"DfE have asked whether we can provide any modelling on the potential impact of different school cohorts for next week, with a particular interest in updating some past analysis of partial opening options based on contact matrices" (5th Feb 2021)

Impact of partial school openings

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on behalf of JUNIPER https://maths.org/juniper/

This version: 17th February 2021

Update from 10th Feb -> 17th Feb: using updated/corrected matrices from James Munday

Acknowledgements: James Munday and *CMMID* for CoMix matrices

Context

Much of this follows from "The effect of school opening or closure on social contacts in England from the CoMix social contact survey, Report for survey week 43b -Updated" – Munday et al., *CMMID COVID-19 Working Group,* LSHTM

- Using the same matrices for Lockdown 2 and Lockdown 3 (LD2 and LD3 respectively) – 1000 bootstrapped matrices for each of these kindly supplied by James Munday.
- Also using the susceptibility and infectivity profiles from Munday et al Table S1
- Appended an additional infectivity profile from ONS fitted household transmission model
- Slightly different assumptions on scaling between LD2 and LD3 for school openings

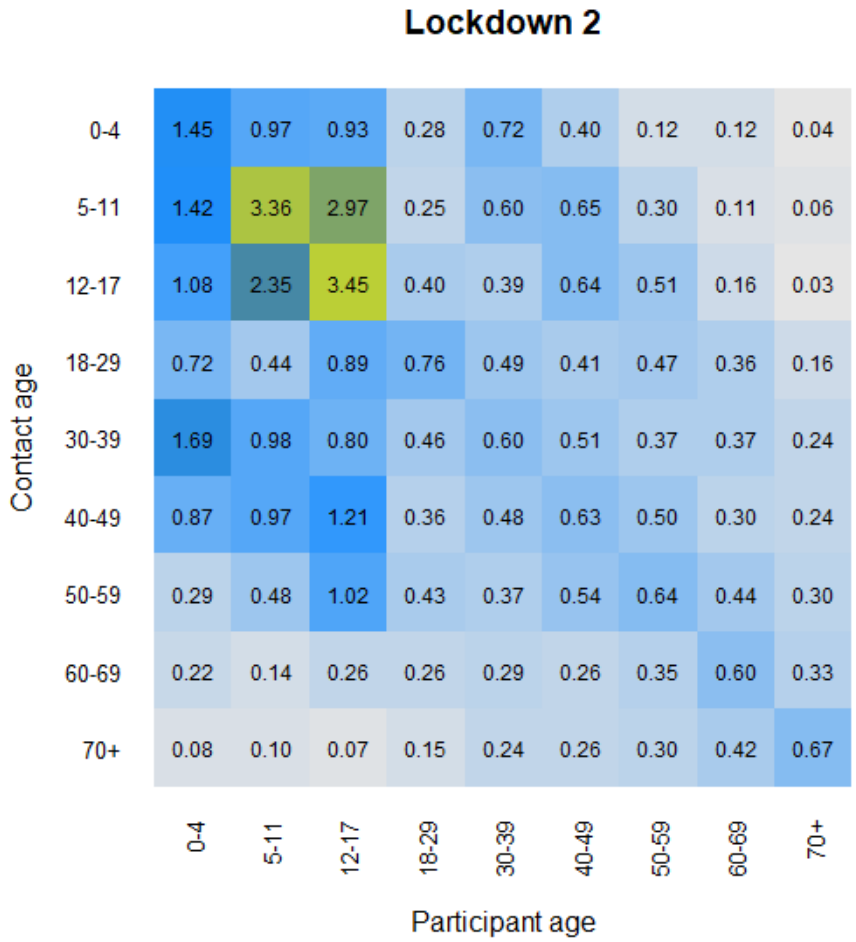
Caveats

As in Munday et al., and with all work based on spectral radii of contact matrices:

- This will be sensitive to extrapolating counts of contacts to transmission exposure, e.g. missing duration of contact, nature of contact, and local structure in repeated contacts between days etc
- Any transmission routes not covered by reported contacts will be missed, e.g. casual contacts or reporting inaccuracies, particularly around adults reporting on behalf of their children
- All of these analyses will be sensitive to assumptions on susceptibility and infectivity by age
- And chiefly here – this is extrapolating LD2/LD3 to represent a continuation of current measures but with schools open/closed, i.e. assigning the reason behind all change in contact structure to the wider effect of schools.

Inputs – mixing matrices (recap of Munday et al)

Age bands and matrices as Munday *et al.*:



UPDATED 17/02/21

Take Lockdown 2 (November) as model for schools open, and Lockdown 3 (January) as model for present with schools mostly closed.

Inputs – infectivity and susceptibility by age

Susceptibility and infectivity by age is explored under six different parameter sets.

The first five are as in Munday et al. and do not differentiate between children of different ages (except slightly in Davies et al in infectivity).

The ONS HH study found a difference between children under 12 and those aged 12-17 (though big caveat in using HH factors for community here).

Relative infectivity

INF	0-4	5-11	12-17	18-29	30-39	40-49	50-59	60-69	70+
Equal	1	1	1	1	1	1	1	1	1
Davies	0.645	0.645	0.605	0.635	0.665	0.7	0.745	0.815	0.845
ONS 1	1	1	1	1	1	1	1	1	1
ONS 2	1.1	1.1	1.1	1	1	1	1	1	1
Viner	1	1	1	1	1	1	1	1	1
ONS HH	1.52	1.495	1.495	1	1	1	1	1	1

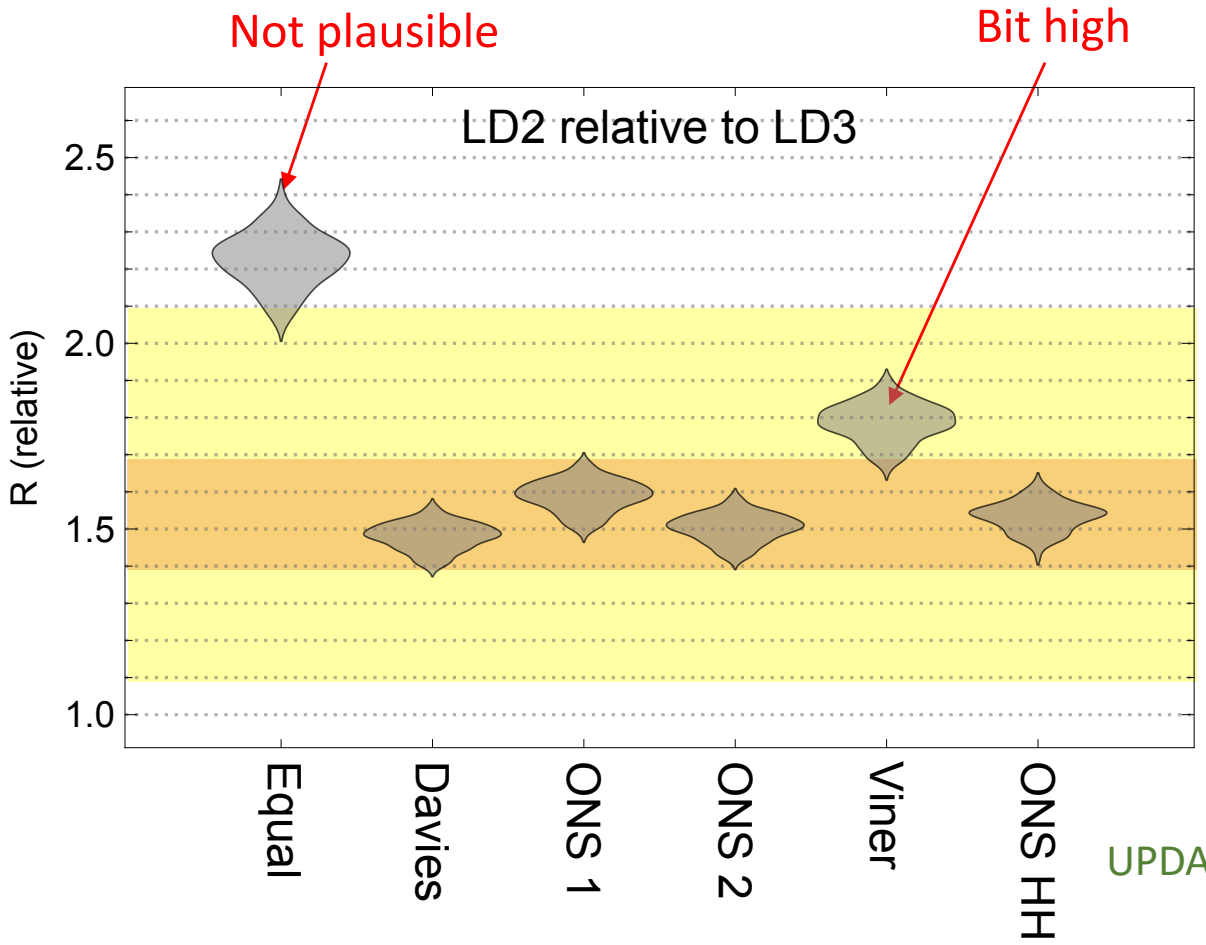
Relative susceptibility

SUS	0-4	5-11	12-17	18-29	30-39	40-49	50-59	60-69	70+
Equal	1	1	1	1	1	1	1	1	1
Davies	0.4	0.4	0.4	0.79	0.86	0.8	0.82	0.88	0.75
ONS 1	0.5	0.5	0.5	1	1	1	1	1	1
ONS 2	0.4	0.4	0.4	1	1	1	1	1	1
Viner	0.64	0.64	0.64	1	1	1	1	1	1
ONS HH	0.22	0.22	0.38	1	1	1	1	1	1

Some plots below omit equal and ONS 1 in interests of scale and space

Inputs – sanity check with observed R

Band shows plausible range for ratio of R from mixing patterns alone.



SPI-M consensus R estimates

18/11/20	1.0-1.1
25/11/20	0.9-1.0
02/12/20	**0.8-1.0**
20/1/21	0.8-1.0
27/1/21	0.7-1.1
03/2/21	**0.7-1.0**

Kitchen table calculation:
Take LD2 as Unif[0.8-1.0]
Take LD3 as Unif[0.7-1.0]
Take new variant factor on R as Unif[1.2-1.7]

Then expected ratio of R = 1.5
(95% CI 1.1-2.1, 50% box 1.4-1.7)

UPDATED 17/02/21

Caveats on this (and all work using mixing matrices) include not capturing NATURE of contacts changing, or more/less repeated contacts with same people. Also assuming no change in immunity.

Inputs – partial reopening as a scaling

This matrix has elements between 0 and 1 representing scaling from LD3 (model for school closed) to LD2 (schools open), thus implicitly our baseline is not schools entirely closed, but with attendance as in January 2021 (with some keyworker and vulnerable children in attendance).

Here we model this scaling by four parameters θ_{pre}, θ_{prim}, θ_{sec} and θ_{adult} representing preschool, primary school, secondary school and adult age mixing respectively. The full matrix is modelled as follows:

0–4	θ_{pre}	$\min[\theta_{pre}, \theta_{prim}]$	$\min[\theta_{pre}, \theta_{sec}]$	θ_{pre}	θ_{pre}	θ_{pre}	θ_{pre}	θ_{pre}	θ_{pre}
5–11	$\min[\theta_{pre}, \theta_{prim}]$	θ_{prim}	$\min[\theta_{prim}, \theta_{sec}]$	θ_{prim}	θ_{prim}	θ_{prim}	θ_{prim}	θ_{prim}	θ_{prim}
12–17	$\min[\theta_{pre}, \theta_{sec}]$	$\min[\theta_{prim}, \theta_{sec}]$	θ_{sec}	θ_{sec}	θ_{sec}	θ_{sec}	θ_{sec}	θ_{sec}	θ_{sec}
18–29	θ_{pre}	θ_{prim}	θ_{sec}	θ_{adult}	θ_{adult}	θ_{adult}	θ_{adult}	θ_{adult}	θ_{adult}
30–39	θ_{pre}	θ_{prim}	θ_{sec}	θ_{adult}	θ_{adult}	θ_{adult}	θ_{adult}	θ_{adult}	θ_{adult}
40–49	θ_{pre}	θ_{prim}	θ_{sec}	θ_{adult}	θ_{adult}	θ_{adult}	θ_{adult}	θ_{adult}	θ_{adult}
50–59	θ_{pre}	θ_{prim}	θ_{sec}	θ_{adult}	θ_{adult}	θ_{adult}	θ_{adult}	θ_{adult}	θ_{adult}
60–69	θ_{pre}	θ_{prim}	θ_{sec}	θ_{adult}	θ_{adult}	θ_{adult}	θ_{adult}	θ_{adult}	θ_{adult}
70+	θ_{pre}	θ_{prim}	θ_{sec}	θ_{adult}	θ_{adult}	θ_{adult}	θ_{adult}	θ_{adult}	θ_{adult}

This is used as an element-wise scaling, where 0 means take LD3 and 1 means take LD2 value, scale linearly in between.

In Munday et al, ”Primary only” was modelled equivalently to $\theta_{prim}=1$, $\theta_{sec}=0$ and similarly “Secondary only” as $\theta_{prim}=0$, $\theta_{sec}=1$, and with $\theta_{pre}=\theta_{adult}=1$ in both, i.e. adults and preschoolers mixing as per LD2.

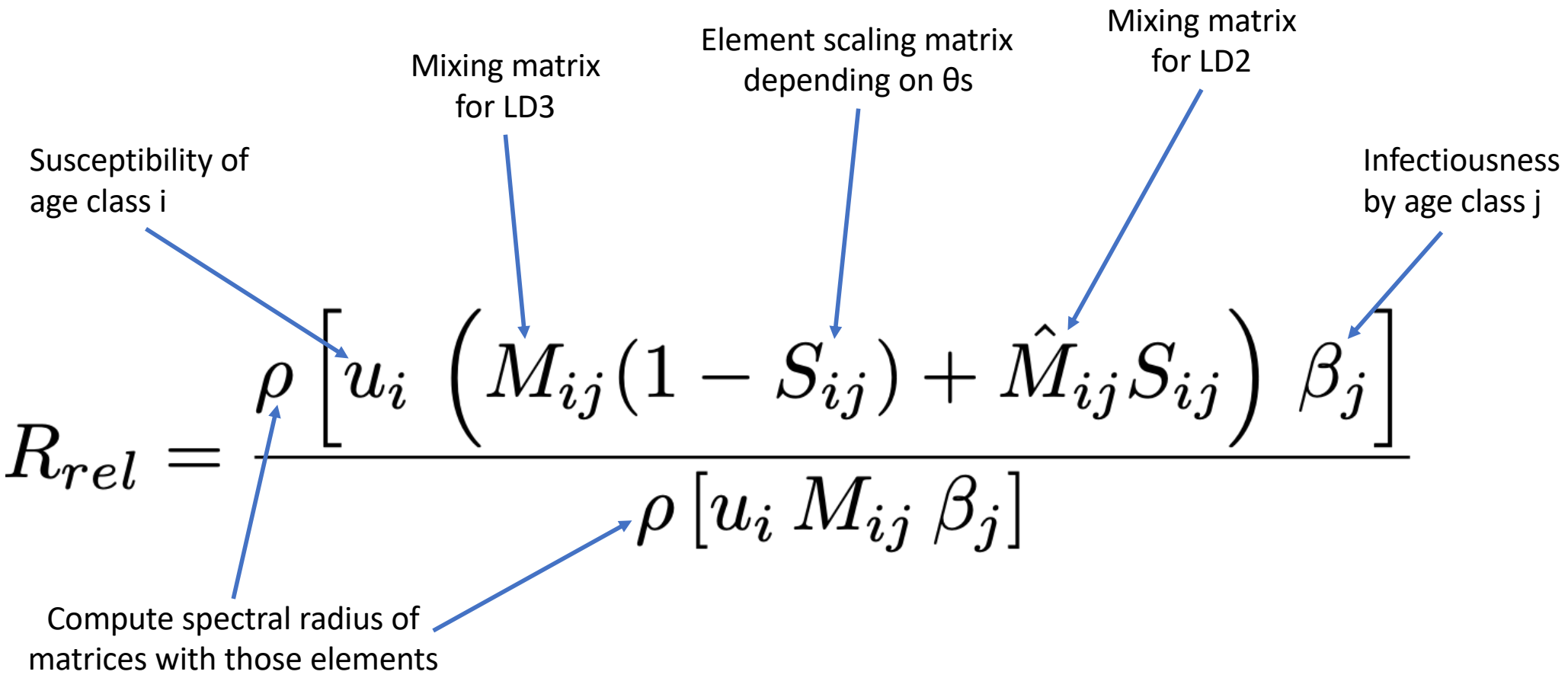
Inputs – translating the ask

			Baseline	R & KS1	Primary	P & Y10+	All but EY	All
	Parameter	**Age class**	Schools open to children of critical workers and vulnerable children	As previous, plus reception and KS1	As previous, plus KS2	As previous, plus exam years 10 to 13 in schools and equivalent exam years in FE	As previous, plus remaining secondary school years	As previous, plus return of early years providers from current to full attendance
Modelled as:	θ_{pre}	**0-4**	0	0.5	0.5	0.5	0.5	1
	θ_{prim}	**5-11**	0	0.4	1	1	1	1
	θ_{sec}	**12-17**	0	0	0	0.5 (or 0.5 X)	1 (or X)	1 (or X)
	θ_{adult}	**18+**	0	0.5 (or varied)	0.5 (or varied)	0.5 (or varied)	0.5 (or varied)	0.5 (or varied)

Clearly these are crude mappings from school cohorts to ages, but we do not expect results to be very sensitive to small changes here. Note again that 0 corresponds to January and 1 to November.

- Least sure about how to model reception and early years within 0-4 - done as 0.5 for each here. (Note, needs to be proportional to effect on mixing matrix, not necessarily proportional to size of group)
- FE not explicitly separately included, only relative age scaling in these groups up to age 17
- Adult mixing is either set as 0.5 or plotted as axis from 0 to 1 in slides below
- Sensitivity to secondary attendance is explored (multiplicative X above)

Methods – find relative R (scenario vs LD3)

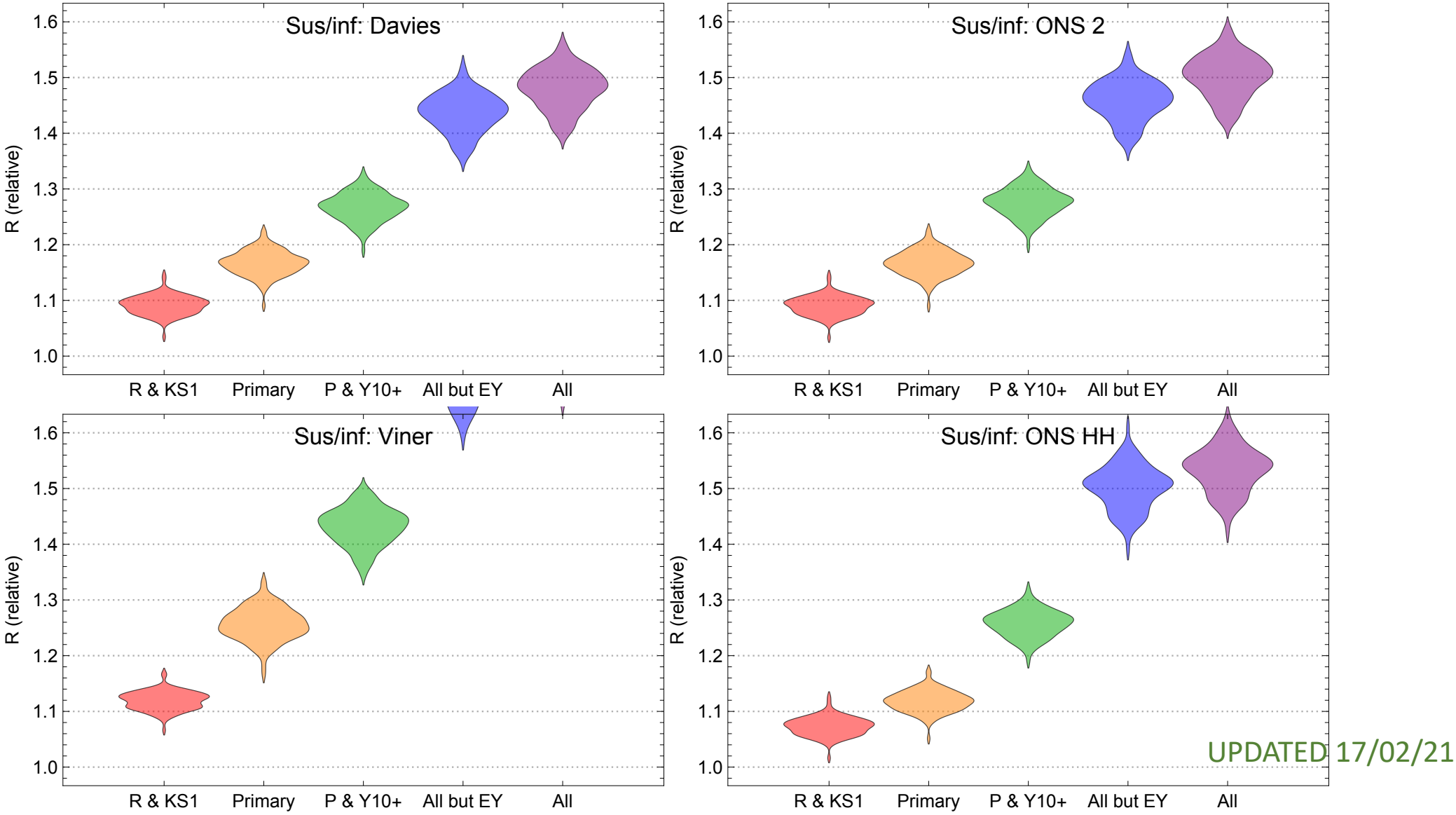


Use the 1000 bootstrap matrices for each of LD2 and LD3 mixing matrices to generate 1000 estimates for relative R for each scenario

Results 1a

Panels correspond to inf/sus parameter sets.

Adult mixing is fixed as 0.5.

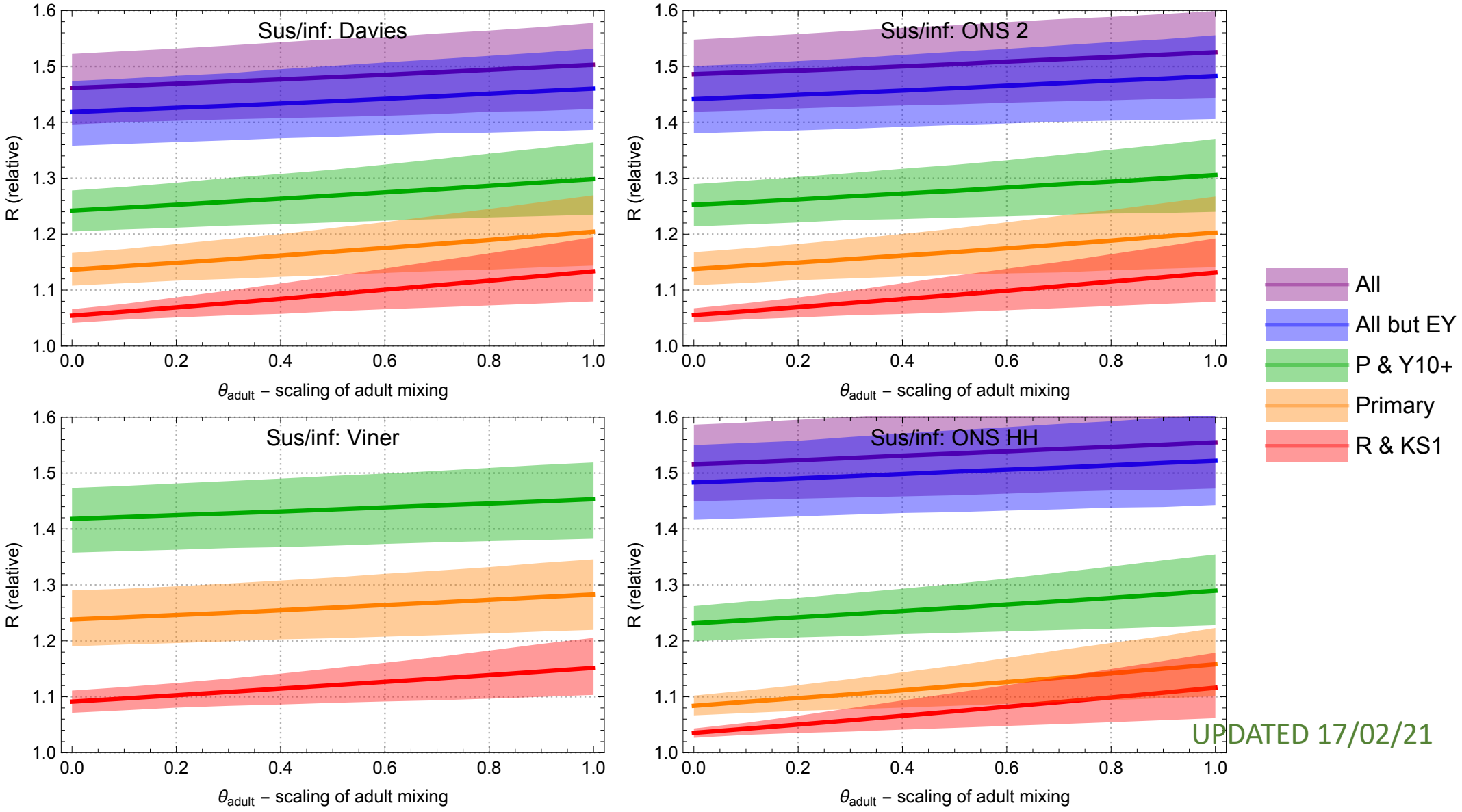


UPDATED 17/02/21

Relative effect of partial reopening is sensitive to assumptions on susceptibility and infectivity by age

Results 2a

Horizontal axis is adult mixing. Panels correspond to inf/sus parameter sets.
Wider bands are 95% of the 1000 bootstrapped values.



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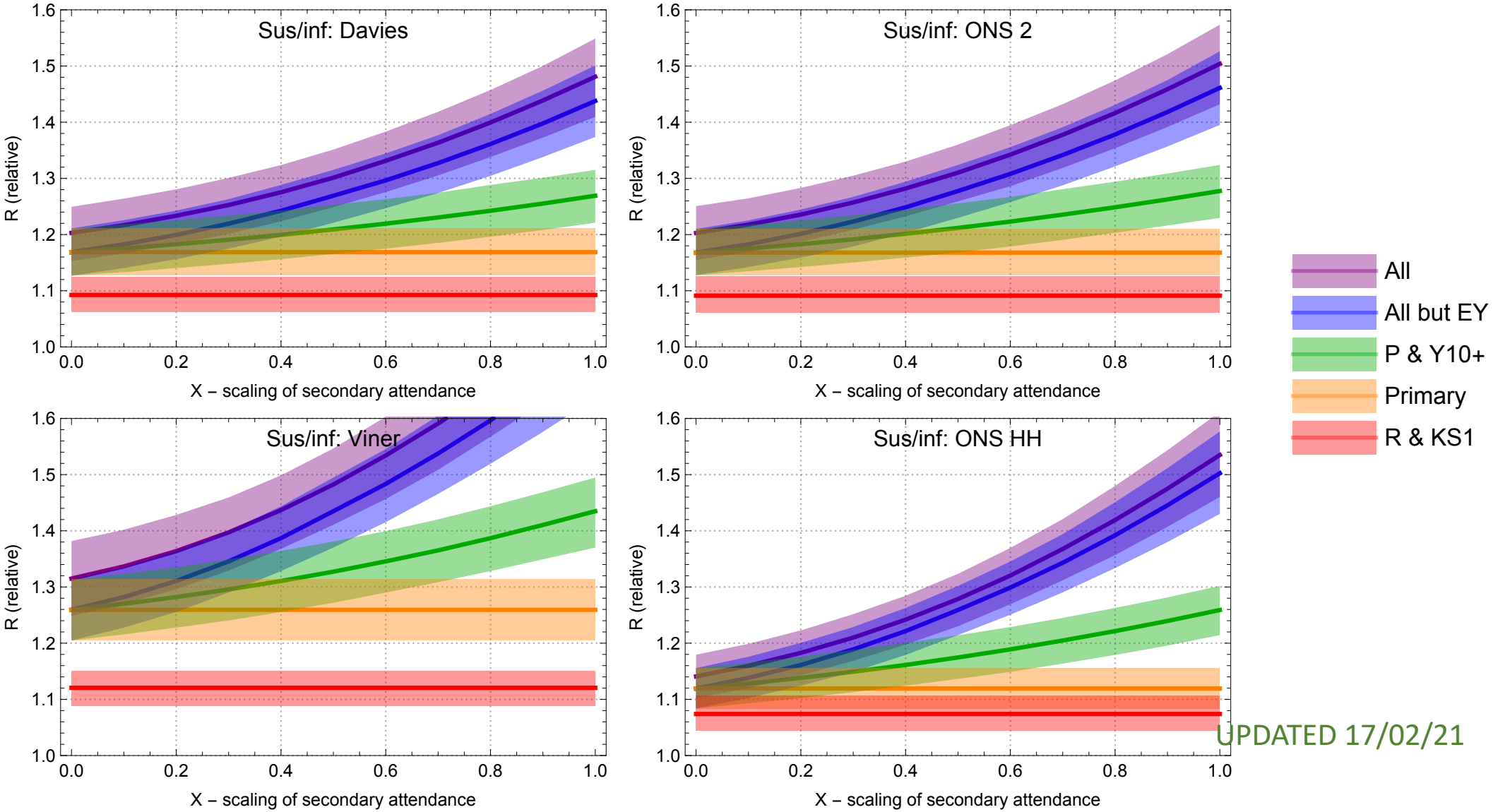
Adult mixing effect is small, except possibly for interaction with R and KS1 (red) and primary (orange).

Results 3a

Horizontal axis is secondary attendance scaling mixing.
(Adults fixed at 0.5)



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Effects will scale with attendance

(roughly as squared, here proportional to $(a+X)^2$ with $a \cong 0.2$)

Conclusions

1. Relative effect of partial reopening is sensitive to assumptions on susceptibility and infectivity by age. In particular, assumptions here that distinguish between children under and over 12 will change the relative impact of opening primaries and secondaries on R

2. When only primaries or some subset of primary year groups are back, results can be sensitive to assumptions on adult mixing, whether more like lockdown 2 or lockdown 3 as schools return. This effect becomes very small, however, with secondaries open.

3. Results are unlikely to be strongly sensitive to small changes in attendance. Larger changes in attendance will scale things in an intuitive way.

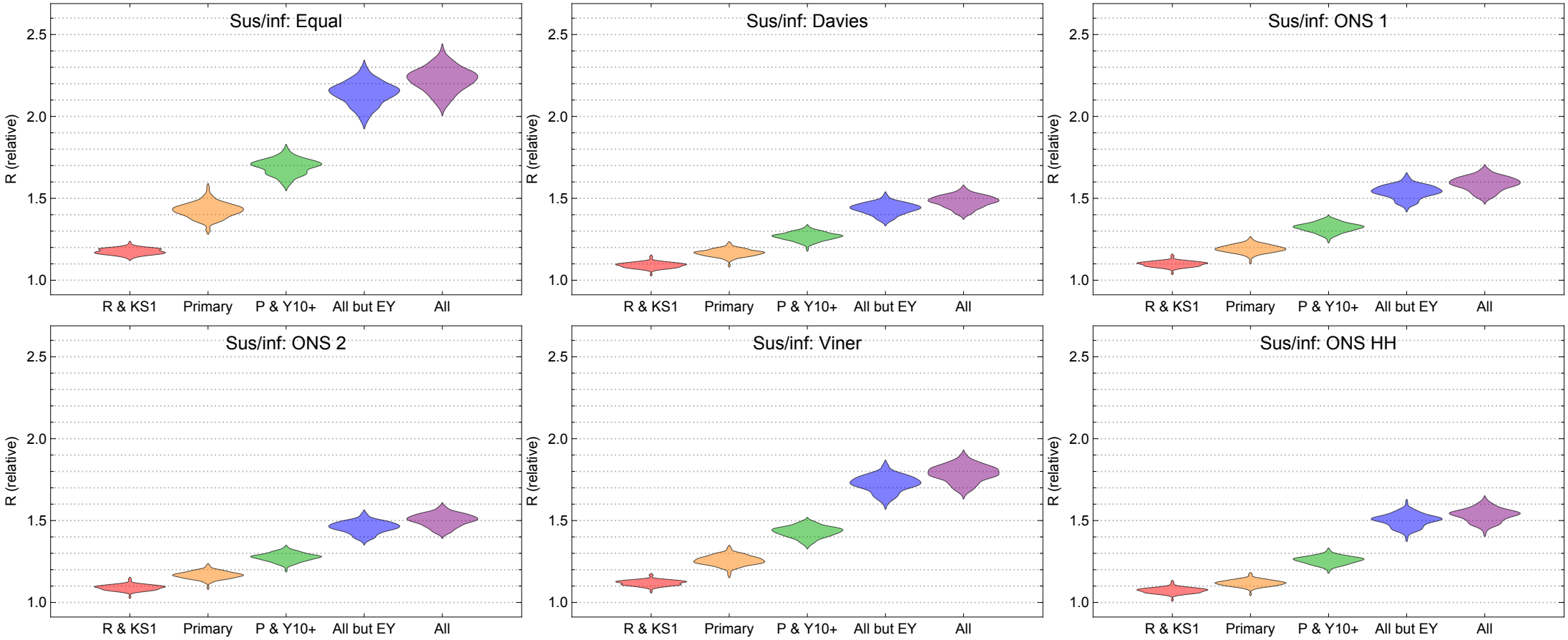
Note, lots of uncertainties and caveats, particularly hard limits of using contact matrices.

Appendix

All the main plots above with 6 inf/sus assumption sets (*i.e.* adding in “Equal” and “ONS 1”)

Results 1b

As before, but including ONS 1 and Equal (and rescaled vertical axis)



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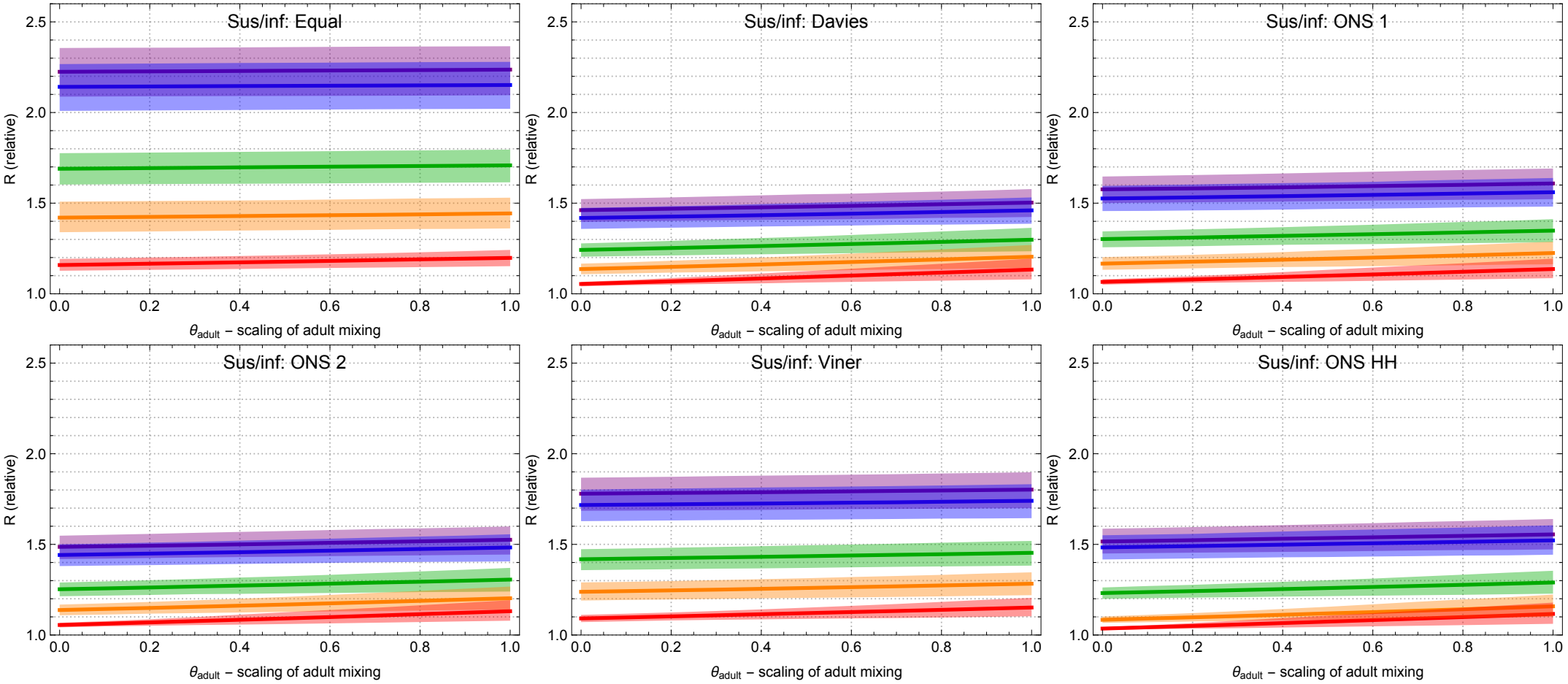
Results 2b

As before, but including ONS 1 and Equal (and rescaled vertical axis)



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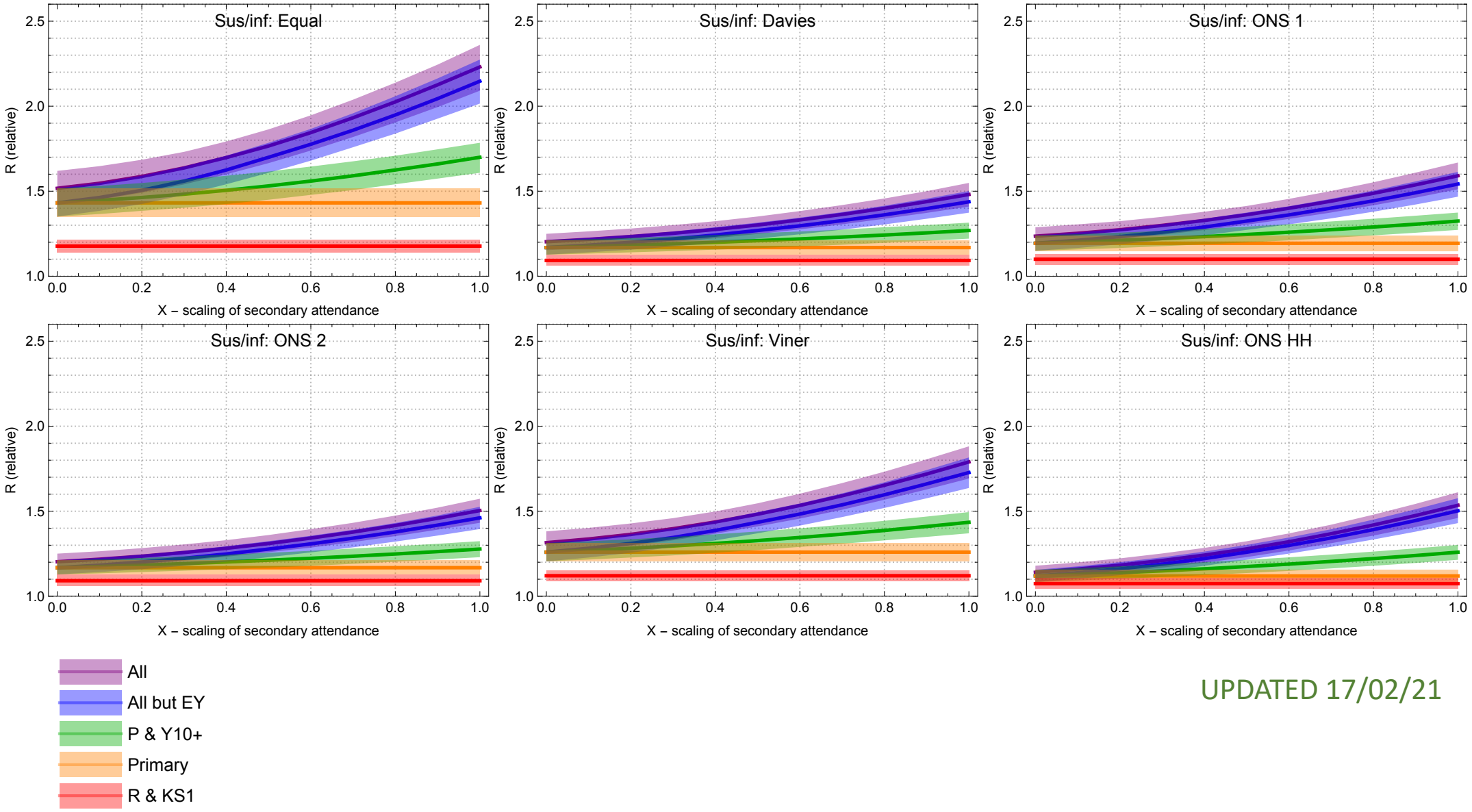
Results 3b

As before, but including ONS 1 and Equal (and rescaled vertical axis)



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