SPI-Kids report: evaluating the increase in transmission for different back-to-school scenarios

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1 Aim

Evaluate increase in transmission for different scenarios for school re-opening using the analysis of contact matrices from BBC Pandemic study filled with missing data from POLYMOD for under 13-year-olds.

2 Introduction

The following scenarios are considered:

- 1. stay shut (4% of EY, 2% other kids in schools) - *baseline (lock-down) matrix*
- 2. more vulnerable children and keyworkers' kids (11% of all years)
- 3. transition years (Y5/6/10/12) (25% of total pupil population -> *changed to include those actual age groups and setting their attendance to 100%*)
- 4. All Early Years settings to resume
- 5. All primary to resume (100% primary, 57% of all school age)
- 6. All secondary to resume (100% secondary)
- *7. Half time A - Full class two weeks on/two off - not done here, temporal spectral analysis)*
- 8. Half time *B - half classes in AM/PM each day* (scale all school contacts 50%)
- 9. All *school contacts back to normal (100%)*

In order to best reflect the age-groups in different school settings (early years, primary, secondary) in different scenarios, and the impact of school re-opening on the rest of the population, we consider the following age groups (as it is close to the end of year): 0-5, 6-9, 10-11, 12-14, 15-15, 16-16, 17-17, 18-18, 19-29, 30-39, 40-49, 50-59, 60-69, and 70+.

3 Methods

As the BBC data doesn't include children 12 years old and younger, we use the individual POLYMOD dataset to infer the contacts in different context in these age groups. We fill out the information for the age-groups 0-5, 6-9, 10-11 from POLYMOD by scaling the missing square with the ratio of dominant eigenvalues of the symmetric subset of the BBC matrix without missing values, and the same subset of the POLYMOD matrix. The scaling factor $q = \rho(\text{BBC}_S)/\rho(\text{POLYMOD}_S)$ where S designates this symmetric subset of the matrix and $\rho()$ is the dominant eigenvalue (spectral radius) ensures that the dominant eigenvalue of the filled in BBC matrix stays intact. We assume that contact information by 13, and 14 year-olds in the BBC data-set is representative of the entire age group 12-14.

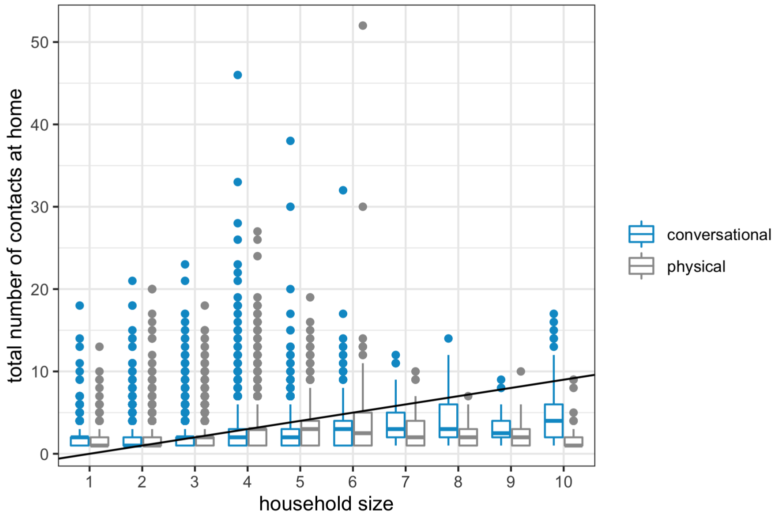

Figure 1: The number of contacts made at home by BBC users in households of different sizes. The line indicates the maximum number of contacts with household members (household size - 1).

To be able to evaluate school re-openings we also need a baseline matrix during current interventions (lock-down). In a previous analysis for SPI-M we have achieved that by changing the contributions of different settings (home, work, school, other) to the overall mixing matrix. In that approach the "home" aspect of the overall mixing matrix remained unchanged. This was under the assumption that most of the contacts at home occur with the household members, and that this wouldn't change under lock-down.

However, analysing the home contacts further shows there is considerable level of contact at home with visitors (26% of all contacts made at home in BBC data, and 27% of households have visitors) (Fig 1) in both BBC and POLYMOD data. We therefore set home contacts during the lockdown to 80% of their pre-pandemic levels, allowing for some non-household at home contacts to still take place (e.g. deliveries).

Note that the maximum number of contacts made at home with other household members is equal to household size minus 1. As some people are still likely to have visitors during the lock-down (e.g. food and parcel deliveries), we account for at most one visitor at home to avoid imposing too low of a bound on at home contacts in our calculation of the baseline intervention matrix.

3.1 Relative R

We build the intervention matrices for different scenarios by allowing school-contacts from specified age-groups and specified target proportion in school for those age groups and compare the change in R relative to the baseline intervention matrix (Scenario 1). Note that we take all the pre-pandemic school contacts for that a given group (scaled by proportion in attendance), so the numbers presented here are an overestimate of school contacts children will experience in partial school openings. The numbers presented here give a conservative view, and can be viewed as the maximum increase in transmission for a given scenario.

To capture different susceptibility in children we multiply *rows* of the contact matrix for age groups i younger than 18 with the assumed reduction in susceptibility v_i compared to adults $\hat{M} = (v_i m_{ij})$. To allow for age-specific infectiousness we multiple the *columns* of the contact matrix for those age-groups j younger than 18 with the assumed reduction in infectiousness compared to adults, $\hat{M} = (m_{ij} w_j)$ for physical only and all contacts (Table 1 and Figs 3 and 4).

We use the 2020 UK population estimate for the reciprocity of contacts in the population.

We analyse the interventions by using the fact that the mixing matrix is proportional to the next generation matrix that has a dominant eigenvalue equal to R_0. We define the relative R as the ratio of spectral radii of intervention matrix $\hat{M}$ to the baseline matrix M, $RR = \frac{\rho(\hat{M})}{\rho(M)}$ and show the

Table 1: Relative R values compared to the current interventions ($\rho(M_{scenario})/\rho(M_{baseline})$) for different interventions and different types of contacts (all, physical) and various assumptions of relative infectiousness of children compared to adults for different scenarios of reopening schools. As matrices are symmetric, assuming different susceptibility in children relative to adults results in the same relative R values.

contact	infectiousness	2	3	4	5	6	8	9
all	0.25	1.001	1.003	1.002	1.004	1.005	1.052	1.106
	0.50	1.002	1.009	1.004	1.013	1.016	1.062	1.132
	0.75	1.004	1.020	1.007	1.035	1.042	1.077	1.179
	1.00	1.007	**1.040**	1.011	1.083	**1.096**	**1.100**	**1.257**
physical	0.25	1.001	1.002	1.006	1.007	1.002	1.019	1.040
	0.50	1.004	1.006	1.017	1.030	1.008	1.036	1.079
	0.75	1.007	1.012	1.030	1.068	1.017	1.058	1.133
	1.00	**1.011**	1.019	**1.043**	**1.118**	1.029	1.083	1.195
contact	susceptibility	2	3	4	5	6	8	9
all	0.25	1.001	1.003	1.002	1.004	1.005	1.052	1.106
	0.50	1.002	1.009	1.004	1.013	1.016	1.062	1.132
	0.75	1.004	1.020	1.007	1.035	1.042	1.077	1.179
	1.00	1.007	**1.040**	1.011	1.083	**1.096**	**1.100**	**1.257**
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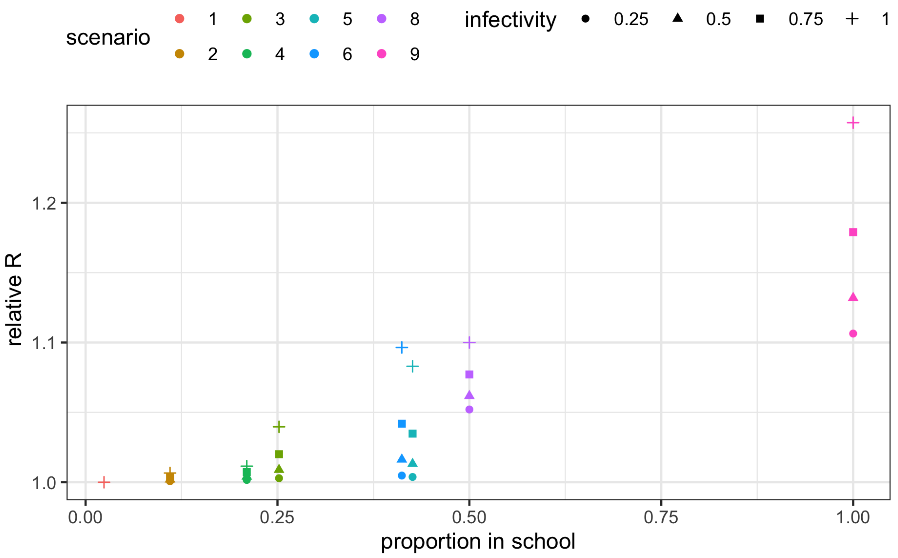

Figure 2: Relative R for different scenarios and different values of infectiousness in children (compared to adults) relative to proportion of the school-age population that is in attendance.

results for different levels of infectiousness and susceptibility in Table 1.

The results are not sensitive to the assumptions on the household contacts in the baseline matrix.

Figure 2 summarises the results from Table 1 and shows the relative increase in transmission with respect to the proportion of the school-age children that are in attendance.

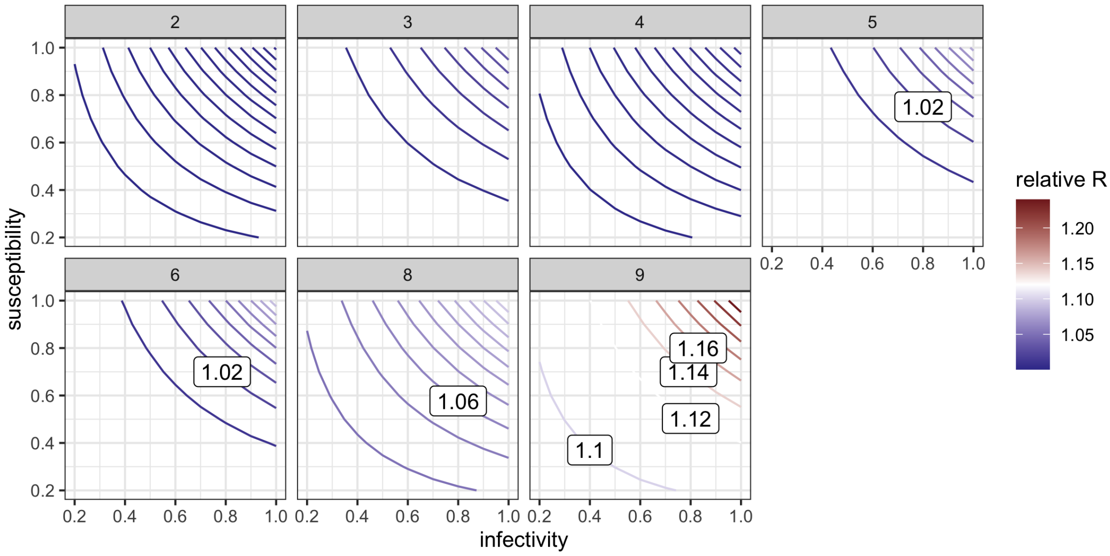

Figure 3: Expected change in R for different school reopening scenarios compared to the baseline (lock-down) mixing matrix for different scenarios considering ALL contacts.

4 Conclusions

Overall, assuming contact structure informed by BBC matrices, scenarios for school re-opening considered here resulted in at most 25.7% increase in overall population transmission, when all school contacts resume at their pre-pandemic levels. The actual increase in transmission following school re-openings is very sensitive to assumptions on the infectiousness and susceptibility of children compared to adults.

For scenarios 2, 4 and 5 (focused on youngest children, primary school) higher increases in relative R are found considering physical-only contacts than all contacts, while the opposite is observed for scenarios 3 and 6-10.

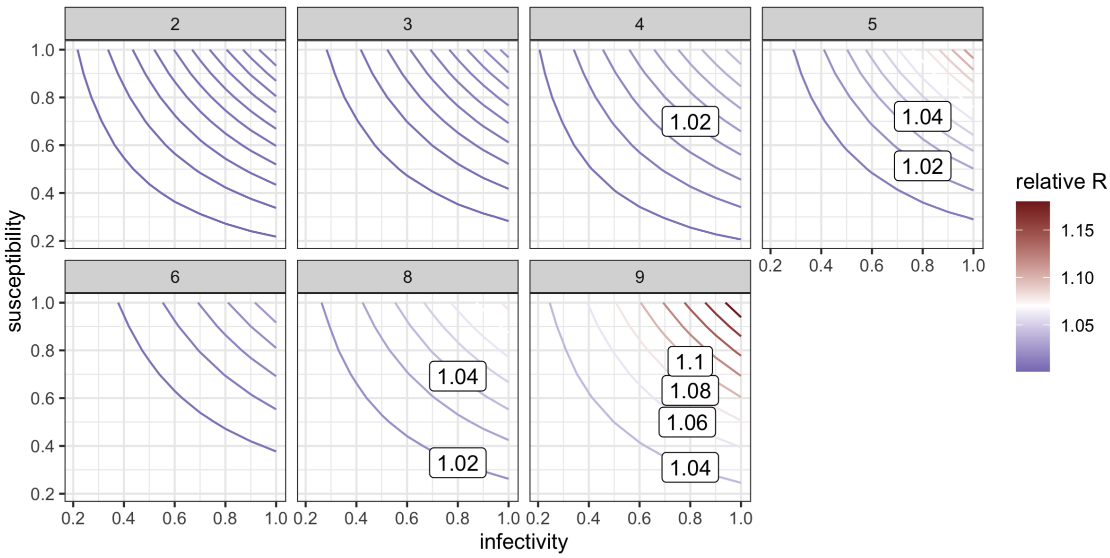

Figure 4: Expected change in R for different school reopening scenarios compared to the baseline (lock-down) mixing matrix for different scenarios considering PHYSICAL contacts.

Table 2: Effect on transmission compared to the current baseline (interventions in place - no effect, 0) and relative to scenario 9 (all school back to normal - 1), or $\frac{RR_{scenario} - RR_{baseline}}{RR_9 - RR_{baseline}}$. Values are for different type of contact (all, physical) and various assumptions of relative infectiousness of children compared to adults for different scenarios of reopening schools. As matrices are symmetric, assuming different susceptibility in children relative to adults results in the same effect on transmission as changes in infectiousness.

contact	infectiousness	1	2	3	4	5	6	8	9
all	0.25	0	0.007	0.027	0.016	0.036	0.045	0.489	1
	0.50	0	0.015	0.067	0.031	0.100	0.123	0.468	1
	0.75	0	0.022	0.112	0.041	0.194	0.234	0.431	1
	1.00	0	0.026	0.154	0.045	0.322	0.375	0.389	1
physical	0.25	0	0.031	0.040	0.162	0.186	0.060	0.479	1
	0.50	0	0.048	0.070	0.217	0.378	0.105	0.452	1
	0.75	0	0.054	0.086	0.224	0.510	0.130	0.434	1
	1.00	0	0.057	0.097	0.221	0.601	0.149	0.424	1