Modelling potential impacts of SARS-CoV-2 variants of concern

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What can mathematical models tell us?

➢ Mathematical models may be used to assess sensitivity to parameter assumptions and convey uncertainty.

➢ We investigate two ways in which variants may be concerning:
  • they may be more transmissible;
  • that they may evade immunity (infection- or vaccine-derived).

Table: Transmissibility and immune escape properties for illustrative VOC scenarios.

	Description	Relative transmissibility	Proportional vaccine efficacy	Proportional prior-infection efficacy
VOC MT	More transmissible	1.5	1	1
VOC E	Immune escape	1	0.75	0.75
VOC LT+E	Less transmissible and immune escape	0.8	0.75	0.75

Talk outline

(1) Exploring parameter space and discerning general principles
- Analysed using a parsimonious deterministic compartment model with homogeneous mixing.

(2) Potential effects of variants on burden of severe cases
- Deterministic compartmental model with age-structure, matched to epidemiological data in the UK.

(3) Timing of VOC targeted vaccines
- Parsimonious model with a VOC targeted vaccine.

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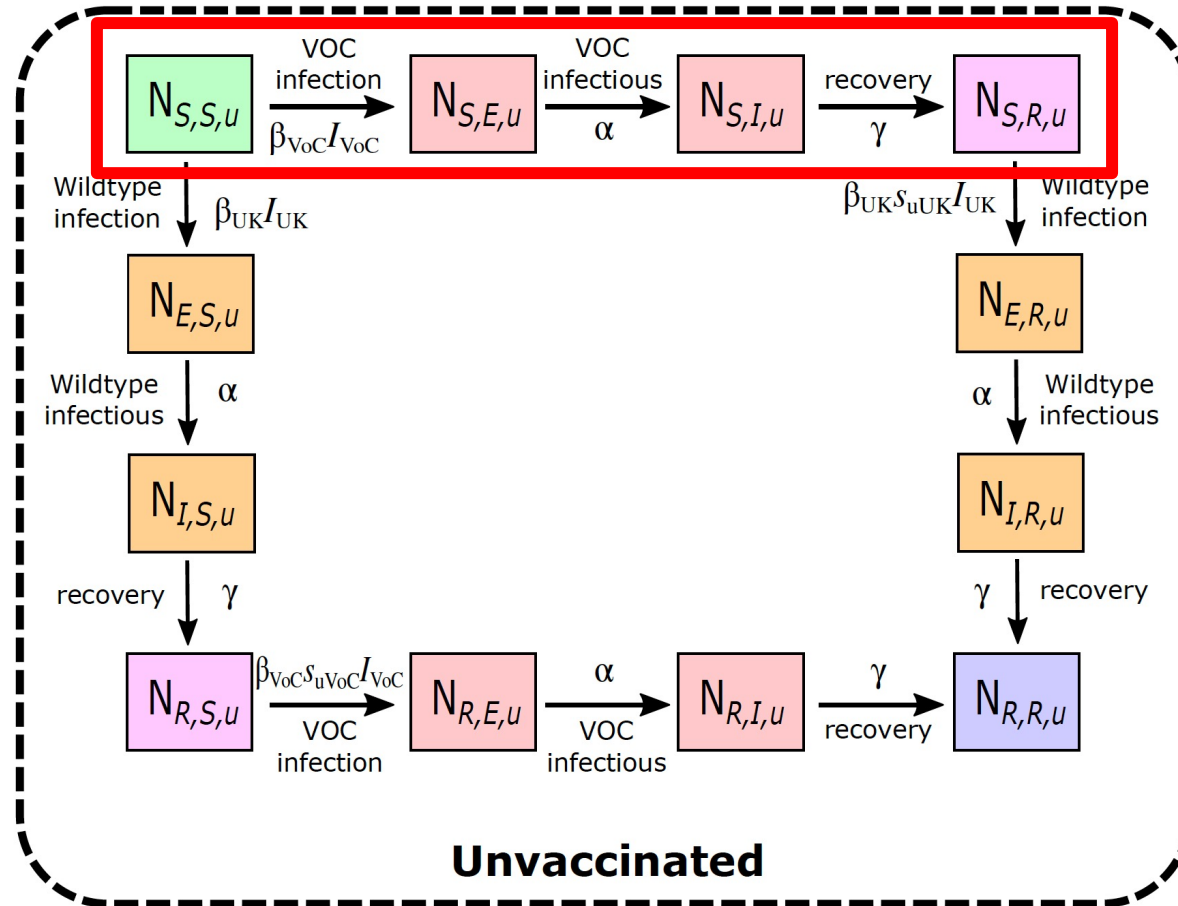- Deterministic compartmental model with age-structure, matched to epidemiological data in the UK.

(3) Timing of VOC targeted vaccines

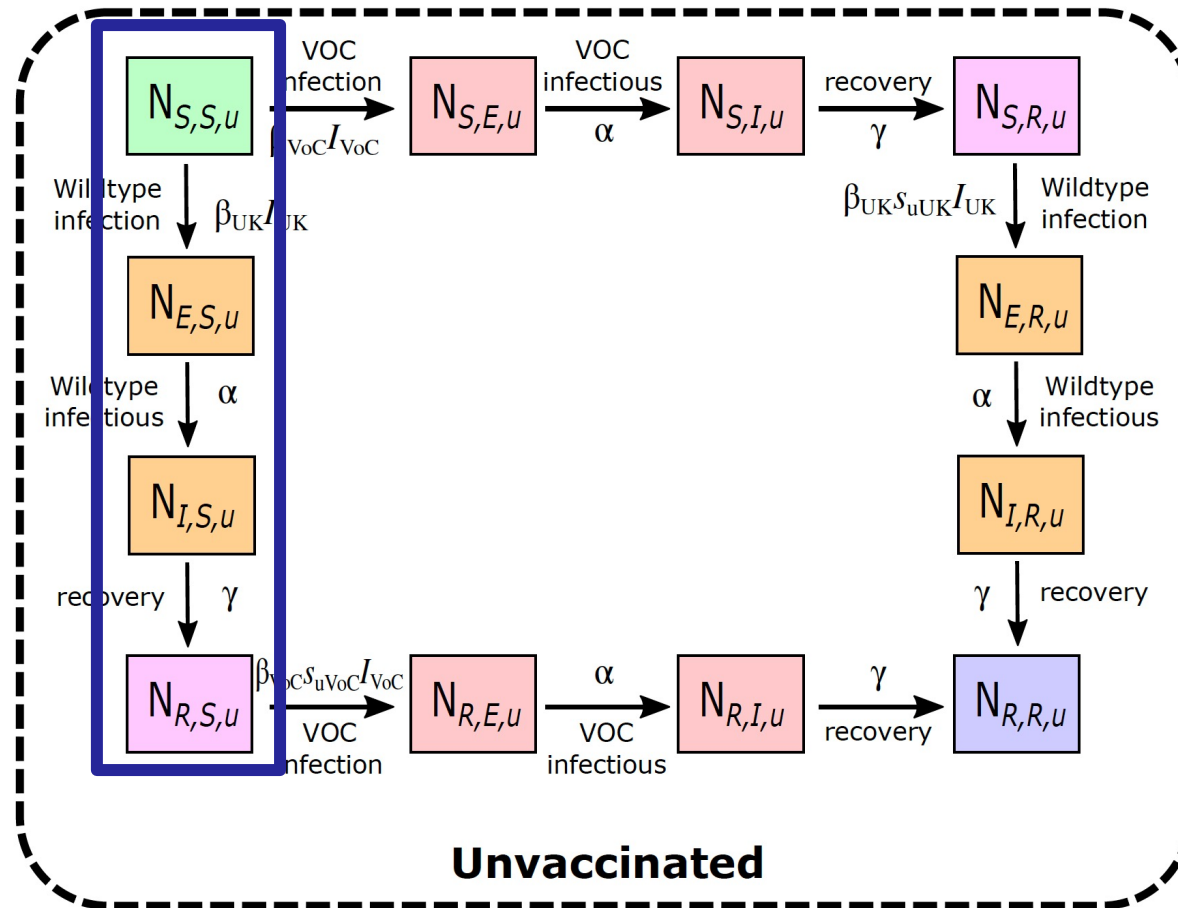- Parsimonious model with a VOC targeted vaccine.
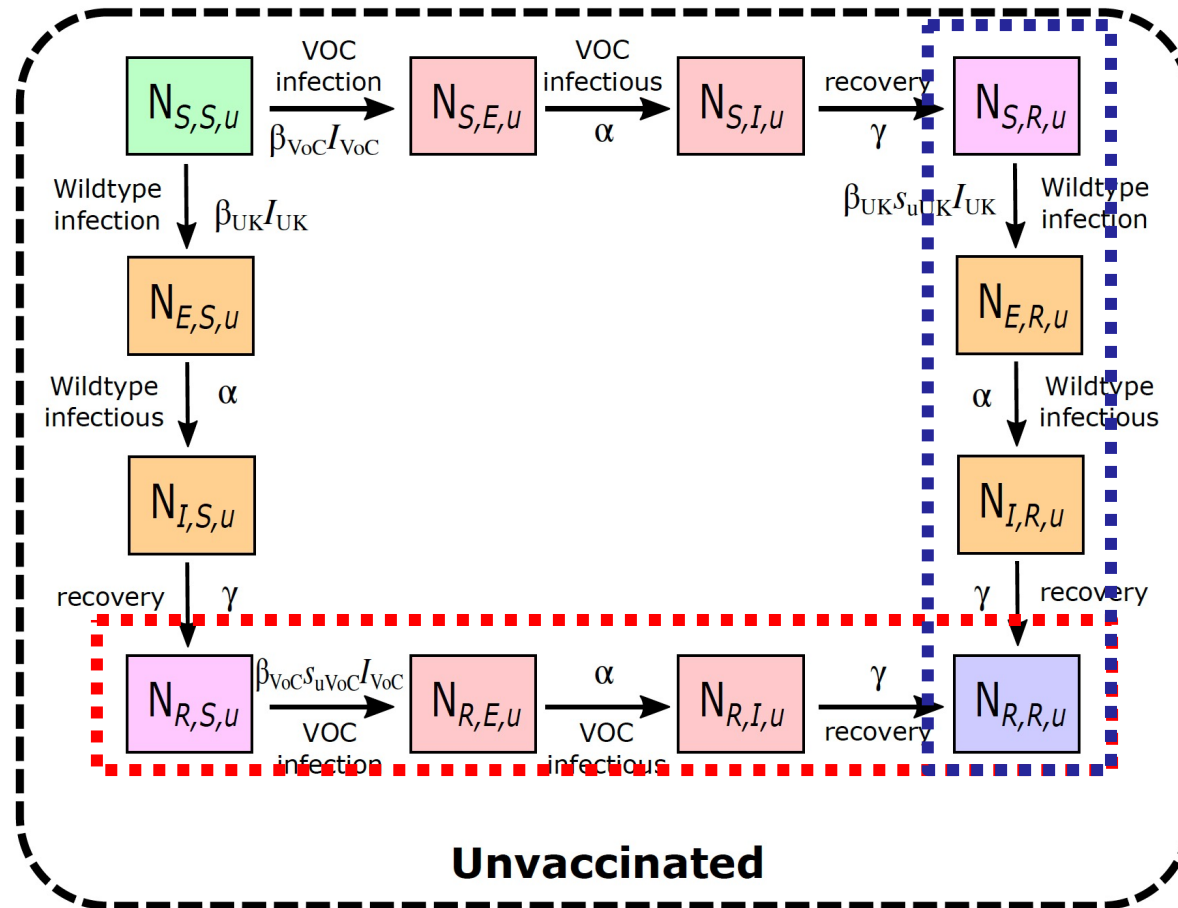
Model schematic
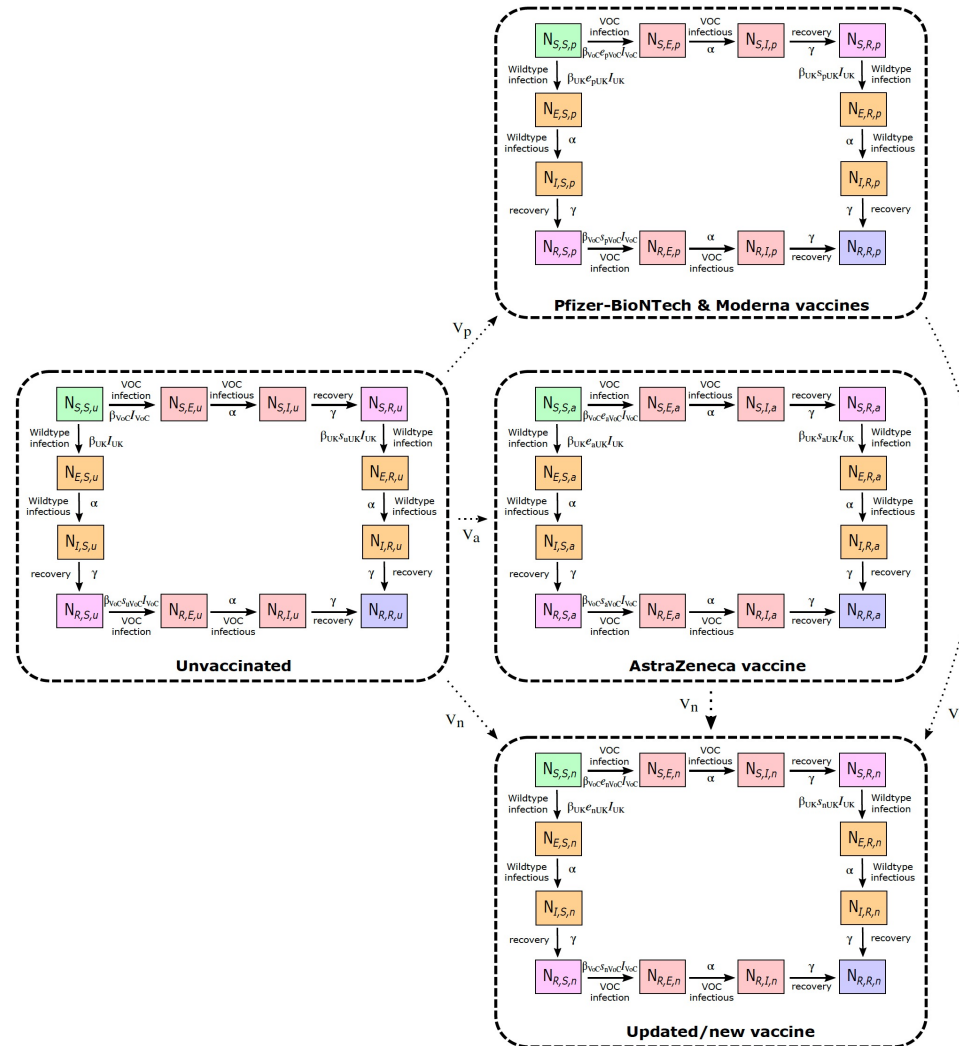
Model schematic

Unvaccinated
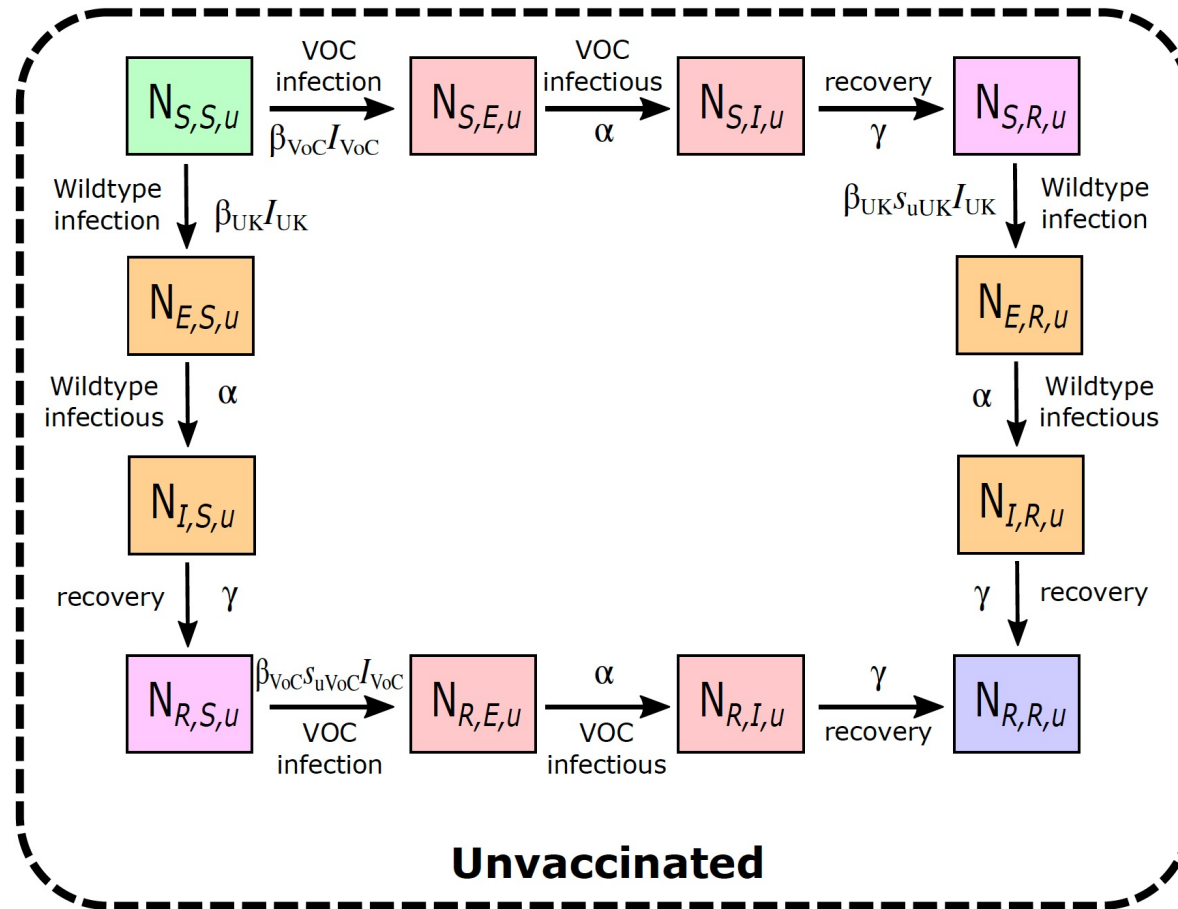
Model schematic

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Simulation overview

➢ **Population:** 56 million.

➢ **Time horizon:** Beginning 10th May 2021, for 365 days.

➢ **VOC initial infecteds:** Introduce 1,000 VOC infected into the system on 1st June 2021.

➢ **NPIs:** Level of NPIs acting on the population is captured by "R excluding immunity", which increases on the earliest date each step of the relaxation Roadmap may be enacted.

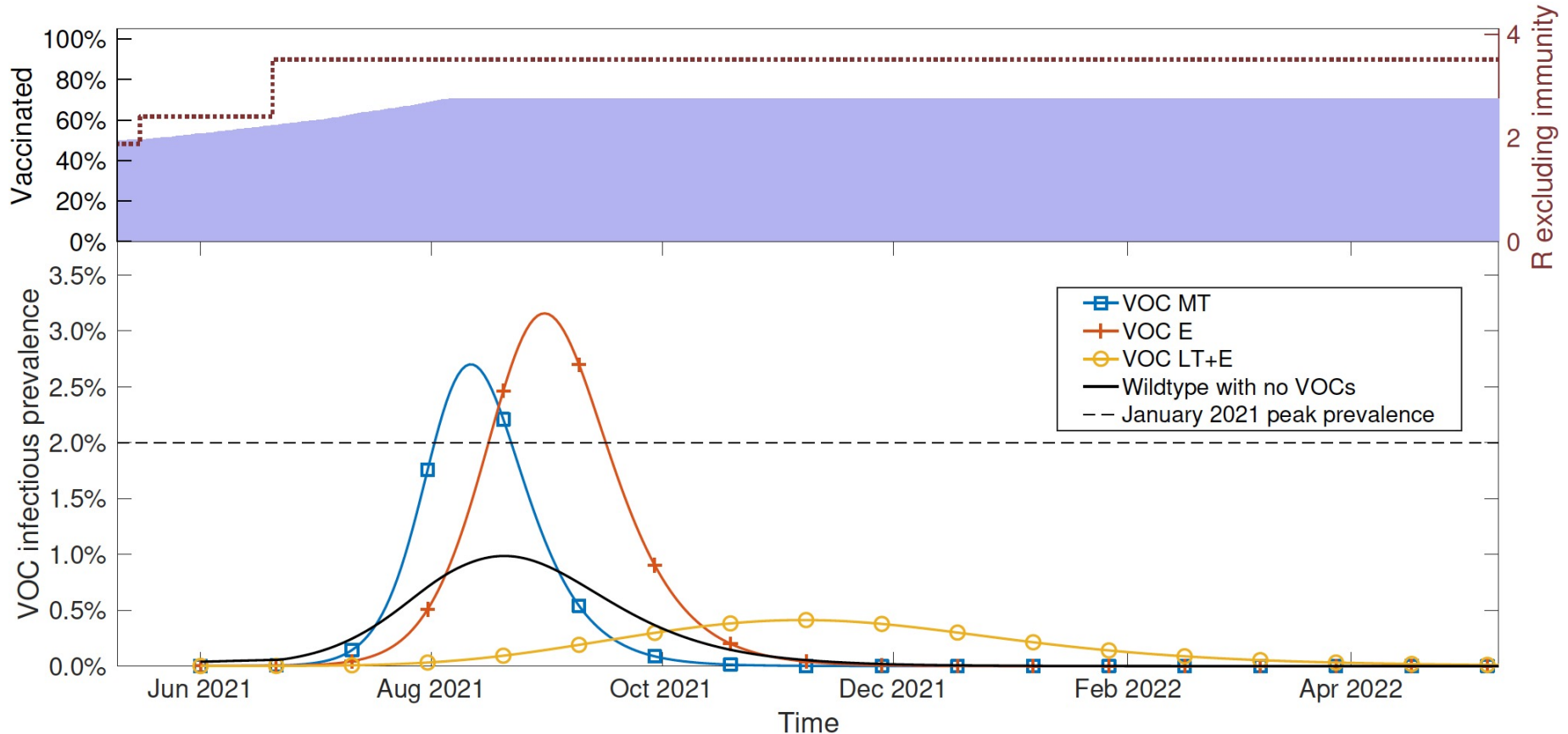➢ **Vaccination:** Vaccine action acts to prevent infection.

VOC transmission dynamics

Figure: Vaccination uptake and the impact of assumed level of NPIs through time.
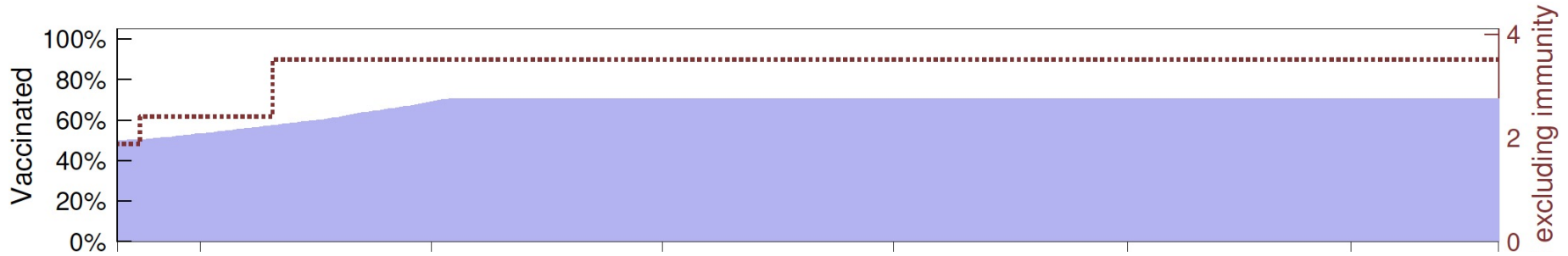
VOC transmission dynamics

Figure: Temporal profiles of the infectious prevalence for the illustrative VOCs.

➤ Novel variants can lead to waves of infection beyond what we would expect from the wildtype (B.1.1.7).

Sensitivity to VOC assumptions

Figure: Sensitivity of epidemiological measures to relative transmissibility of the VOC versus the wildtype variants and proportional efficacy (vaccine and natural-immunity) against the VOC.
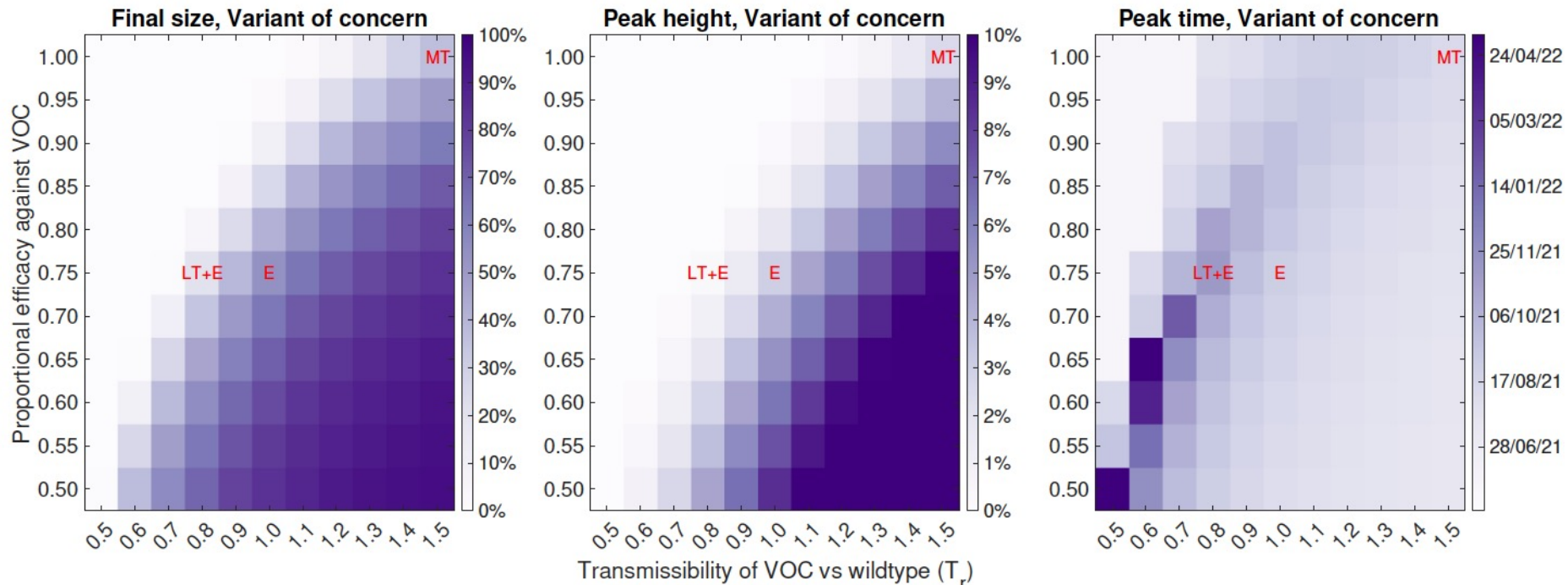
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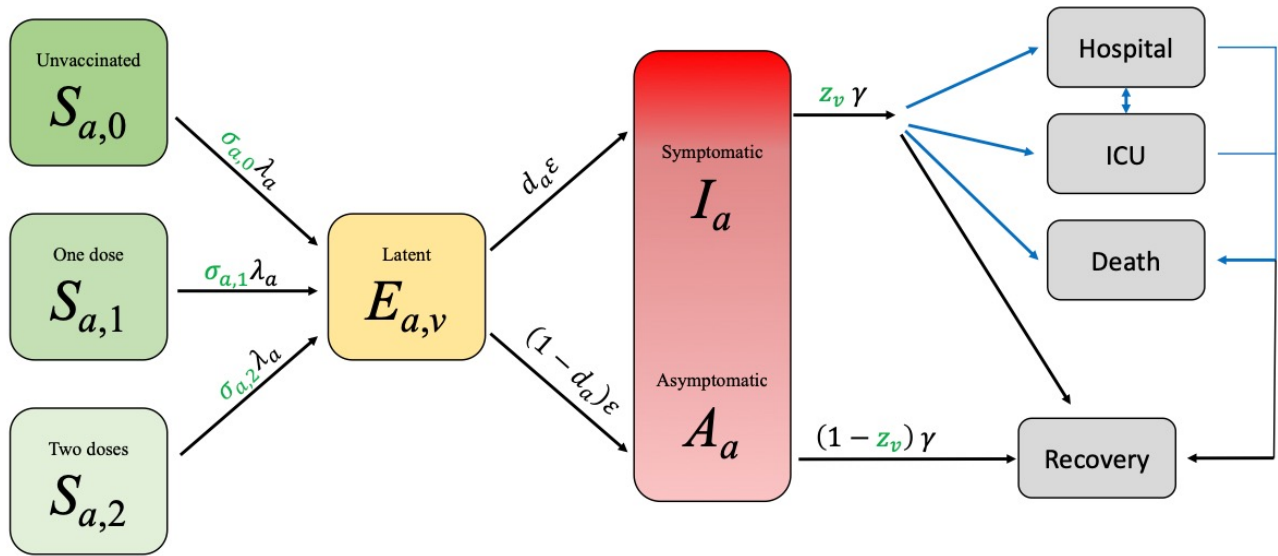
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- Parsimonious model with a VOC targeted vaccine.

Warwick SARS-Cov-2 transmission model

Vaccination and non-pharmaceutical interventions for COVID-19: a mathematical modelling study
Moore *et al.* (2021)
Lancet Infectious Diseases.
doi:10.1016/S1473-3099(21)00143-2

Cases of severe disease

Figure: Hospital admissions for a novel variant with higher transmission rates. Reproduced from Figure 23 of "Road Map Scenarios and Sensitivity: Steps 3 and 4 " (https://tinyurl.com/zyyz9edu), considered at SAGE 88 on 5 May 2021.
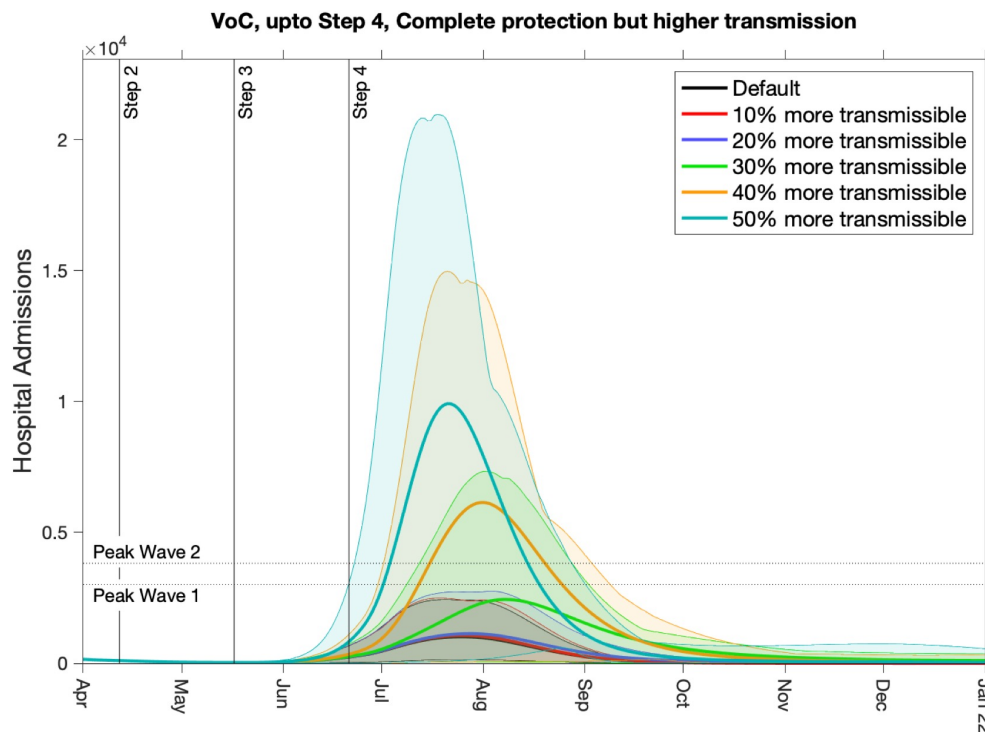
VoC, upto Step 4, Complete protection but higher transmission

➤ Even though the vaccines protect against severe infection, the number of infections can be high, and so the number of hospitalisations can be high

Early signals of VOC attributes

Figure: Illustrative example of the impact of novel VOCs on the distribution of public health measurable quantities across groups stratified by vaccine status when
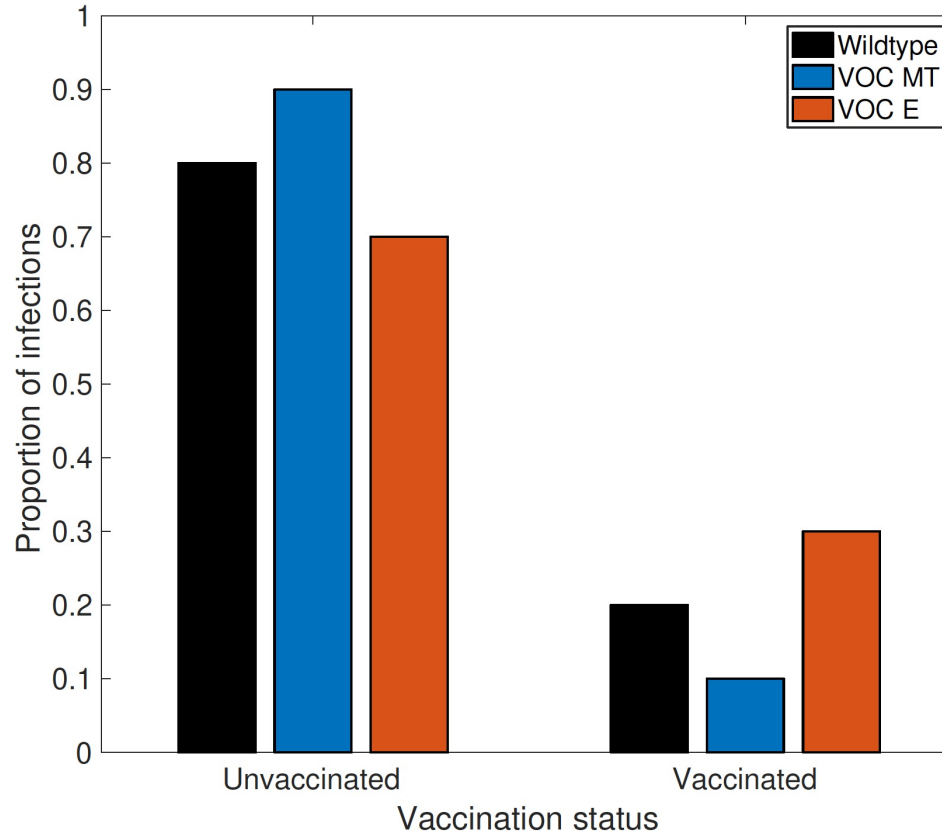
➤ An early signal of whether a variant has immune escape or higher transmissibility may be given by looking at the age distribution of cases.

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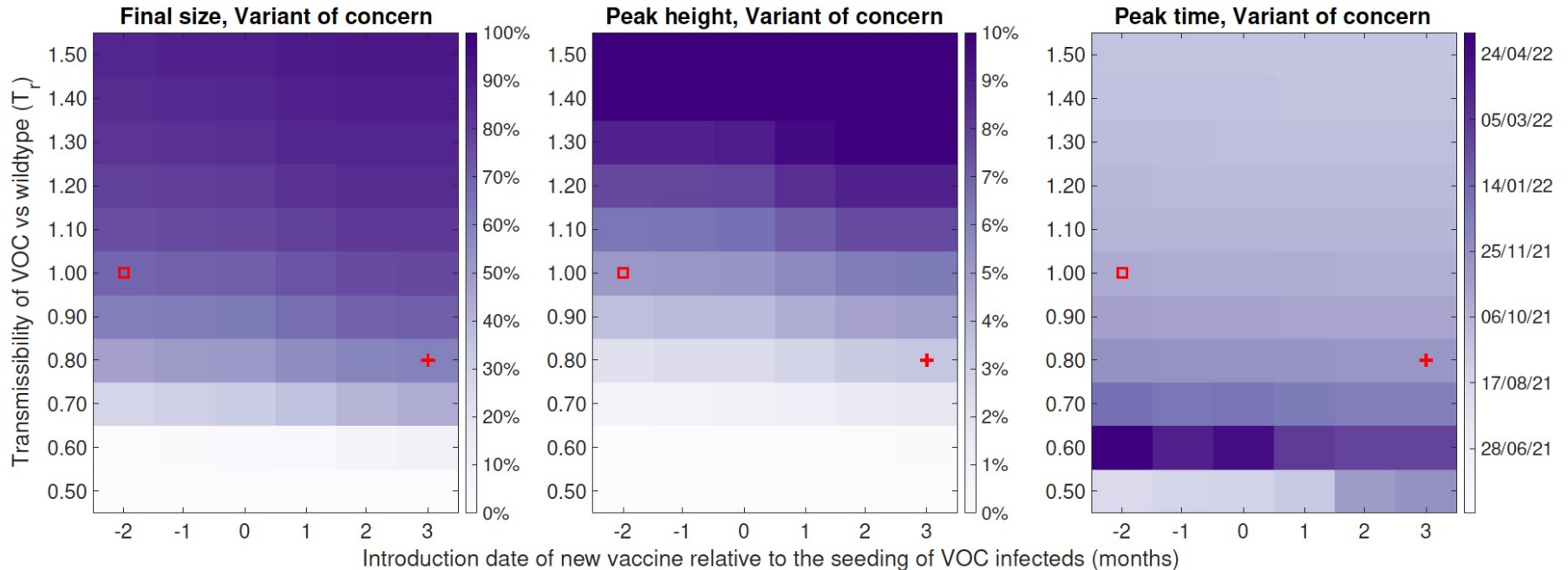
VOC targeted vaccines

Figure: Infectious prevalence dependence upon introduction date of a vaccine targeted against a novel VOC with immune escape properties (equal transmissibility to wildtype, proportional vaccine & prior-infection efficacy of 0.75).
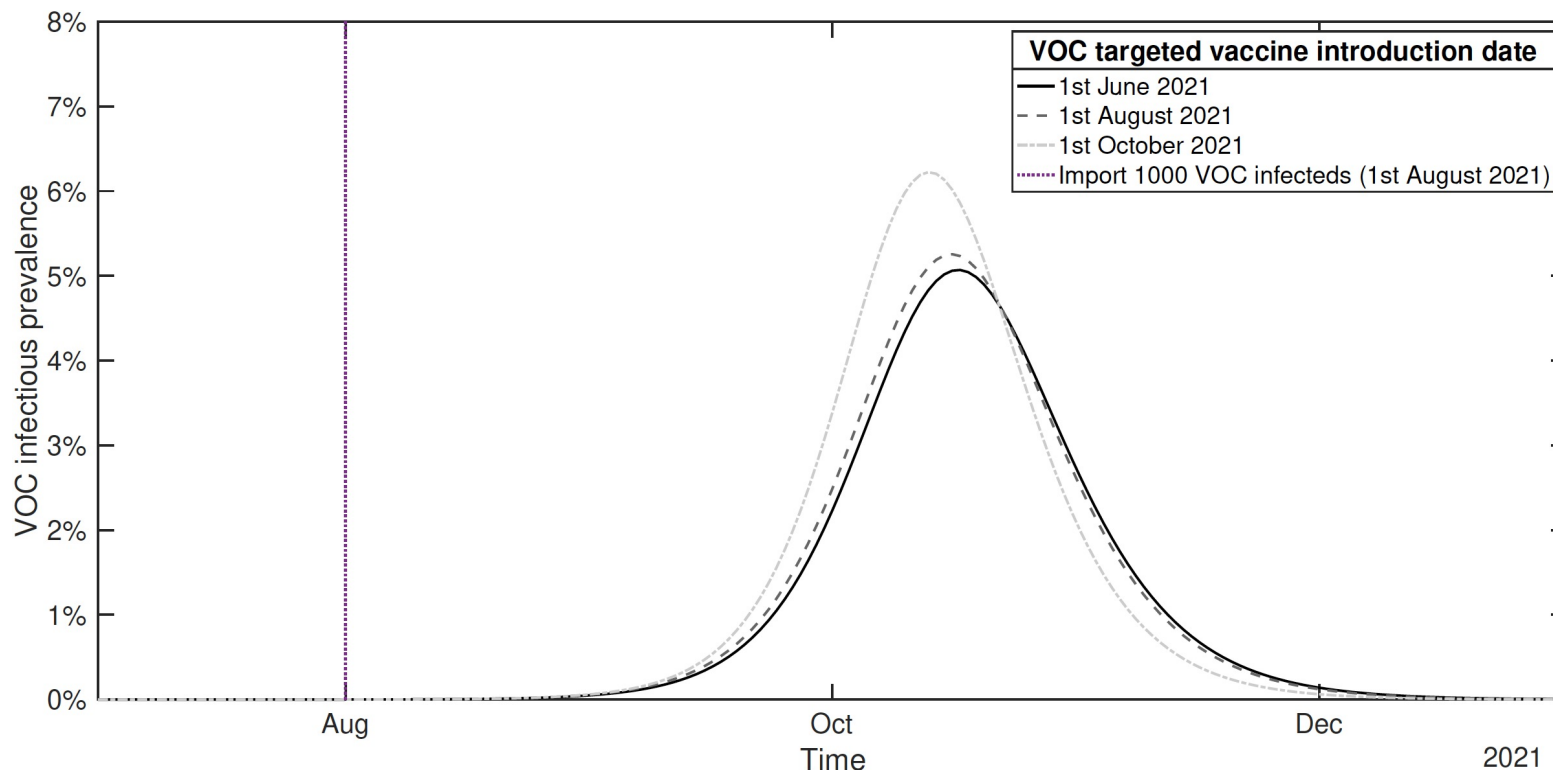
➤ An earlier introduction of a vaccine with improved efficacy against the novel VOC can lessen and delay the peak in infection.

VOC targeted vaccines

Figure: Sensitivity of epidemiological measures to the deployment date of a VOC targeted vaccine relative to the seeding of VOC infecteds and relative transmissibility of the VOC.

➤ Increased relative impact of earlier VOC targeted vaccine introduction date for VOCs that are less transmissible than the wildtype variant.

Summary

(1) Exploring parameter space and discerning general principles

- Novel variants can lead to waves of infection beyond what we would expect from the wildtype.
- Can occur even if the novel variant is not more transmissible than the wildtype, if it has immune escape.

(2) Potential effects of variants on burden of severe cases

- Even though the vaccines protect against severe infection, the number of infections can be high, and so the number of hospitalisations can be high.

(3) Timing of VOC targeted vaccines

- Variable impact, dependent upon lag until it is available, how much more transmissible the VOC is and the improvement in efficacy.

Acknowledgements

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Webpages:
https://tinyurl.com/warwickCOVID;   https://edmhill.github.io;