Projections of SARS-CoV-2 transmission and COVID-19 disease until June 2022: Exploration of Control

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Predicting the level of control needed in the future is fraught with uncertainty, in part due to the unknown behaviour of the epidemic and in part due to the unknown cause of any future spikes in infection. Tackling this with scenario modelling is unlikely to yield useful generalities, as the magnitude of future spikes are dependent upon multiple factors including the speed of response. Instead we consider the model generic problem in which infection begins to double every week (or every two weeks) and determine the level of precautionary behaviour (the reduction in mixing) necessary to overcome the doubling and return R to approximately 1 (Fig. 1). We stress that this should be seen as a minimal level of control, as it only stops the increase – it does not lead to a reduction in the levels of infection.

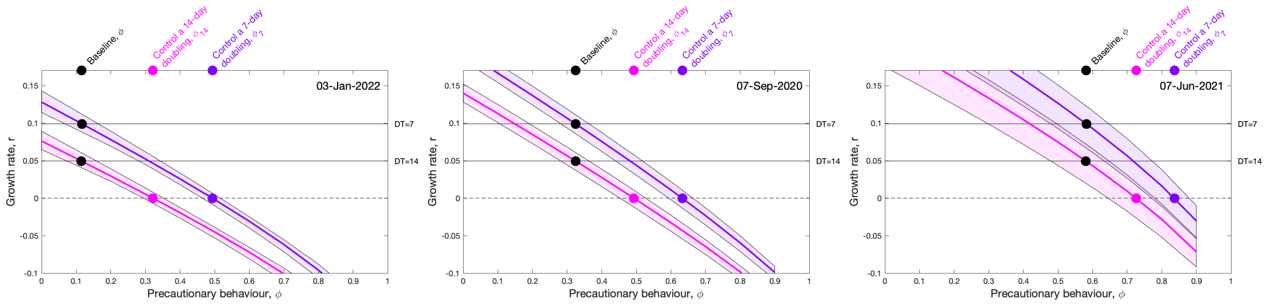

Fig. 1: Growth rate at different levels of precautionary behaviour at different time points in the projected epidemic (date in top right-hand corner). For the estimated level of precautionary behaviour at any given date in the epidemic (referred to as the baseline ϕ, shown by black dots), we initiate a change in transmission such that infection doubles every week (purple curve) or every two weeks (pink curve). The level of precautionary behaviour needed to control the growth ($r = 0$) is shown with a coloured dot and labelled ϕ_7 and ϕ_{14} respectively. (Solid lines are the means of simulations, while the shaded areas show the 95% prediction intervals).

We take the scenarios in which precautionary behaviour decays to zero (pre-COVID levels) by December 2021 or June 2022 (top and bottom rows in Fig. 5 in the main paper), and assume that an external event occurs which leads to a doubling of infection every week or every two weeks. This can be conceptualised as the invasion of a novel variant, but could potentially be driven by other factors (such as waning infection-derived or vaccine-derived immunity). We then increase the level of precautionary behaviour (equivalent to reducing population-level mixing) to achieve zero growth rate (Fig. 1). We then plot the initial level of precautionary behaviour (ϕ) against the levels needed to regain control (ϕ_7 and ϕ_{14}) (Fig. 2). Clearly an increase in precautionary behaviour is needed to mitigate the doubling, hence all points lie above the diagonal.

The level of precautionary behaviour needed to overcome the doubling (y-axis) is compared to five values that have been inferred for England in 2021 (see Fig. 2 in the main paper). We note that the maximum value occurred during the July/August 2021 pingdemic, with the January 2021 lockdown, Steps 1, 2 and 4 all having lower values. From these results we find that a weekly doubling of infection under current precautionary behaviour ($\phi \approx 0.36$) would require a return to lockdown-type behaviour to bring R to approximately 1. However, it should be noted that we expect there to be considerable hysteresis in the system; for example, the scale of population mixing that occurred after 12th April when moving into Step 2 from Step 1, is not necessarily the same as the mixing that would happen if Step 2 regulations are brought in as a control measure after being in Step 4. The re-opening of non-essential retail in Step 2 may have taken some time to be an accepted norm in the population whereas moving back to Step 2 is unlikely to change people's attitude to non-essential shops; however the closure of some indoor hospitality that would be mandated by a return to Step 2 would necessarily have an immediate effect whereas its opening in Step 3 may have taken longer to change behaviour.

At the current level of precautionary behaviour ($\phi \approx 0.36$), to prevent the doubling of infection every week would require at least the same level of behaviour as seen in the third lockdown, whereas to

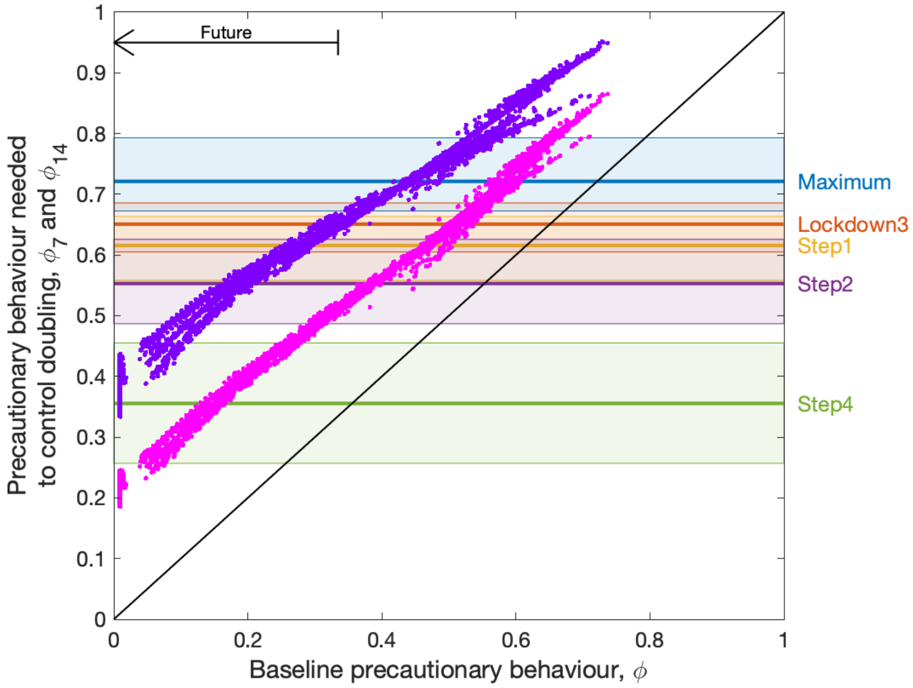

Fig. 2: The necessary change in precautionary behaviour to overcome a doubling every week (purple dots, upper set of points) or every two weeks (pink dots, lower set of points). This is shown as a function of the level of precautionary behaviour at the time that doubling starts (x-axis). Results are combined for the three assumptions about the asymptotic levels of waning efficacy, and for the two extremes of decline in precautionary behaviour. The arrow indicates the values of precautionary behaviour below the current level that we expect to observe into the future. Horizontal lines (together with 95% credible intervals) correspond to values inferred for 2021.

prevent doubling every two weeks would require mixing to reduce to levels last observed in Step 2. These increases in control measures would prevent further doublings in infection (although a single doubling of hospital admissions is already within the system) but would not redress the doubling that has already occurred. In contrast, doublings that occur once the population has returned to pre-COVID mixing might be balanced by a return to the behaviour in the early stages of Step 4.