The impact of opening schools on the effective reproduction number: Analysis of the Social Contact Survey

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Summary

- We used the Social Contact Survey to estimate the impact of strategies for opening schools.
- The Social Contact Survey had school-specific recruitment, therefore there is good representation of school-aged children in the data.
- The impact of re-opening schools is dependent on the baseline reproduction number, adherence to other social distancing measures and the infectiousness of children.
- With $R_0 = 3.1$, reinstating primary school contacts is consistent with a reproduction number less than 1, if other social contacts are severely limited.
- Re-opening schools under a scenario with a higher baseline reproduction number results in $R_t > 1$.
- Reinstating primary school contacts has a smaller impact than reinstating secondary school contacts due to the greater numbers of contacts reported by 15 to 19-year olds, compared to younger age groups.
- The infectiousness of children has a small, but potentially important impact on the reproduction number.

Methods

Data description

The Social Contact Survey surveyed 5,861 individuals in the UK in 2010 about their social contacts[1]. Participants were recruited using three approaches: a paper survey sent to people in the post, an online survey and an online survey aimed specifically at school-aged children. Participants were asked about the number of people they met, duration of the contact and the context.

Estimating the Reproduction Number

We use an individual-based approach for to calculate a reproduction number of each of the participants of the Social Contact Survey[2]. The reproduction number for an individual is given by

$$R_{ind} = \tau \sum_{i=1}^{k} n_i d_i$$

Where k is the number of contact events reported by each participant, n_i is the number individuals in that contact (participants could report groups of similar contacts), d_i is the duration of the contact and τ is the probability of transmission. The duration of the contact was scaled by the number of people in a group if the group contained more than 20 individuals.

The population-wide reproduction number, R_0, is calculated as the age-adjusted mean of the individual reproduction numbers squared, i.e.

$$R_0 = \frac{\sum_{j=1}^{N} a_j \left(\alpha_j R_{ind}^{j}\right)^2}{\sum_{j=1}^{N} a_j}$$

Where N is the number of participants in the Social Contact Survey and $0 \leq \alpha_j \leq 1$ is the relative infectiousness of children relative to adults. a_j is the age-specific weighting estimated to match the age distribution in the UK population, calculated as the ratio of the proportion of individuals aged a in the UK to the Social Contact Survey sample,

$$a_j = \frac{P_{UK}(a)}{P_{SCS}(a)}$$

We estimated the transmission probability τ by scaling the population-wide R_0 to match the measured reproduction number in the UK pre-control measures of 3.0-4.0.

The impact of social distancing on the reproduction number

We use the participant's age, the contact context and contact duration to simulate the impact of opening schools. For each intervention, we sample the contacts to be restricted at random for a given level of adherence, remove those contacts and recalculate the reproduction number. We investigated:

- S1: Schools closed, with 2% of children attending.
- S2: Schools open for 11% of children.
- S3: School attendance for school-aged children aged 10, 11, 16 and 18 years old (Transition years).
- S4: School attendance for school-aged children aged 5 and 6 years old (Early years).
- S5: School attendance for school-aged children aged 5, 6, 7, 8, 9, 10, 11 years old (Primary school years).
- S6: School attendance for school-aged children aged 12, 13, 14, 15, 16, 17, 18 years old (Secondary school years).
- S8: School attendance for 50% of all school-aged children.
- S9: School attendance for all school-aged children.

Results

The dedicated school survey boosted participation rates of children. There were 575 (9.8%) participants under 18, of which 326 were between 11 and 18 years old and 277 were between 5 and 10 years old. Figure 1 shows the number of reported contacts by five-year age group. 15 to 20-year olds and 40 to 44-year olds reported the highest median number of contacts of 16 unique contacts per day. Participants over 65 years old had the lowest median number of contacts.

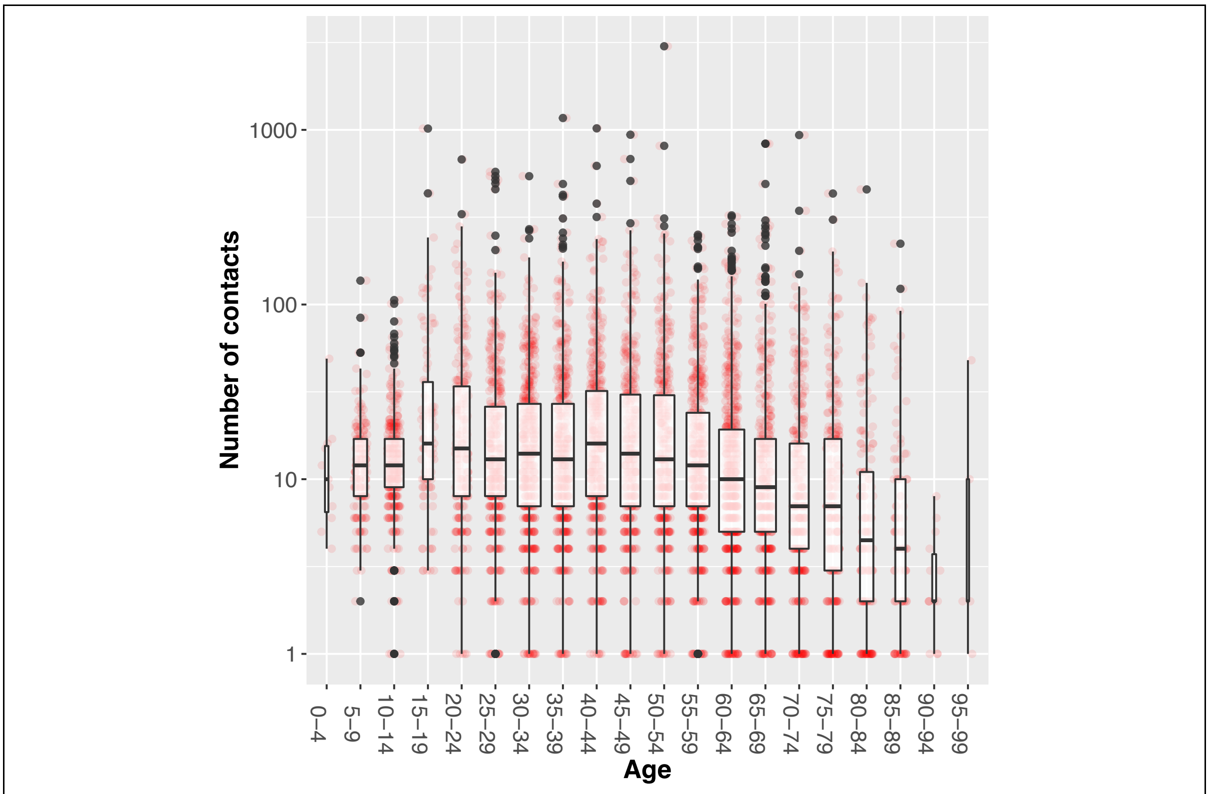

Figure 1: Number of reported contacts by five-year age group. The red points show individual degree, the box plots show the median and interquartile ranges for each age group. The width of the box is proportional to the number of participants in that age group.

Figures 2 and 3 show the impact of school contacts on R_t for different levels of adherence to other social distancing measures.

Figure 2 shows estimated R_t values for all strategies considered for 30%, 80% and 95% adherence to other measures for $R_0 = 3.1$. When adherence is 95%, strategies S1, S2, S3, S4, S5 and S8 are consistent with a reproduction number slightly less than 1. When adherence drops to 80%, then only strategies S1, S2, and S4 remain consistent with a reproduction number less than 1. For low levels of adherence, no strategies are consistent with a reproduction number less than 1.

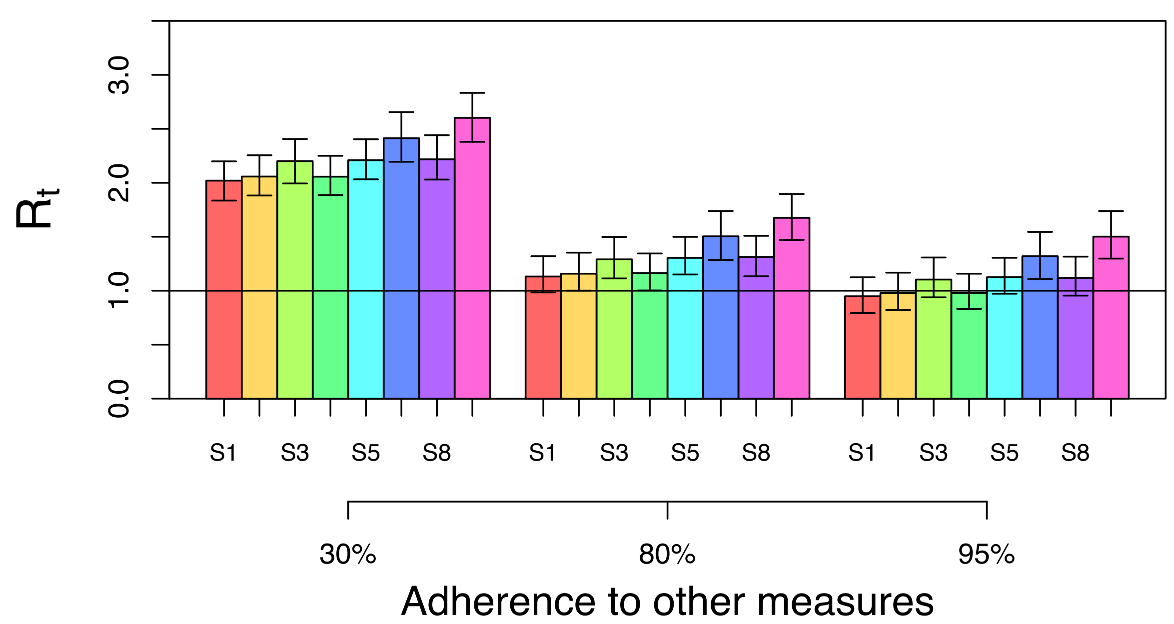

Figure 2: The effective reproduction number after re-instating school-aged contacts for 8 strategies, S1, S2, S3, S4, S5, S6, S8, S9. We have assumed here that children are as infectious as adults. Baseline R_0=3.1.

Figure 3 compares opening primary schools with opening secondary schools in more detail. For most levels of adherence to other social distancing measures, we estimate that re-instating primary-school contacts has a lower impact on increasing transmission than re-instating secondary-school contacts.

The baseline estimate of R_0 is important for assessing the impact of opening schools. For $R_0 = 3.1$ we find that, for the highest levels of adherence to other social distancing measures, opening primary schools is consistent with R_t less than 1, but opening secondary schools is not.

For $R_0 = 3.9$ we find that, for the highest levels of adherence to other social distancing measures, re-instating schools is not consistent with a reproduction number less than 1.

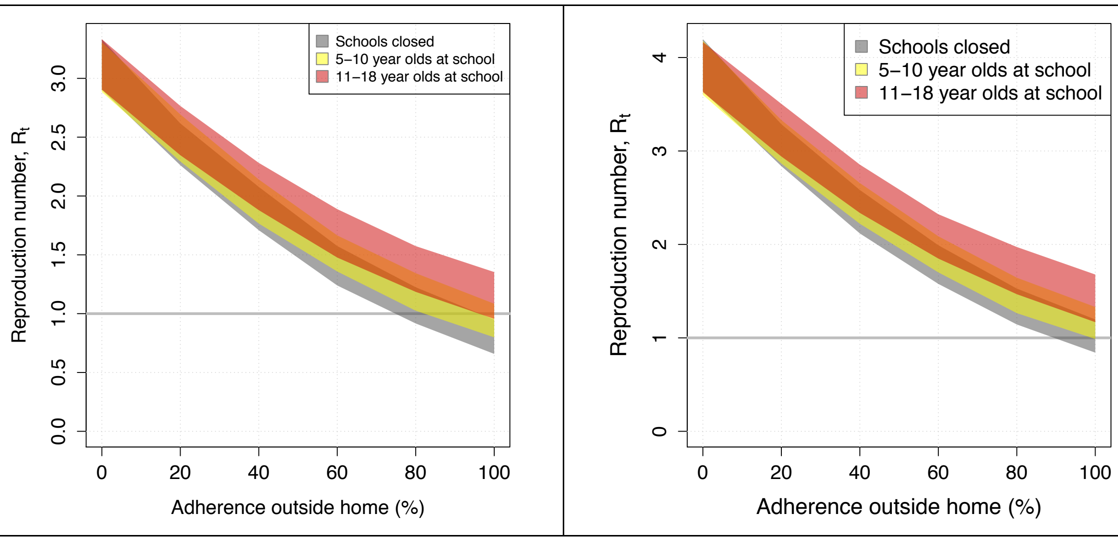

Figure 3: The effective reproduction number comparing strategies S1: schools closed, S5: opening primary schools and S6: opening secondary schools. We have assumed here that children are as infectious as adults. Left panel: baseline R_0=3.1, right panel: R_0=3.9.

The impact of the relative infectiousness of children is greater when re-instating secondary school contacts than when re-instating primary school contacts (Figure 4). For secondary schools with a 90% reduction in other non-home contacts, the mean R_t is 0.9 (95%CI 0.8, 1.1) if children are not infectious at all and 1.3 (1.1, 1.5) if children are as infectious as adults. For primary schools with a 90% reduction in other non-home contacts, the mean R_t is 0.9 (0.8, 1.1) if children are not infectious at all and 1.1 (0.9, 1.2) if children are as infectious as adults.

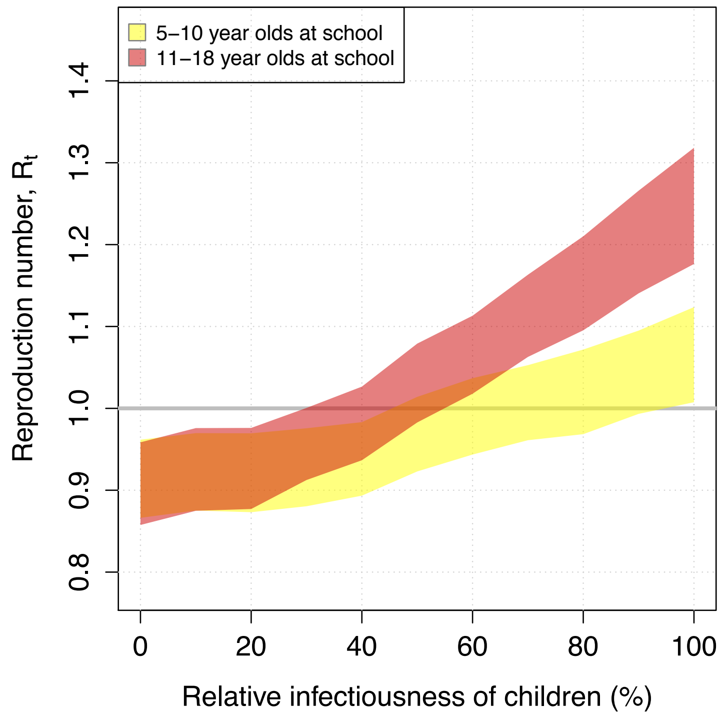

Figure 4: The impact of infectiousness of children on effective reproduction number when primary schools are open. We have assumed an 90% reduction in all other contacts outside the home. Baseline R_0=3.1.

Strengths

- Due to the school-specific recruitment, we have good representation of school-aged children.
- The contacts reported here are self-reported contacts by children. So, a child might report 5 contacts, even though they are in a class of 30.

Weaknesses

- We haven't accounted for other contacts increasing associated with schools opening – e.g. parent-parent contact and additional work, travel or leisure contacts that could occur due to schools opening.