# Incorporating behaviour into models – Challenges and Questions

**Ed Hill**

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https://maths.org/juniper/ @JuniperConsort1

# Previous workshops on modelling behaviour

## Modelling Behaviour to Inform Policy for Pandemics

Tuesday 2nd November 2021 to Friday 5th November 2021

**Background**

Over the course of the COVID-19 pandemic, modelling has taken centre stage both in forecasting, policy formulation and in informing the public, featuring prominently in the advice given to government in the UK and beyond. The pandemic has had profound influence on social and economic activity, meaning that different policy interventions such as lockdowns and furlough schemes cannot be seen as merely public health policies or as economic policies in isolation. It is therefore important to better understand how policies interact through intertwined economic and disease dynamics and how different policies must be designed to work together.

## Behaviour and Policy During Pandemics: Models and Methods

Tuesday 22nd February 2022

**Background**

Over the course of the COVID-19 pandemic, modelling has taken centre stage both in forecasting, policy formulation and in informing the public, featuring prominently in the advice given to government in the UK and beyond. The pandemic has had profound influence on social and economic activity, meaning that different policy interventions such as lockdowns and furlough schemes cannot be seen as merely public health policies or as economic policies in isolation. It is therefore important to better understand how policies interact through intertwined economic and disease dynamics and how different policies must be designed to work together.

Flavio Toxvaerd (University of Cambridge)

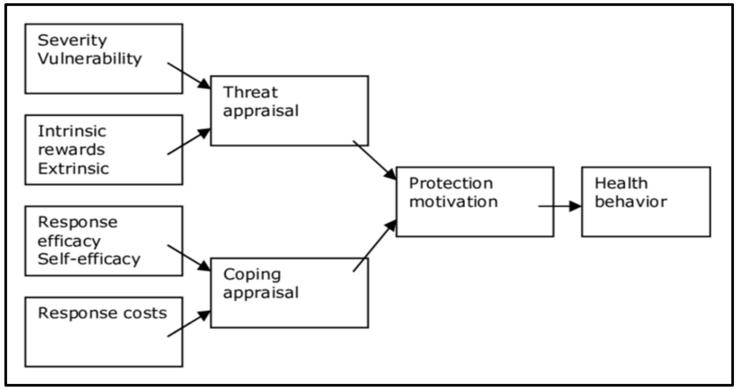
**Academic Organiser**

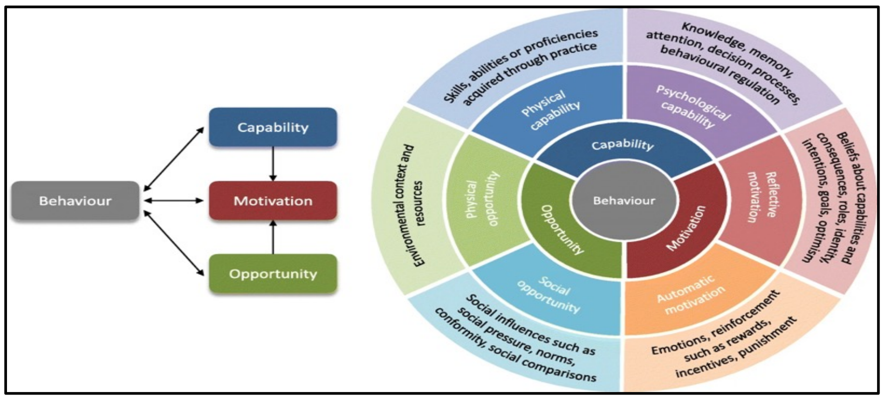
Dr Flavio Toxvaerd is a Lecturer at the Faculty of Economics at the University of Cambridge and a member of the Microeconomic Theory Research Group. Flavio holds degrees from the University of Copenhagen (BSc Economics, MSc Economics), the London School of Economics (MSc Econometrics and Mathematical Economics) and the London Business School (PhD Economics) and was awarded a Mid-Career Fellowship by the British Academy (2012-2013).

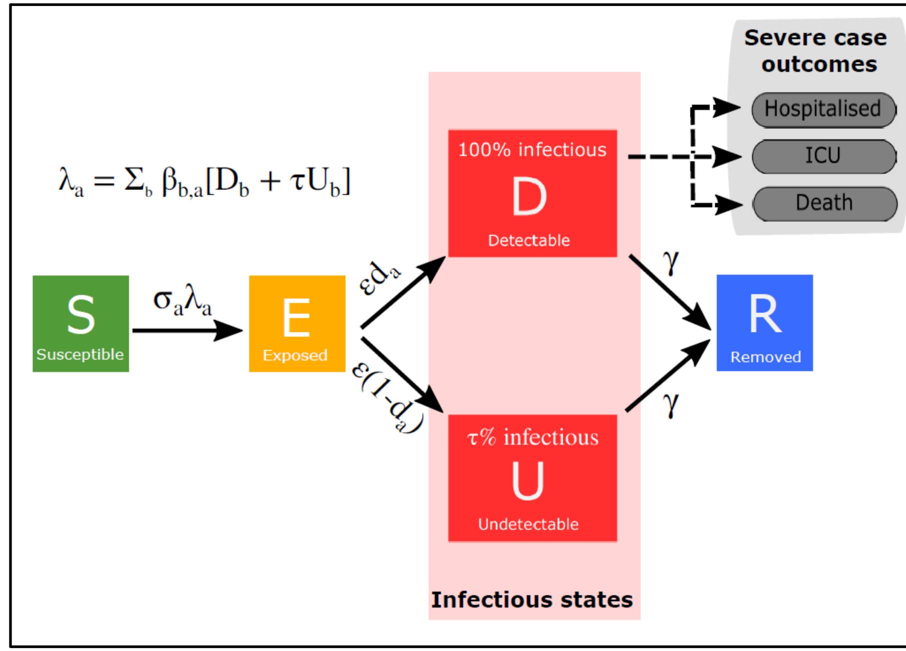
**Research Interests:** Microeconomic Theory. Game Theory. Finance. Industrial Organisation. Economic Epidemiology.

**Personal Webpage:** https://sites.google.com/site/toxvaerd11/

# The ultimate challenge?




**Unifying theoretical frameworks from behavioural science and infectious disease dynamics.**

# Talk outline

1. Scenario modelling – Intervention engagement
2. Scenario modelling – Contact rates & mobility
3. Models with behavioural feedback
4. Behaviour and Policy During Pandemics workshops - Themes

# Talk outline

1. Scenario modelling – Intervention engagement
    a) Vaccine acceptability
    b) NPIs in enclosed settings
    c) Adherence

2. Scenario modelling – Contact rates & mobility

3. Models with behavioural feedback

4. Behaviour and Policy During Pandemics workshops - Themes

# (1A) Vaccine acceptability

PLOS COMPUTATIONAL BIOLOGY

OPEN ACCESS PEER-REVIEWED

RESEARCH ARTICLE

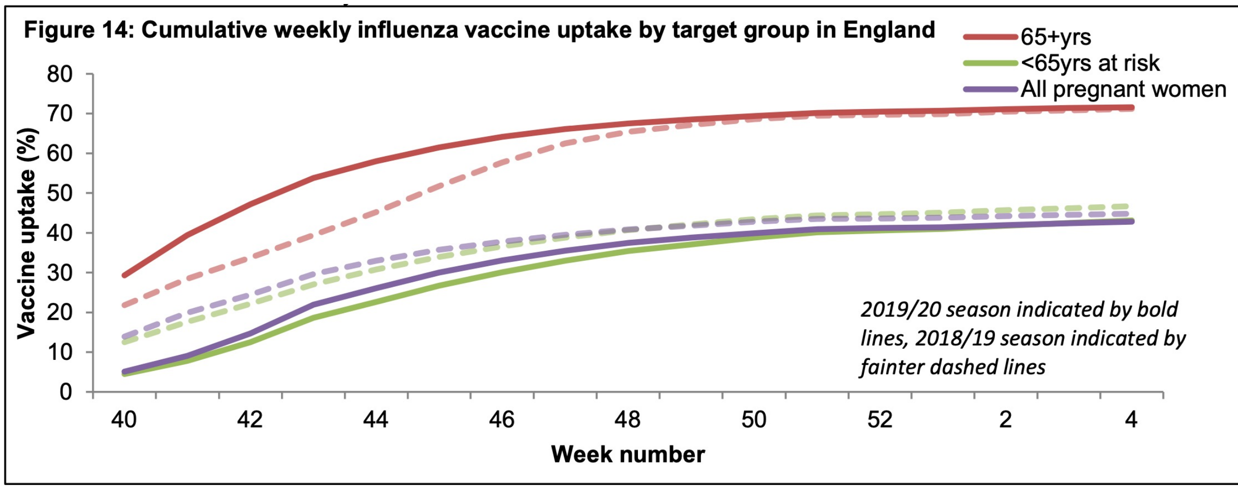
## Modelling optimal vaccination strategy for SARS-CoV-2 in the UK

Sam Moore, Edward M. Hill, Louise Dyson, Michael J. Tildesley, Matt J. Keeling

Published: May 6, 2021 • https://doi.org/10.1371/journal.pcbi.1008849

**Citation:** Moore S, Hill EM, Dyson L, Tildesley MJ, Keeling MJ (2021) Modelling optimal vaccination strategy for SARS-CoV-2 in the UK. PLoS Comput Biol 17(5): e1008849. https://doi.org/10.1371/journal.pcbi.1008849

For simplicity, we assumed 70% vaccine uptake across all age-groups based on what has been obtainable for vaccines targeting other infections, such as within elder age groups and healthcare workers for the UK seasonal influenza vaccination programme [46]. In practice,




**Is it reasonable to "repurpose" intervention response data?**

# (1B) NPIs in enclosed settings

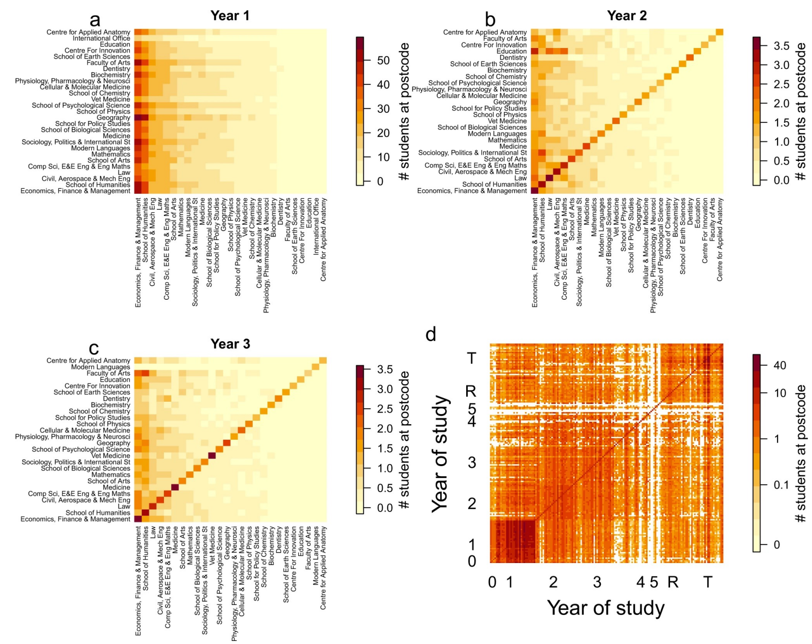
Article | Open Access | Published: 17 August 2021

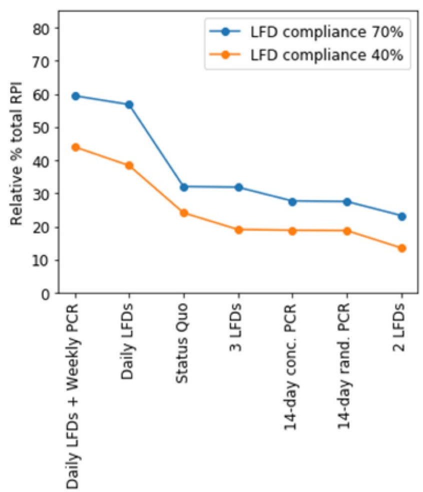
**High COVID-19 transmission potential associated with re-opening universities can be mitigated with layered interventions**

Ellen Brooks-Pollock, Hannah Christensen, Adam Trickey, Gibran Hemani, Emily Nixon, Amy C. Thomas, Katy Turner, Adam Finn, Matt Hickman, Caroline Relton & Leon Danon

*Nature Communications* **12**, Article number: 5017 (2021) | Cite this article

**8258** Accesses | **6** Citations | **103** Altmetric | Metrics



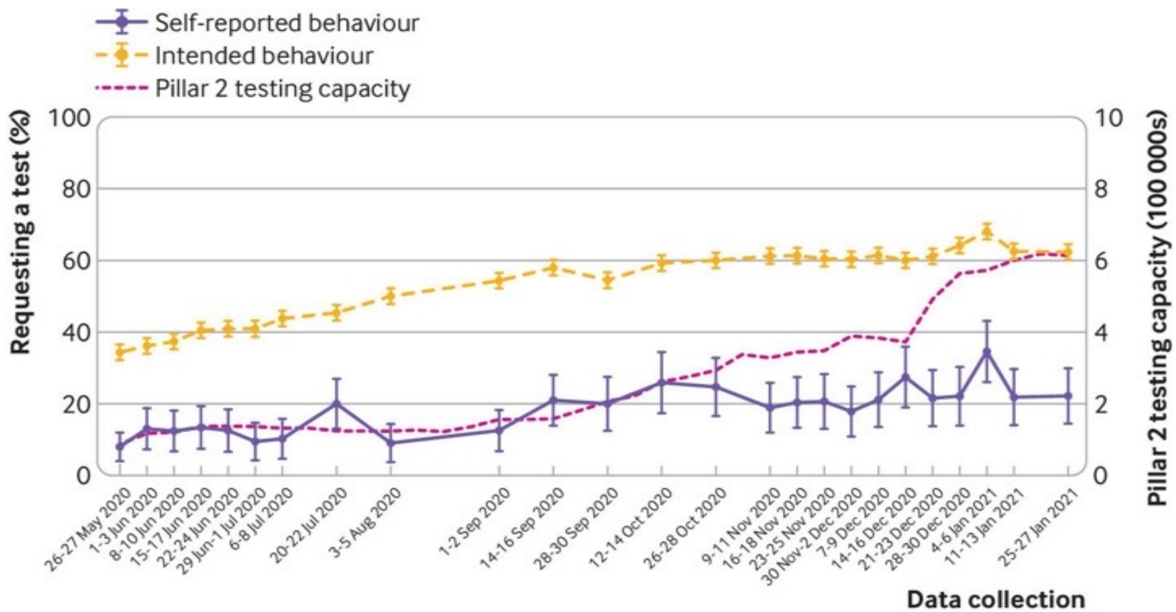




C. Whitfield & I. Hall. Social Care Working Group chairs summary of role of shielding. (Annex A) https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1043615/S1453_SCWG_chairs_summary_of_role_of_shielding.pdf

**Impact of heterogeneity & what level of detail to include?**

# (1C) Adherence

**Figure:** Percentage of people who reported requesting a test after developing COVID-19 symptoms and who reported intending to request a test if they were to develop COVID-19 symptoms.




Reproduced from Smith LE et al. (2021) Adherence to the test, trace, and isolate system in the UK: results from 37 nationally representative surveys. *BMJ*. 372; n608.

**How to reconcile intended behaviour vs actual behaviour?**

# Talk outline

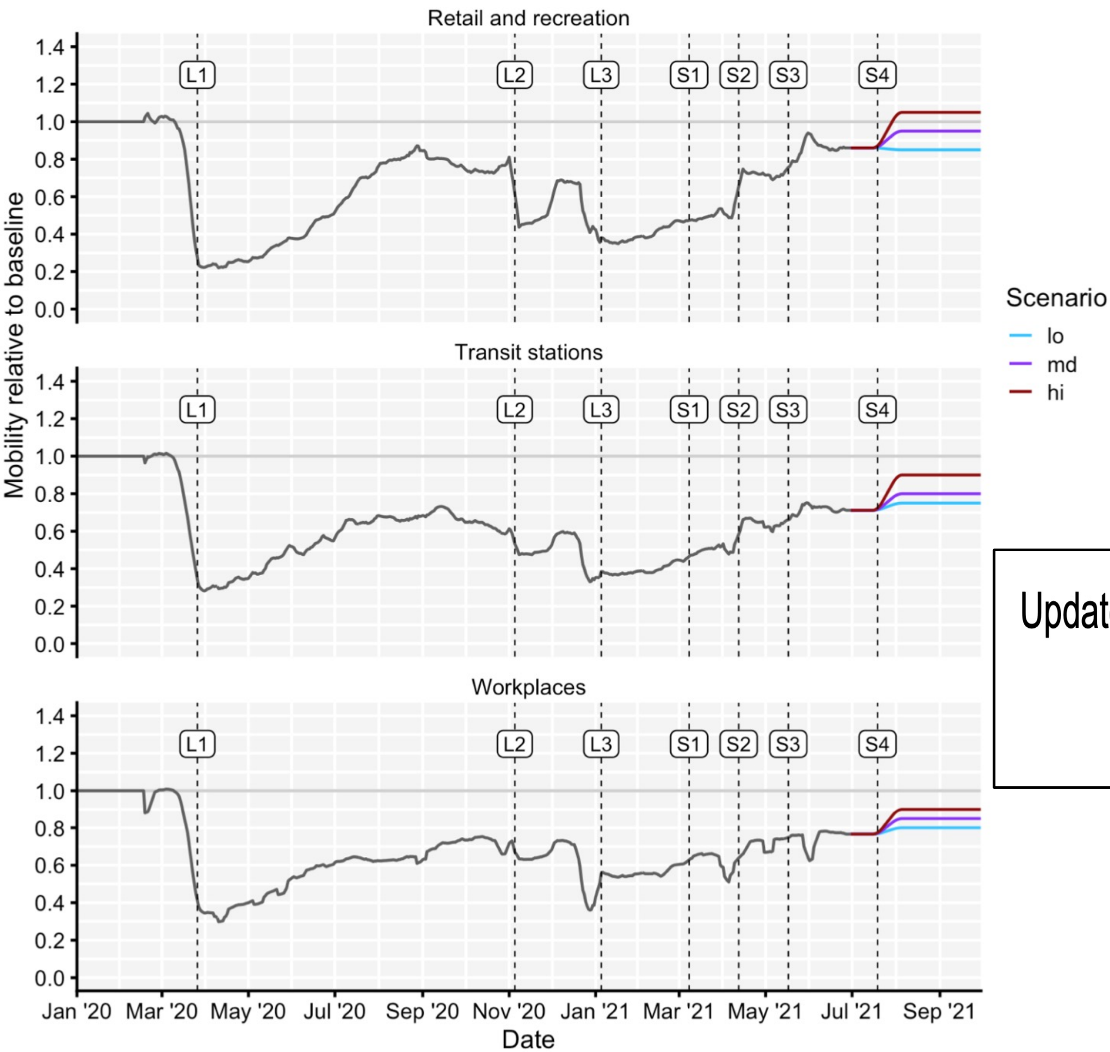
1. Scenario modelling – Intervention engagement

2. Scenario modelling – Contact rates & mobility
   a) Roadmap
   b) USA COVID-19 Scenario Modelling Hub
   c) Voluntary risk mitigation

3. Models with behavioural feedback

4. Behaviour and Policy During Pandemics workshops - Themes

# (2A) Roadmap modelling




**Updated roadmap assessment: prior to delayed step 4**

Rosanna C. Barnard, Nicholas G. Davies, Mark Jit & W. John Edmunds
London School of Hygiene & Tropical Medicine
7th July 2021

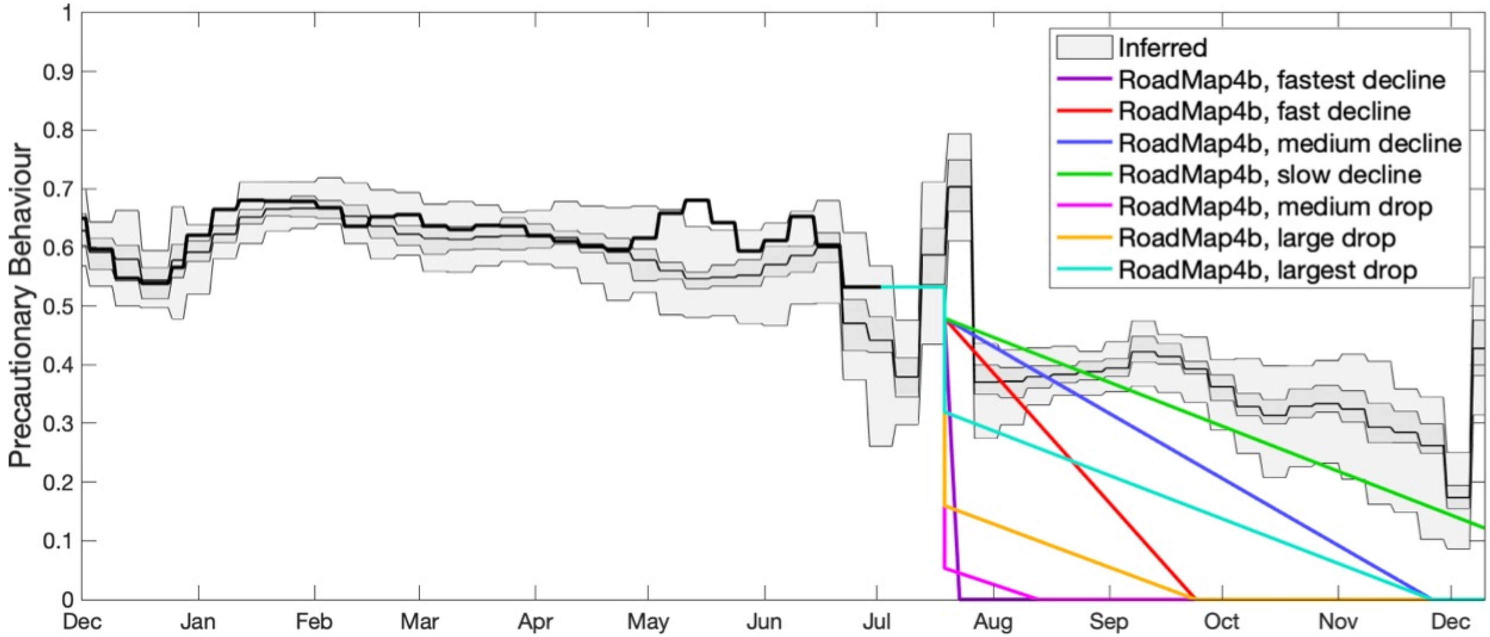
URL:
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1001174/S1304_LSHTM_Updated_roadmap_assessment_prior_to_delayed_step_4.2__7_July_2021__1_.pdf

# (2A) Roadmap modelling

**Comparison of the 2021 COVID-19 'Roadmap' Projections against Public Health Data**

Matt J. Keeling, Louise Dyson, Michael J. Tildesley, Edward M. Hill, Samuel Moore

**doi:** https://doi.org/10.1101/2022.03.17.22272535




**How to account for uncertainty in behavioural response in the face of changing restrictions and changing risk?**

# (2B) COVID-19 Scenario Modelling Hub

Borchering et al. (2022) Impact of SARS-CoV-2 vaccination of children ages 5-11 years on COVID-19 disease burden and resilience to new variants in the United States, November 2021-March 2022: a multi-model study. *medRxiv.* https://doi.org/10.1101/2022.03.08.22271905.

Table S2: additional model-specific assumptions including those about nonpharmaceutical interventions (NPIs).

| | CU-AGE-ST | JHUAPL_Bucky | JHU_IDD-CovidSP | NotreDame-FRED | MOBS_NEU-GLEAM_COVID | UNCC-hierbin | USC-SIkJalpha | UVA-adaptive | UVA-EpiHiper |
|---|---|---|---|---|---|---|---|---|---|
| **Model Type** | Compartmental | Meta-population compartmental | Meta-population compartmental | Agent-based | Meta-population compartmental | Trajectory tracking (non-mechanistic) | Discrete time heterogeneous rate compartmental | Meta-population compartmental | Agent-based |
| **Geography** | County | County | State | State | County | State | State | County | State |
| **Mobility and contact data** | SafeGraph mobility, POLYMOD contact rates | SafeGraph mobility, age-based contact matrices | Commuting | Google mobility | Google mobility, commuting, flight, age-based contact matrices | Not used | Cuebiq contact scores data to model future NPI changes | Not used | ACS Commute, National Household Travel Survey |
| **NPI relaxation** | Maximum relaxation reached | Linear | Linear | NPIs relaxed for the projection period | Linear | NPIs held constant | Linear | Linear | NPIs held constant |

# (2C) Voluntary risk mitigation

**Impact of voluntary risk-mitigation behaviour on transmission of the Omicron SARS-CoV-2 variant in England**

Ellen Brooks-Pollock, Kate Northstone, Lorenzo Pellis, Francesca Scarabel, Amy Thomas, Emily Nixon, David A. Matthews, Vicky Bowyer, Maria Paz Garcia, Claire J. Steves, Nicholas J. Timpson, Leon Danon

**doi:** https://doi.org/10.1101/2022.01.26.22269540

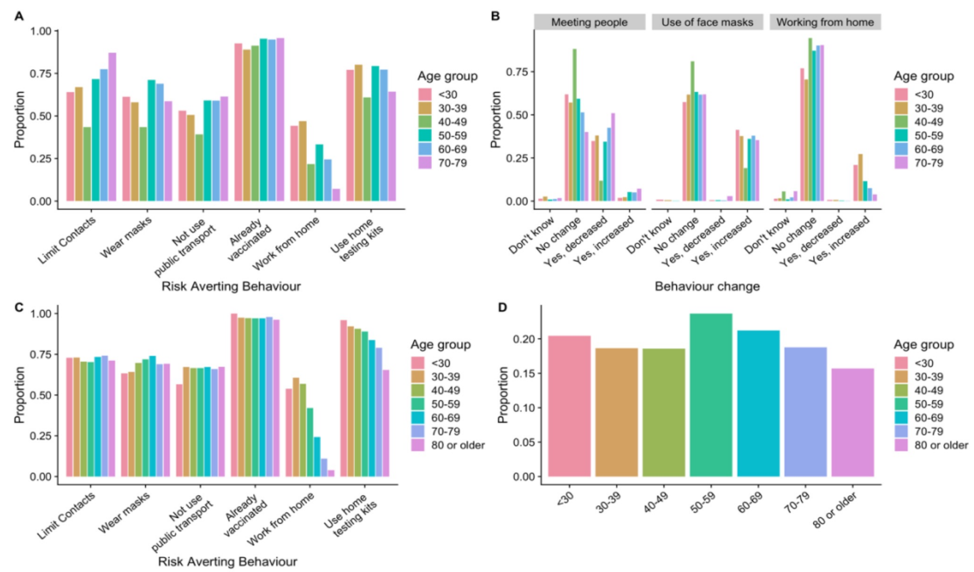



*Figure 1*: Survey responses from ALSPAC (Avon Longitudinal Survey of Parents and Children) and TwinsUK/CSS Biobank. (A): The proportion of ALSPAC respondents (N=2,686) by age group reporting risk mitigation measures during the period 20 December 2021 to 2 January 2022 inclusive. (B): The proportion of ALSPAC respondents who changed their behaviour (meeting people, use of face masks, working from home) due to the announcement of "plan B". (C): The proportion of TwinsUK/CSS Biobank respondents (N=6,155) by age group reporting risk mitigation measures during the period 20 December 2021 to 2 January 2022 inclusive. (D): The proportion of TwinsUK/CSS Biobank respondents who changed their behaviour due to the announcement of "plan B".

# (2C) Voluntary risk mitigation

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Ellen Brooks-Pollock, Kate Northstone, Lorenzo Pellis, Francesca Scarabel, Amy Thomas, Emily Nixon, David A. Matthews, Vicky Bowyer, Maria Paz Garcia, Claire J. Steves, Nicholas J. Timpson, Leon Danon

**doi:** https://doi.org/10.1101/2022.01.26.22269540

FIGURE 2

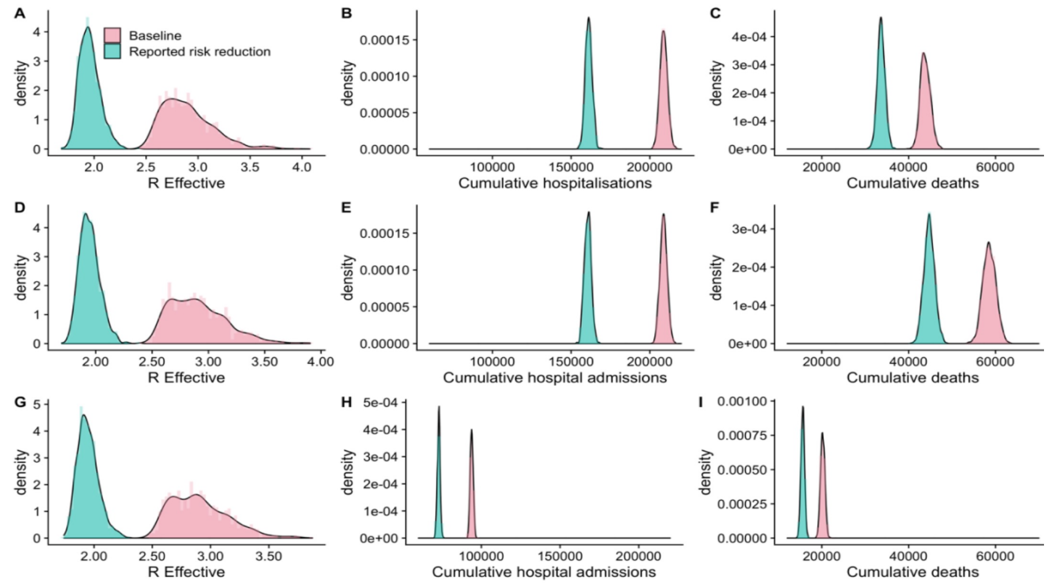



*Figure 2*: The estimated size of the effective reproduction number (panels A, D, G), cumulative hospital admissions (panels B, E, H) and cumulative deaths (panels C, F, I) with and without reported risk mitigation measures. Panels A, B, C: with a 40% reduction in severity associated with Omicron relative to Delta. Panels D, E, F: with a 20% reduction in severity associated with Omicron relative to Delta. Panels G, H, I: with a 20% reduction in severity associated with Omicron relative to Delta and assuming that vaccine effectiveness against severe disease is not reduced with Omicron infection. Vaccine distribution as of 26 November 2021.

# (2C) Voluntary risk mitigation

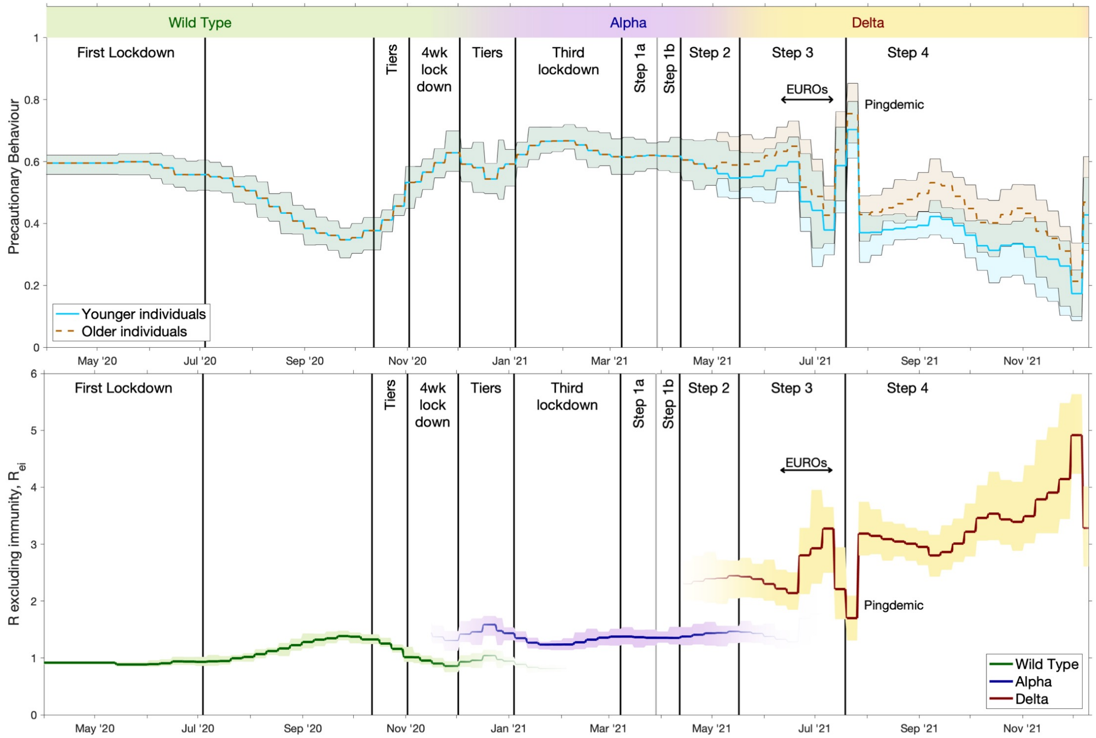



**Fig. 1:** Changes in the inferred precautionary behaviour from April 2020 to December 2021 (top panel), together with the resultant changes to $R$ excluding immunity for the three main variants (lower panel). Vertical lines indicate the time of key changes to the control measures, while the top bar specifies the dominant variant over time. From May 2021 onwards, we have inferred two levels of precautionary behaviour applying to younger (under 40) and older (over 65) individuals, with those between 40 and 65 scaling between the two.

**Do we have the means to parameterise behaviour change attributable to policy vs voluntary action?**

# Talk outline

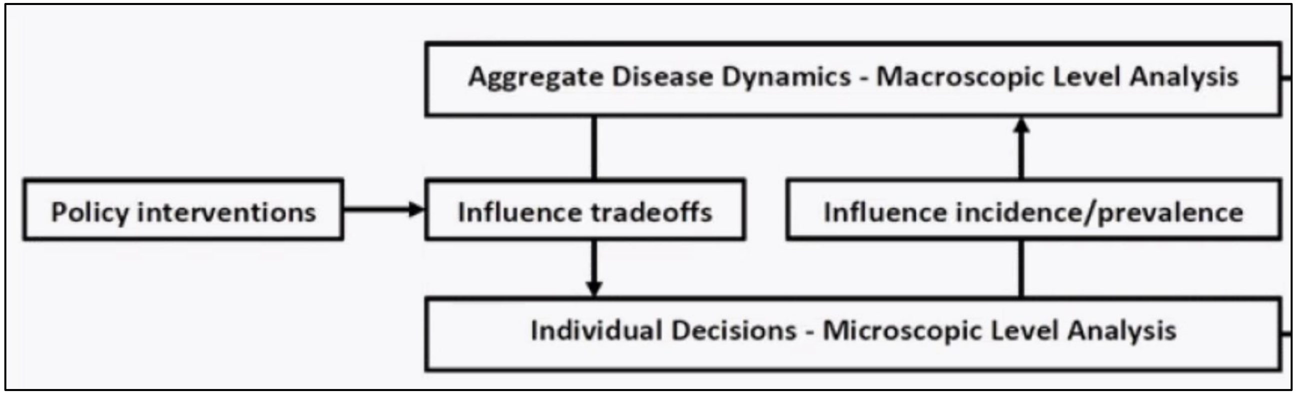
1. Scenario modelling – Intervention engagement

2. Scenario modelling – Contact rates & mobility

3. Models with behavioural feedback
    a) Disease awareness
    b) Statens Serum Institut model

4. Behaviour and Policy During Pandemics workshops - Themes

# Models with behavioural feedback




Schematic by Flavio Toxvaerd

**Can these processes be realistically characterised by a unified behavioural science and infectious disease modelling framework?**

# (3A) Disease awareness

PLOS MEDICINE

OPEN ACCESS PEER-REVIEWED

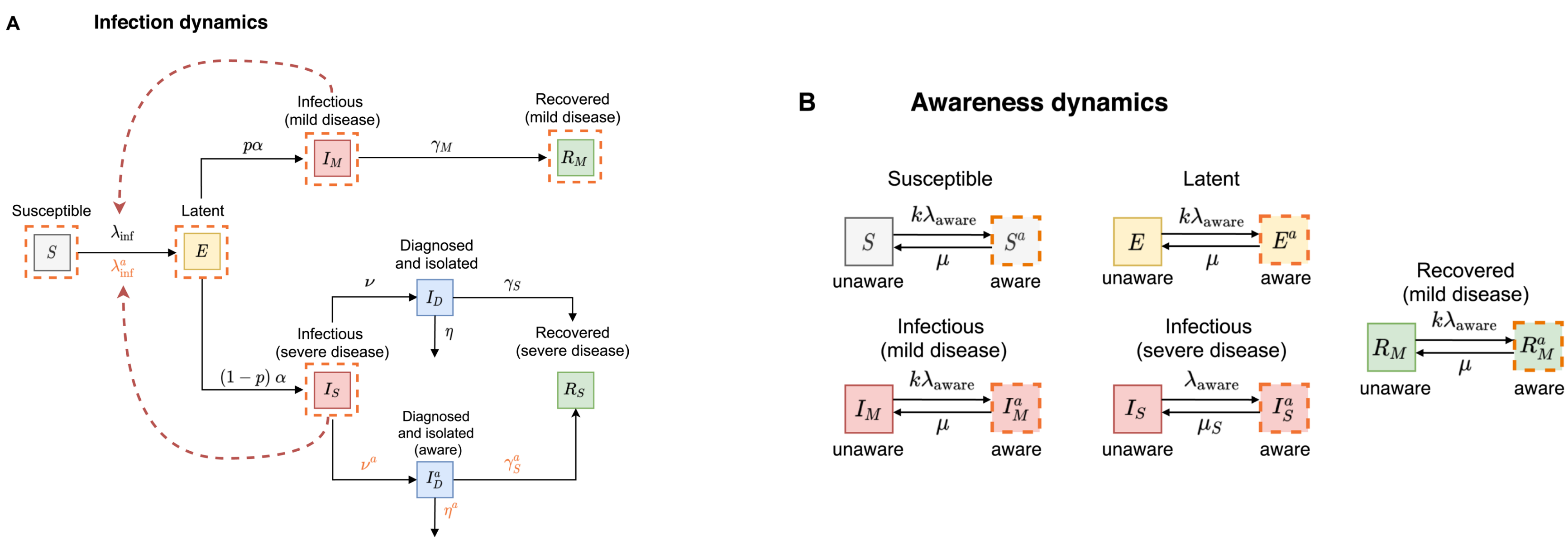
RESEARCH ARTICLE

## Impact of self-imposed prevention measures and short-term government-imposed social distancing on mitigating and delaying a COVID-19 epidemic: A modelling study

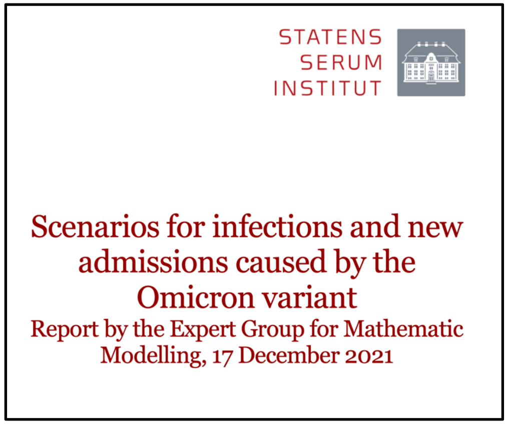
Alexandra Teslya, Thi Mui Pham, Noortje G. Godijk, Mirjam E. Kretzschmar, Martin C. J. Bootsma, Ganna Rozhnova

Published: July 21, 2020 • https://doi.org/10.1371/journal.pmed.1003166

**Citation:** Teslya A, Pham TM, Godijk NG, Kretzschmar ME, Bootsma MCJ, Rozhnova G (2020) Impact of self-imposed prevention measures and short-term government-imposed social distancing on mitigating and delaying a COVID-19 epidemic: A modelling study. PLoS Med 17(7): e1003166. https://doi.org/10.1371/journal.pmed.1003166

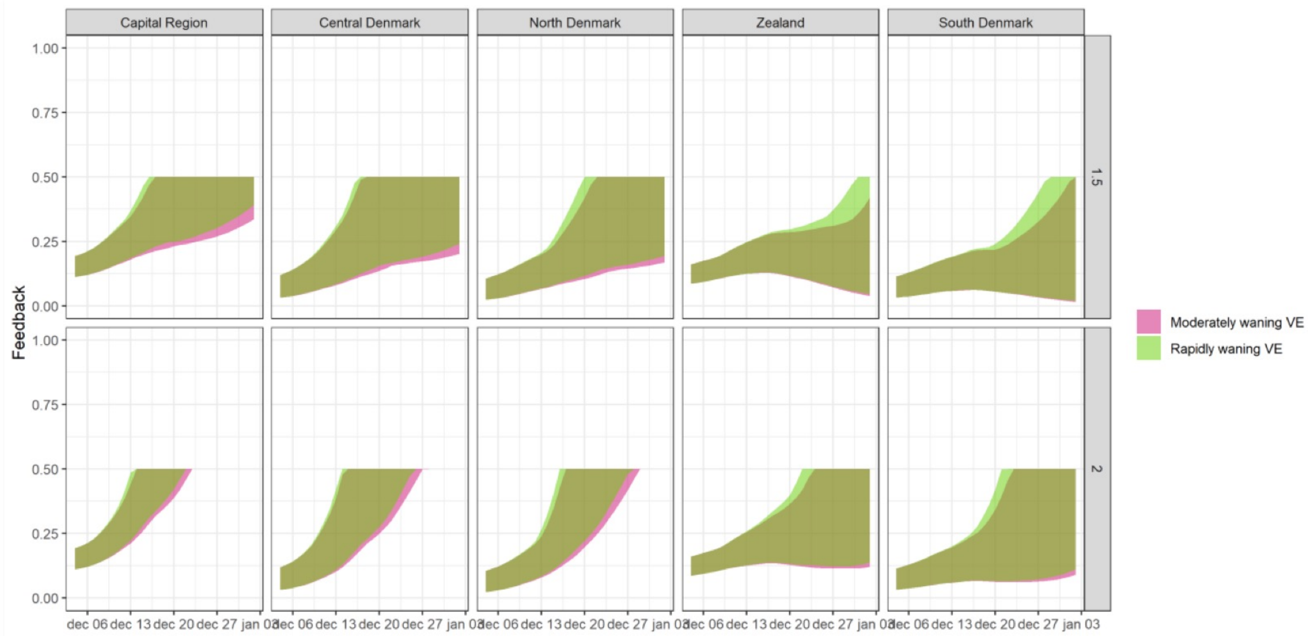


# (3B) Statens Serum Institut model



STATENS
SERUM
INSTITUT

Scenarios for infections and new admissions caused by the Omicron variant
Report by the Expert Group for Mathematic Modelling, 17 December 2021




Statens Serum Institut. Scenarios for infections and new admissions caused by the Omicron variant. Report by the Expert Group for Mathematical Modelling, 17 December 2021.

# Talk outline

1. Scenario modelling – Intervention engagement
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3. Models with behavioural feedback
4. Behaviour and Policy During Pandemics workshops – Themes
    a) Data
    b) Model complexity
    c) Informing policy

# (4A) Themes: Data

- Data collection - “Striking a balance”
- Pipelines to synthesise a range of data sources
- Format and accessibility
- What already exists that could be used/repurposed/tweaked that would be informative?

# (4B) Themes: Integrated models

- Should behaviour always be included in models?
- A checklist for constructing an interdisciplinary model?
- Building the team that has the expertise across research disciplines
- Having flexible frameworks to cater for future challenges, when we do not even know what those challenges may be…

# (4C) Themes: Policy

- Objective matters, Perspective matters
- What is the end game in the face of uncertainty?
- Role of the public in the research process – Public Involvement
- Scientific communication

# Challenges and Questions

**Is it reasonable to "repurpose" intervention response data?**

**Impact of heterogeneity & what level of detail to include?**

**How to reconcile intended behaviour vs actual behaviour?**

**How to account for uncertainty in behavioural response in the face of changing restrictions and changing risk?**

**Do we have the means to parameterise behaviour change attributable to policy vs voluntary action?**

**Unifying theoretical frameworks from behavioural science and infectious disease dynamics – The ultimate challenge?**