The effect of social distancing on the reproduction number and number of contacts in the UK from a social contact survey
Report for survey week 36

Christopher Jarvis, James Munday, Amy Gimma, Kerry Wong, Kevin Van Zandvoort, Sebastian Funk, John Edmunds on behalf of CMMID COVID-19 Working Group, London School of Hygiene and Tropical Medicine.

Report for SPI-M-O and SAGE, 9th December 2020
Data up to 28th of November

Summary

- We estimate R_0 for England to be 1.1 (95% interval 0.7 1.5) for the period of 18th - 28th November.
- The average contacts across the nations for adults have reduced since September. As of November 28th the contacts are consistent with those seen during April to June at close to 2 contacts per person per day. This pattern is present across for 18-60 year olds and across all English regions.
- The average contacts for children in the UK remain high reflecting that schools are open, which will increase our estimate of R_0.
- We removed R_0 estimates of Scotland, Wales, and Northern Ireland due to low numbers of participants in these areas and lower confidence in our estimates. We have therefore moved to presenting average contacts whilst exploring this issue with further modelling.
- R_t estimates will be somewhat lower than R_0 estimates due to the accumulation of immunity. This effect will be greatest in those areas which have experienced the highest rates of infection.

Estimating R_0 in UK countries

We present two-weekly rolling estimates of R_0 using data from October 1st until November 28th (Figure 1). Over the most recent 6 estimates, England has remained consistently between 0.7 and 1.5 (Table 1). In general, measured contact behaviour suggests that transmission potential appears to have remained stable over this time (Figure 1). Due to lower numbers of participants we have removed R_0 estimates and focused on average contact overall for Scotland, Wales, and Northern Ireland, see methods for details.

Estimates are calculated from contact survey data alone and measure the expected relative transmission in a susceptible population based on contact data from a period with no restrictions on social contacts. Estimates will be higher than estimates of the effective reproduction number due to some immunity in the population.

Table 1: Estimate of R_0 by country, comparing CoMix with POLYMOD over time. Values of R_0 for two week periods, excluding the most recent estimate with 95% intervals.

Country	2020-10-15 to 2020-10-28	2020-10-22 to 2020-11-04	2020-10-29 to 2020-11-10	2020-11-04 to 2020-11-18	2020-11-11 to 2020-11-23	2020-11-18 to 2020-11-28
England	1.1 (0.7 1.4)	1.0 (0.7 1.4)	1.1 (0.7 1.5)	1.1 (0.7 1.5)	1.1 (0.7 1.4)	1.1 (0.7 1.5)

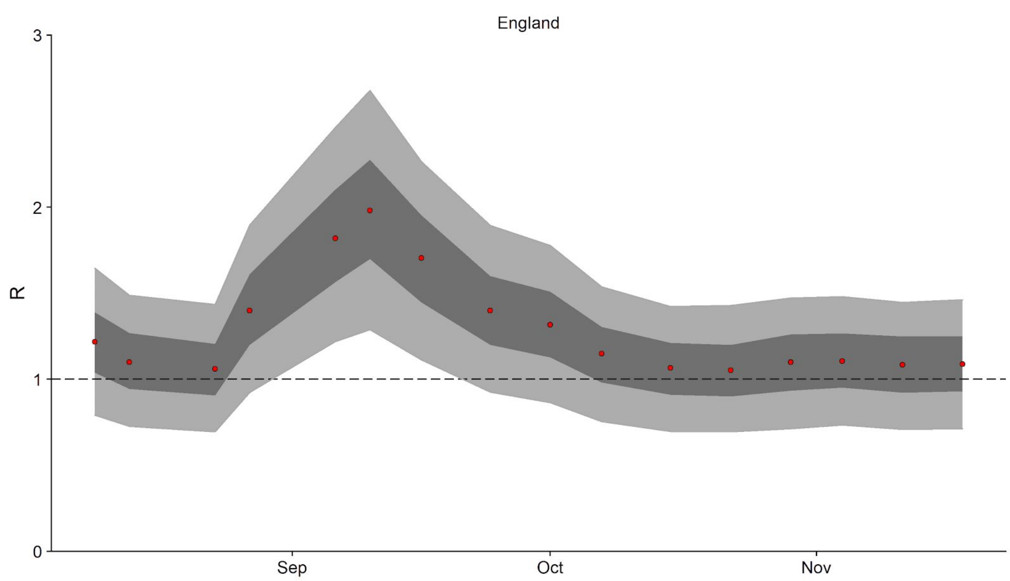

Figure 1: Estimates of R_0 from CoMix by country. Estimates of R_0 by country, using truncation at 200. R_0 was calculated by applying the ratio of the dominant eigenvalues of CoMix and POLYMOD to an assumed R_0 of 2.6. The dark and light ribbons show the inter quartile range and the 95% interval. England was calculated using nine age groups.

Mean contact rates in England have steadily reduced since September from about 4 per person per day to just over 2 per person per day (Figure 2). This is more marked in ‘other’ settings (not home or work/school) though the size of these contacts remains low. Work/school contacts have also reduced albeit less substantially and are more subject to fluctuation from week to week. Overall contacts have reached similar levels to those recorded during the period of restrictions between April and July. Although uncertainty in our estimates is high, the other nations in the UK and in each region of England (Figure 3) appear to have followed a similar pattern, reducing gradually since September.

These patterns appear to be consistent through all adult age-groups (Figure 4), however the reported number of contacts has been notably lower in over 60 year olds. In contrast to adults, contacts of children aged 5-17 years old have remained high with greater variability from week to week, driven by education contacts with the exception of a period of time in October, which coincides with the half-term break (Figure 5).

These results indicate that increased contacts of children relative to earlier in 2020 are an important factor in our estimate of R_0 remaining high compared to the period of restrictions between April and July (Figure 1).

Figure 2: Setting-specific mean contacts of Adults for UK nations over time. Uncertainty calculated using Bootstrapped accounting. Contacts truncated to 50 contacts per participant. Observations are smoothed over two weeks to account for panel effects. Educ = education setting.

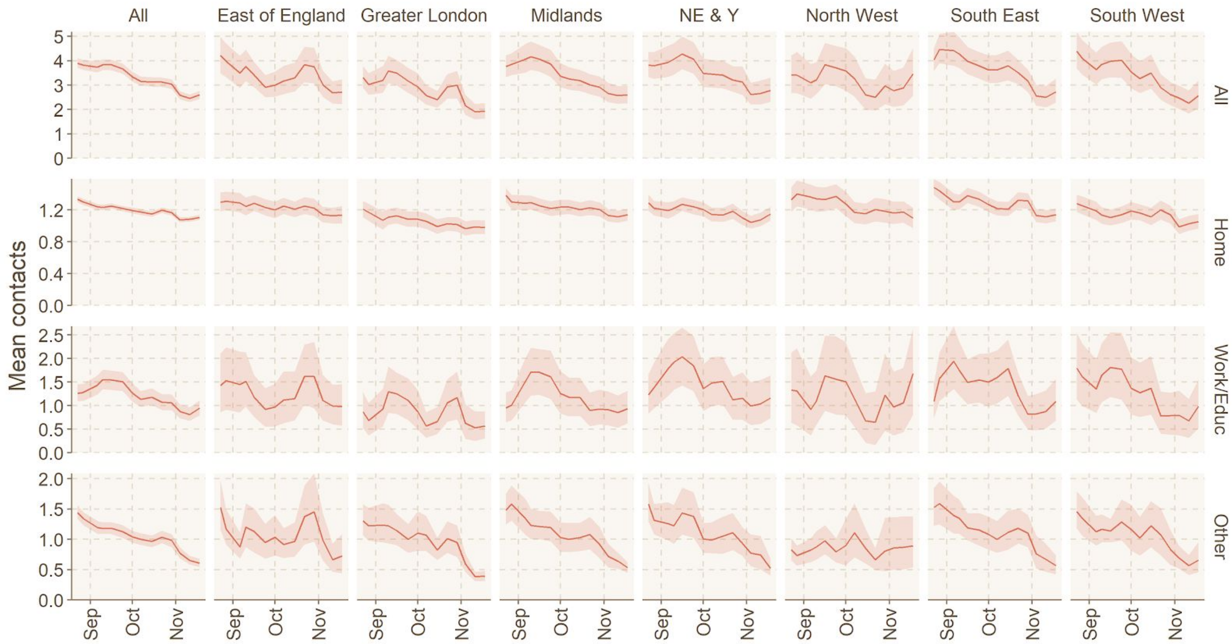

Figure 3: Setting-specific mean contacts for adults by English region over time. Uncertainty calculated using bootstrapping. Contacts truncated to 50 contacts per participant. Observations are smoothed over two weeks to account for panel effects. NE & Y = North East and Yorkshire. Educ = educational setting.

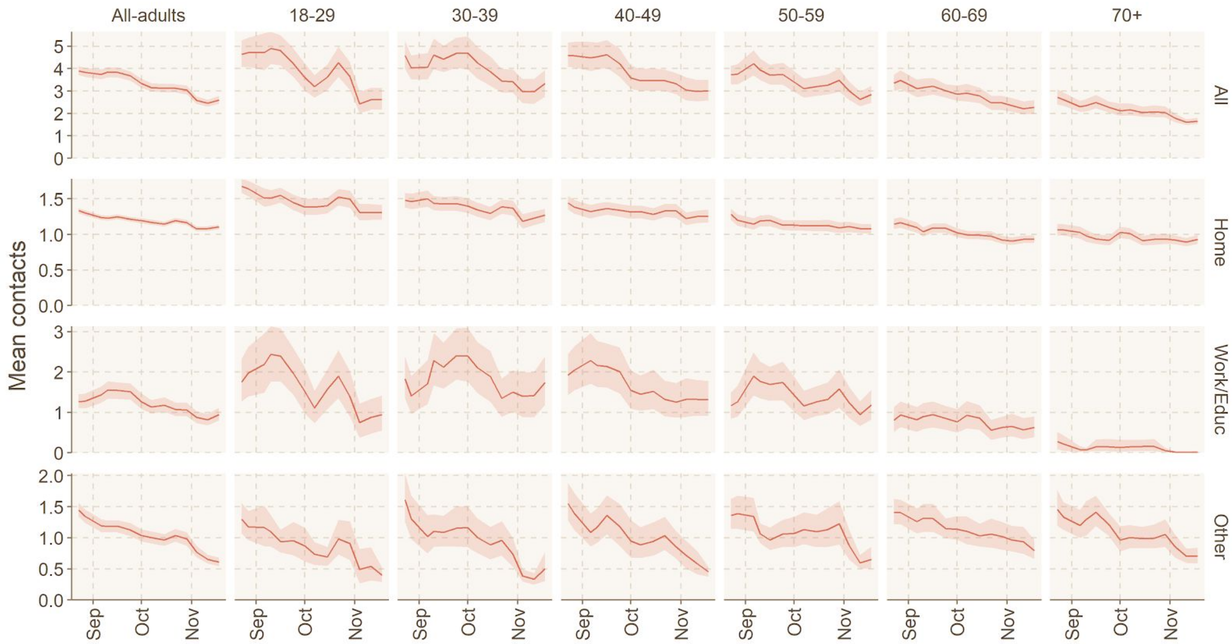

Figure 4: Setting-specific mean contacts by age-group for adults over time. Uncertainty calculated using bootstrapping. Contacts truncated to 50 contacts per participant. Observations are smoothed over two weeks to account for panel effects. Educ = educational setting.

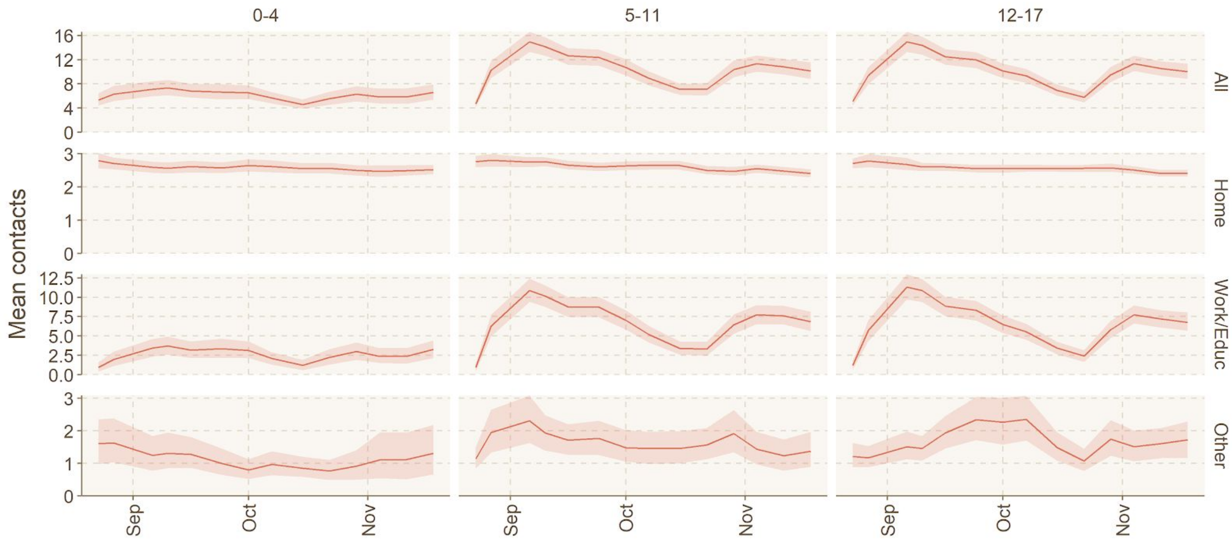

Figure 5: Setting-specific mean contacts by age-group for children over time. Uncertainty calculated using bootstrapping. Contacts truncated to 50 contacts per participant. Observations are smoothed over two weeks to account for panel effects. Educ = educational setting.

Methods

CoMix is a behavioural survey, launched on 24th of March 2020. The sample is broadly representative of the UK adult population. Participant's are invited to respond to the survey once every two weeks. We collect weekly data by running two alternating panels. Parents complete the survey on behalf of children (17 years old or younger). Participants record direct, face-to-face contacts made on the previous day, specifying certain characteristics for each contact including the age and sex of the contact, whether contact was physical (skin-to-skin contact), and where contact occurred (e.g. at home, work, while undertaking leisure activities, etc). Further details have been published elsewhere[1]. The contact survey is based on the POLYMOD contact survey[2].

We calculated the mean contacts using 1000 bootstrap samples. Bootstrap samples were calculated at the participant level, then all observations for those participants are included in a sample to respect the correlation structure of the data. We collect data in two panels which alternate weekly, therefore we calculated the mean smoothed over the 2 week intervals to give a larger number of participants per estimate and account for panel effects. We calculated the mean number of contacts in the settings home, work and school (including all educational establishments, including childcare, nurseries and universities and colleges), and other. We look at the mean contacts by age, country, and region of England. The mean number of contacts is influenced by a few individuals who report very high numbers of contacts (often in a work context). The means shown here are calculated based on truncating the maximum number of contacts recorded at 50 per individual per day.

We constructed age-stratified contact matrices for nine age-groups (0-4, 5-11, 12-17, 18-29, 30-39, 40-49, 50-59, 60-69, and 70+) for England. For child participants and contacts, we did not have exact ages and therefore sampled from the reported age-group uniformly. We fitted a negative binomial model to contact rates between age groups capped at 200 to calculate the mean contacts between each participant and contact age-groups. To find the population normalised symmetrical contact matrix, we multiplied the columns of the matrix by the mean-normalised proportion of the UK population in each age-group. To account and correct for variation in contact patterns at weekends, we calculated rates of contact between age groups for weekends and weekdays separately and combined them by taking the weighted mean for each combination of age-groups . Uncertainty in the contact matrices mean is quantified by performing 1000 bootstrap samples between each age group contact.

Using the same approach, we constructed an age-stratified contact matrix for POLYMOD with the same age bands. Since contacts in polymod are right censored at 29, we corrected for this by fitting a truncated negative binomial distribution. For all participants with 29 recorded contacts, we increased the number of contacts according to the fitted distribution with a left censor at 28, and assigned age-groups proportionally to the contacts the participant reported.

We estimated R_0 by applying a scaling factor of the ratio of the dominant eigenvalues of the CoMix contact matrix over the POLYMOD contact matrix. This scaling factor was applied to an estimate of R_0 sampled from a normal distribution with mean of 2.6 and standard deviation of 0.56. We applied this approach to each UK nation with a truncation of 200 per participant contact age group pair.

Since report 34 in addition to our bootstrapping method, we have implemented a Bayesian approach for estimating the contact matrices using Hamiltonian Monte Carlo to fit a negative binomial distribution. This approach requires a prior distribution of estimates to be set which is then updated by observations from the survey returning a posterior distribution of estimates, which we use to describe the uncertainty in the estimate. In areas where the number of participants was low we found that the results from each of these methods diverged, since the data was insufficient to update the prior. We have only included results where the two approaches had good agreement. We continue to present estimates from the bootstrapping method in the report.

References

1. Jarvis, C. I. *et al.* Quantifying the impact of physical distance measures on the transmission of COVID-19 in the UK. *BMC Med.* **18**, 124 (2020).

2. Mossong, J. *et al.* Social contacts and mixing patterns relevant to the spread of infectious diseases. *PLoS Med.* **5**, e74 (2008).