

COVID-19 Reckoners with Vaccination – Update

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Summary

- Vaccination is incorporated into the ready reckoners.
- The ready reckoners are snapshots of the epidemic with the reproduction number mapped to % of active social contacts.
- The latest version includes:
 - Baseline reproduction number with no controls (default value 4)
 - Seroprevalence (default 25%)
 - COVID security (default 25%)
 - Contact tracing (default 20%)
 - Reduced susceptibility/infectiousness of children (under 11s 25% as infectious as adults, 12-18 year olds 50% as infectious as adults)
 - Vaccine-induced protection against infection (default 60%)
 - Vaccine-induced protection against onward transmission (default 50%)
 - Variable vaccine uptake in the low risk groups (default 80%. Vaccine uptake in oldest age groups is taken to be 95%).
- The behaviour of the reckoners can be explored at <https://ellenbp.shinyapps.io/reckoners/>

Methods

Ready Reckoners

The Ready Reckoners are a mapping from social contact data to the COVID-19 reproduction number, using data from the Social Contact Survey (SCS)(6).

Individual reproduction numbers

Each participant in the Social Contact Survey reports the number, duration and context of their social contacts for a given day. From these data, we calculate their individual reproduction number R_{ind}^j as a product of the number of individuals reported during the contact, the contact duration, transmission modifiers (for reduced susceptibility of children and due to COVID security measures) and indicator functions depending on whether the contact is active (permitted under social distancing measures with a given level of adherence and not prevented due to contact tracing).

$$R_{ind}^j = \beta \sum_{i=0}^{j_k} \chi_c \chi_T \tau_{child} (1 - \tau_{CS}) n d$$

Scaling factor to achieve desired reproduction number	β	Calculated to achieve $R = 4$
Number of contact events reported by individual j	j_k	From data
Number of individuals involved in contact	n	From data
Duration of contact	d	From data

Indicator based on context (home, work, school, leisure, other)	$\chi_c = \begin{cases} 1 & \text{if contact is active/allowed} \\ 0 & \text{otherwise} \end{cases}$	Varied
Modifier for reduced susceptibility/infectiousness of children	τ_{child}	$\tau_{child} = \begin{cases} 0.25 & \text{if age} < 12 \\ 0.5 & \text{if } 11 < \text{age} < 19 \\ 1 & \text{if age} > 18 \end{cases}$
Modifier for reduced infectiousness due to COVID security (does not operate on home contacts)	τ_{cs}	0.25
Contact tracing indicator which is dependent on the age-specific probability of symptoms. If contact tracing takes place then the number of individuals in the contact is reduced by a fraction CTF . This assumes that a fraction CTF of secondary cases are prevented (i.e. successfully traced and isolated).	$\chi_T = \begin{cases} 1 & \text{if } rand > prob(symptoms) \\ CTF & \text{otherwise} \end{cases}$	Varied.

We reduce the contribution of children under 11 by multiplying their individual reproduction number by 0.25. This could equally represent reduced infectiousness or reduced susceptibility. We reduce the contribution of children aged 12 to 18 years by multiplying their individual reproduction number by 0.5.

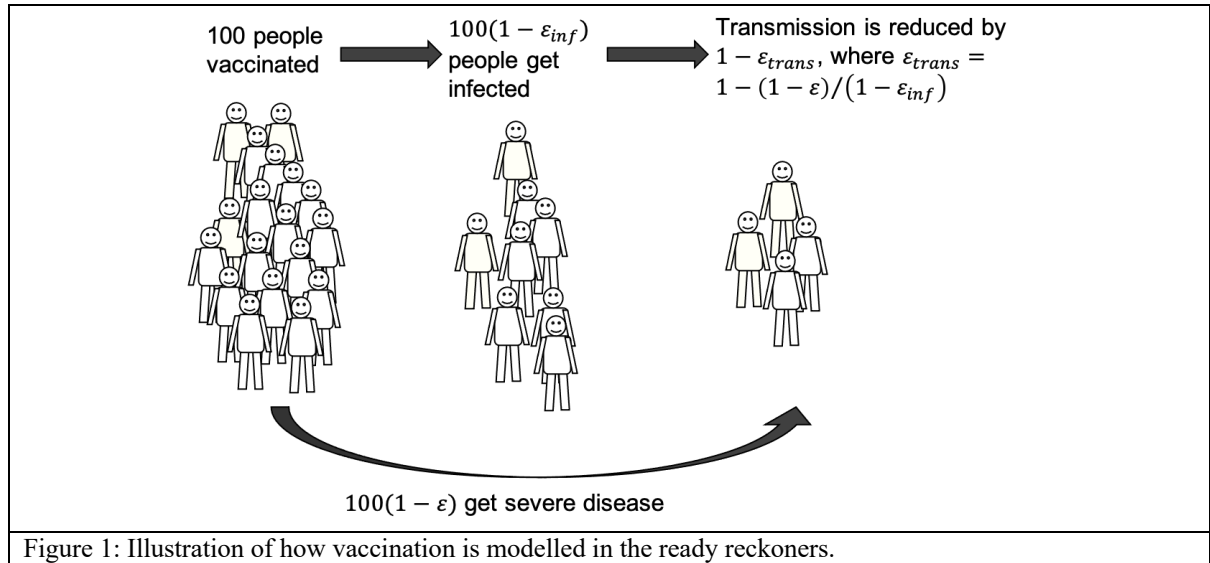
The population-level reproduction number is a bootstrap resample (random sample with replacement) of the individual reproduction numbers with associated weights, α_j , where $\sum_{i=1}^N \alpha_j = 1$:

$$R_t^* = Boot \left((R_{ind}^j)^2, \alpha_j \right) \quad j = 1 \dots N \quad (2)$$

where N is the number of participants in the Social Contact Survey. The age-specific weighting for participant j , α_j , is calculate to match the age distribution of the UK population.

Vaccination

We model two modes of vaccine action: a reduction in the probability of becoming infected and a reduction in the probability of onward transmission – see figure 1.



To model the reduction in susceptibility, we modify an individual's weighting according to the probability that someone in their age group is vaccinated, so $\alpha'_j = \alpha_j(1 - \epsilon_{inf}P_{vac})$, where P_{vac} is the probability that the individual is vaccinated, ϵ_{inf} is the reduction in infection risk. To capture the reduced infectiousness of vaccinated individuals, we reduce the probability of onward transmission by $v_t = 1 - \epsilon_{trans}P_{vac}$, where ϵ_{trans} is the reduction in onward transmission risk associated with vaccination calculated as $\epsilon_{trans} = 1 - (1 - \epsilon)/(1 - \epsilon_{inf})$ where ϵ is the vaccine effectiveness against severe disease. The reproduction number with vaccination is given by:

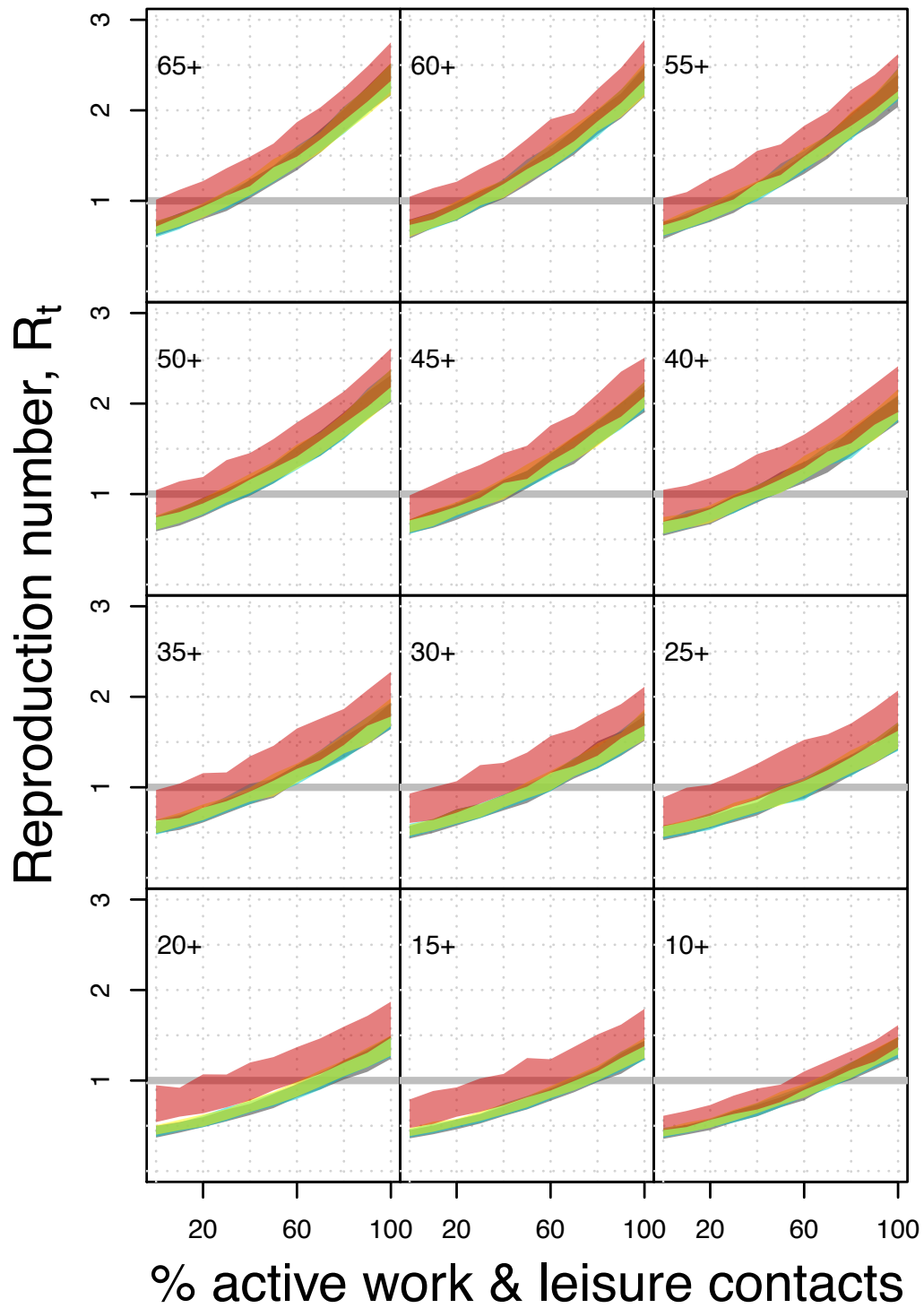
$$R_t^* = Boot \left(v_t (R_{ind}^j)^2, \alpha'_j \right) \quad j = 1 \dots N$$

The probability that an individual is vaccinated is dependent on age only. We assume that uptake increases linearly with age from u in the under 25 year olds to 95% in the over 80s. Natural immunity acts in the same manner as vaccine-induced immunity. We assume that vaccinated individuals are protected by vaccination, i.e. after any delays to reaching full vaccine-induced immunity.

Ready Reckoners with vaccination

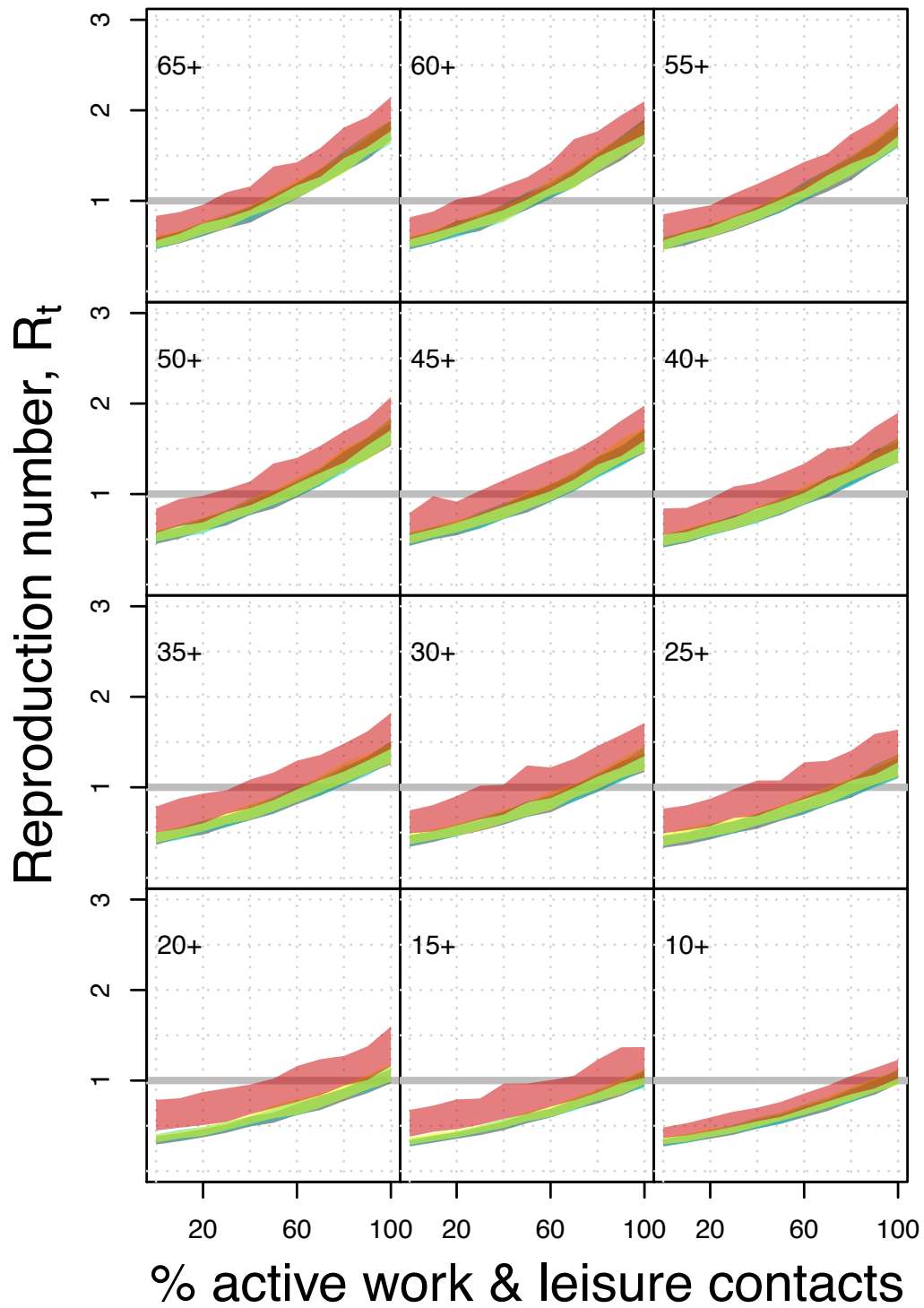
The figures below show the Reproduction Number against the percentage of active social contacts as vaccination across the age groups is rolled out for three levels of contact tracing: a) no contact tracing, b) 20% of contacts of symptomatic cases successfully traced and isolated and c) 40% of contacts successfully traced and isolated. The baseline values used are 25% seroprevalence, a 60% vaccine-induced protection against infection, a 50% vaccine-induced protection against onward transmission and 80% vaccine uptake in the youngest age groups.

The behaviour of the reckoners can be explored at <https://ellenbp.shinyapps.io/reckoners/>.



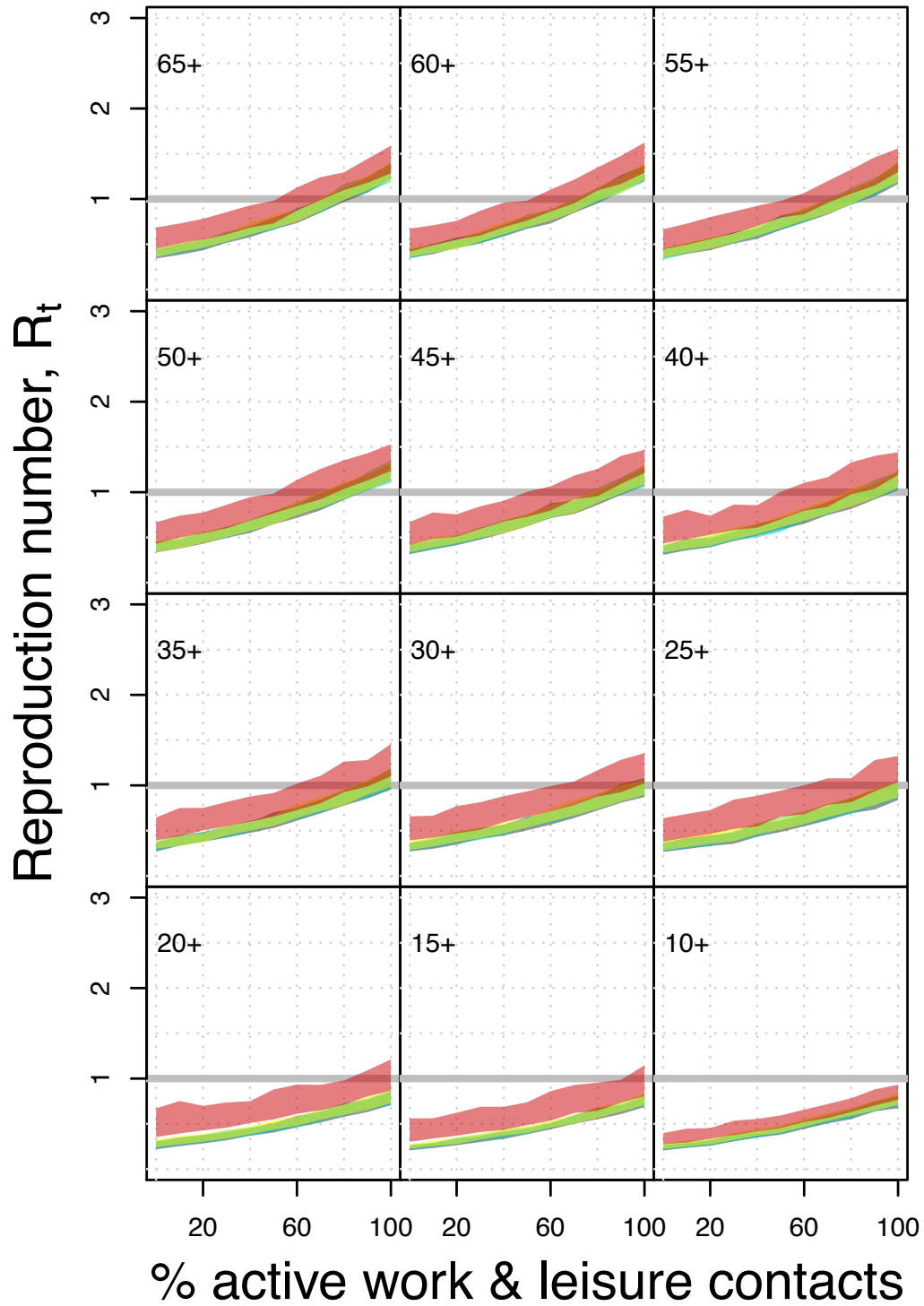
$R=4, \text{seroprev}=0.25, \text{infchild}=0.25, \text{covidsec}=0.25$
 $\text{CTF}=0, \text{ve_inf}=0.6, \text{ve_trans}=0.5, \text{uptake_low}=0.8$

Figure 2: Reproduction number charts with no contact tracing.



$R=4, \text{seroprev}=0.25, \text{infchild}=0.25, \text{covidsec}=0.25$
 $\text{CTF}=0.2, \text{ve_inf}=0.6, \text{ve_trans}=0.5, \text{uptake_low}=0.8$

Figure 3: Reproduction number charts for 20% of contacts of symptomatic cases successfully traced and isolated.



$R=4, \text{seroprev}=0.25, \text{infchild}=0.25, \text{covidsec}=0.25$
 $\text{CTF}=0.4, \text{ve_inf}=0.6, \text{ve_trans}=0.5, \text{uptake_low}=0.8$

Figure 4: Reproduction number charts for 40% of contacts of symptomatic cases successfully traced and isolated.