Evaluating the effectiveness of social distancing interventions against COVID-19: delaying the epidemic or flattening the curve?

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1 Motivation

2 Methods

3 Results

4 Conclusions

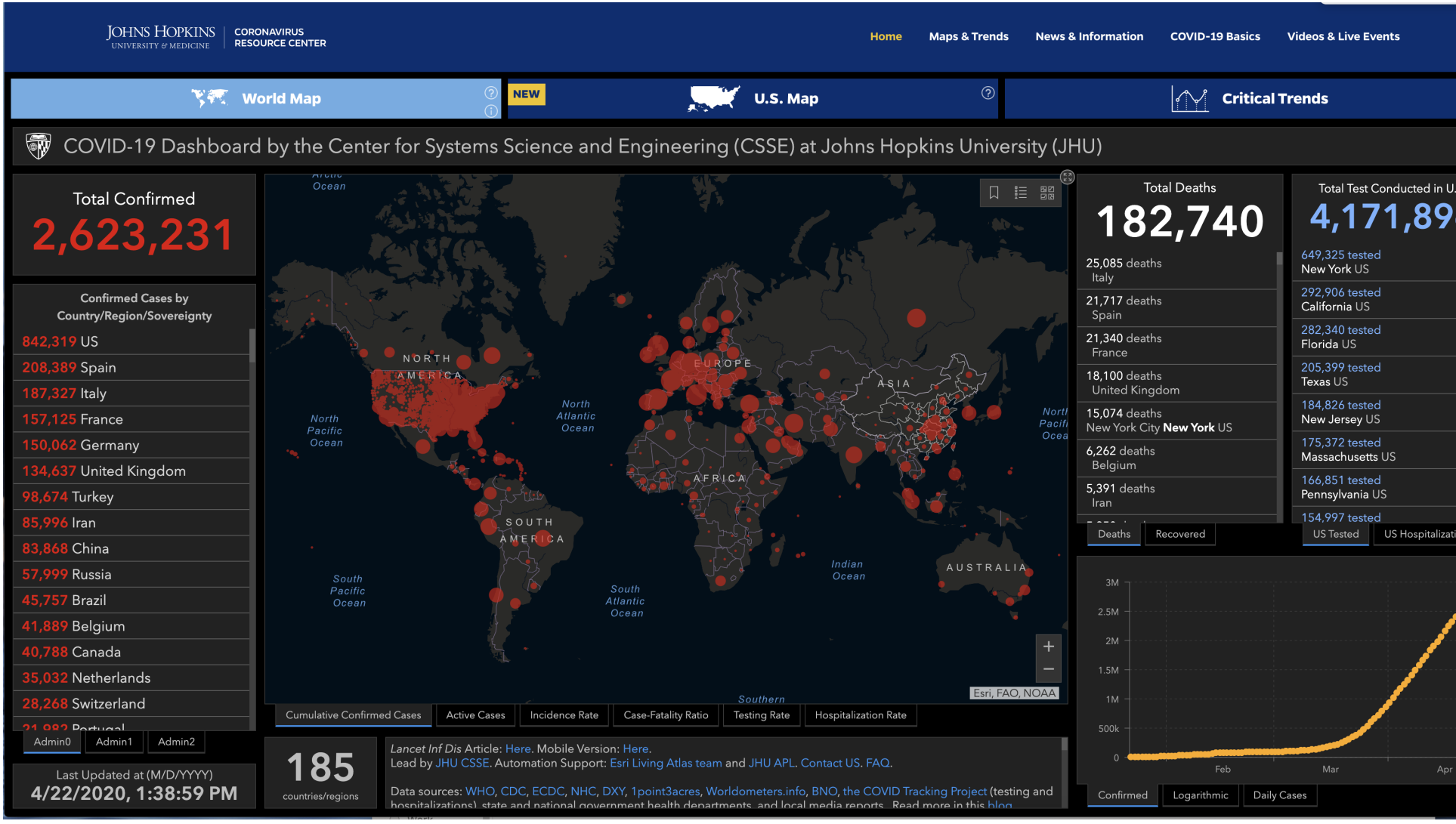
This work has been accepted at Emerging Infectious Diseases

https://wwwnc.cdc.gov/eid/article/26/8/20-1093_article

EMERGING INFECTIOUS DISEASES

A Peer-Reviewed Journal Tracking and Analyzing Disease Trends

Today...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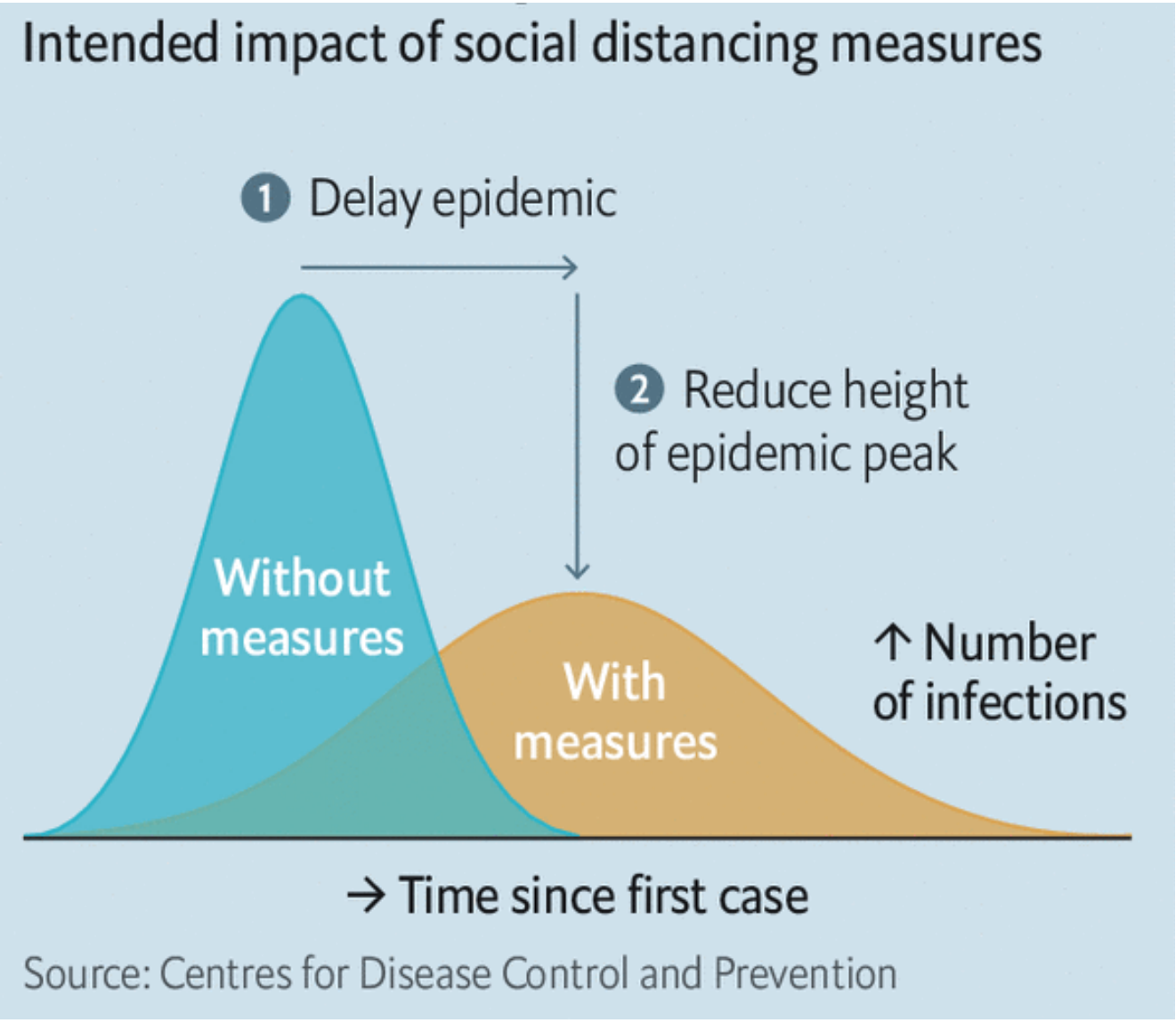
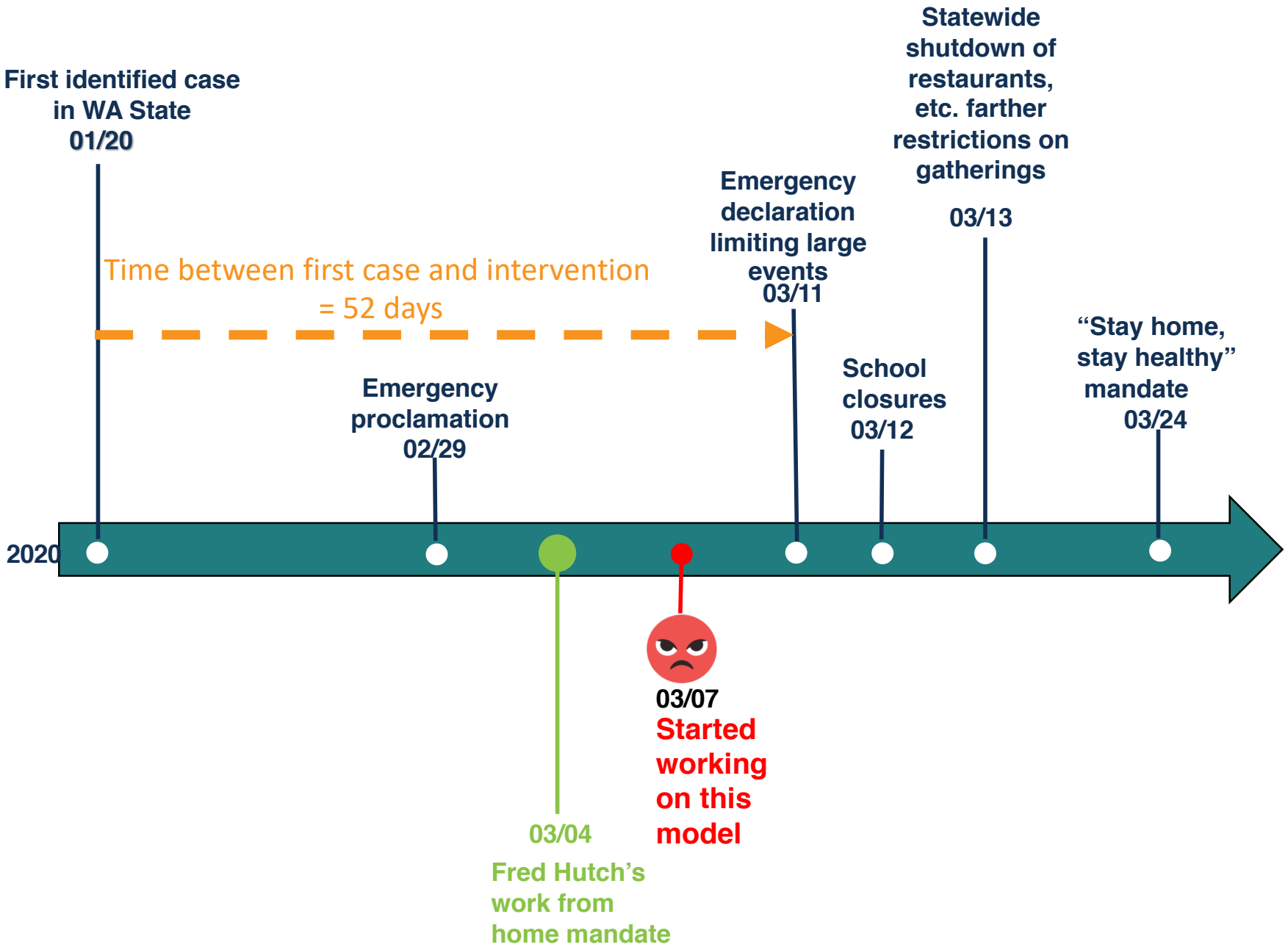
NEW
U.S. Map
Critical Trends
COVID-19 Dashboard by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University (JHU)
Total Confirmed
2,623,231
Confirmed Cases by Country/Region/Sovereignty
842,319 US
208,389 Spain
187,327 Italy
157,125 France
150,062 Germany
134,637 United Kingdom
98,674 Turkey
85,996 Iran
83,868 China
57,999 Russia
45,757 Brazil
41,889 Belgium
40,788 Canada
35,032 Netherlands
28,268 Switzerland
Admin0
Admin1
Admin2
Last Updated at (M/D/YYYY)
4/22/2020, 1:38:59 PM
NORTH AMERICA
EUROPE
ASIA
AFRICA
SOUTH AMERICA
AUSTRALIA
North Pacific Ocean
North Atlantic Ocean
South Pacific Ocean
South Atlantic Ocean
Indian Ocean
Southern
Esri, FAO, NOAA
Cumulative Confirmed Cases
Active Cases
Incidence Rate
Case-Fatality Ratio
Testing Rate
Hospitalization Rate
185
countries/regions
Lancet Inf Dis Article: Here. Mobile Version: Here.
Lead by JHU CSSE. Automation Support: Esri Living Atlas team and JHU APL. Contact US. FAQ.
Data sources: WHO, CDC, ECDC, NHC, DXY, 1point3acres, Worldometers.info, BNO, the COVID Tracking Project (testing and
Total Deaths
182,740
25,085 deaths Italy
21,717 deaths Spain
21,340 deaths France
18,100 deaths United Kingdom
15,074 deaths New York City New York US
6,262 deaths Belgium
5,391 deaths Iran
Deaths
Recovered
Total Test Conducted in U
4,171,89
649,325 tested New York US
292,906 tested California US
282,340 tested Florida US
205,399 tested Texas US
184,826 tested New Jersey US
175,372 tested Massachusetts US
166,851 tested Pennsylvania US
154,997 tested
US Tested
US Hospitalizati
3M
2.5M
2M
1.5M
1M
500k
0
Feb
Mar
Apr
Confirmed
Logarithmic
Daily Cases

“Flattening the curve”

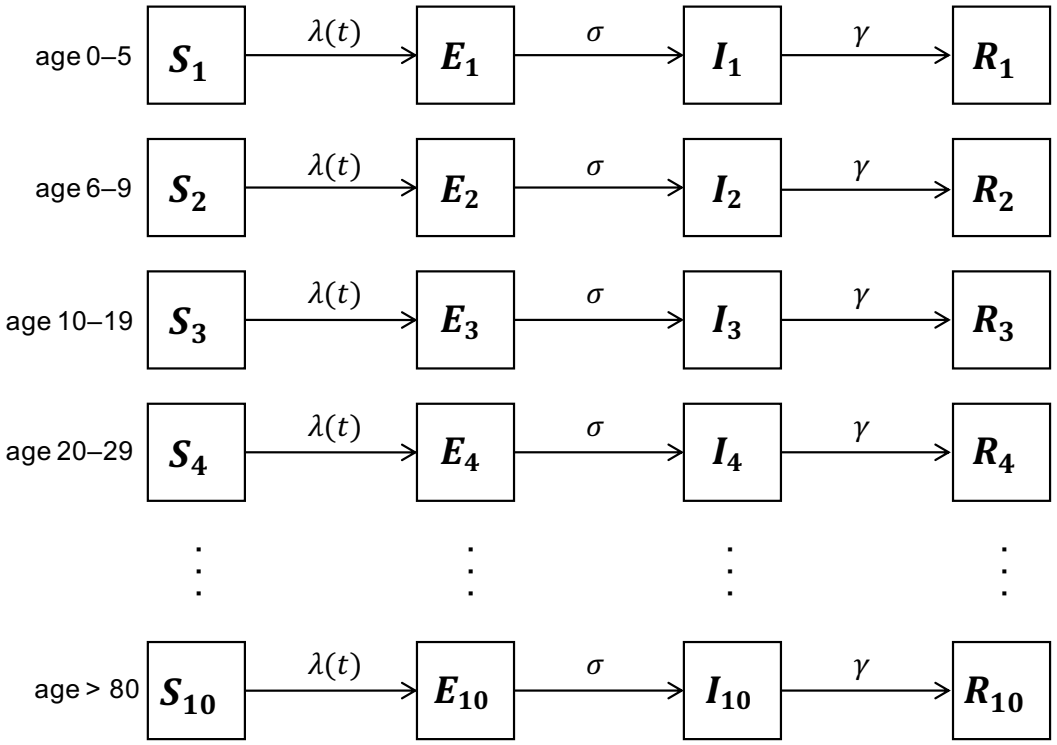


- Started by the CDC
- There was no quantitative analysis of what “flattening the curve” actually meant.

Timeline of events in WA state

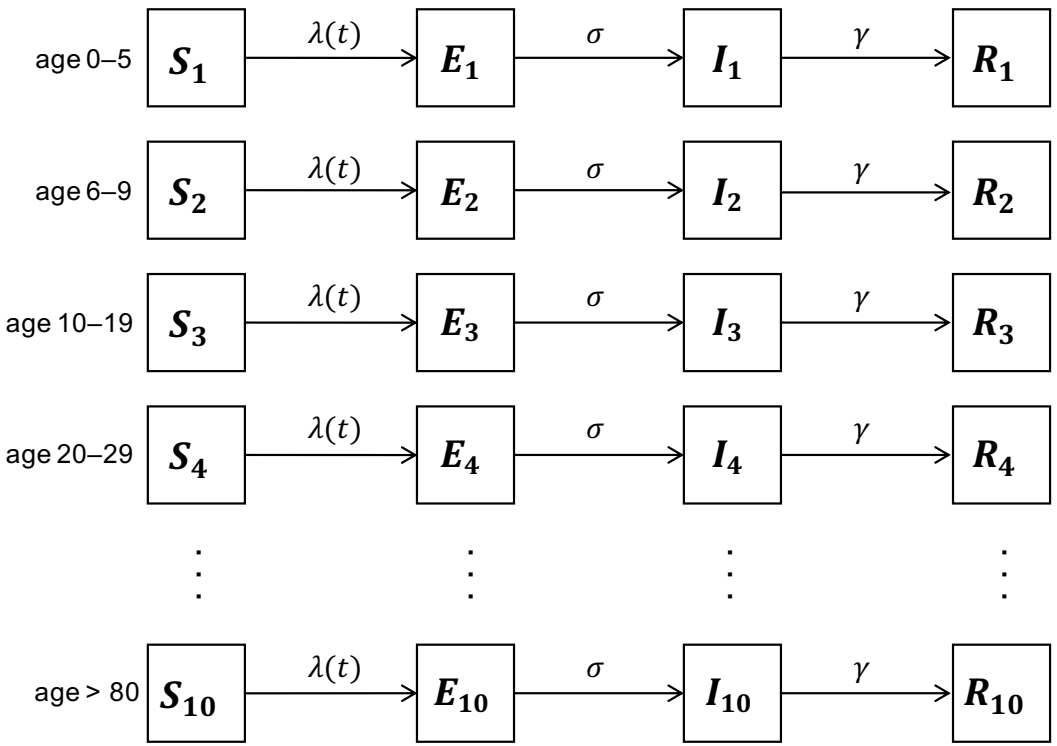


Mathematical model



- Deterministic mathematical model with 10 age groups.
- Contacts depend on the age-groups.
- Age-distribution was calibrated to Seattle metropolitan area.

Mathematical model



For $i = 1 \ldots 10$,

$$\frac{dS_i}{dt} = -\lambda S_i \,,$$
$$\frac{dE_i}{dt} = \lambda S_i - \sigma E_i \,,$$
$$\frac{dI_i}{dt} = \sigma E_i - \gamma I_i \,,$$
$$\frac{dR_i}{dt} = \gamma I_i$$

with $\lambda = \sum_{j=1}^{10} \beta \frac{c_{ij}}{N_j} I_j$,
and c_{ij} corresponds to the estimated number of contacts per day between age class i and j in a total population size N.

Important parameters

Parameter	Meaning	Value	Range
$1/\sigma$	Mean latent period	5.16 d	4.5-5.8
R_0	Reproduction number	2.26	1.6-3
$1/\gamma$	Mean infectious period	5.02 d	3-9
β	Infection rate	Calculated	-

Other important assumptions

- We assumed that 20% of the cases would be observed (or ascertained).
- We assumed that mild and severe cases are equally infectious.
- Case fatality rates would be similar to those seen in China.
- Hospitalization rates would be similar to those seen in China.

Scientific questions considered:

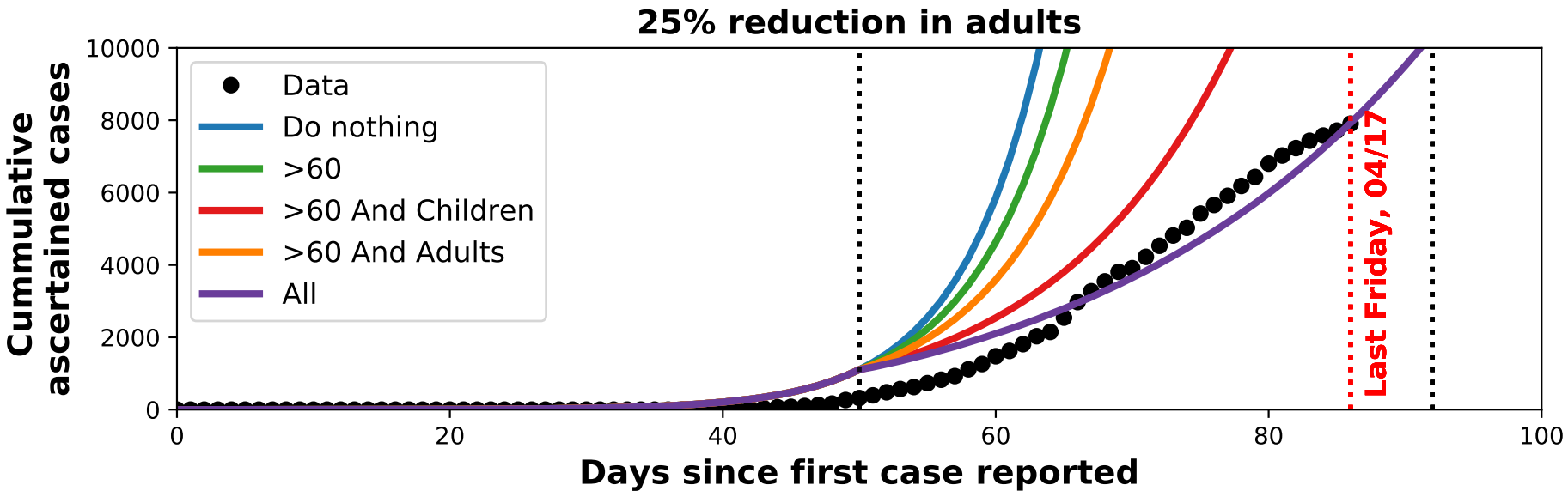
When is the intervention started relative to the epidemic?

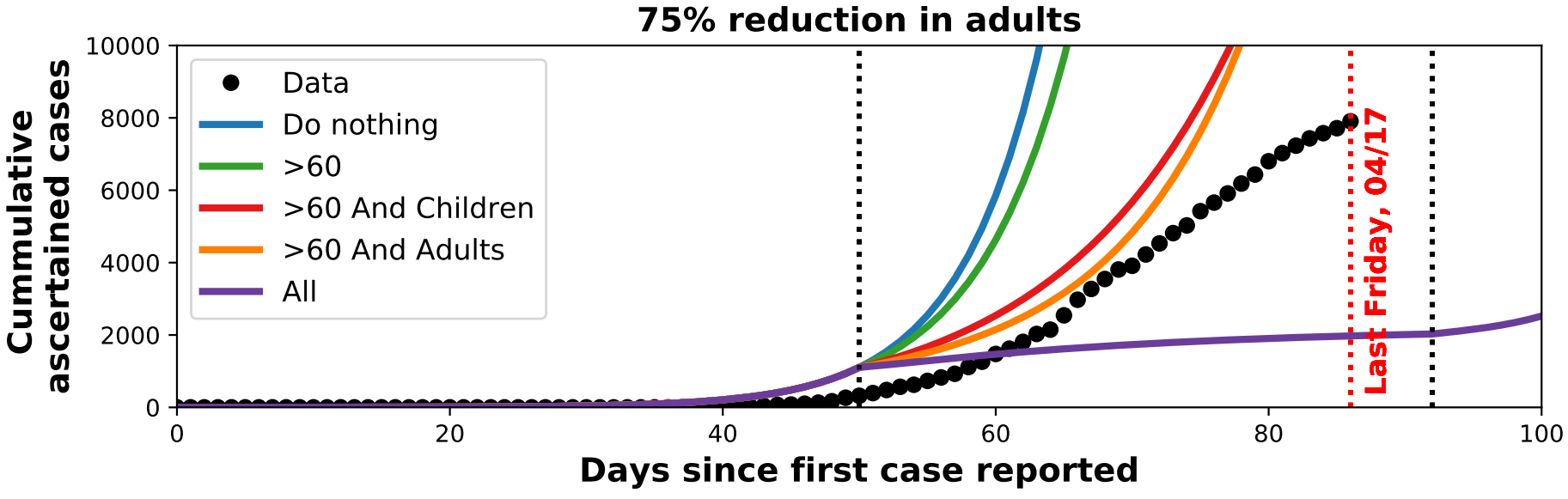
- Early on, before the exponential phase: day 50 after first case identified.
- Later, during the exponential phase: day 80 after first case is identified.

Who is reducing their contact rates?

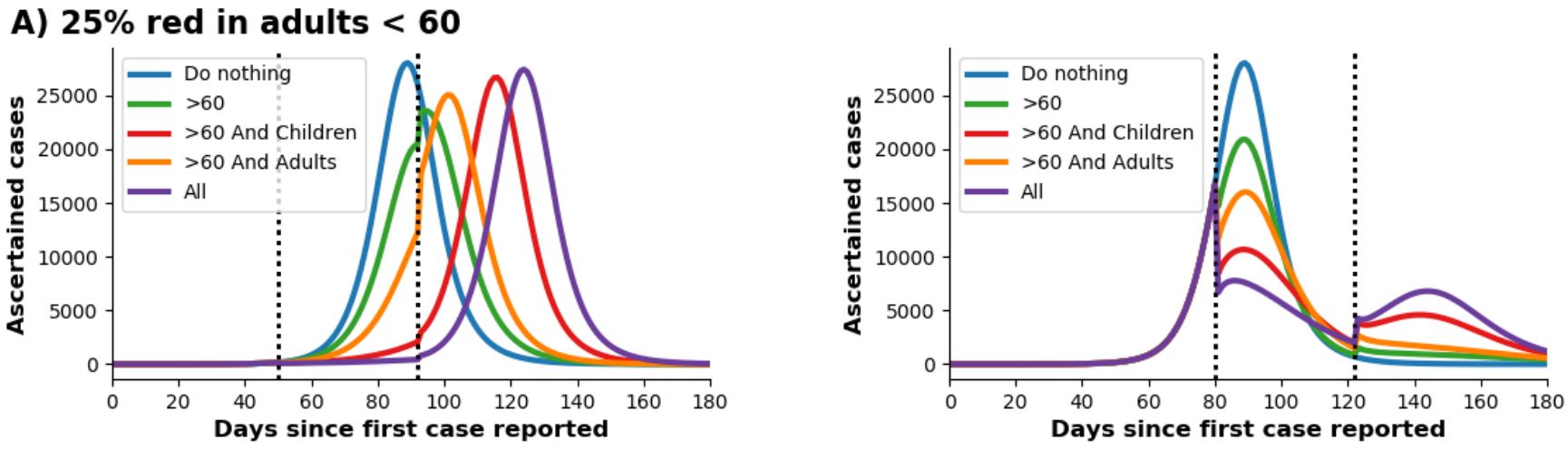
- ***Do nothing:***No intervention.
- ***$\geq$60:*** contacts of adults over 60 yo are reduced by 95%,
- ***$\geq$60 and Children:*** contacts of adults over 60 yo are reduced by 95% and contacts of children are reduced by 85%,
- ***$\geq$60 and Adults:*** contacts of adults over 60 yo are reduced by 95% and contacts of adults under 60 yo by 25, 75, or 95%
- ***All:*** contacts of adults over 60 yo are reduced by 95%, contacts of children are reduced by 85%, and contacts of adults under 60 yo by 25, 75, or 95%.

How well does the model do?



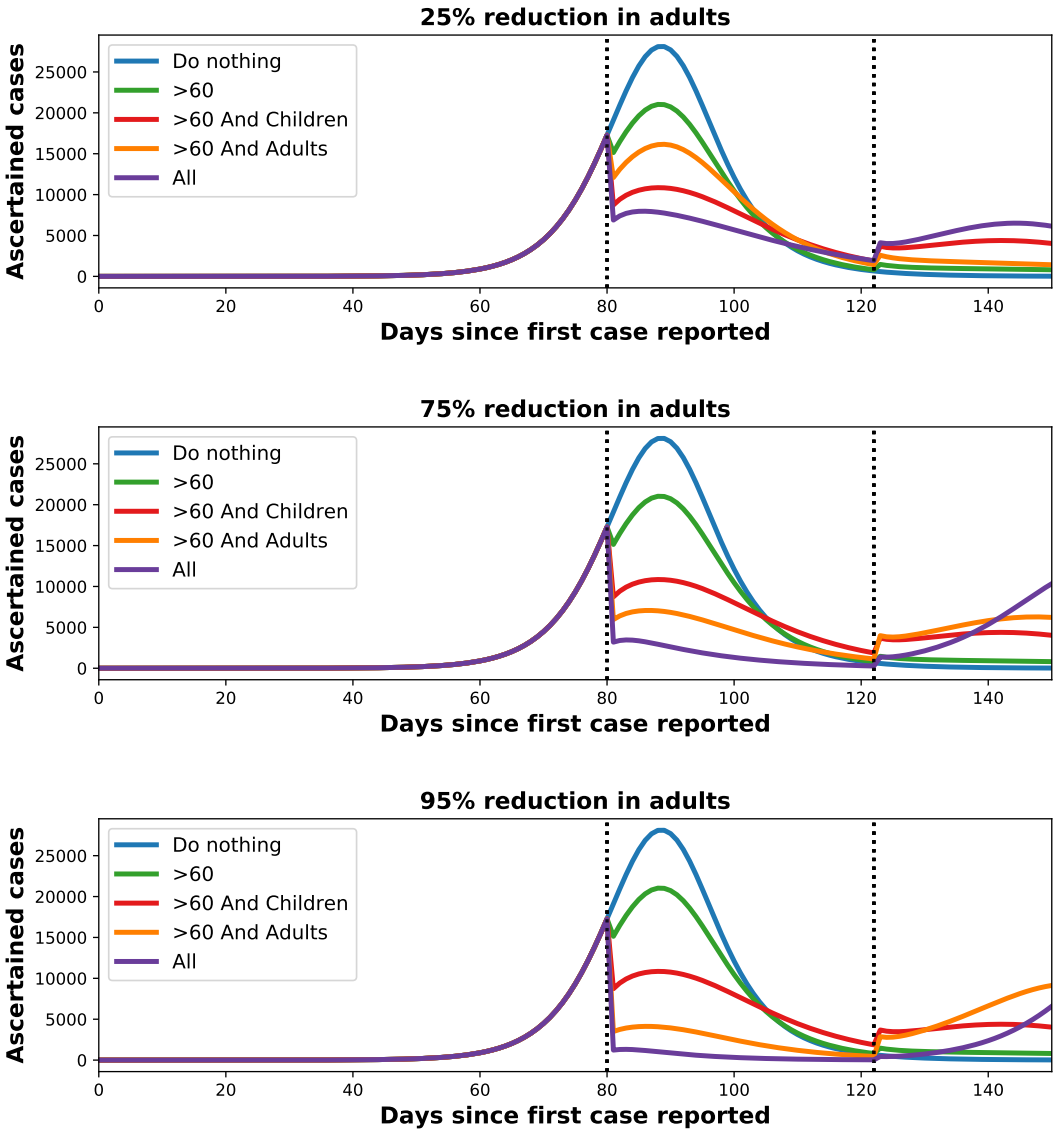


When the intervention is started matters:



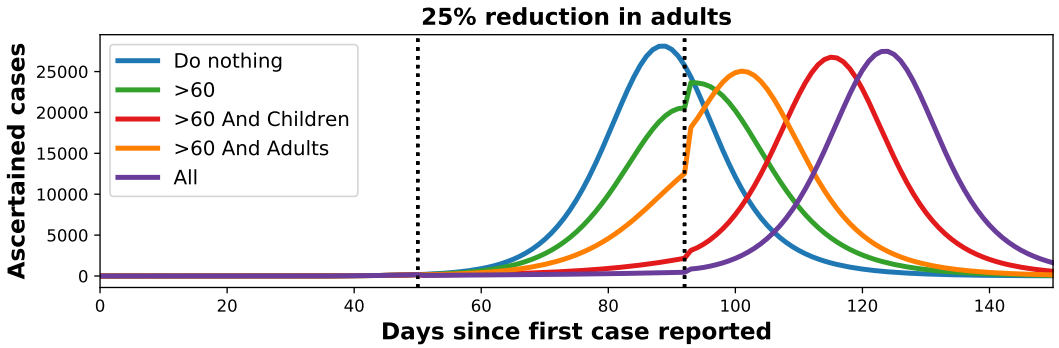
- If started early, it delays the epidemic, irrespective of which intervention is considered.
- If started late, it actually “flattens the curve”.

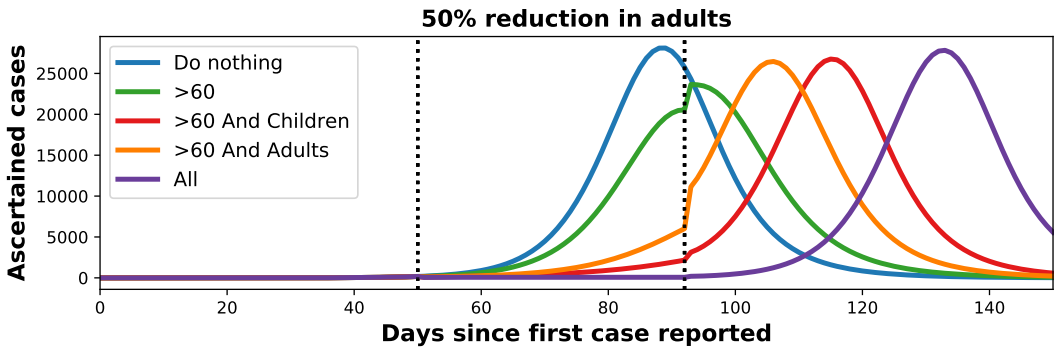
Flattening the curve: starting during the exponential phase of the epidemic

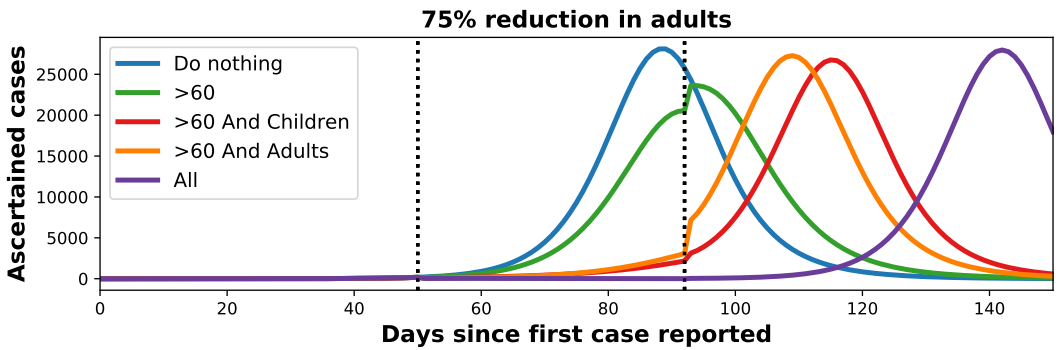


- All strategies flatten the curve, irrespective of proportion of contacts reduced in younger adults.
- There is a rebound for all strategies except for the ≥ 60 strategy.
- The rebound is bigger as adults reduce contacts more.
- For the All strategy there is a 68% - 92% less cases at the epidemic peak.

In a city like Seattle...

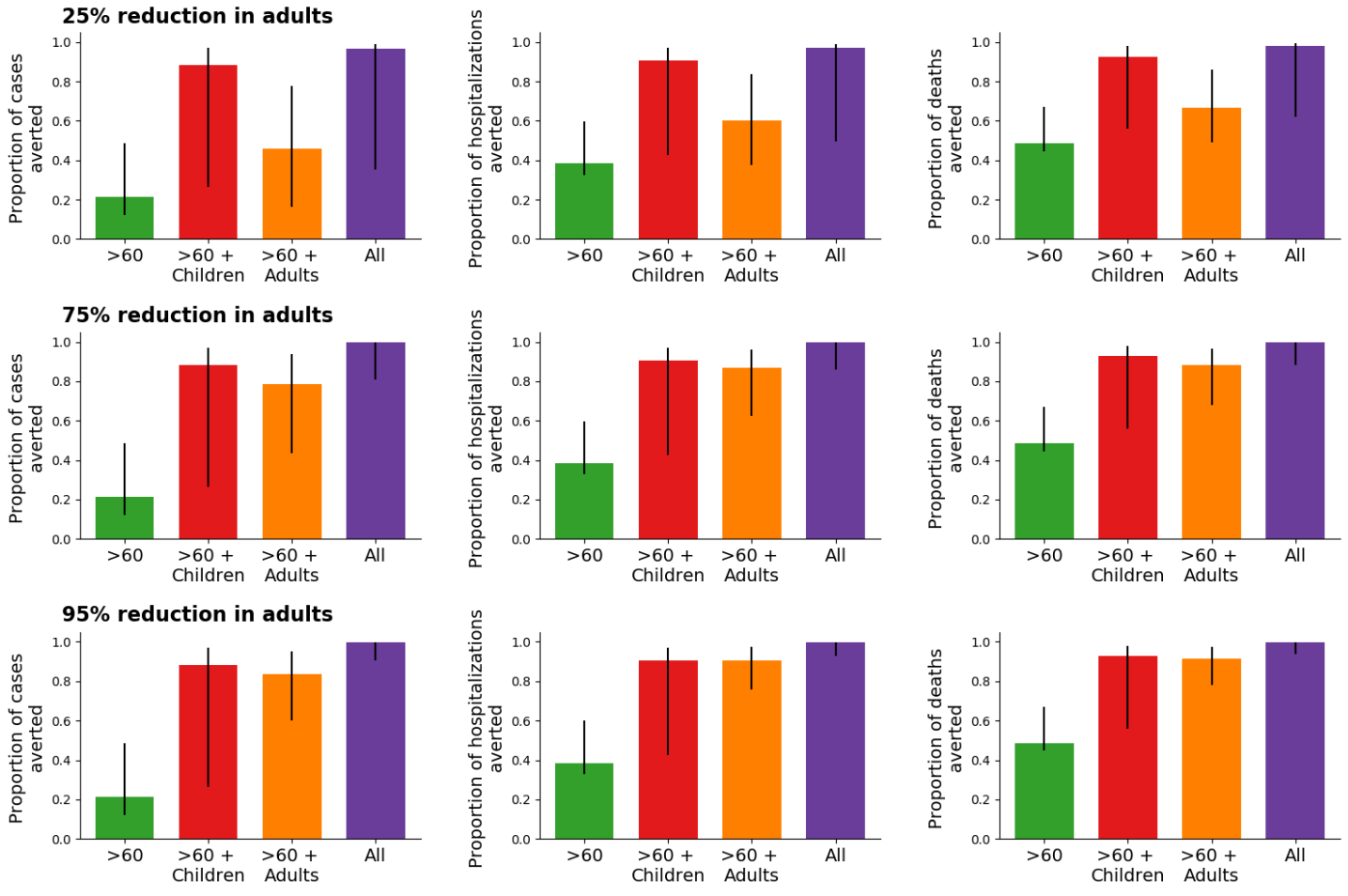






- Assume interventions start on day 50
- All interventions result in delaying the epidemic, regardless of proportion of contacts reduced in younger adults.
- The strategy ≥ 60 delays the epidemic the shortest, by ~ 1 week.
- The strategy ≥ 60 + *Children* delays the epidemic more than the ones with adults only.
- The strategy *All* delays the epidemic the longest, by 50 days.
- The highest the reduction in contacts in adults, the longest the epidemic is delayed for the ≥ 60 + *adults* strategy.

How effective are these interventions over the first 100 days



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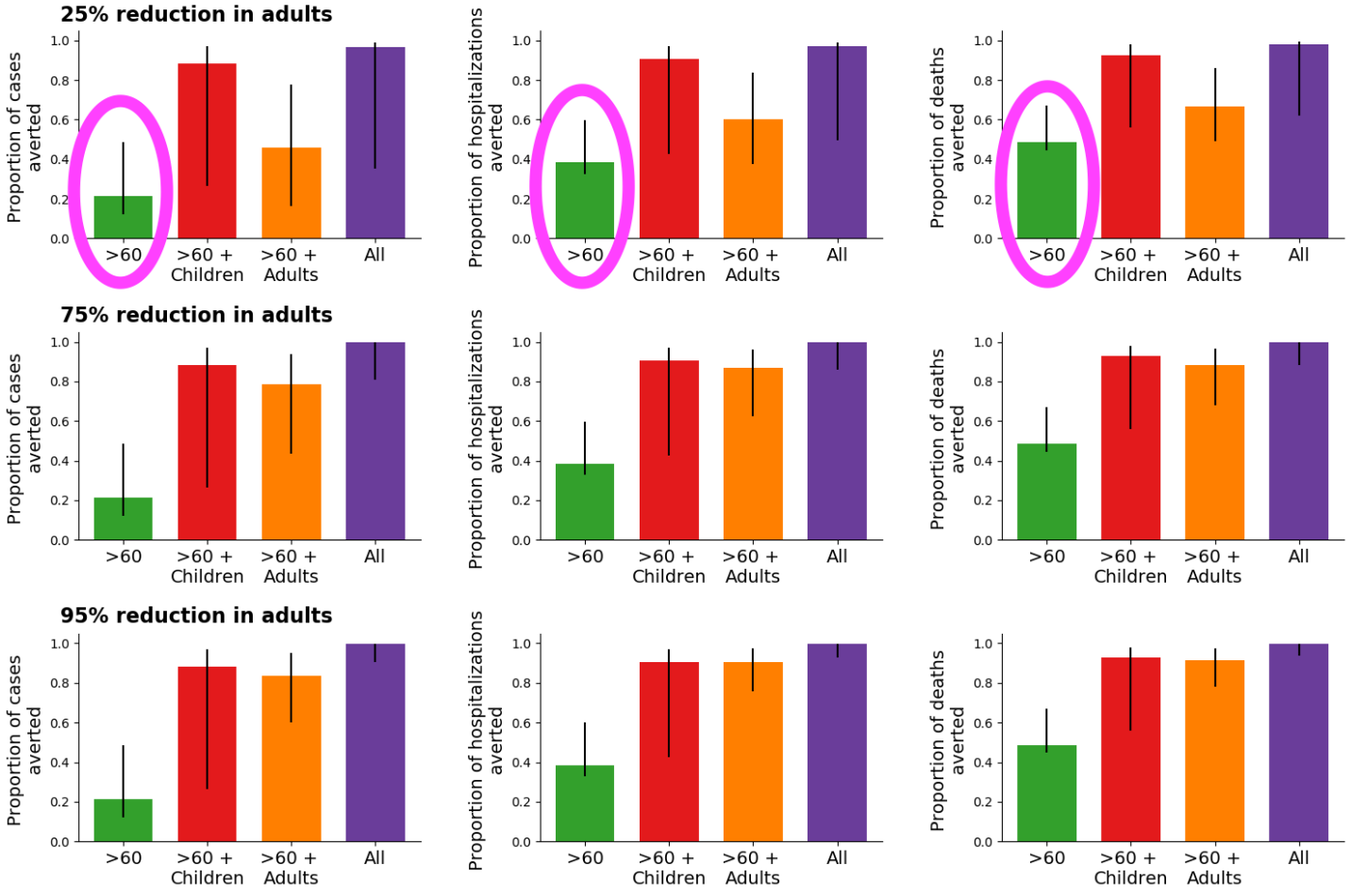
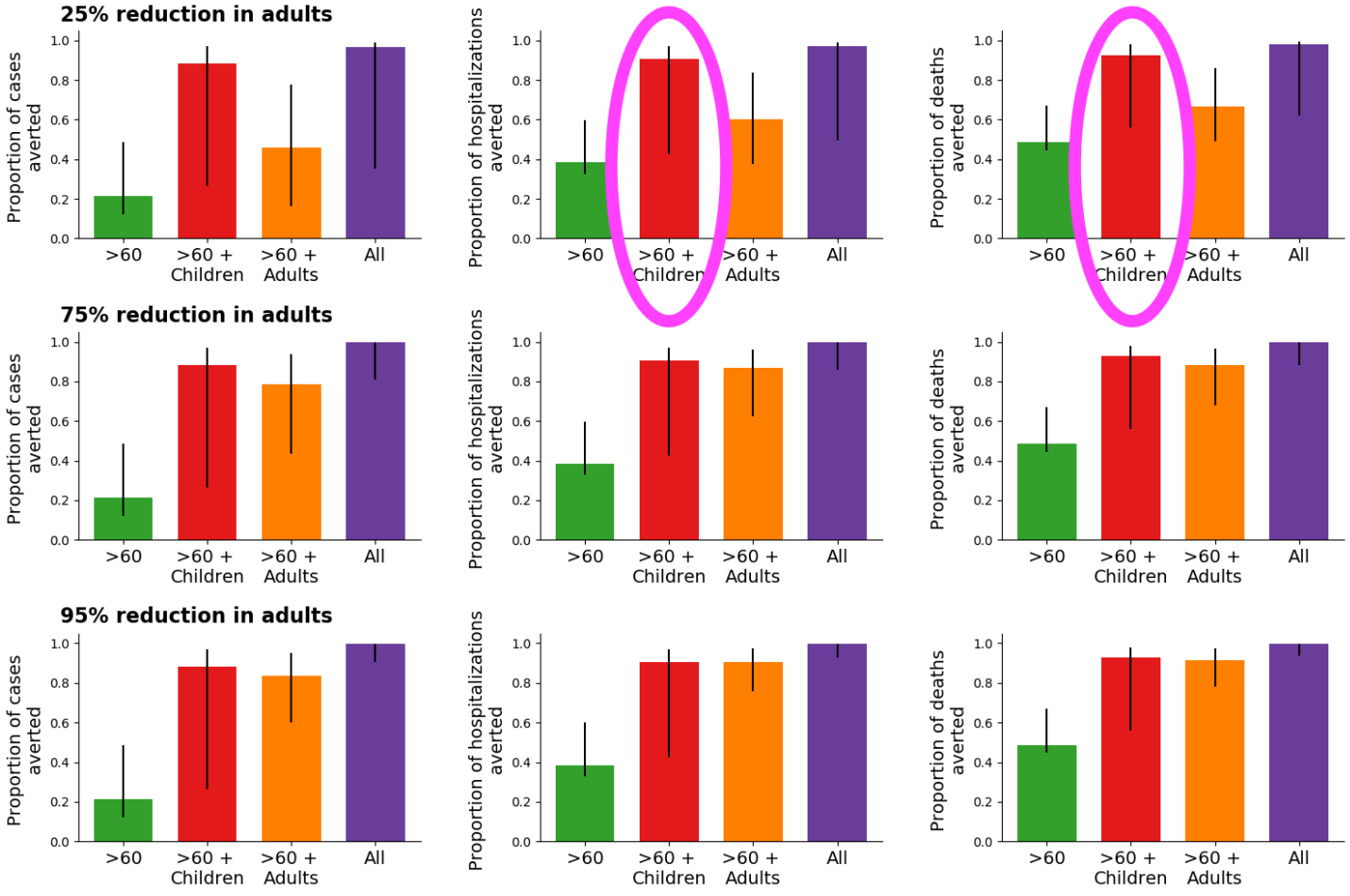


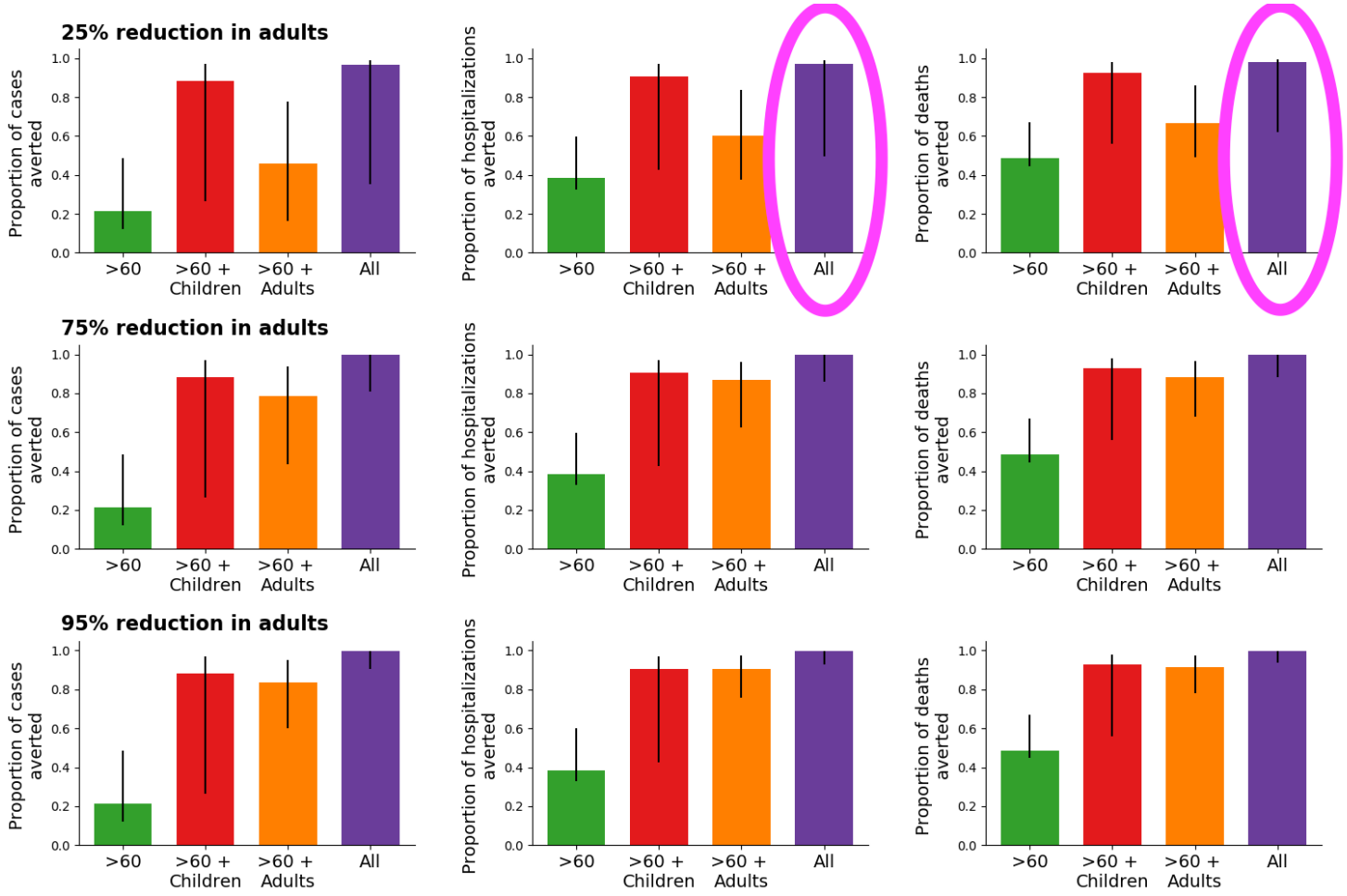
- The strategy ≥ 60 averts 36% hospitalizations and 47% of deaths.

How effective are these interventions over the first 100 days



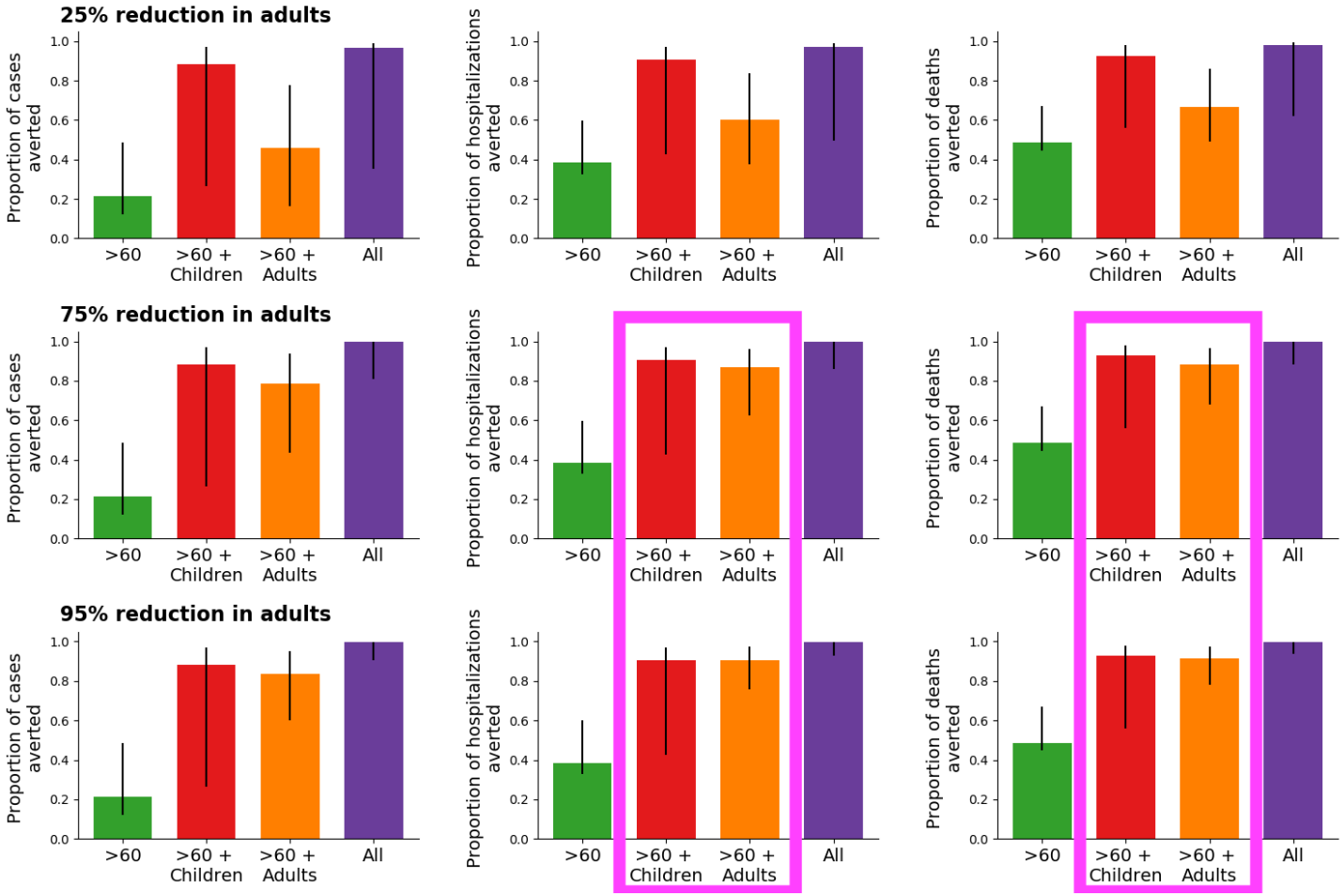
- The strategy ≥ 60 + *Children* further averts 75% hospitalizations and 80% of deaths.

How effective are these interventions over the first 100 days



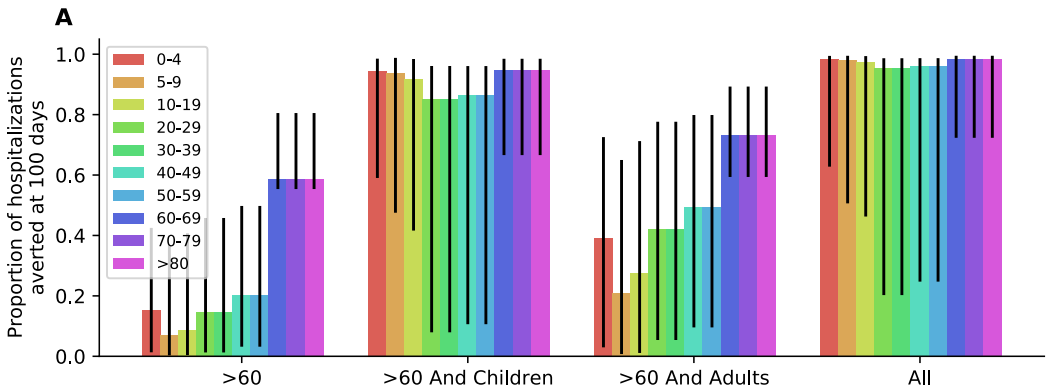
- The strategy *All* averts over 90% of hospitalizations and deaths even with 25% reduction in contacts in younger adults.

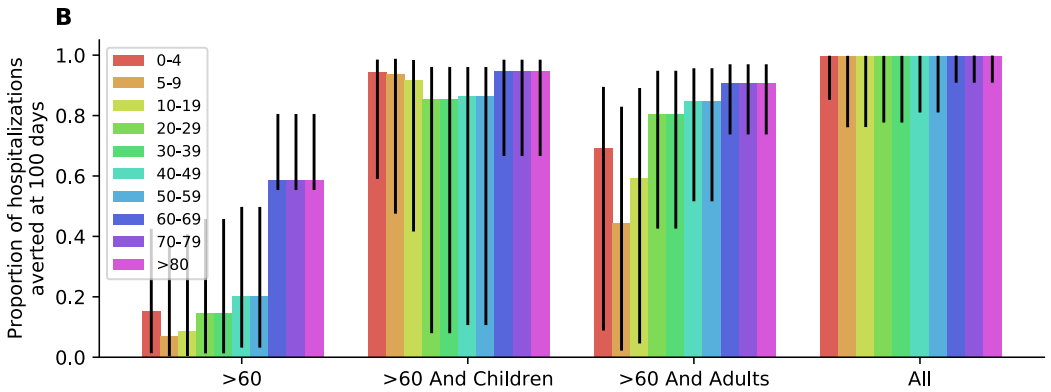
How effective are these interventions over the first 100 days

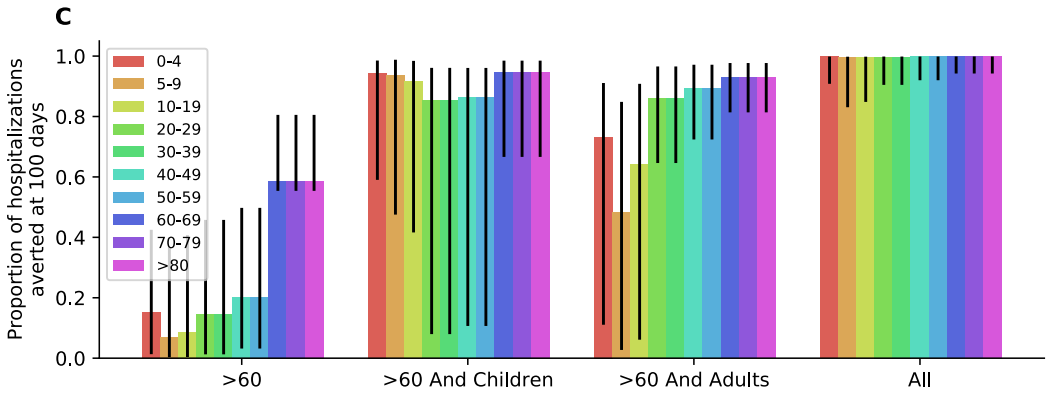


- The strategy ≥ 60 + *adults* averts as many hospitalizations and deaths as ≥ 60 + *Children*.

Who is getting the most out of these interventions?







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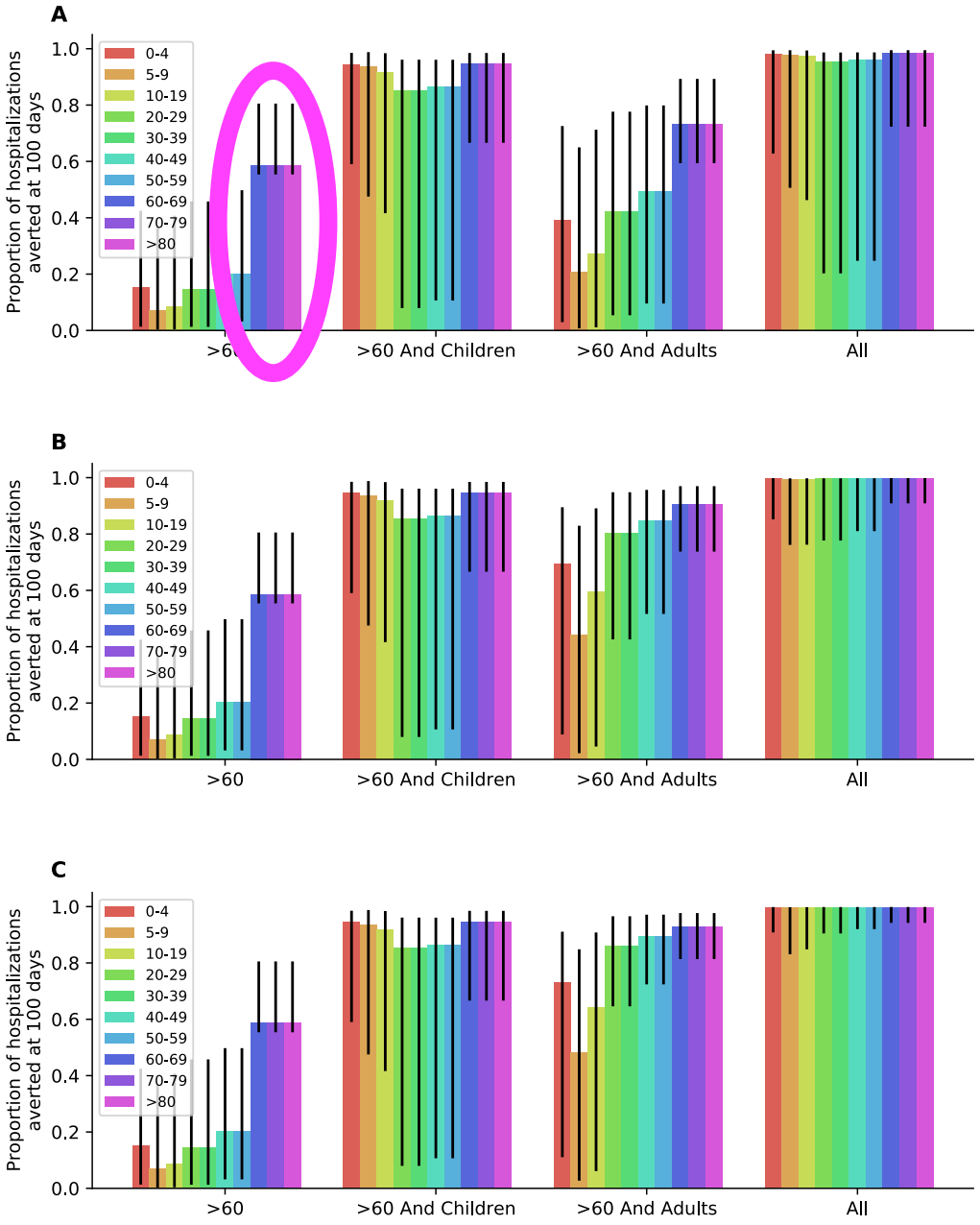
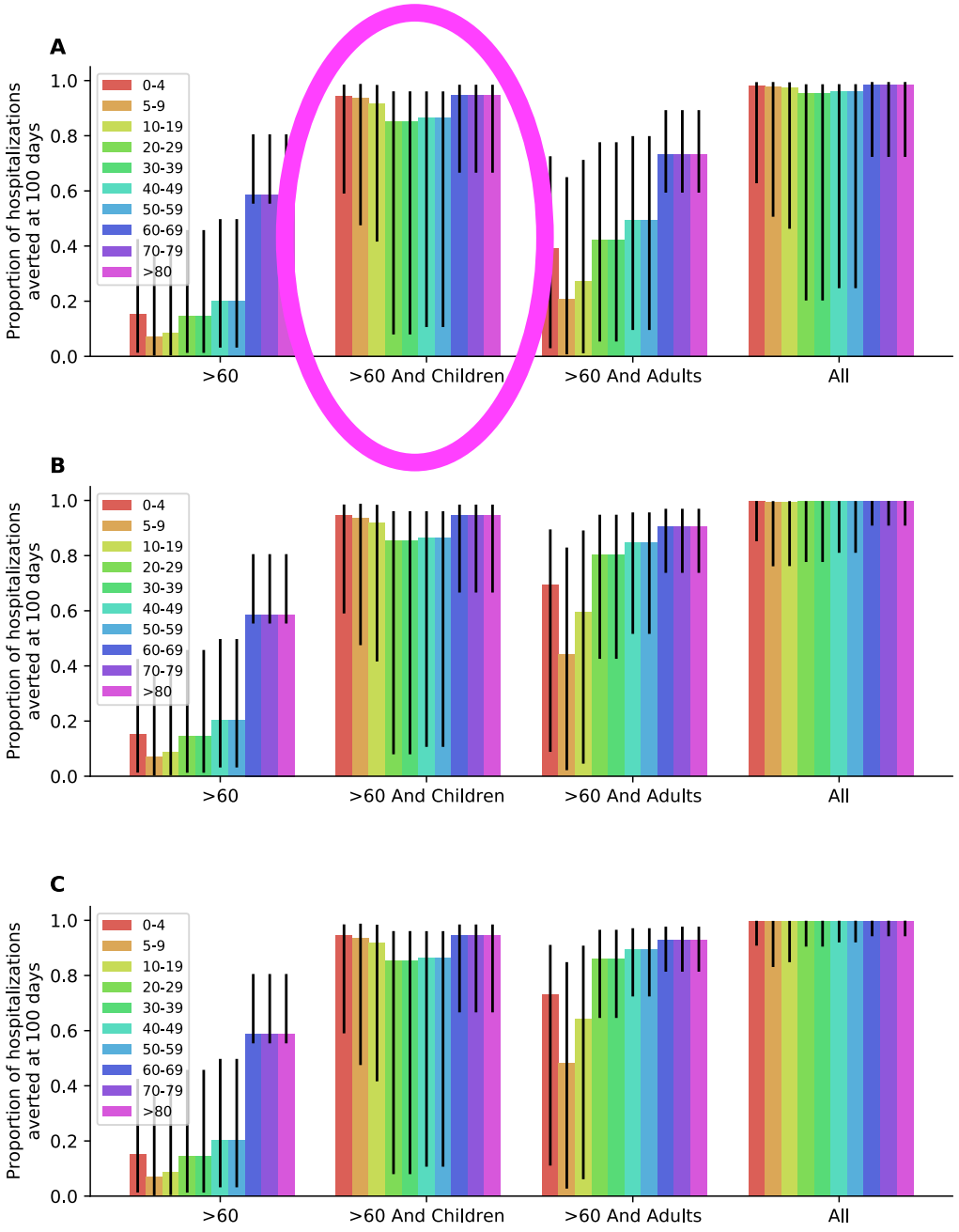


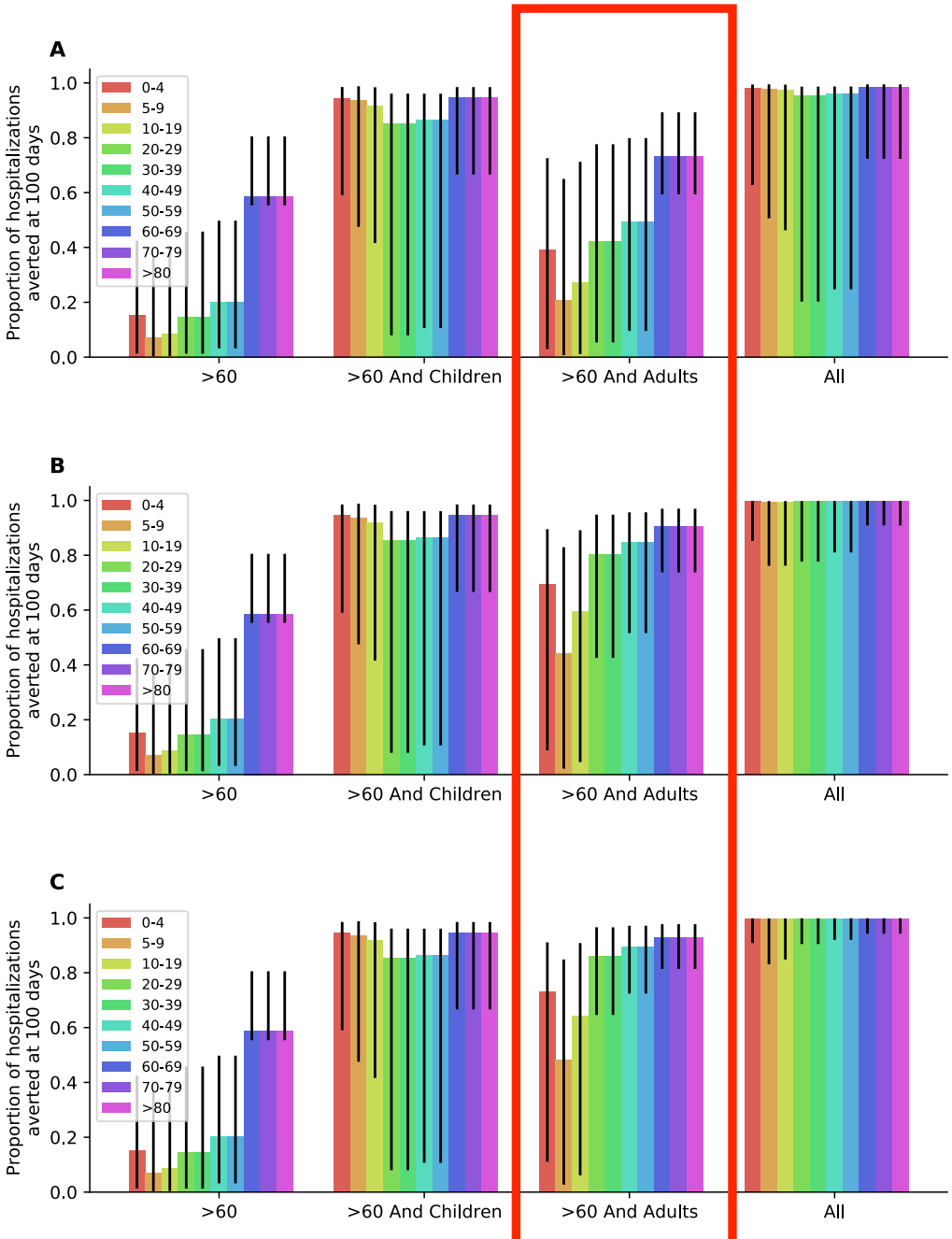
- The strategy ≥ 60 is protecting the older adults the most.

Who is getting the most out of these interventions?



- The strategy ≥ 60 + *Children* is protecting all age groups roughly equally.

Who is getting the most out of these interventions?



- The strategy ≥ 60 + *adults* is protecting younger and older adults mostly.
- As more contacts are reduced, a higher percentage of the adult hospitalizations is averted.

Summary

Timing of the intervention

- The timing of the social distancing intervention is crucial:
  - Early on ➧Delay the epidemic.
  - Once in the exponential phase ➧Flatten the curve.

Which intervention works best?

- Reducing everyone's contacts can avert over 90% of hospitalizations, even when younger adults reduce their contacts by only 25%.
- Reducing older adults contacts only averts $\geq$ 30% of hospitalizations and deaths (probably not enough not to overwhelm the health system).
- Children are an important part of the chain of transmission.
- ALL INTERVENTIONS are set to rebound if we lift the social distancing interventions.

Summary c'ed

Other thoughts

- There is a lot of uncertainty around key parameters, and that can affect widely the results (eg proportion of cases ascertained, duration of infectiousness, etc).
- We will have to be very creative to reopen the economy.
- Well-done Seroprevalence studies are a most.

- Peter Gilbert
- Tiffany Leung

Thank you!

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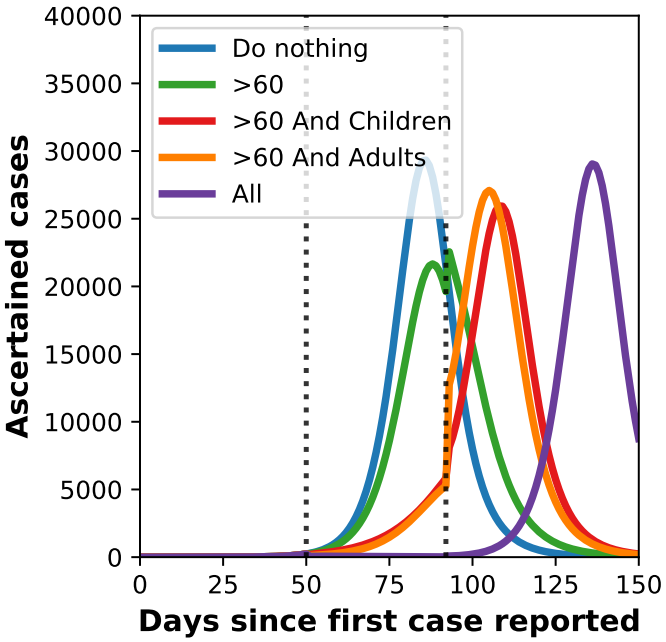
Do nothing
>60
>60 And Children
>60 And Adults
All
Ascertained cases
Days since first case reported
0
5000
10000
15000
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25000
30000
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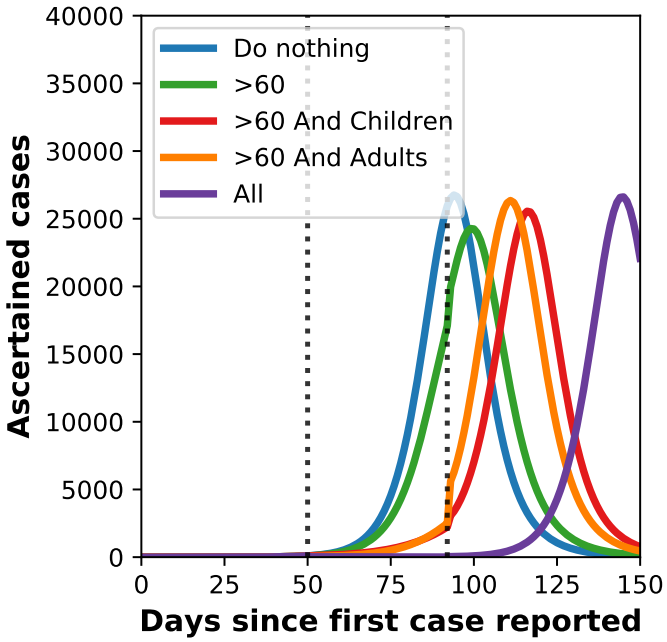
40000
0
25
50
75
100
125
150


Do nothing
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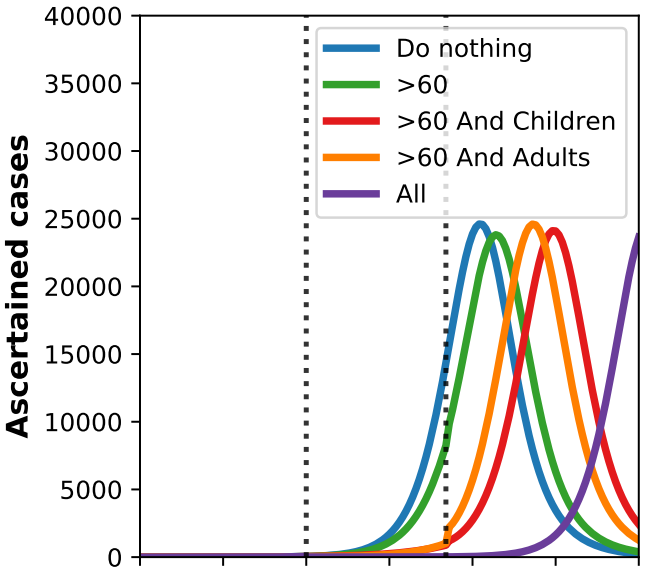
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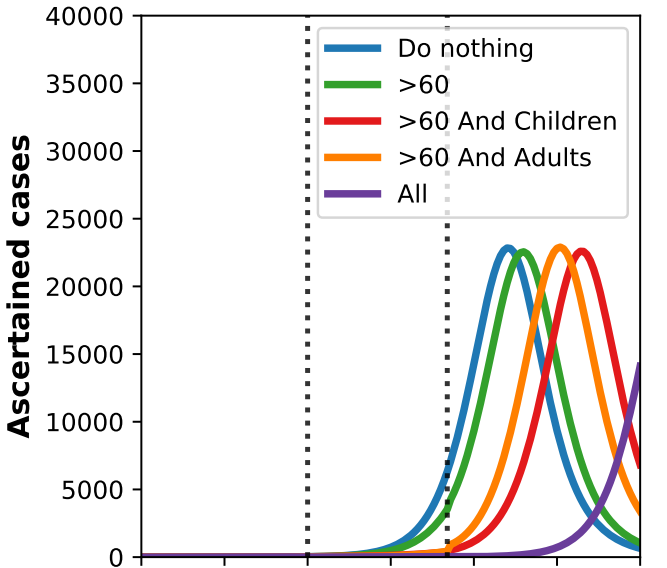
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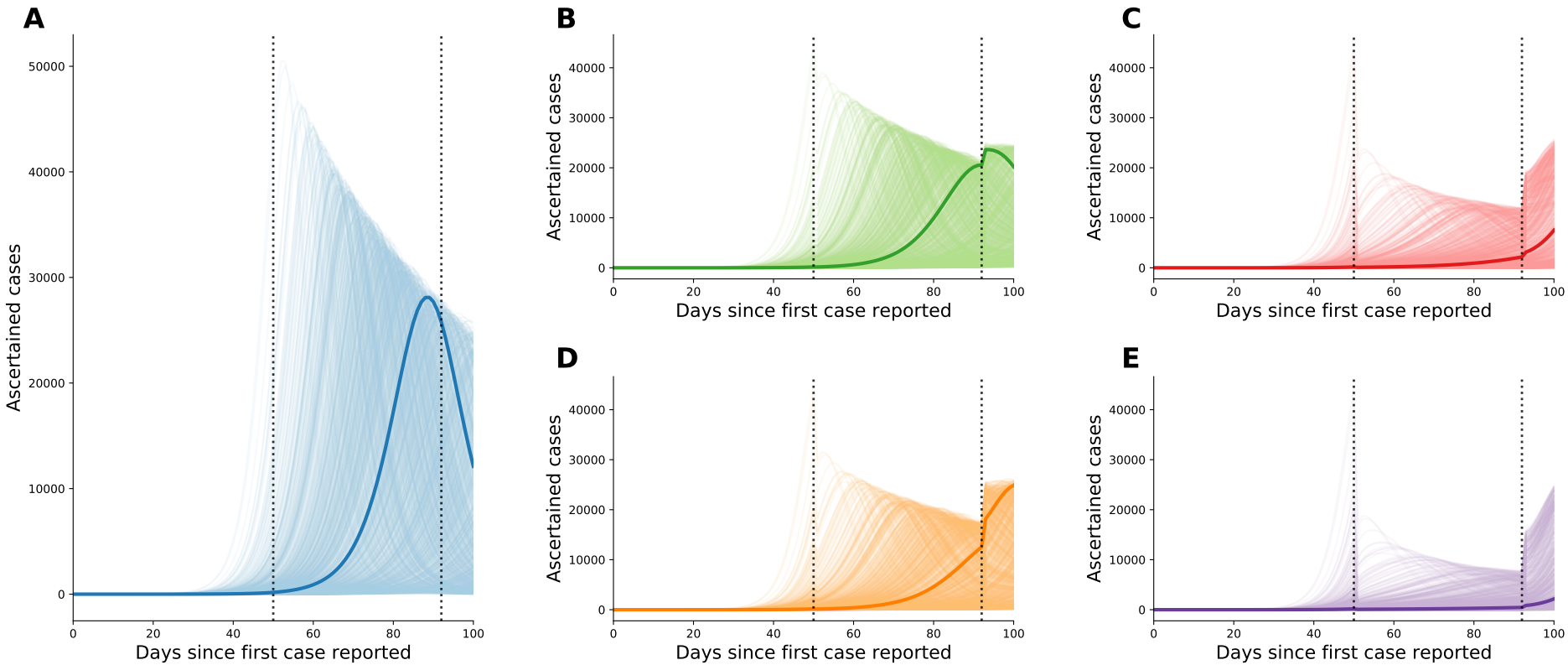
A
B
C
D
E
Ascertained cases
Days since first case reported
0
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40
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80
100