NPIs and household generation structure

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In this analysis we estimate the impact of a wave of infection in terms of prevalence in individuals age 65 and over under interventions which reduce transmission on different levels:

- Controls on within-household transmission;

- Controls on between-household transmission;

- Controls on both within- and between-household transmission;

- A targeted strategy which reduces transmission into households containing at least one individual aged 65 or over.

In this analysis we do not attempt to model any specific intervention in detail; our reductions in transmission could be due to non-pharmaceutical measures, booster vaccines, or antivirals.

1 Model outline and assumptions

We use an age- and household-structured infection model (development code available at `https://github.com/JBHilton/covid-19-in-households-public`, preprint to appear January 2022) which takes households as the basic unit of population. Age classes correspond to 0 to 19 years, 20 to 64 years, and 65+ years, with household composition in terms of age of household members distributed according to 2011 England and Wales census data.

Main assumptions/sources:

- Course of infection follows a susceptible-exposed-prodromal infectious-symptomatic infectious-recovered (SEPIR) compartmental structure, with no waning of immunity;

- Mean latent period of 1.16 days, mean prodromal period of 4.64 days, mean symptomatic period of 5 days. Prodromal cases are 3 times more infectious than symptomatic (cf. Hart *et al.* 2020, *High infectiousness immediately before COVID-19 symptom onset highlights the importance of continued contact tracing*, eLife). This is based on 2020 wild type estimates with no adjustment for omicron.

- Within-household transmission rate is fit to estimates of within-household transmission probabilities (House *et al.* 2021, *Inferring Risks of Coronavirus Transmission from Community Household Data*, arXiv preprint), then doubled to account for higher infectiousness of omicron.

- Between-household transmission rate is callibrated to a doubling time of 3 days (all populations are assumed to have same doubling time).

- Within-household mixing is homogeneous across age classes, between-household mixing is age structured based on POLYMOD estimates;

- We do not explicitly model vaccination in this analysis.

2 Results

We start by simulating the dynamics in the absence of any specific interventions from a starting prevalence of 1%. The projected instantaneous and cumulative prevalence in the 65+ age class over the 120 day simulation period is plotted in Figure 1, stratified by household generation composition. Prevalence is higher than the average among the 65+ age class for 65+ year old's living in households with at least one 0-19 or 20-64 year old, and three-generation households (at least one member of each age class) are associated with particularly high levels of 65+ prevalence.
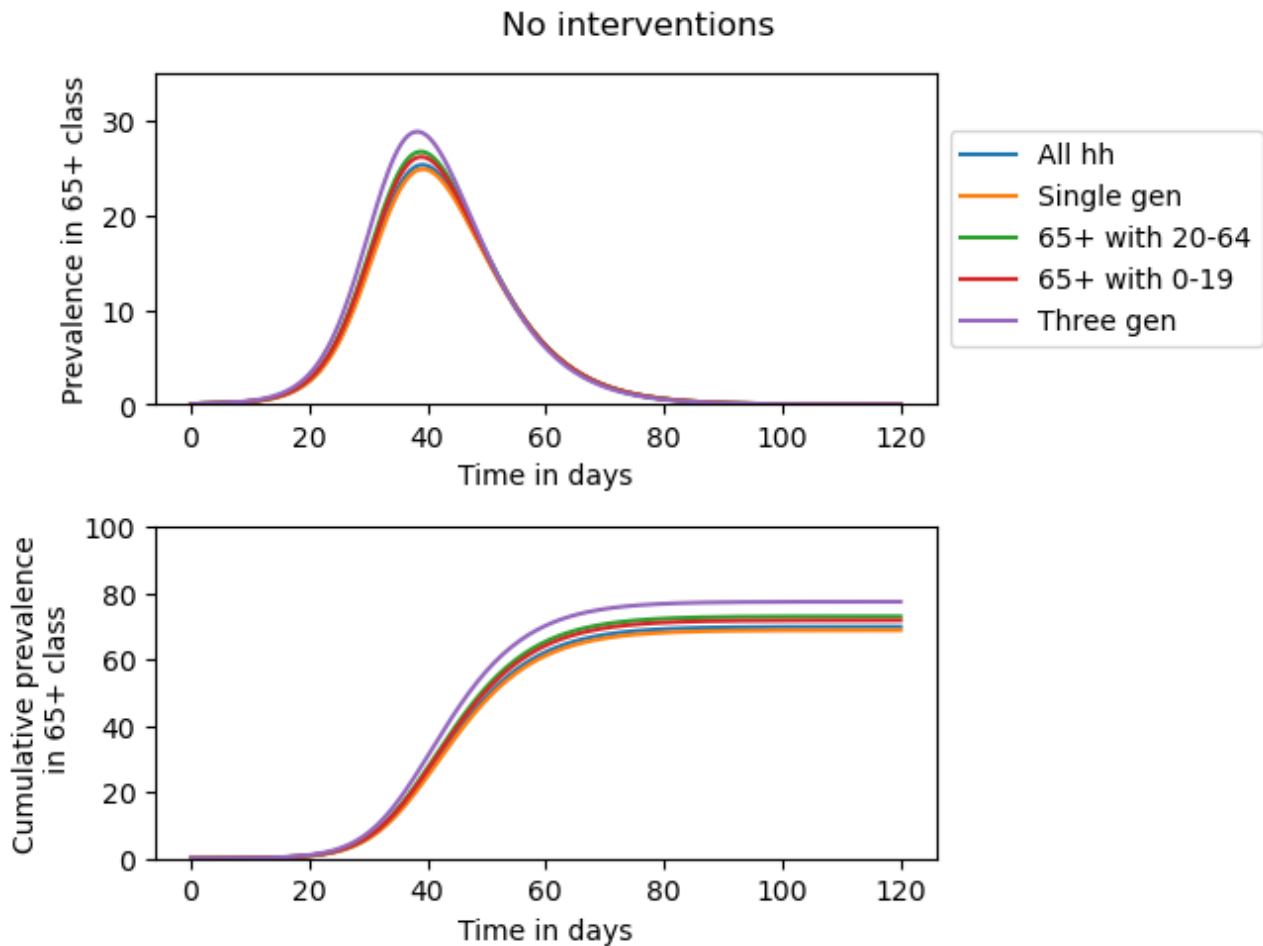
Figure 1: Projected prevalence and cumulative prevalence with no measures applied.

2.1 Within-household measures

Here we reduce the within-household transmission rate. The instantaneous and cumulative prevalence in the 65+ age class stratified by household generation composition for a 25% reduction is plotted in Figure 2, and for a 50% reduction in Figure 3. These within-household measures appear to have limited impact, although the difference in prevalence between three-generation households and other households is smaller under these measures.
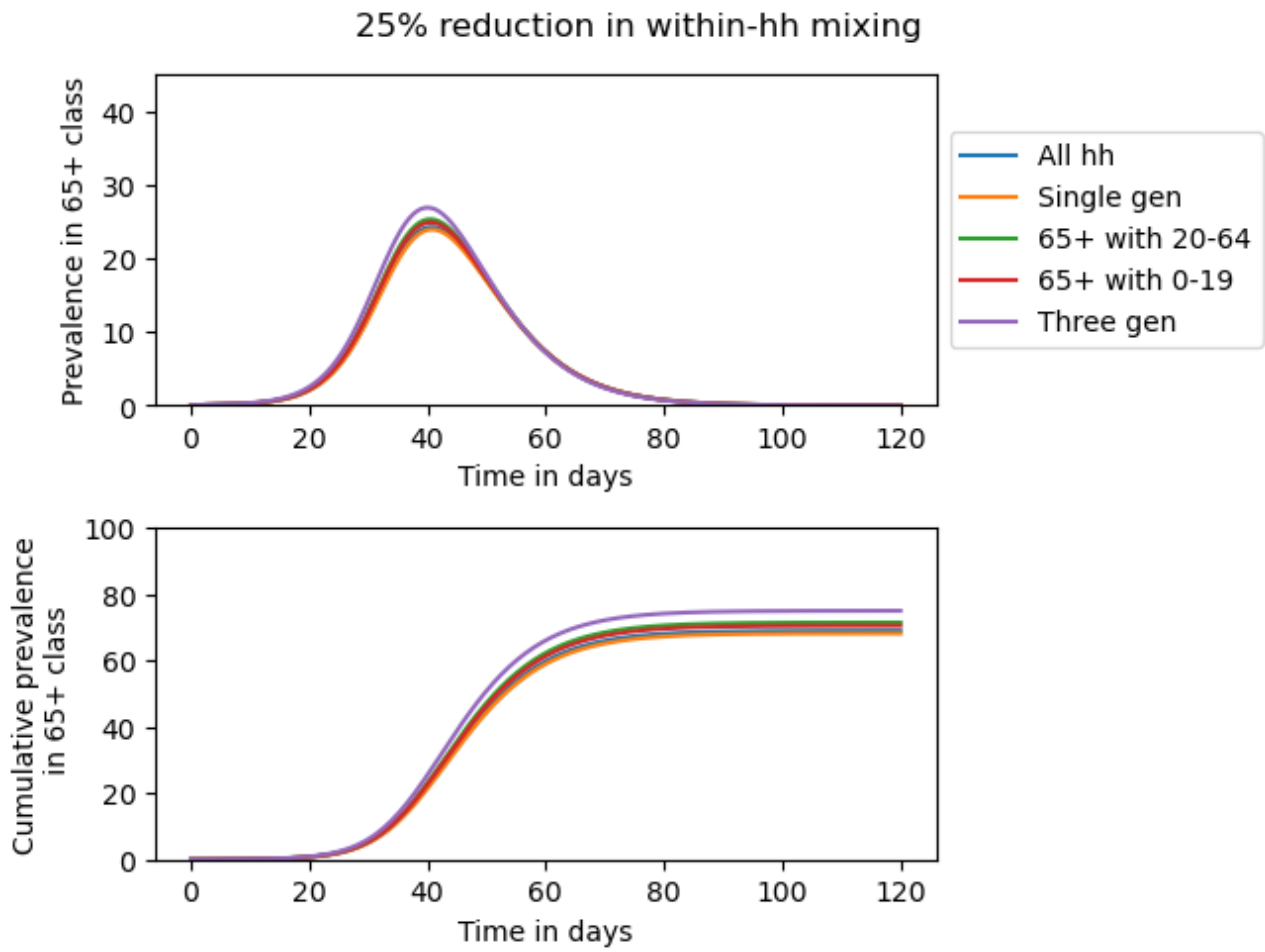
Figure 2: Projected prevalence and cumulative prevalence with 25% reduction in within-household transmission.
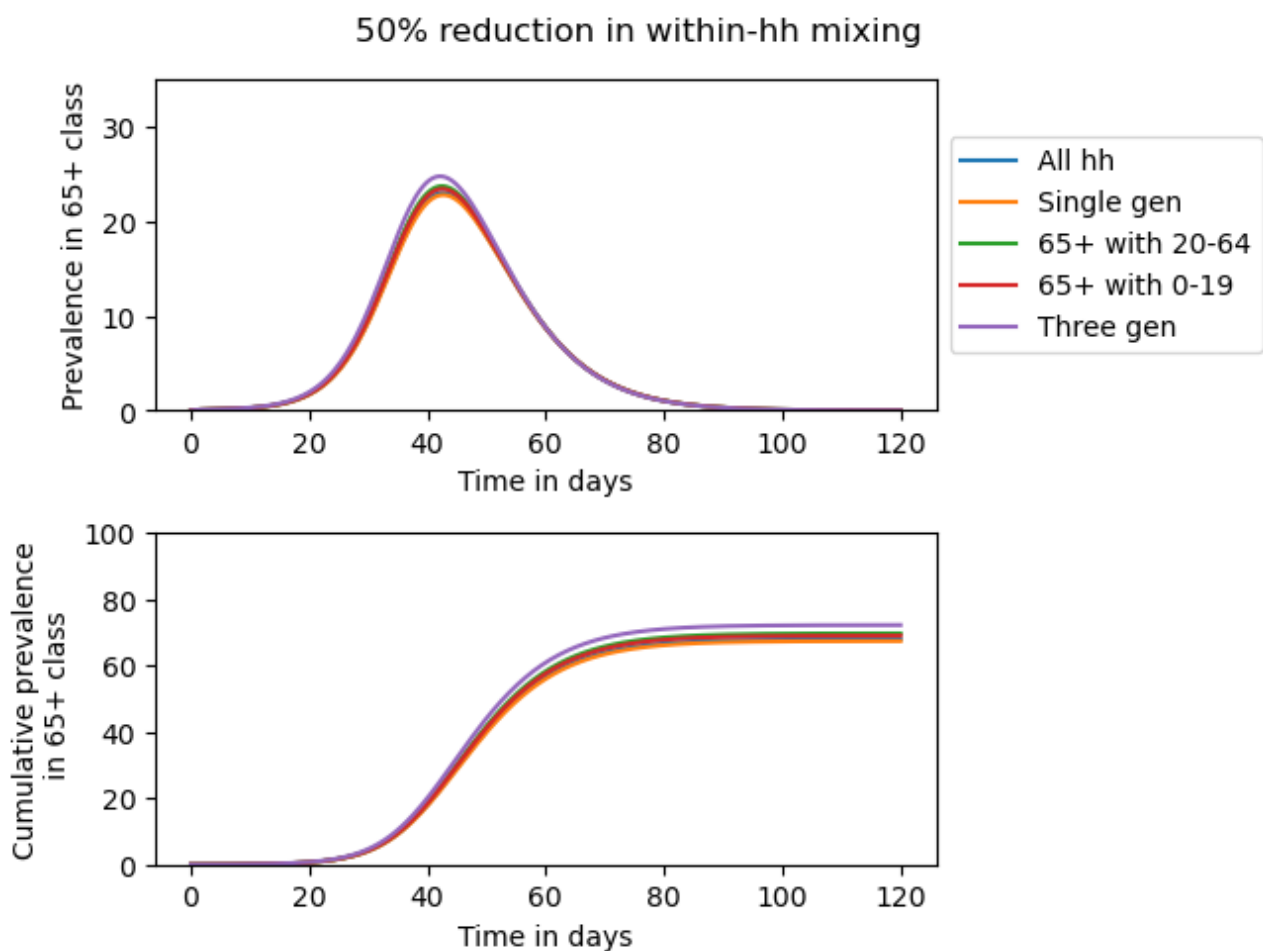
Figure 3: Projected prevalence and cumulative prevalence with 50% reduction in within-household transmission.

2.2 Between-household measures

Here we reduce the between-household transmission rate. The instantaneous and cumulative prevalence in the 65+ age class stratified by household generation composition for a 25% reduction is plotted in Figure 4, and for a 50% reduction in Figure 5. A 50% reduction in between-household transmission substantially reduces cases in the 65+ age group, with cumulative prevalence across all household generation structures dropping to less than half the baseline no-intervention level. A 25% reduction achieves a less substantial reduction in prevalence, but is still more effective than similar reductions in within-household transmission. The reduction in risk from between-household reductions in transmission is projected to be smaller for over 65 year old's living in two- or three-generation households than for those living in single generation households.
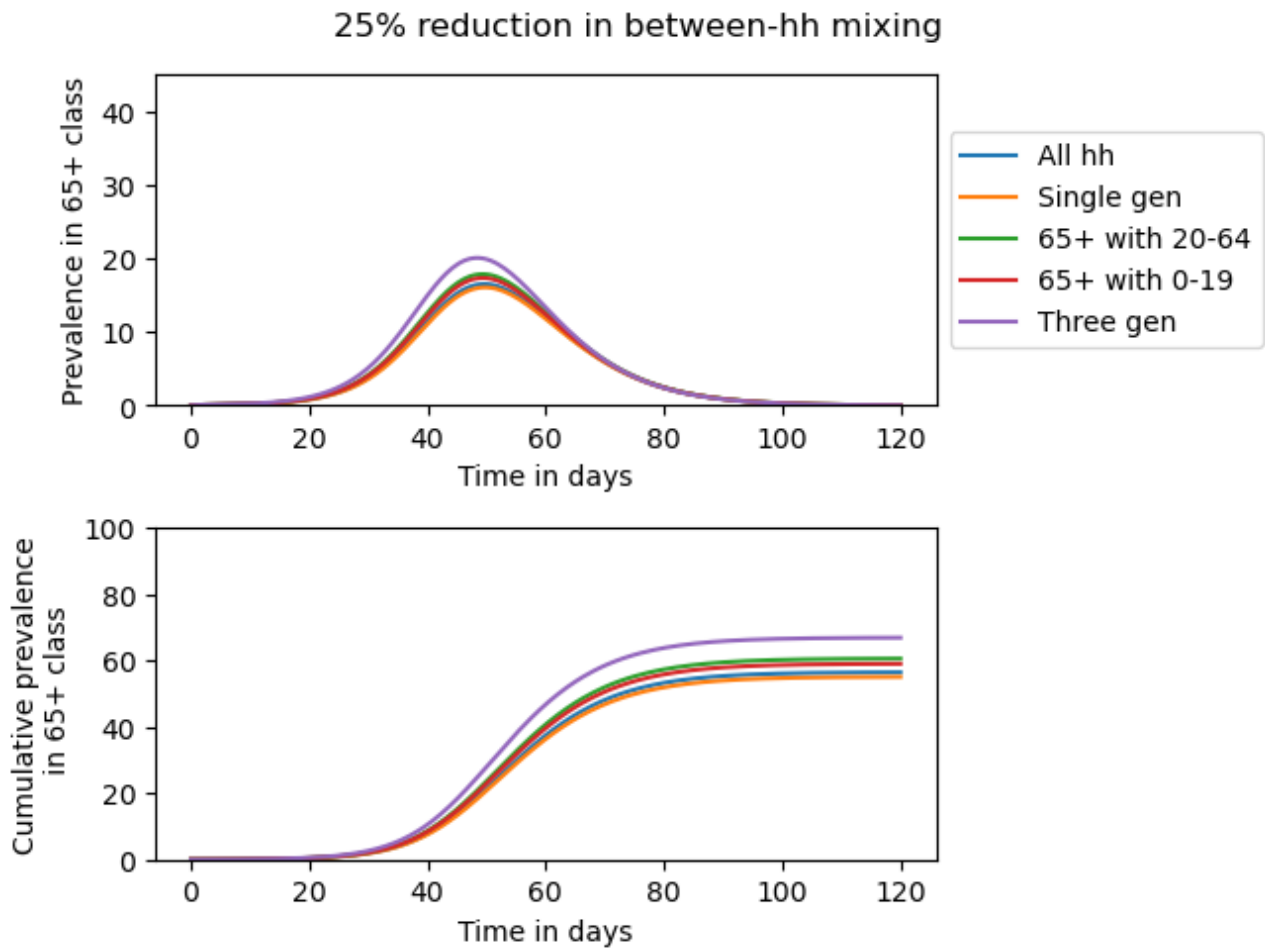
Figure 4: Projected prevalence and cumulative prevalence with 25% reduction in between-household transmission.
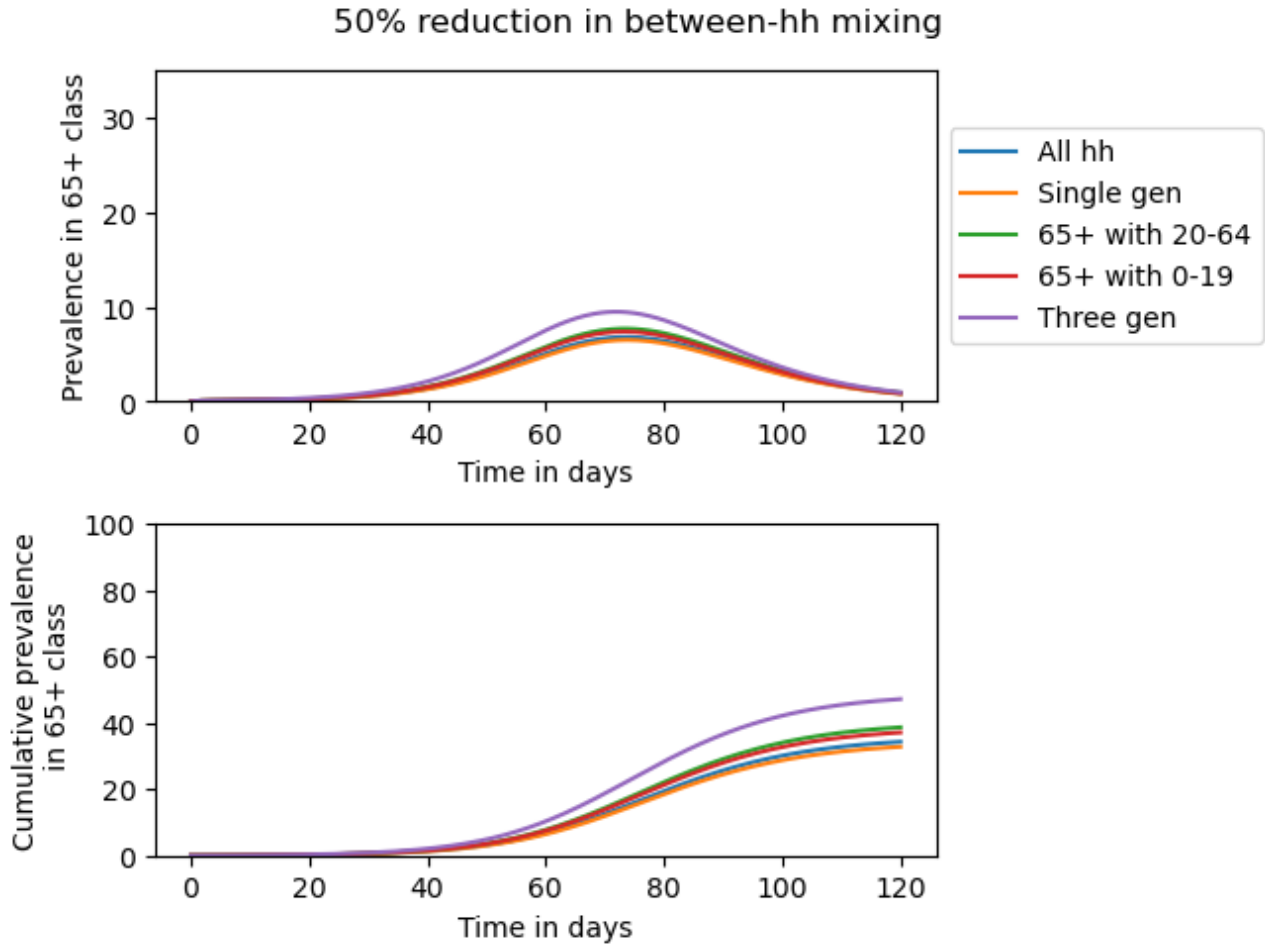
Figure 5: Projected prevalence and cumulative prevalence with 50% reduction in within- and between-household transmission.

2.3 Within- and between-household measures

Here we reduce the transmission rate on both the within- and between-household level. The instantaneous and cumulative prevalence in the 65+ age class stratified by household generation composition for a 25% reduction is plotted in Figure 6, and for a 50% reduction in Figure 7. A 50% reduction in transmission on both levels is projected to substantially reduce over 65 prevalence over the simulation period, with less substantial although still non-negligible reductions if transmission is reduced by 25%.
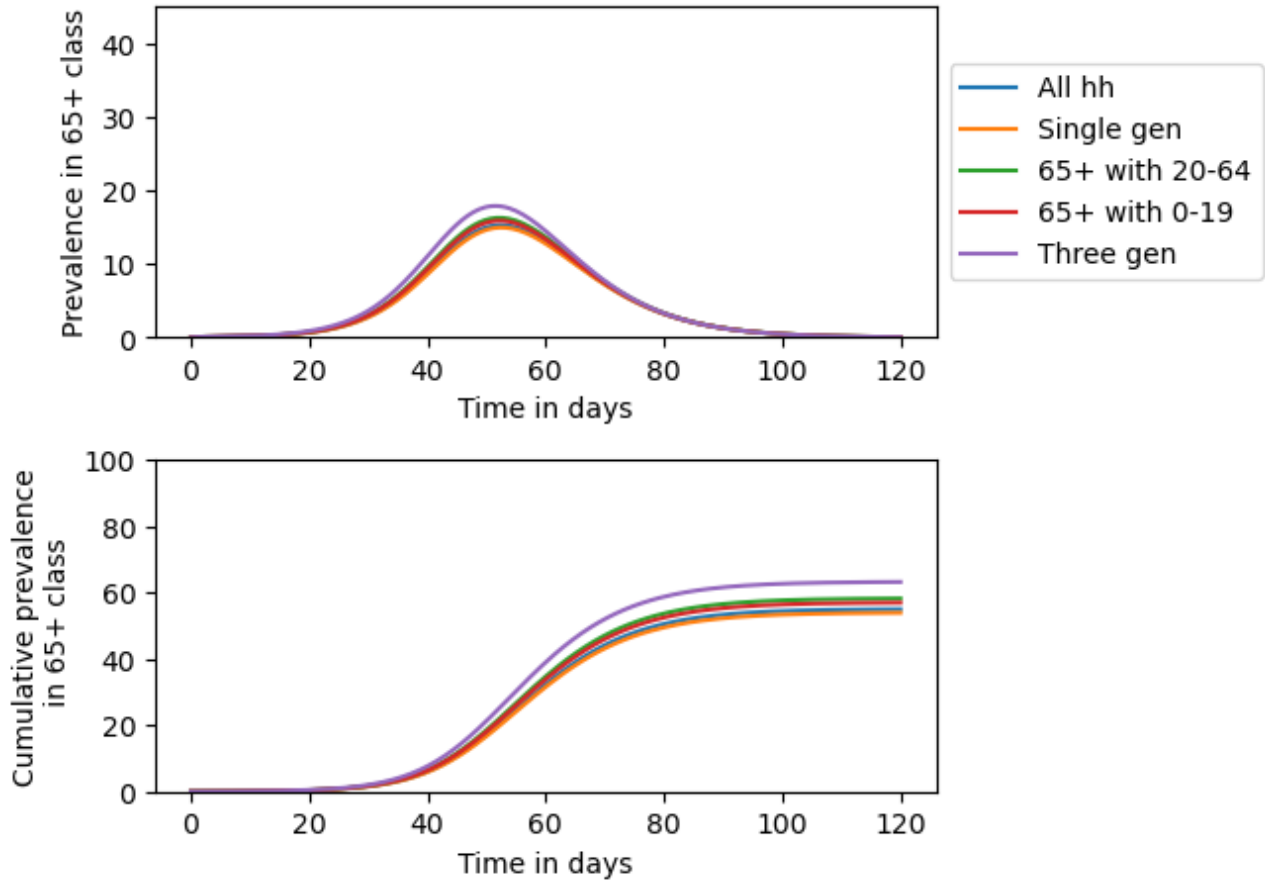
Figure 6: Projected prevalence and cumulative prevalence with 25% reduction in within- and between-household transmission.
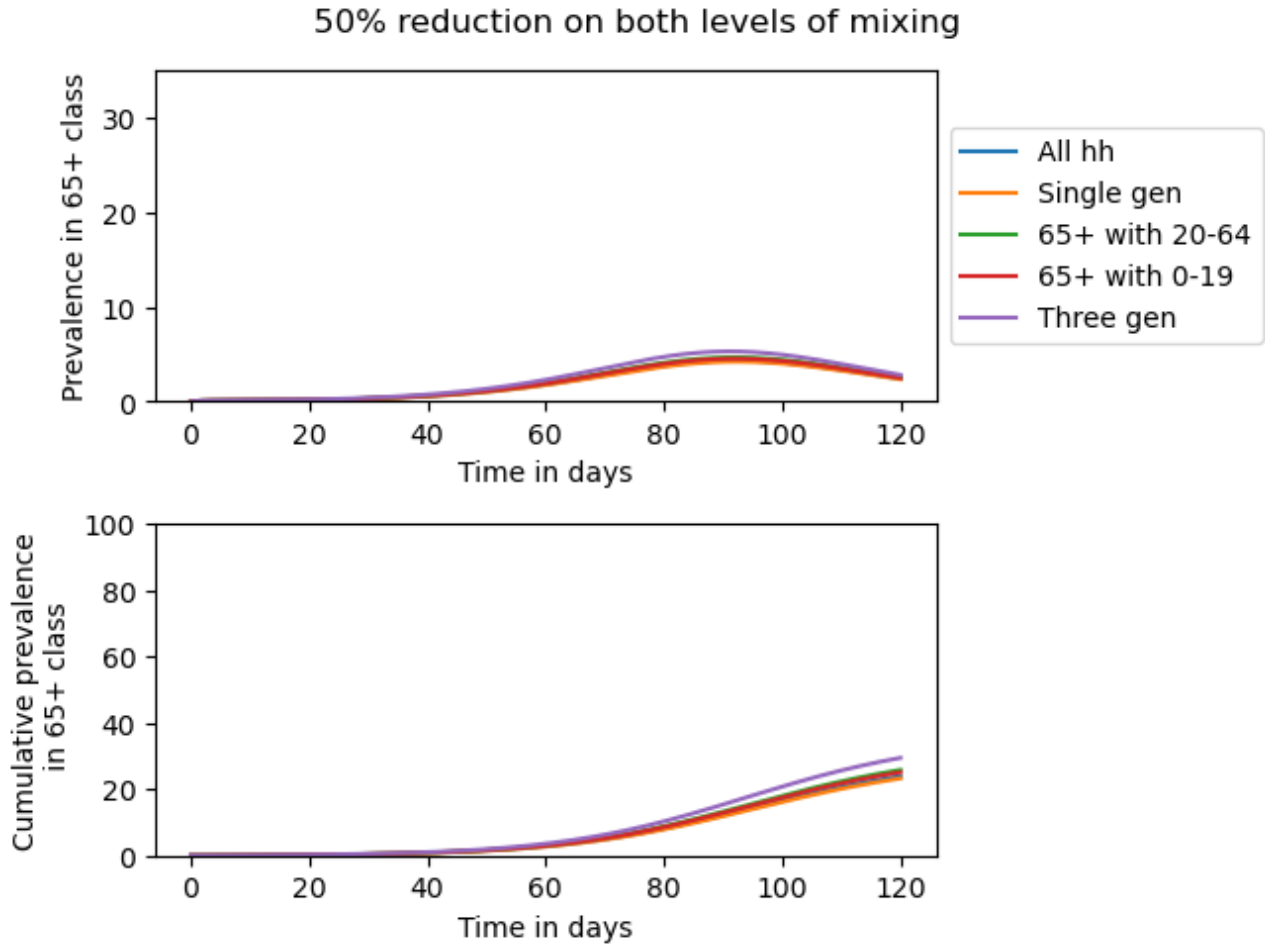
Figure 7: Projected prevalence and cumulative prevalence with 50% reduction in within- and between-household transmission.

2.4 Targeted between-household measures

Here we model a targeted intervention where we reduce the rate at which individuals in households containing at least one individual over 65 are infected from outside the household. The main population-level epidemic is unconstrained, but the rate at which anyone belonging to one of these households picks up external transmission is scaled down appropriately. This scaling applies both to individuals over 65, and to individuals in the 0-19 and 20-64 age classes who share a household with at least one individual in the 65+ age class. The instantaneous and cumulative prevalence in the 65+ age class stratified by household generation composition for a 25% reduction is plotted in Figure 8, and for a 50% reduction in Figure 9. Targeted reductions in between-household mixing are less effective than population-level reductions because under the targeted measures more infection is allowed to circulate than under blanket measures while the rate at which cases in the population transmit into households containing individuals over 65 remains the same as under blanket measures. However, targeted measures still have a noticeable impact in terms of peak and cumulative prevalence relative to the baseline no-intervention projections, particularly at the 50% level. As with the blanket between-household measures, the gap between prevalence in three-generation households and one- or two-generation households appears to grow as overall prevalence decreases, suggesting that it may be difficult to minimise risk to members of the over 65 group living in these households through population-level measures.
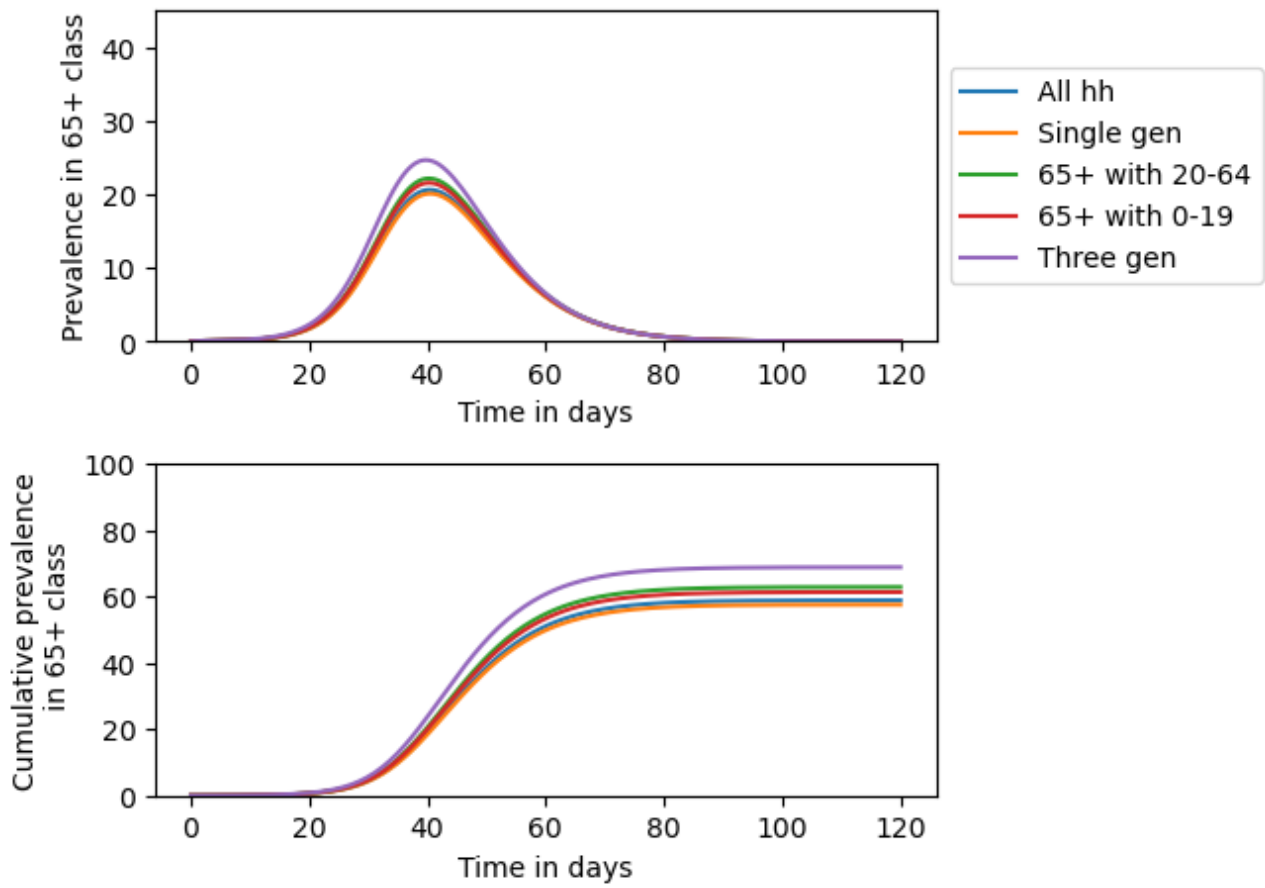
Figure 8: Projected prevalence and cumulative prevalence with targeted 25% reduction in between-household transmission.
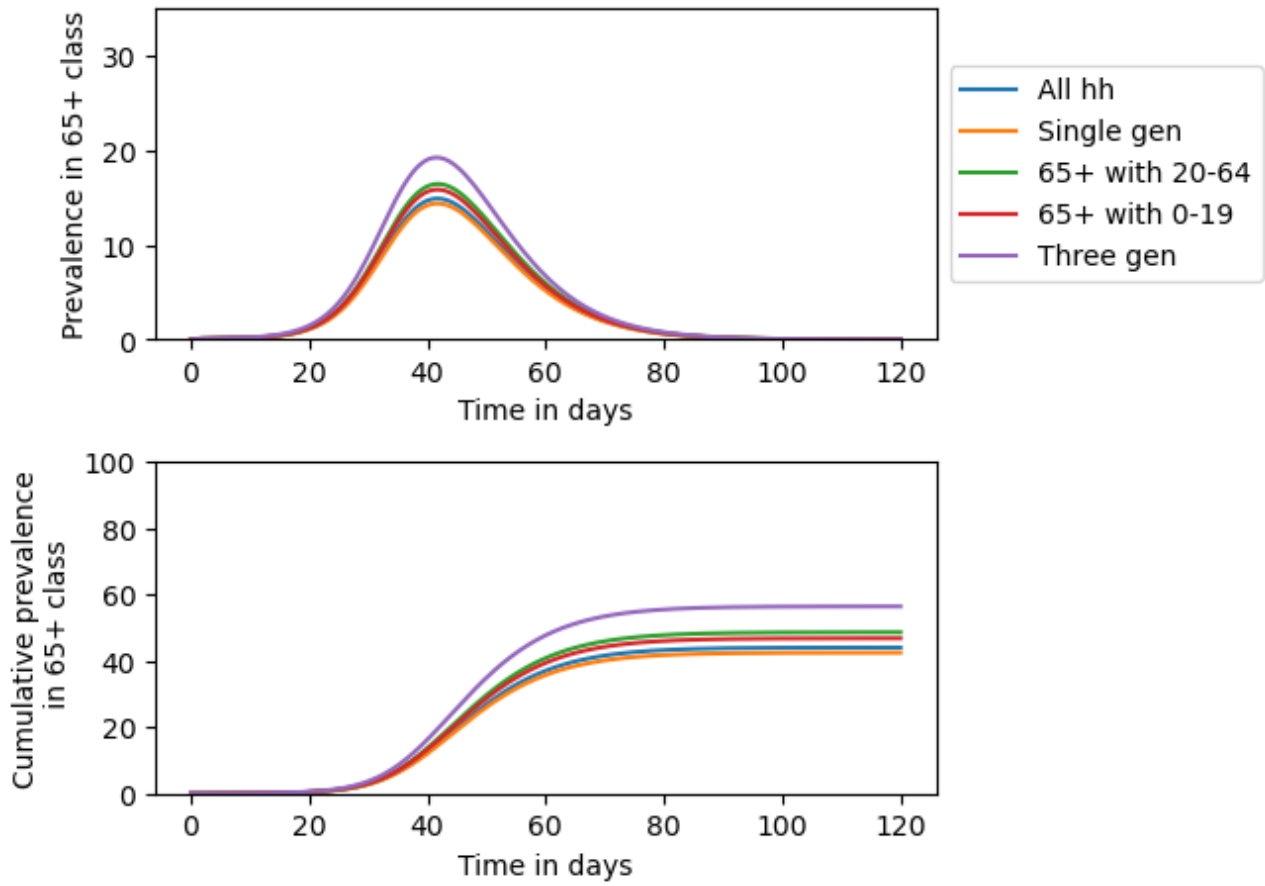
Figure 9: Projected prevalence and cumulative prevalence with targeted 50% reduction in between-household transmission.