This is a draft that has since evolved.

1. We have refined the equation for R_0, so that the "individual R$_0$" is

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

And the population-level reproduction number is

$$R_t = \frac{\sum_{j=1}^{N} \alpha_j \varepsilon_j \left(R_{ind}^j\right)^2}{\sum_{j=1}^{N} \alpha_j}.$$

This does not affect the overall results. The confidence bounds are now smaller and less variable with wider adherence.

2. We have incorporated more data on children's social contact patterns. The overall results are similar.

BSI and Relaxed Interventions: Social Contact Survey analysis

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Summary of methods:

The Social Contact Survey surveyed 5,388 individuals in the UK in 2010 about their social contacts [1]. Participants were asked about the number of people they met, duration of the contact and the context.

We calculate R_0 using the contact survey by calculating a reproduction number per person and then taking a weighted mean of the individual reproduction numbers, where individuals are weighted according to age to match the UK age distribution. The population-level R_0 is:

$$R_0 = \tau \langle and \rangle$$

Where $\langle \cdot \rangle$ is the average over all participants, n is the number of unique contacts, d is the duration of the contact, a is the age-specific weighting and τ is the transmission constant. We estimated the transmission constant τ by using an estimated R_0 for the UK of 2.8. Then $\tau = 2.8/\langle and \rangle$.

To estimate the impact of restricting social contacts, we randomly sample contacts for a given level of adherence and recalculate the reproduction number.

Additionally, participants were able to list "groups" of contacts as multiple similar contacts, e.g. I met four people for 3 hours. We investigate the impact of limiting the size of groups of contacts by setting the group size equal to min(max group permitted size, group size) for leisure/other contacts, while assuming a given level of adherence to the restricting work contacts, then recalculating the reproduction number.

Mean and confidence intervals are calculated by bootstrapping data 1000 times.

Results

R_t Estimates

Estimates of R_t depend critically on levels of adherence to social distancing measures. For instance, options 5, 6 and 7 result in R_t less than 1 for high levels of adherence, but R_t values greater than 1 for low levels of adherence (figure 1).

Table 1 gives indicative values for R_t for given levels of adherence, based on an interpretation of the social distancing options 1-7. The assumptions behind the estimates are given in the third column.

The most stringent measures are estimated to result in reproduction numbers less than 1, on average. However, the confidence intervals for options 5 and 6 include values greater than 1.

All options with schools open resulted in average reproduction numbers greater than 1. However, for high levels of adherence, option 4a, which permitted non-essential retail

(modelled as contacts less than 10 minutes) and some other leisure and other contacts, included reproduction numbers less than 1.
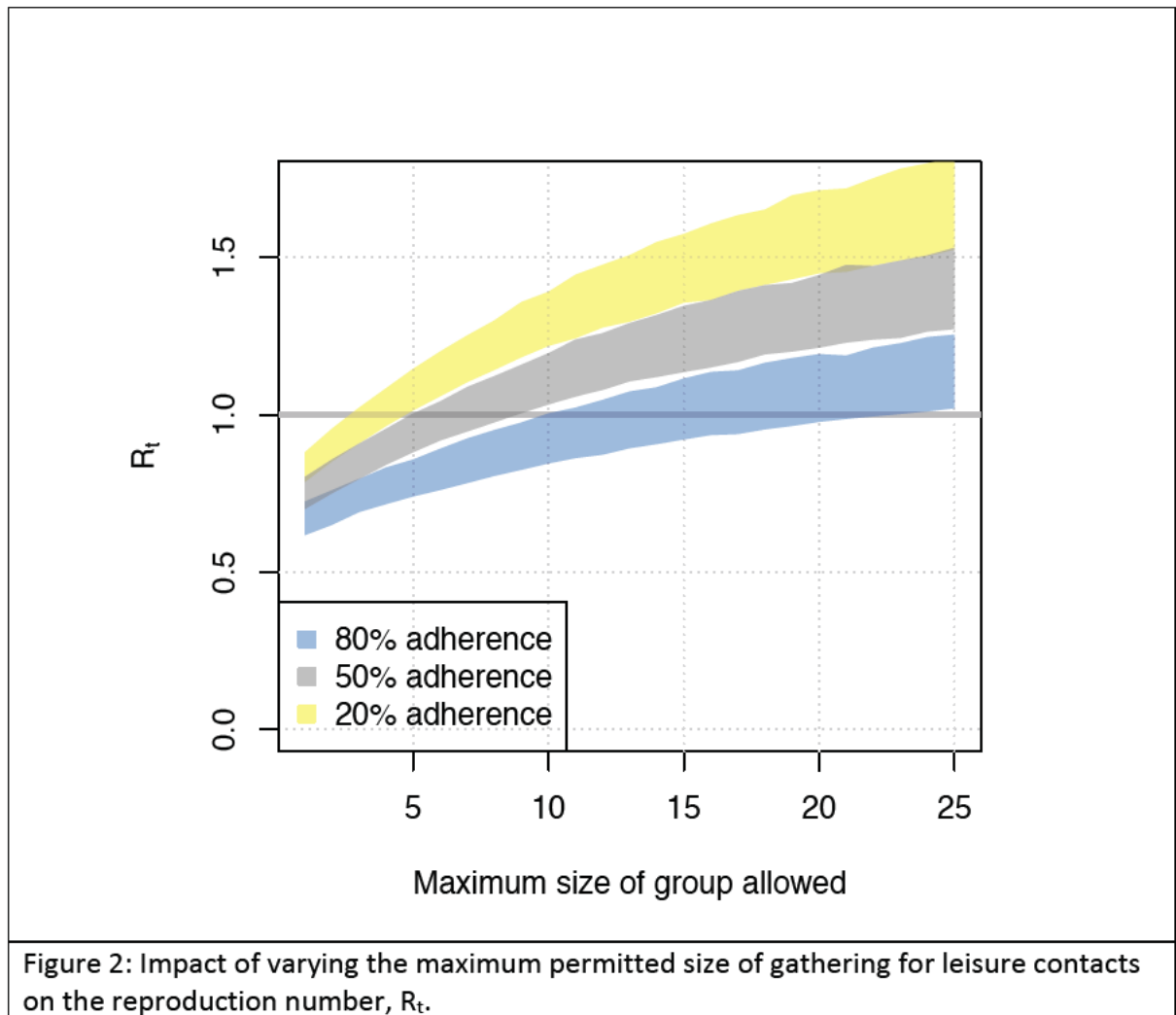
Table 1: Estimated R_t values for different social distancing measures.

Interventions	R_t	Comments
Option 1,2,3	0.54 (0.49, 0.59)	80% reduction in work contacts, 95% reduction in school contacts, no other or leisure contacts, home contacts as usual
Option 4	0.54 (0.49, 0.60)	80% reduction in work contacts, 95% reduction in school contacts, home as usual, other contacts < 10 mins allowed
Option 4a	1.03 (0.78, 1.33)	Option 4 + schools open
Option 5	0.86 (0.73, 1.08)	60% reduction in work contacts, 95% reduction in school contacts, 60% reduction in leisure contacts (up to 5 people), home as usual
Option 5a	1.33 (1.02, 1.72)	Option 5 + schools open
Option 6	0.87 (0.73, 1.11)	60% reduction in work contacts, 95% reduction in school contacts, 60% reduction in leisure contacts (up to 5 people), other contacts < 10 mins allowed, home as usual
Option 6a	1.34 (1.02, 1.73)	Option 6 + schools open
Option 7	1.6 (1.3, 1.97)	30% reduction in work contacts, schools open, 30% reduction in leisure contacts (and up to 5 people), other contacts < 10 mins allowed, home as usual

Figure 1: Impact of adherence on social distancing options
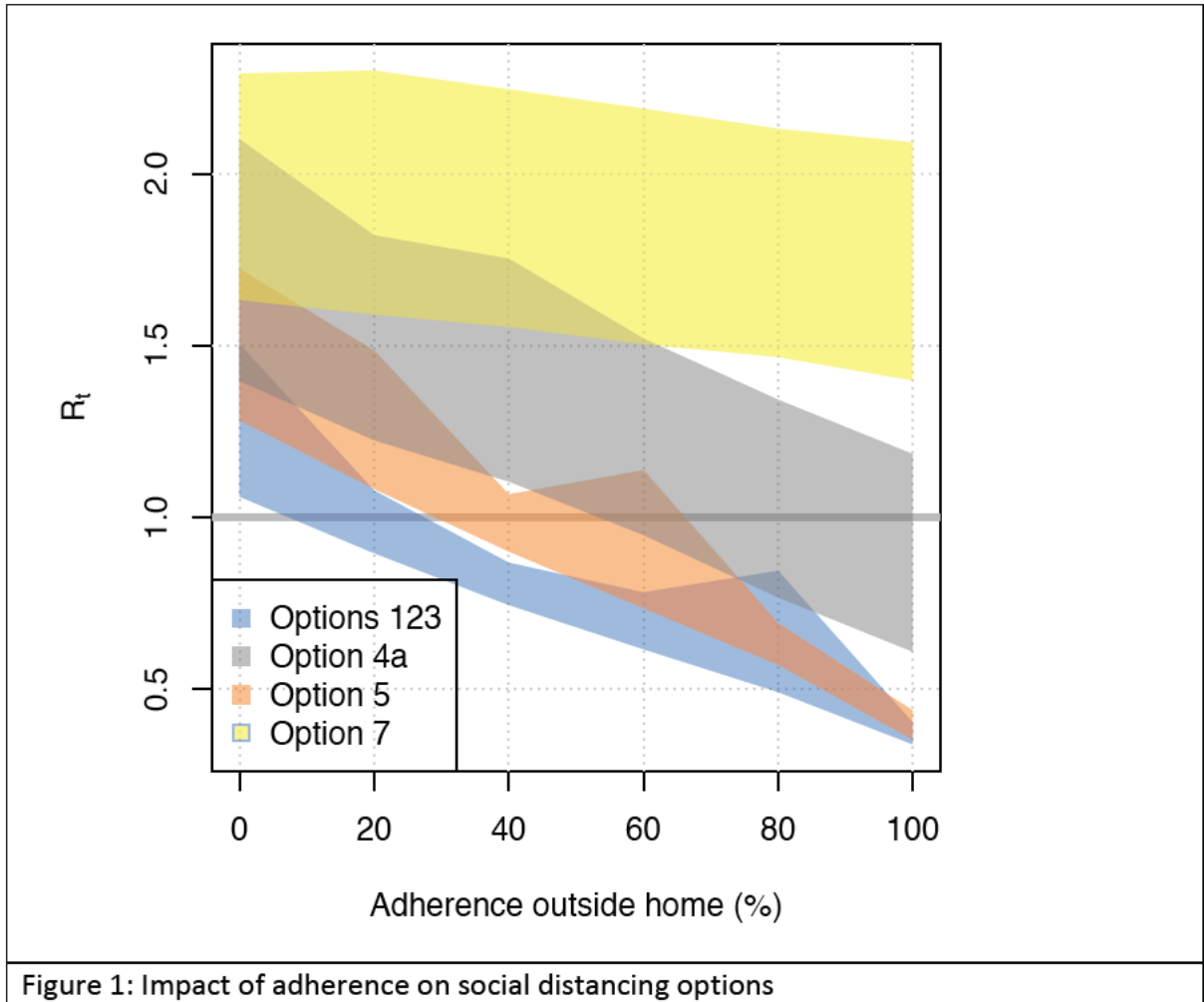
Impact of group size on R_t

The maximum size of a group that keeps $R_t<1$ depends on the level of adherence to social distancing measures for work and school contacts. For an 80% adherence to other social distancing measures, groups between 10 and 21 people can occur while still achieving $R_t<1$. For 50% adherence to other social distancing measures, groups between 5 and 8 people can occur while still achieving $R_t<1$. For 20% adherence to other social distancing measures, groups between 3 and 5 people can occur while still achieving $R_t<1$ (figure 2).

Figure 2: Impact of varying the maximum permitted size of gathering for leisure contacts on the reproduction number, R_t.

Conclusions

Based on our findings and the Social Contact Survey data, work contacts have the biggest impact on the reproduction number. Some scenarios with schools open were consistent with reproduction numbers less than 1, although high adherence to other measures would be necessary.

With high levels of adherence to other measures, small groups of social contacts were consistent with reproduction numbers less than 1.

Limitations

- We are modelling individuals as egos, therefore we don't know about connections between highly connected individuals.
- This analysis assumes a totally susceptible population. Once immunity in the population accumulates then social distancing measures will be more effective than predicted here.
- We modelled adherence at a contact level; with further data, we will investigate modelling adherence at an individual level
- The survey data is from 2010, and included ~5,000 participants, although was broadly geographically representative.

References

[1]   Danon L, Read JM, House TA, Vernon MC, Keeling MJ. Social encounter networks: Characterizing great Britain. Proc R Soc B Biol Sci 2013;280. doi:10.1098/rspb.2013.1037.