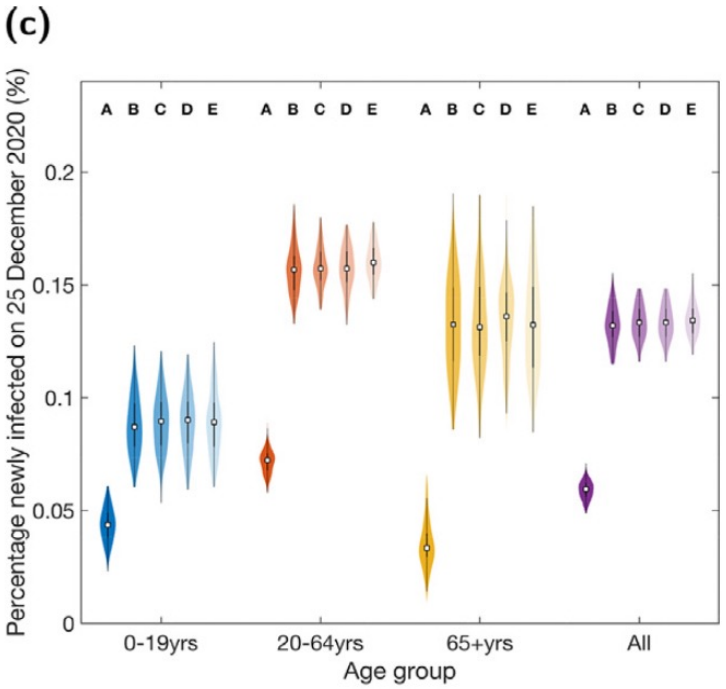
Methods: (5) Simulation overview

- Study evaluated **five** different household bubble scenarios.
- **Bubbling period:** 23-27 December 2020
- **Simulated time horizon:** 23 December 2020 – 06 January 2021
- Performed **100 model simulations** for each scenario
- Assessment comprised **incidence** and **cumulative infection** metrics

Inspection of daily incidence

Figure: Distributions for the daily incidence under each Christmas bubble scenario. **(a)** 23 December 2020; **(c)** 25 December 2020.





Inspection of daily incidence

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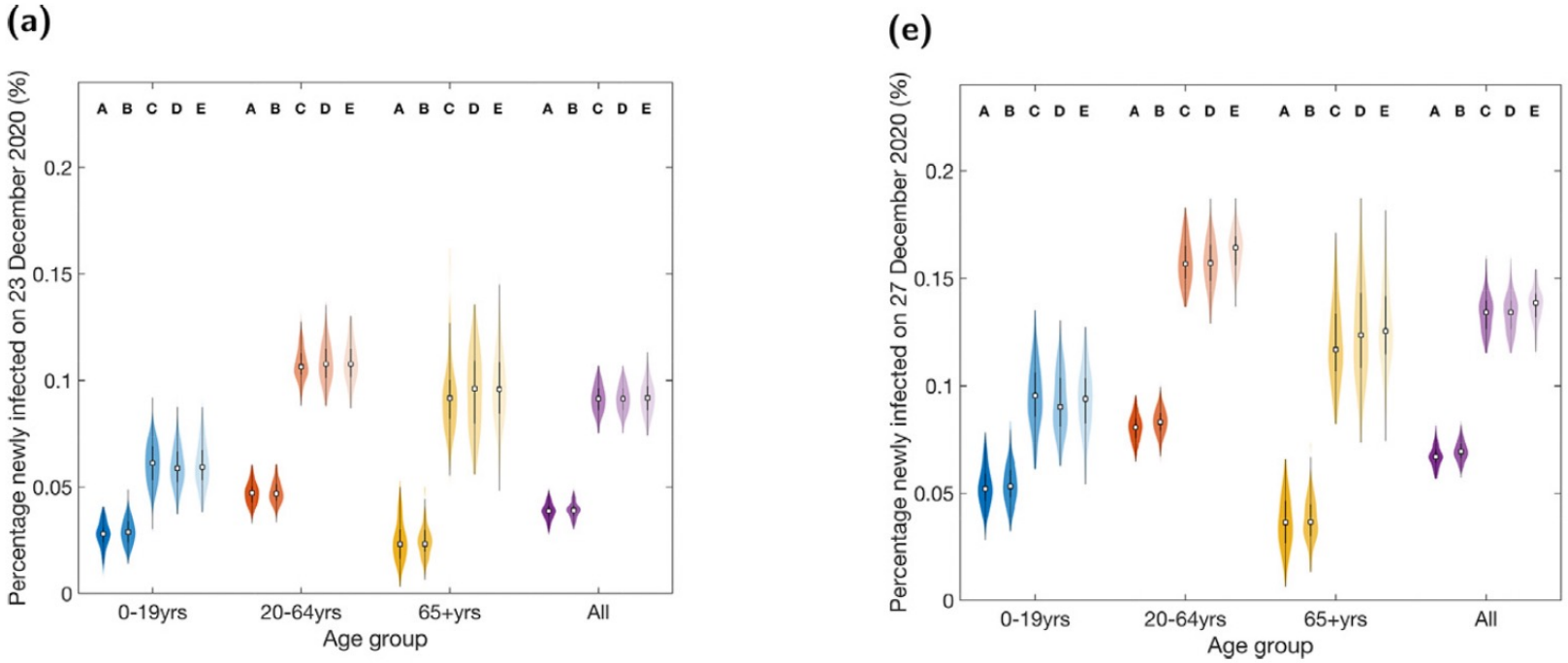
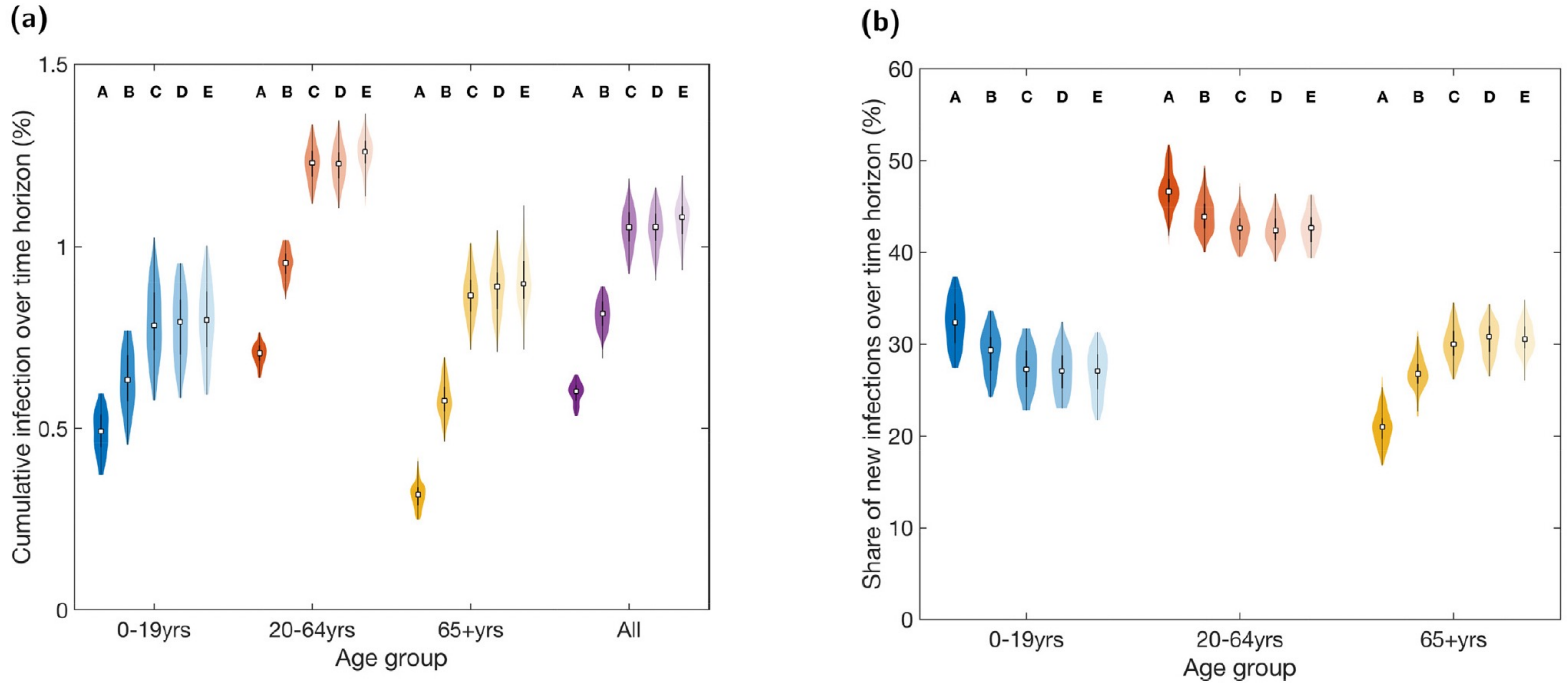


- Appreciable decline in daily incidence for a **shorter duration** and/or **smaller group** gatherings (Scenarios A & B).

Heightened risk of infection with age

Figure: Cumulative infection distribution for the entire 15-day time horizon (23 Dec 2020 – 06 Jan 2021): **(a)** Percentage of each age group infected; **(b)** Percentage share of new infections over the time horizon attributed to each age group.



- Increase in infection from greater amounts of social mixing **disproportionately impacted the eldest**.

Limitations

- Assumptions regarding **bubble formation** were a **simplified representation** of the real-world social system.
- Whilst the model considered infection resulting from person-to-person interactions due to household mixing, it **did not consider** transmission arising from **other settings**.
- Findings may be **sensitive** to alternative epidemiological model structures and intervention assumptions, particularly **adherence** to isolation and test-and-trace measures.

Implications

Shows potential use of stochastic individual-based models representing synthetic population of households.

When needing to assess the epidemiological impact of extending contacts beyond the immediate household, provides a methodology that is swift to develop & deploy.

Acknowledgements

- Zeeman Institute: Systems Biology & Infectious Disease Epidemiology Research (SBIDER)

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SBIDER COVID-19 webpage:
https://tinyurl.com/warwickCOVID19

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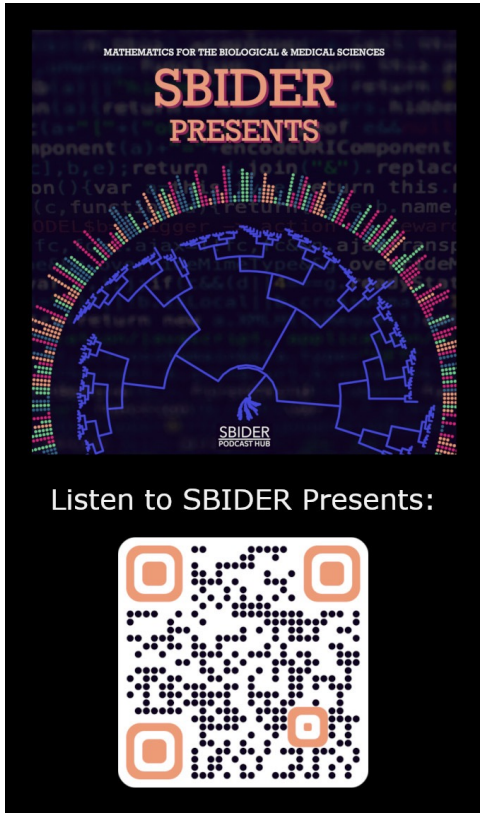

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