Modelling of COVID-19 epidemic and interventions within IDP camps

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PaxSyriana Foundation

crowdfight COVID-19

Model preliminaries

Between December 2019 and March 2020, 1M new IDP → Informal settlements

HIGH DENSITY and no management

~700 camps with 600 person per camp on average (log-normal)

80% family-sized tents (~7 people)

Most of the informal camps have no management.

Source: UN- REACH report, January-March 2020

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NO POSSIBLE lockdown

50% no access to electricity

External water, with 25% not have enough drinking water

External letrines, and 10% households have 1 member disable/elderly.

360% drop of Syrian pound (no access to goods) → high motility to work

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HIGH comorbidity

10% population has chronic diseases, 17% of them have no access to medicines.

Source: UN- REACH report, January-March 2020

AIM

Identify feasible interventions:

– Immediate applicability

– No need of complex technical infrastructure (e.g. testing, protection)

– Cost: as low as possible

Outlook

Modelling

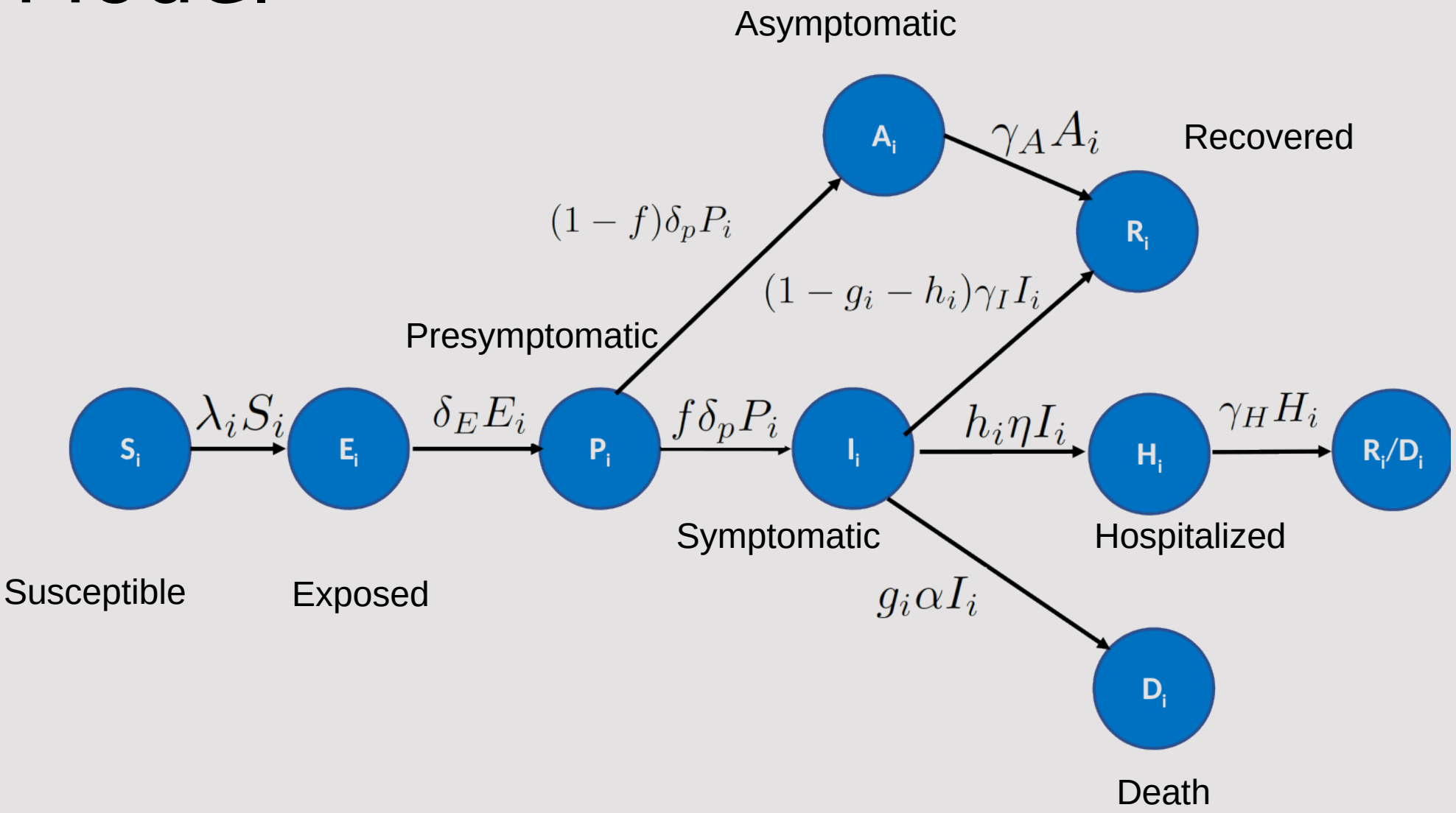
- Compartment models.
- Age-structured.
- Deterministic and stochastic simulations.
- Parameters estimated for IDPCs.
- Different camp sizes.
- ~50 different interventions modelled
- ~100K different simulations.

Strategies

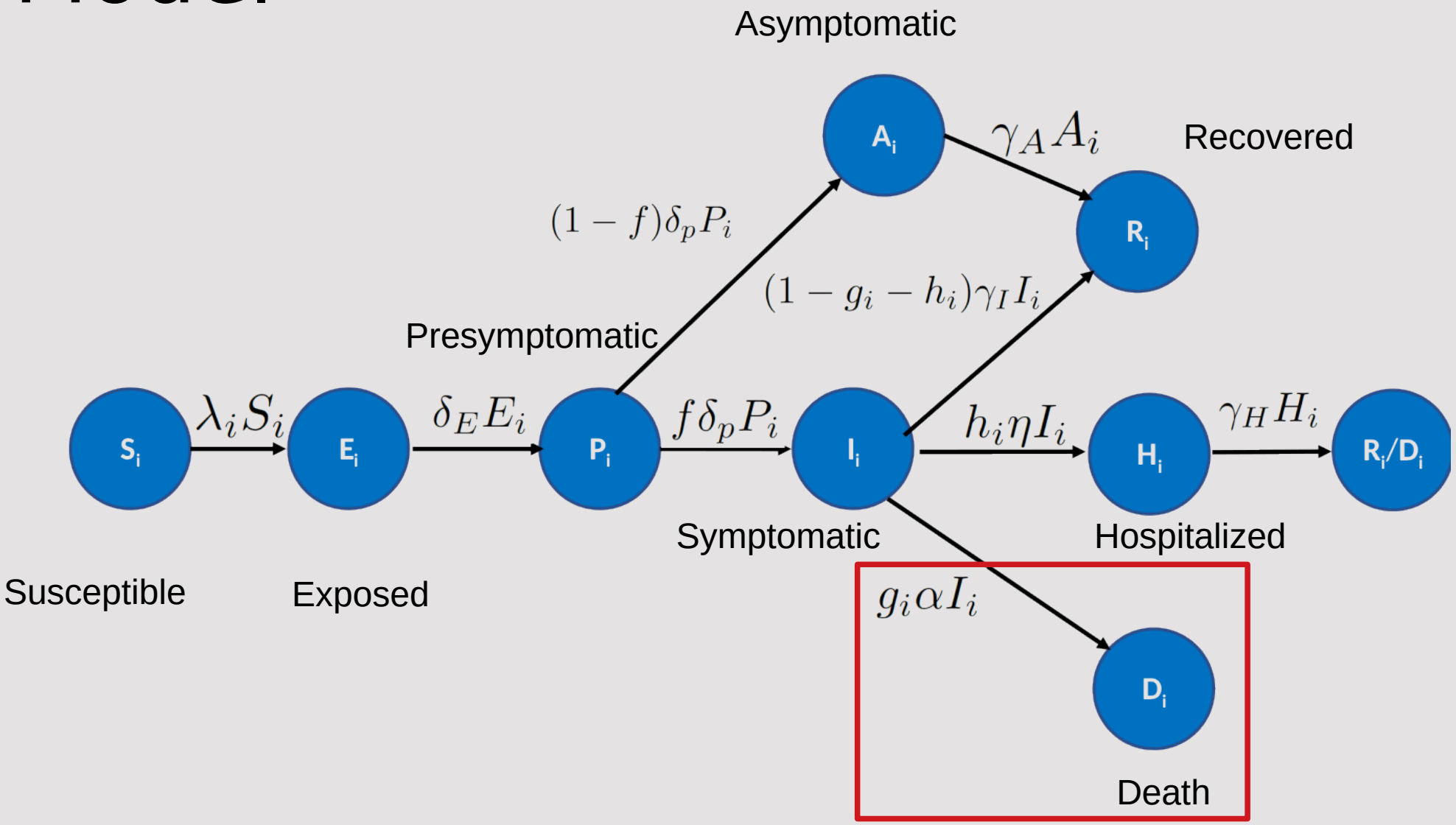
- Self-distancing
- Shielding, lockdown
- Isolation
- Combined strategies

The model

Model


Asymptomatic
A_i
$\gamma_A A_i$
Recovered
R_i
$(1-f)\delta_p P_i$
$(1-g_i-h_i)\gamma_I I_i$
Presymptomatic
S_i
$\lambda_i S_i$
E_i
$\delta_E E_i$
P_i
$f\delta_p P_i$
I_i
$h_i \eta I_i$
H_i
$\gamma_H H_i$
R_i/D_i
Symptomatic
Hospitalized
Susceptible
Exposed
$g_i \alpha I_i$
D_i
Death

Model


Asymptomatic
A_i
$\gamma_A A_i$
Recovered
R_i
$(1-f)\delta_p P_i$
$(1-g_i-h_i)\gamma_I I_i$
Presymptomatic
S_i
$\lambda_i S_i$
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R_i/D_i
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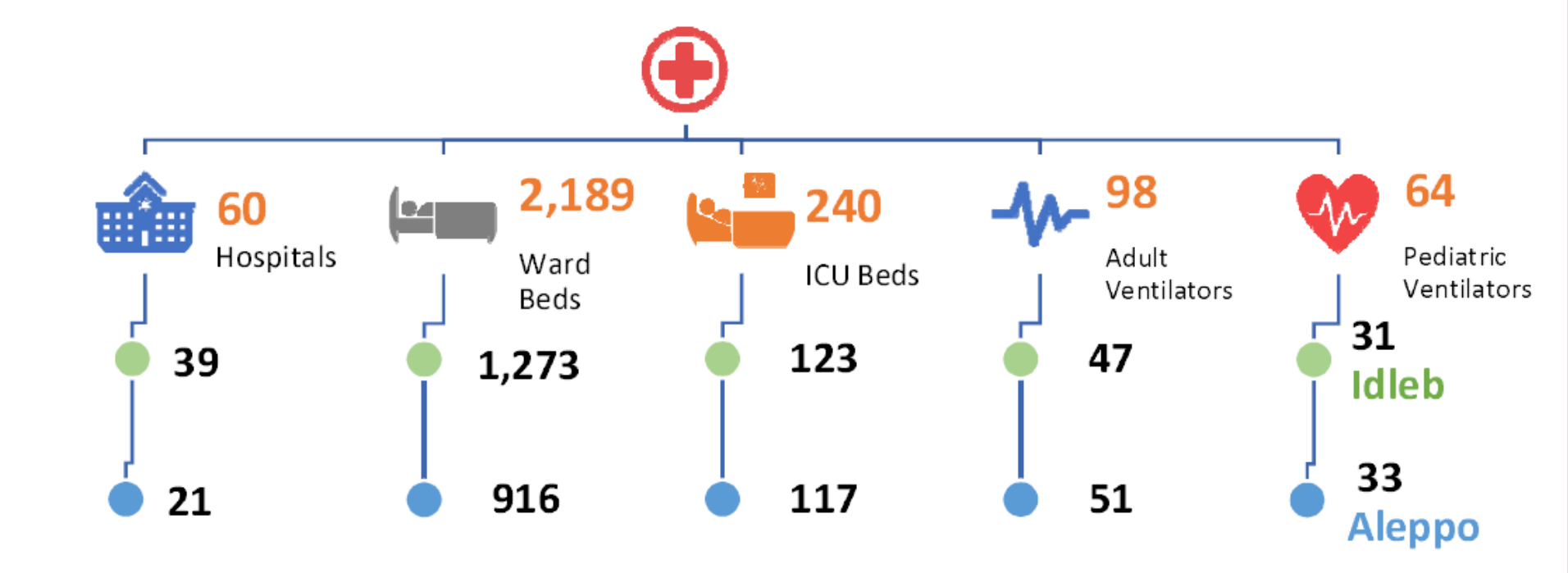
Death

Hospitalization capacity



Hariri et al. The COVID-19 forecast in NW Syria. *MedRxiv* (2020)

Hospitalization capacity

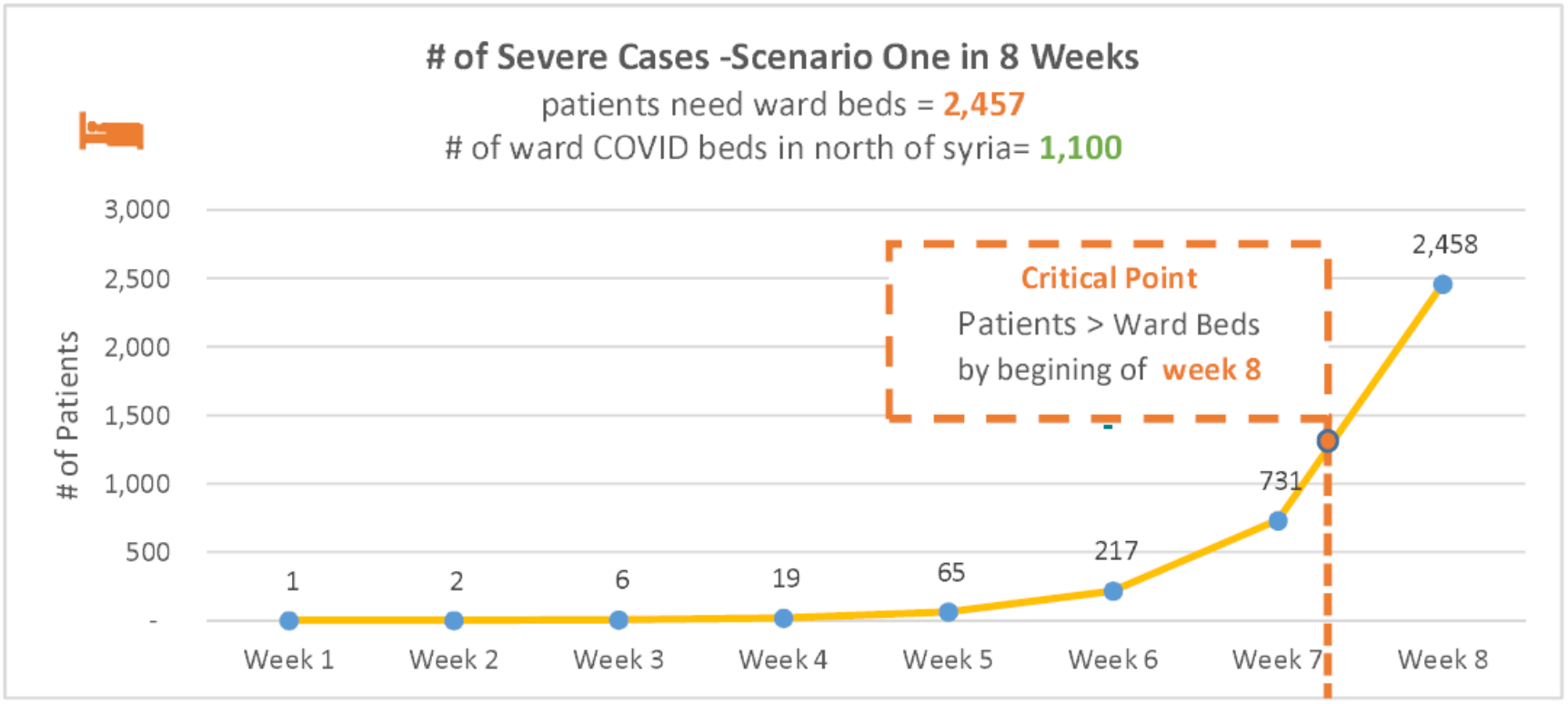
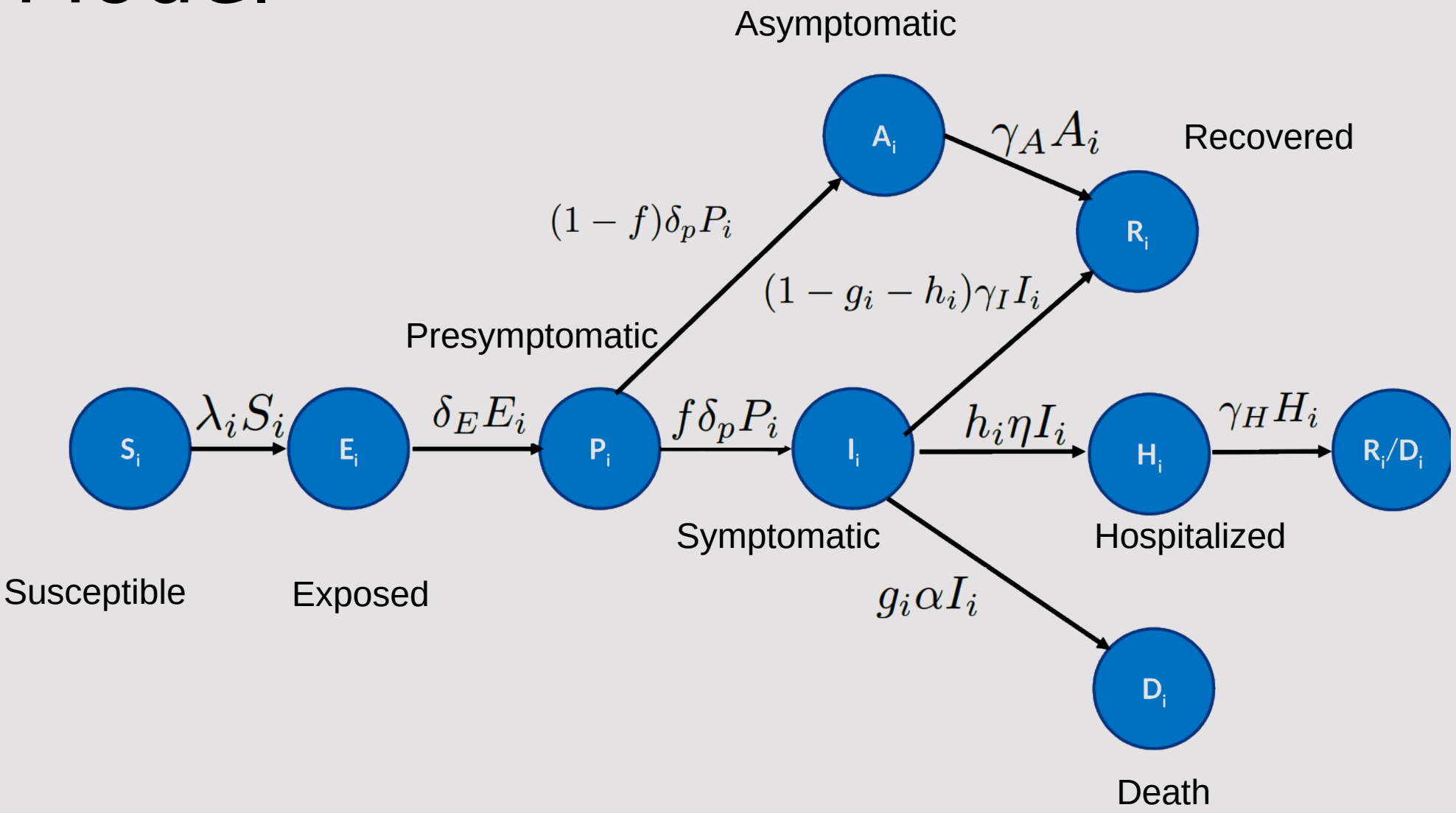


Figure 6 Scenario One predicted severe cases

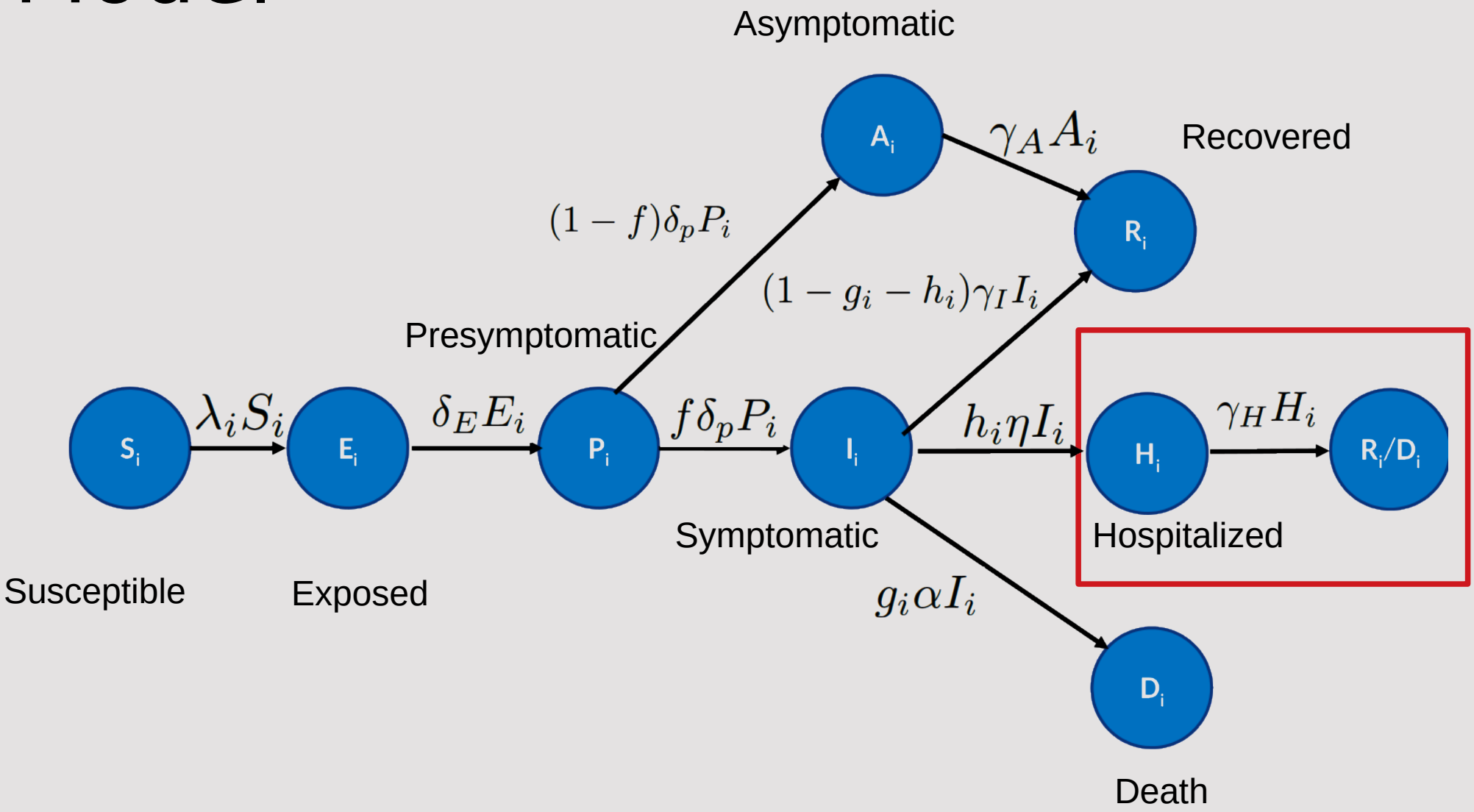
The health system in NW Syria would be unable to cope by the beginning of week 8; as such, severe cases could become critical and mortality could increase

Hariri et al. The COVID-19 forecast in NW Syria. *MedRxiv* (2020)

Model


Asymptomatic
A_i
$\gamma_A A_i$
Recovered
R_i
$(1-f)\delta_p P_i$
$(1-g_i-h_i)\gamma_I I_i$
Presymptomatic
S_i
$\lambda_i S_i$
E_i
$\delta_E E_i$
P_i
$f\delta_p P_i$
I_i
$h_i \eta I_i$
H_i
$\gamma_H H_i$
R_i/D_i
Symptomatic
Hospitalized
Susceptible
Exposed
$g_i \alpha I_i$
D_i
Death

Model


Asymptomatic
A_i
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Recovered
R_i
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I_i
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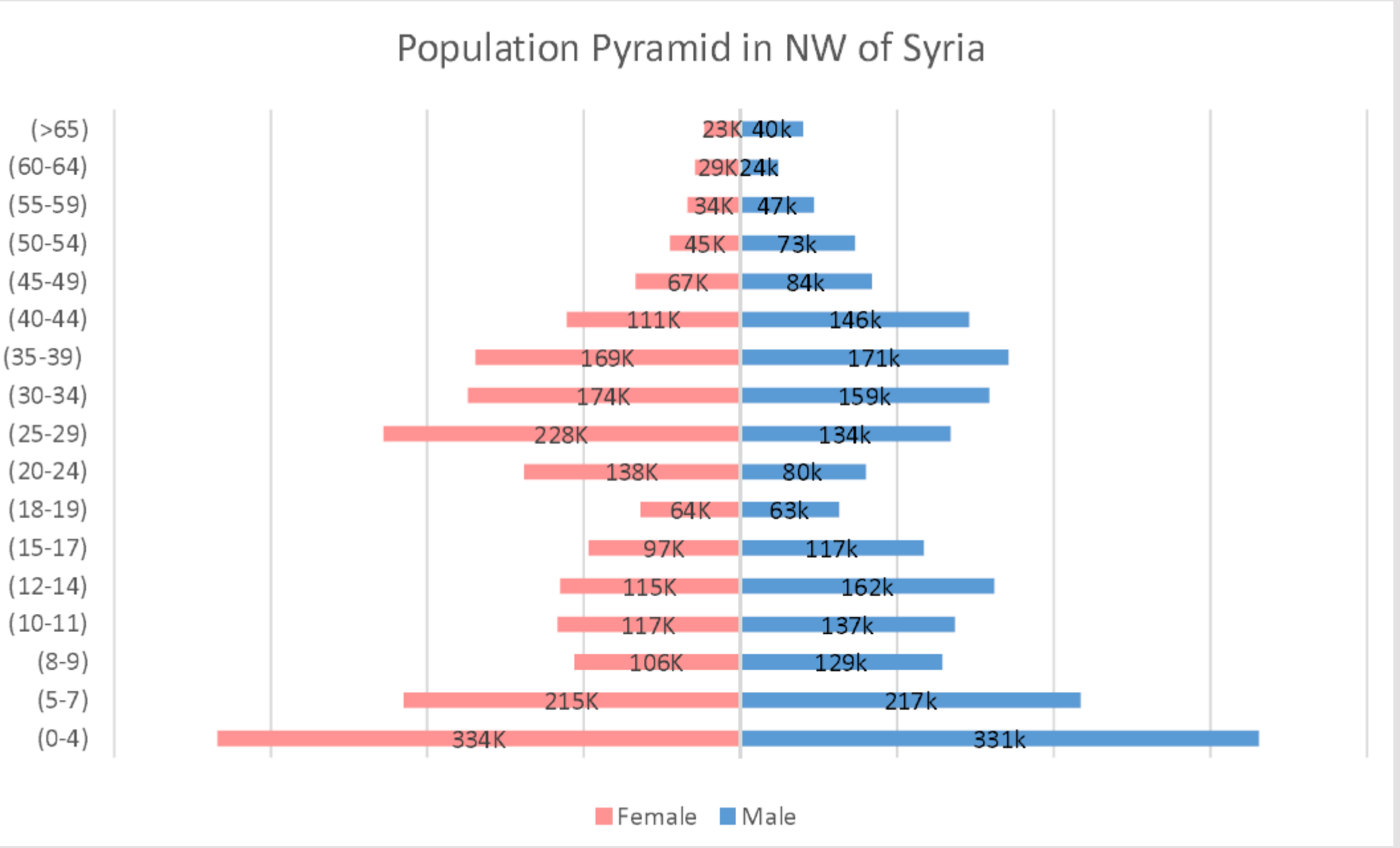
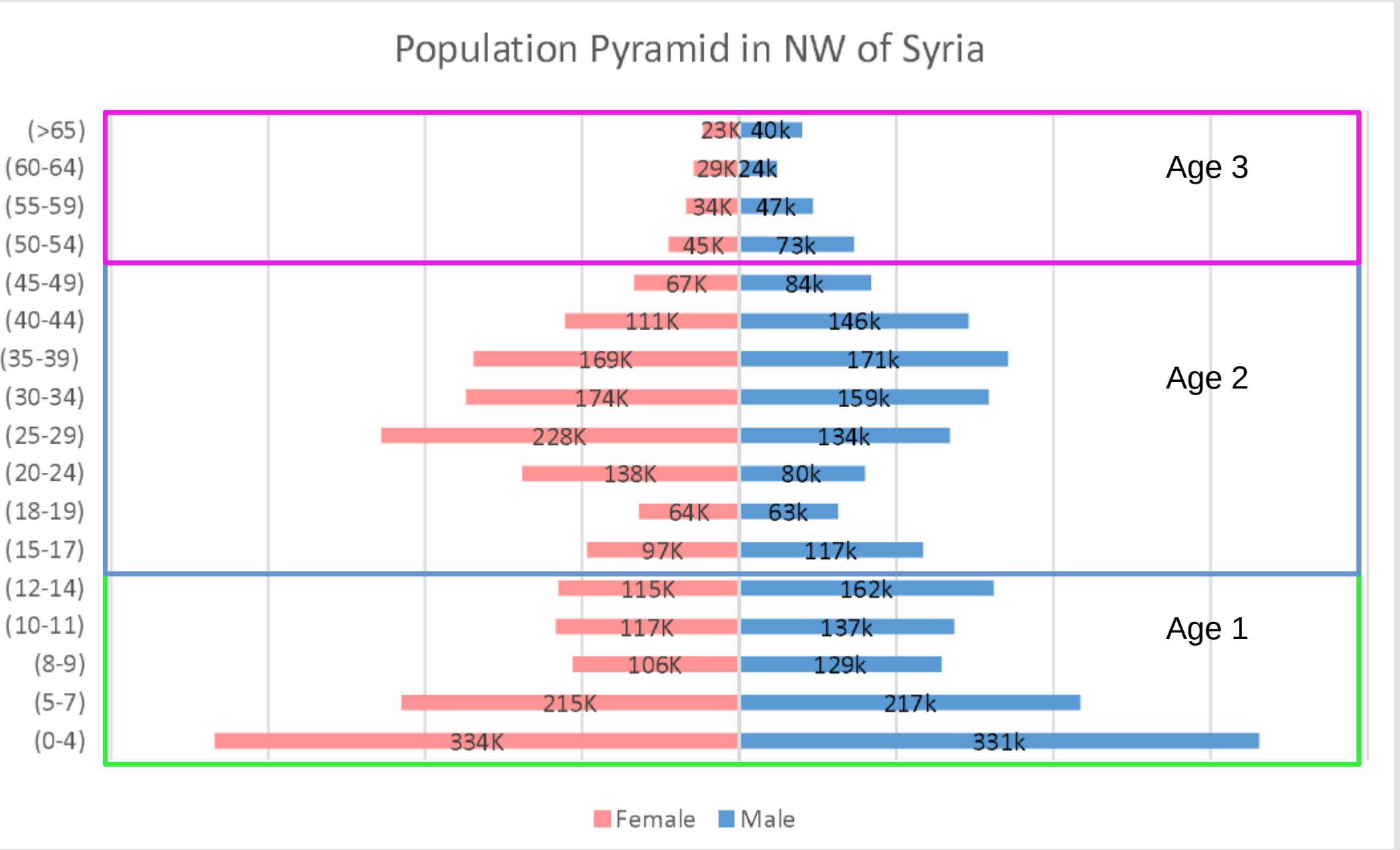
H_i
$\gamma_H H_i$
R_i/D_i
Symptomatic
Hospitalized
Susceptible
Exposed
$g_i \alpha I_i$
D_i
Death


Population Pyramid in NW of Syria
(>65)
(60-64)
(55-59)
(50-54)
(45-49)
(40-44)
(35-39)
(30-34)
(25-29)
(20-24)
(18-19)
(15-17)
(12-14)
(10-11)
(8-9)
(5-7)
(0-4)
23K
40k
29K
24k
34K
47k
45K
73k
67K
84k
111K
146k
169K
171k
174K
159k
228K
134k
138K
80k
64K
63k
97K
117k
115K
162k
117K
137k
106K
129k
215K
217k
334K
331k
Female
Male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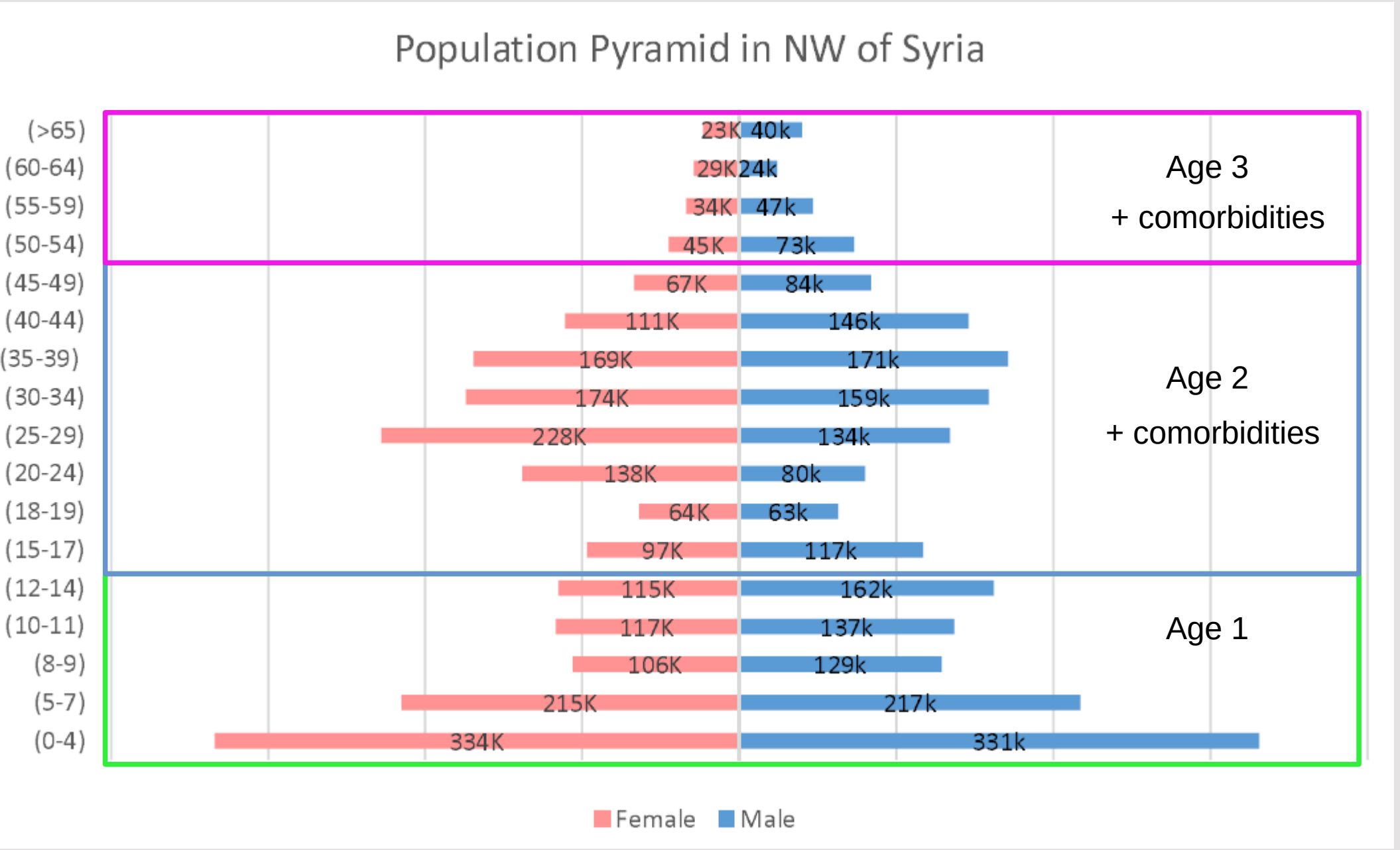
Age 3
Age 2
Age 1
Female
Male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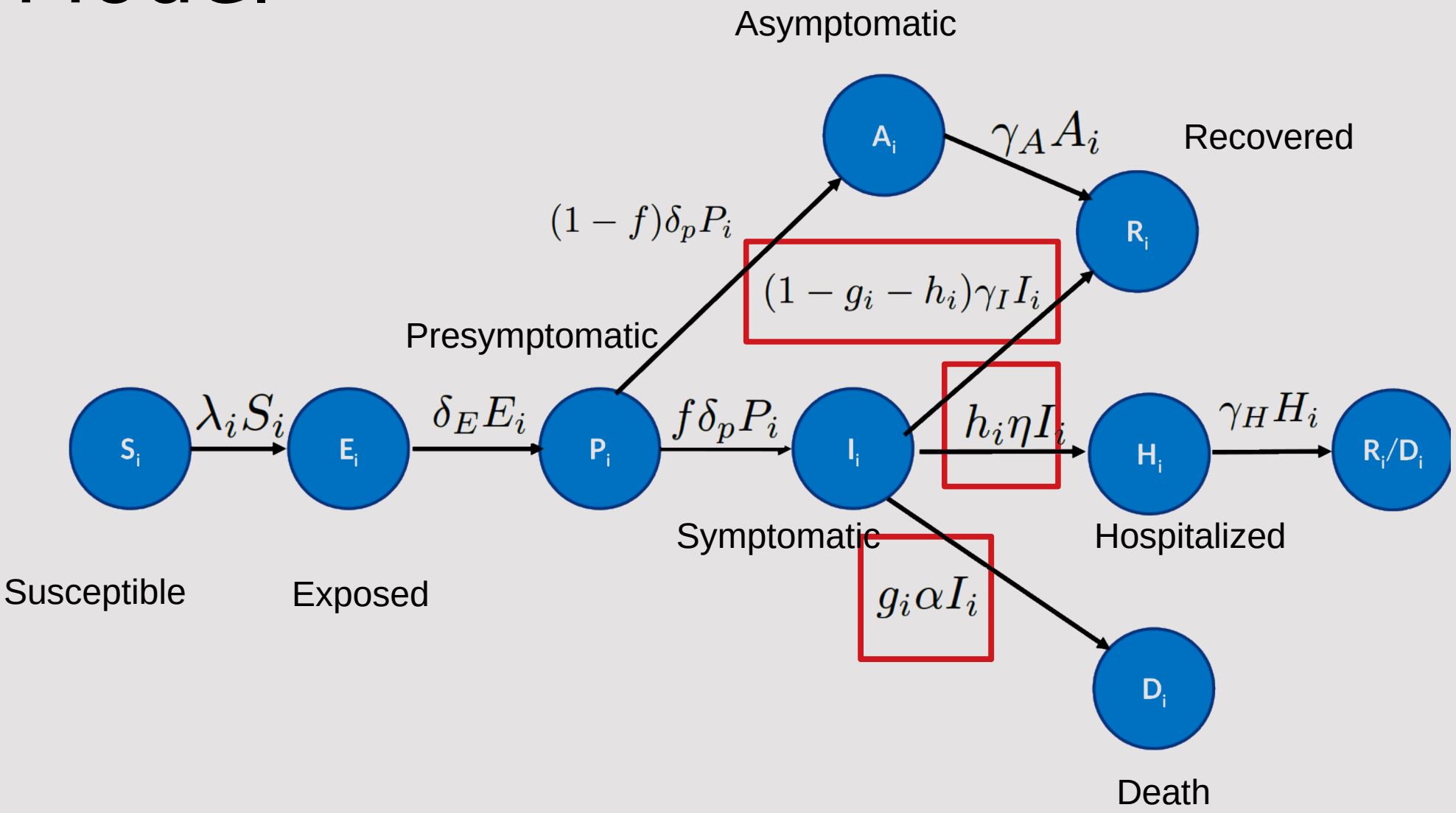
80k
64K
63k
97K
117k
115K
162k
117K
137k
106K
129k
215K
217k
334K
331k
Age 3
+ comorbidities
Age 2
+ comorbidities
Age 1
Female
Male

Model


Asymptomatic
A_i
$\gamma_A A_i$
Recovered
R_i
$(1-f)\delta_p P_i$
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Exposed
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D_i
Death

Parameter	Description	Value	Distribution	Reference
$1/\delta_E + 1/\delta_P$	Duration of incubation period in days	5.2 (95% CI: 4.1-7.0)	Lognormal	[1]
$1/\delta_E$	Duration of latency in days	$1/\delta_E + 1/\delta_P - 1/\delta_P$		[2]
$1/\delta_P$	Duration of preclinical infectiousness in days	2.3 (95% CI: 0.8-3.0)	Gompertz	[2]
$1/\gamma_A = 1/\gamma_I$	Duration of clinical ($1/\gamma_I$) and subclinical ($1/\gamma_A$) infectiousness in days	7		[2, 3]
$1/\eta$	Delay from symptoms onset to hospitalization in days	7 (IQR: 4-8)	Gamma	[4]
$1/\alpha$	Delay from symptoms onset to ICU (here death) in days	10 (IQR: 6-12)	Gamma	[4]
$1/\gamma_H$	Delay from hospitalization to recovery in days	10 (IQR: 7-14)	Gamma	[4]
f	Fraction of infected people who develop symptoms	0.84 (95% CI: 0.8-0.88)	Binomial	[5]
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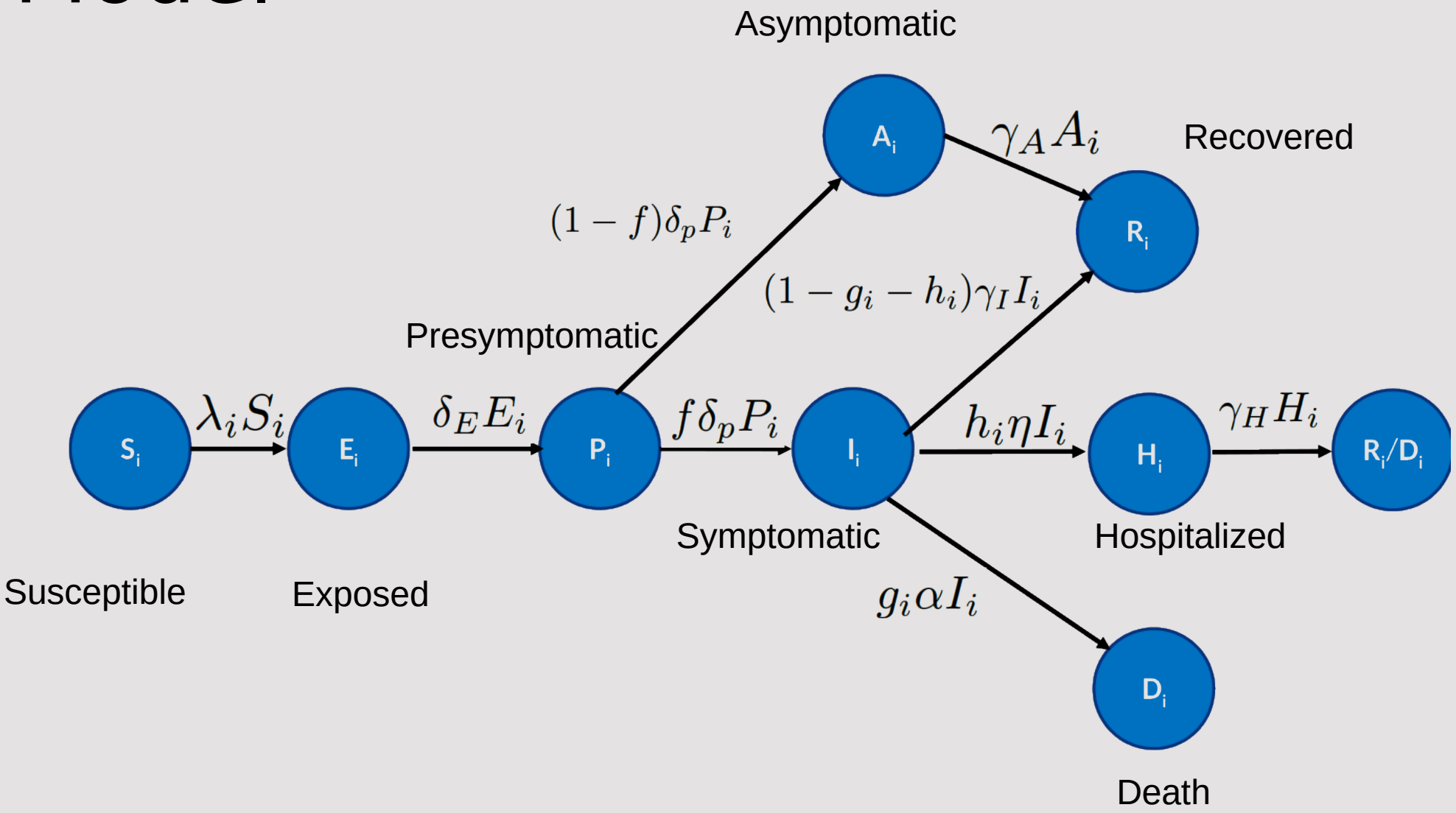
Model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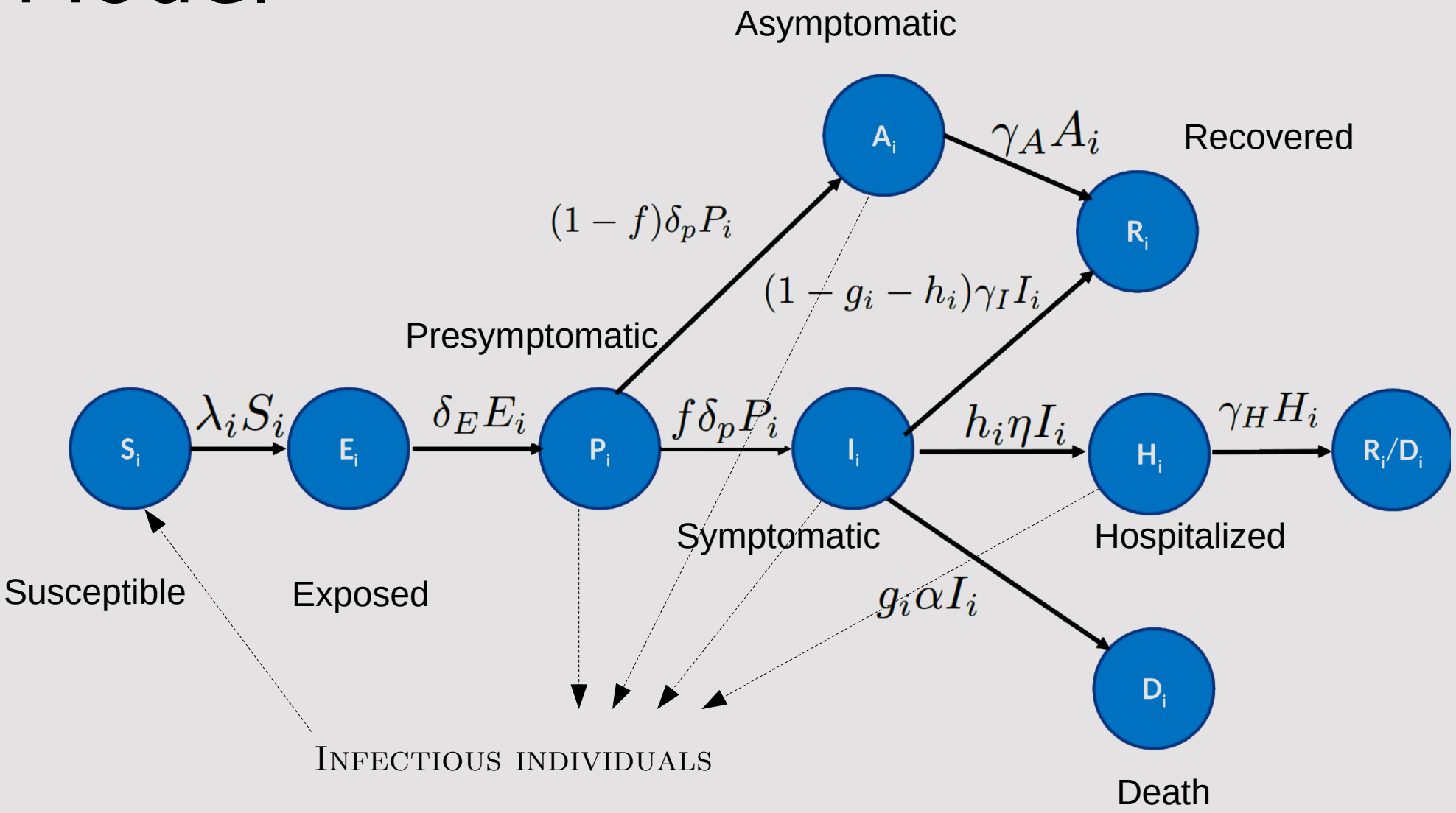
D_i
Death

Model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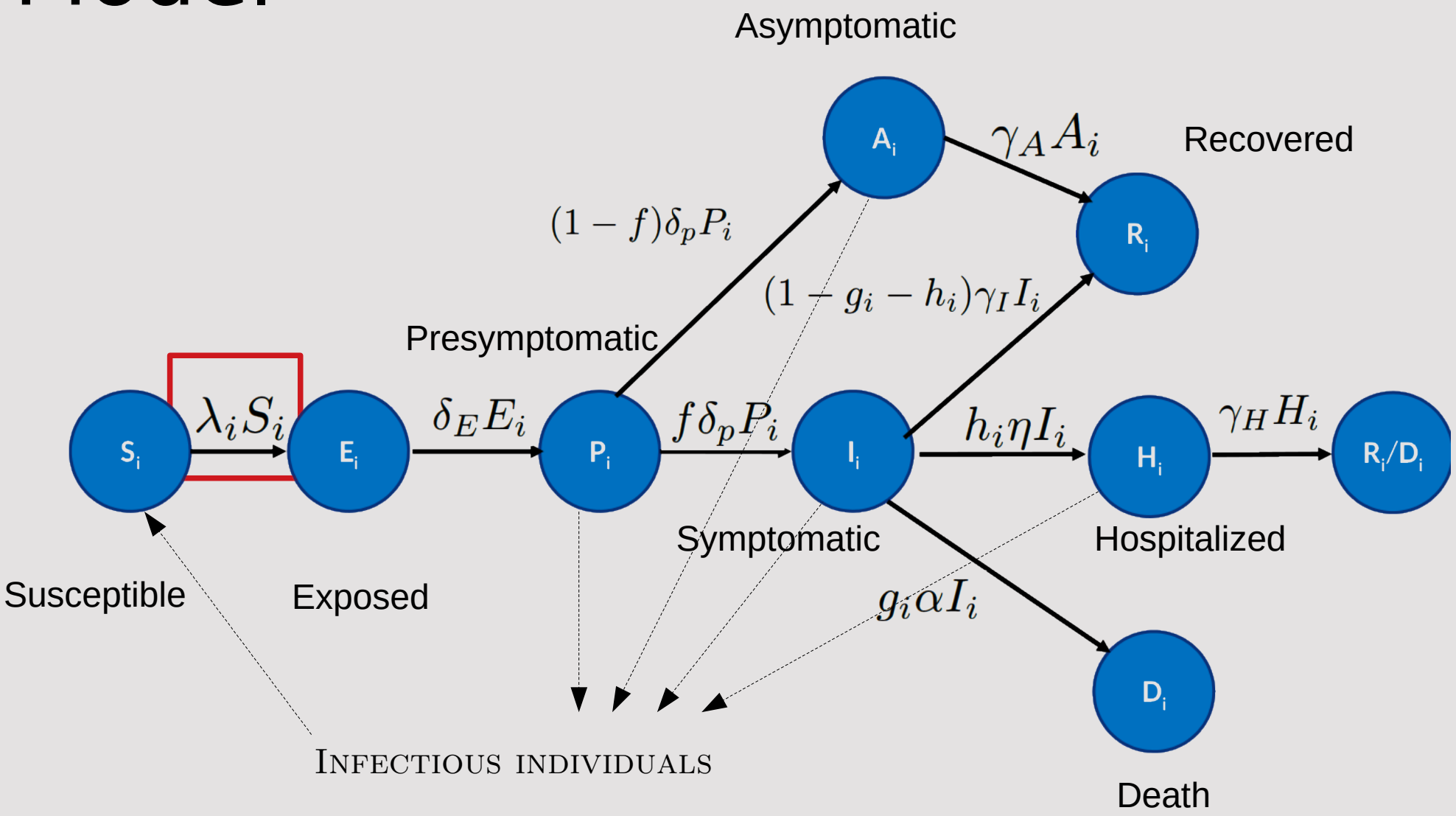
H_i
$\gamma_H H_i$
R_i/D_i
Symptomatic
Hospitalized
Susceptible
Exposed
$g_i \alpha I_i$
D_i
Death
Infectious individuals

Model


Asymptomatic
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Hospitalized
Susceptible
Exposed
$g_i \alpha I_i$
D_i
Death
Infectious individuals

$$\lambda_i = \sum_{j=1}^{n} \beta_{ij} \frac{P_j + A_j + I_j + H_j}{N_j}$$

With: $\beta_{ij} = \tau C_{ij}$

τ is the probability of infection if there is a contact

C is the number of contacts between population classes i and j

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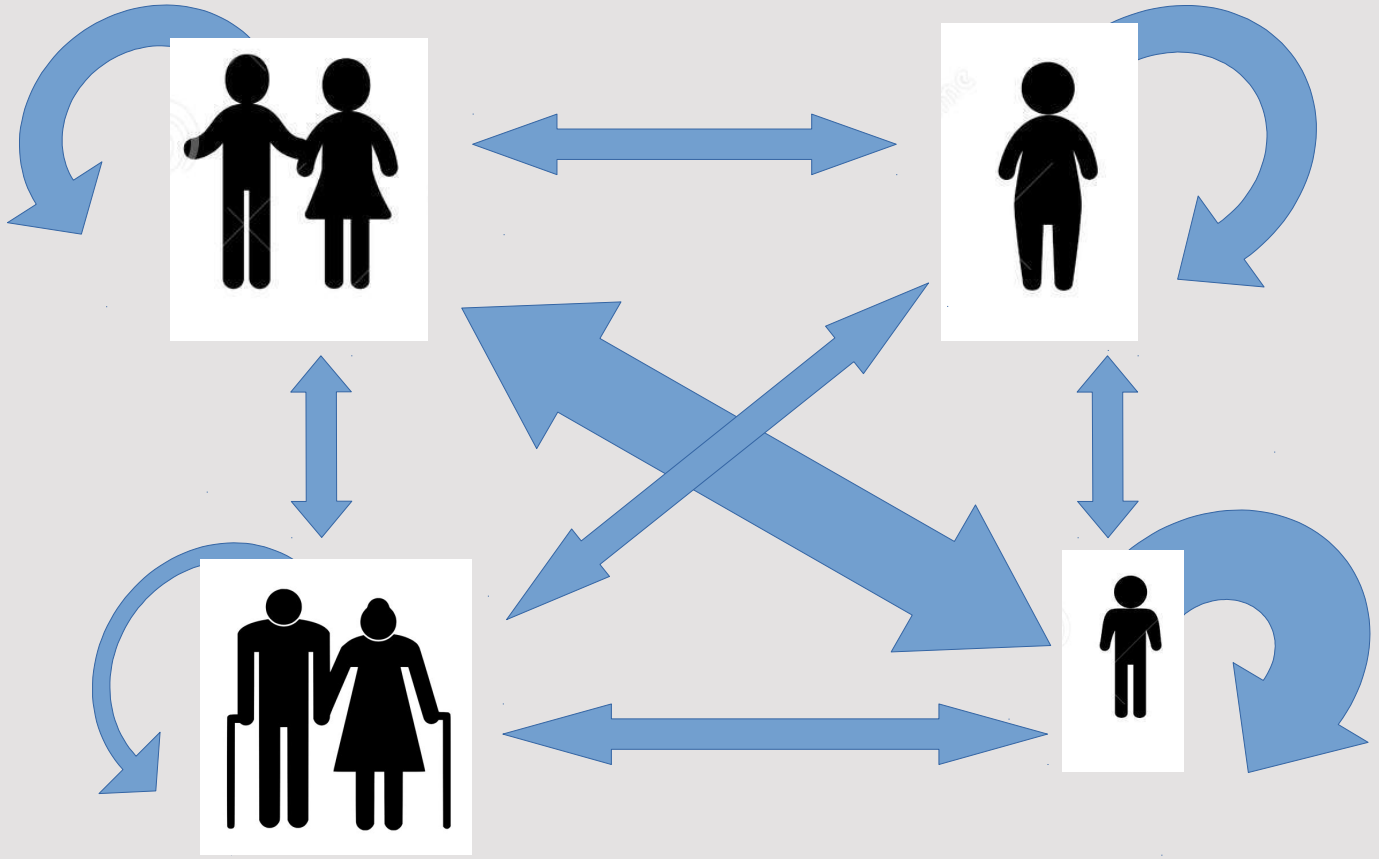
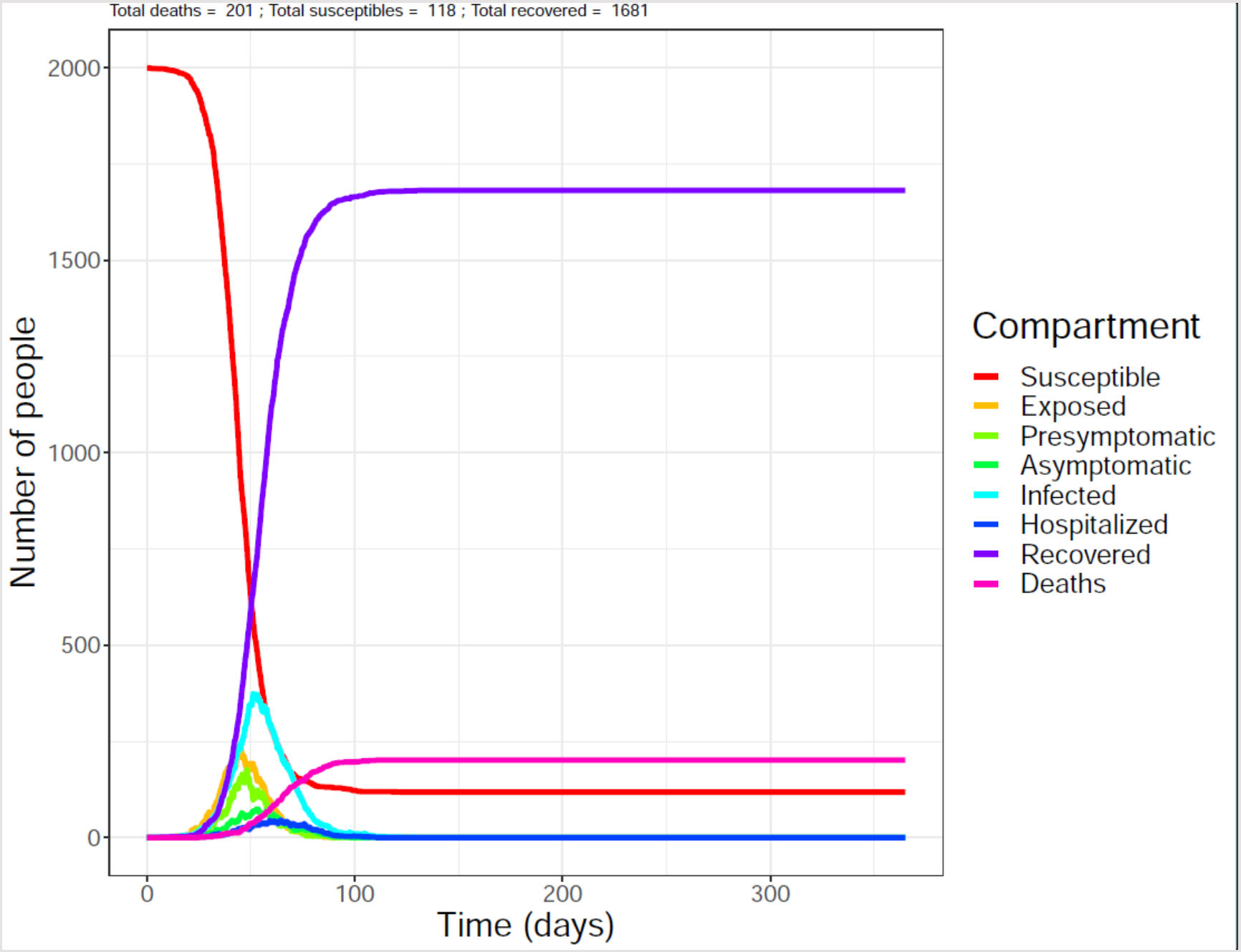
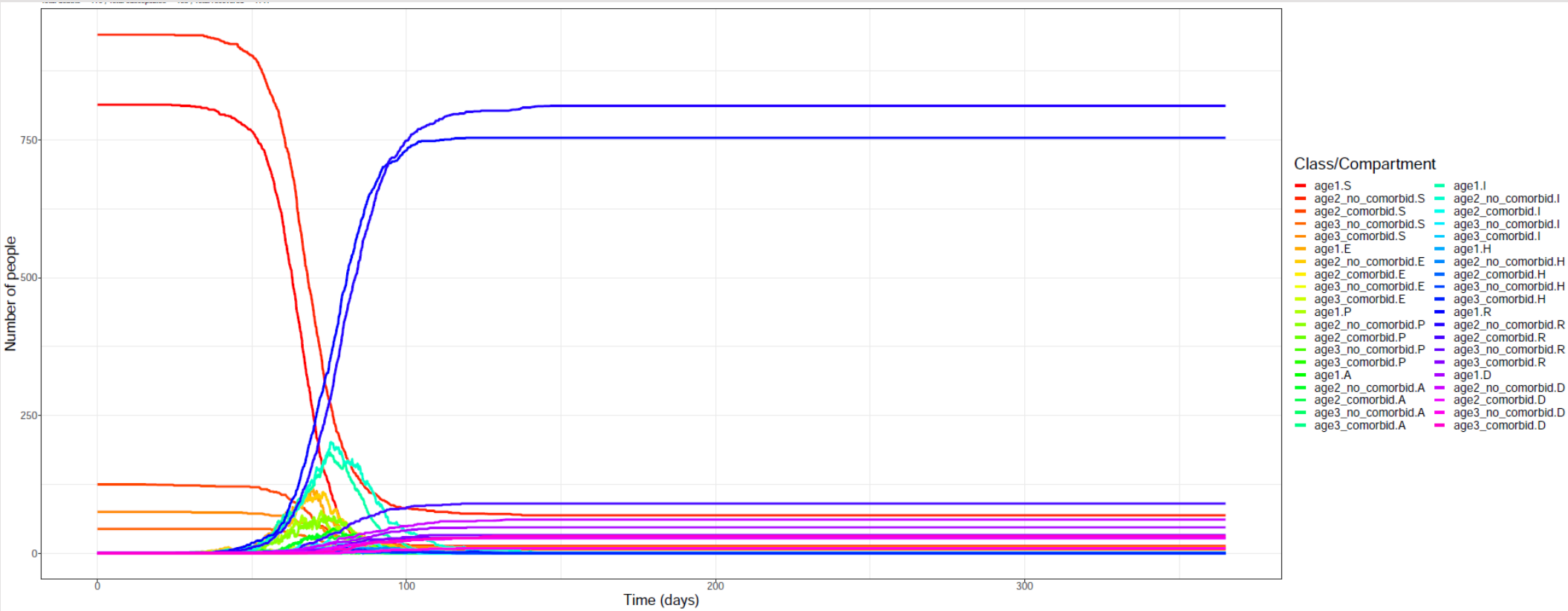


Model


Total deaths = 201 ; Total susceptibles = 118 ; Total recovered = 1681
Number of people
2000
1500
1000
500
0
0
100
200
300
Time (days)
Compartment
Susceptible
Exposed
Presymptomatic
Asymptomatic
Infected
Hospitalized
Recovered
Deaths

Model


Number of people
750
500
250
0
0
100
200
300
Time (days)
Class/Compartment
age1.S
age2_no_comorbid.S
age2_comorbid.S
age3_no_comorbid.S
age3_comorbid.S
age1.E
age2_no_comorbid.E
age2_comorbid.E
age3_no_comorbid.E
age3_comorbid.E
age1.P
age2_no_comorbid.P
age2_comorbid.P
age3_no_comorbid.P
age3_comorbid.P
age1.A
age2_no_comorbid.A
age2_comorbid.A
age3_no_comorbid.A
age3_comorbid.A
age1.I
age2_no_comorbid.I
age2_comorbid.I
age3_no_comorbid.I
age3_comorbid.I
age1.H
age2_no_comorbid.H
age2_comorbid.H
age3_no_comorbid.H
age3_comorbid.H
age1.R
age2_no_comorbid.R
age2_comorbid.R
age3_no_comorbid.R
age3_comorbid.R
age1.D
age2_no_comorbid.D
age2_comorbid.D
age3_no_comorbid.D
age3_comorbid.D

The results

Strategy 1: Self-distancing

Description

- Reduction of contacts between individuals.

Key-points

- Simple and rapid implementation.
- Educational-based, long-term benefit
- Starting investment

  then mouth-to-word

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Description

- Reduction of contacts between individuals.

Population class	Null model	Reduction 20%	Reduction 50%
Kids	25	20	12.5
Adults	15	11	7.5
Elderly	10	8	5

Key-points

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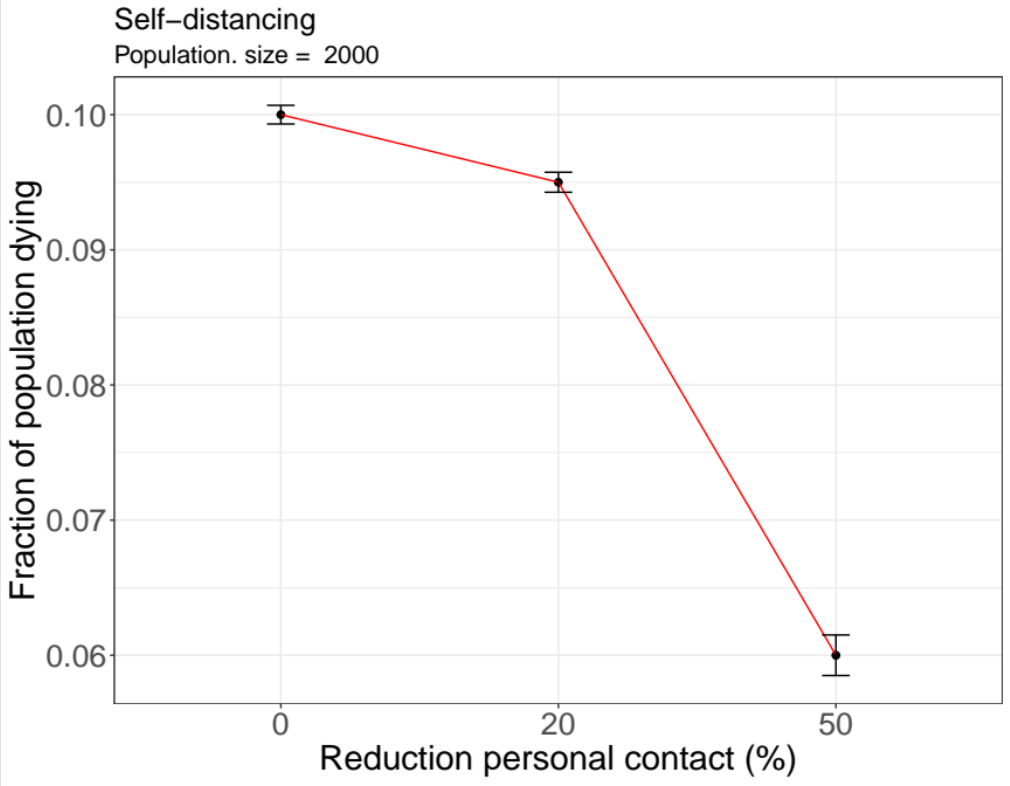
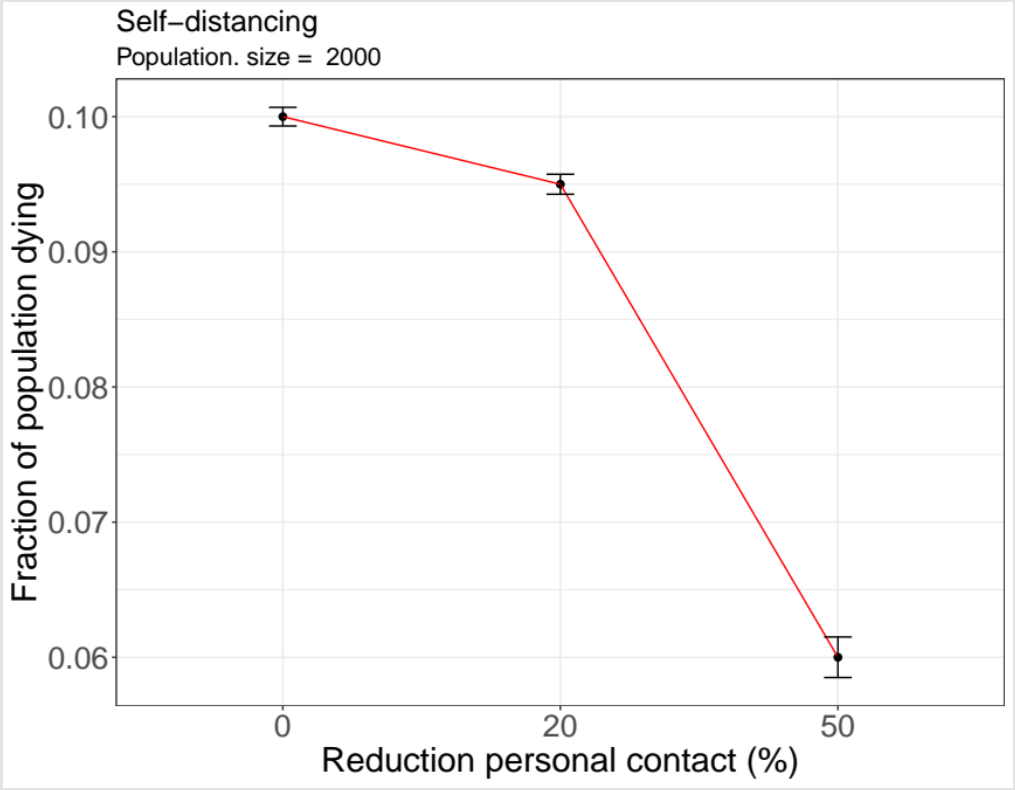
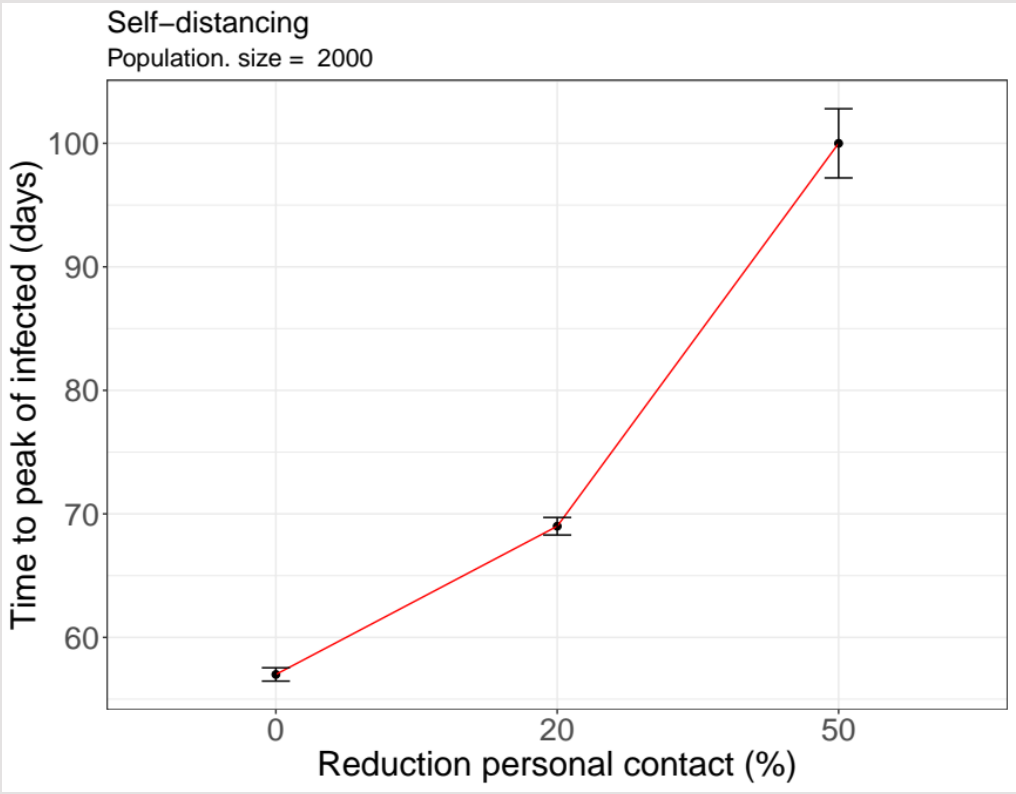
Strategy 1: Self-distancing

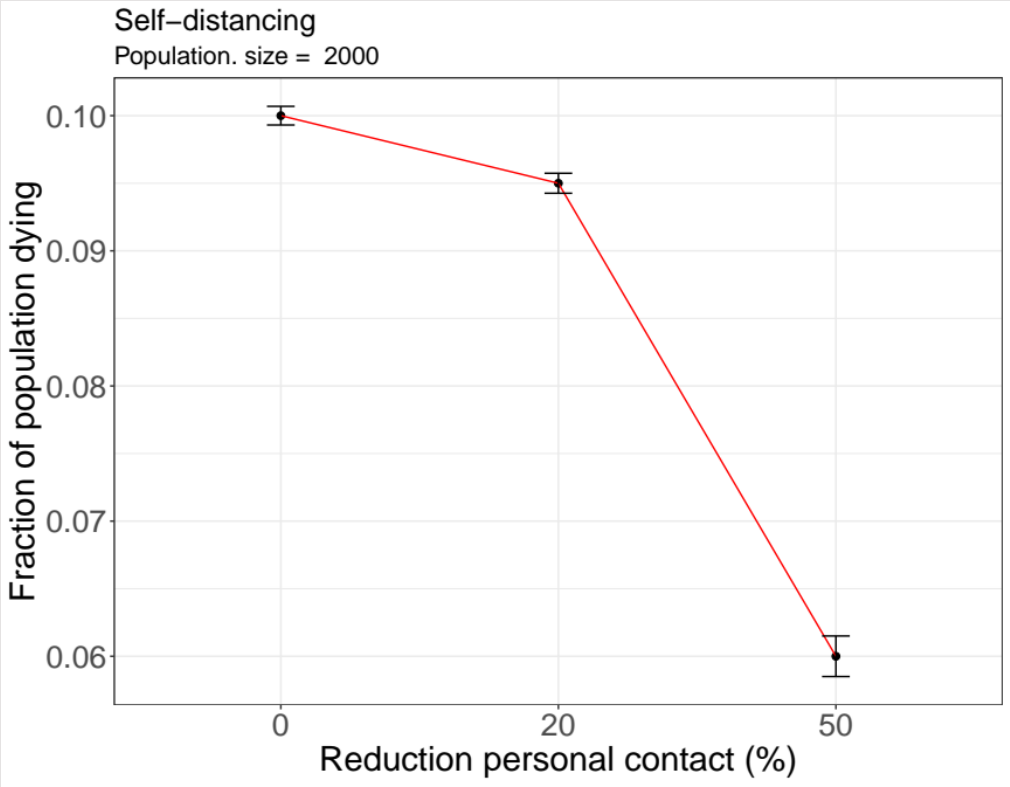


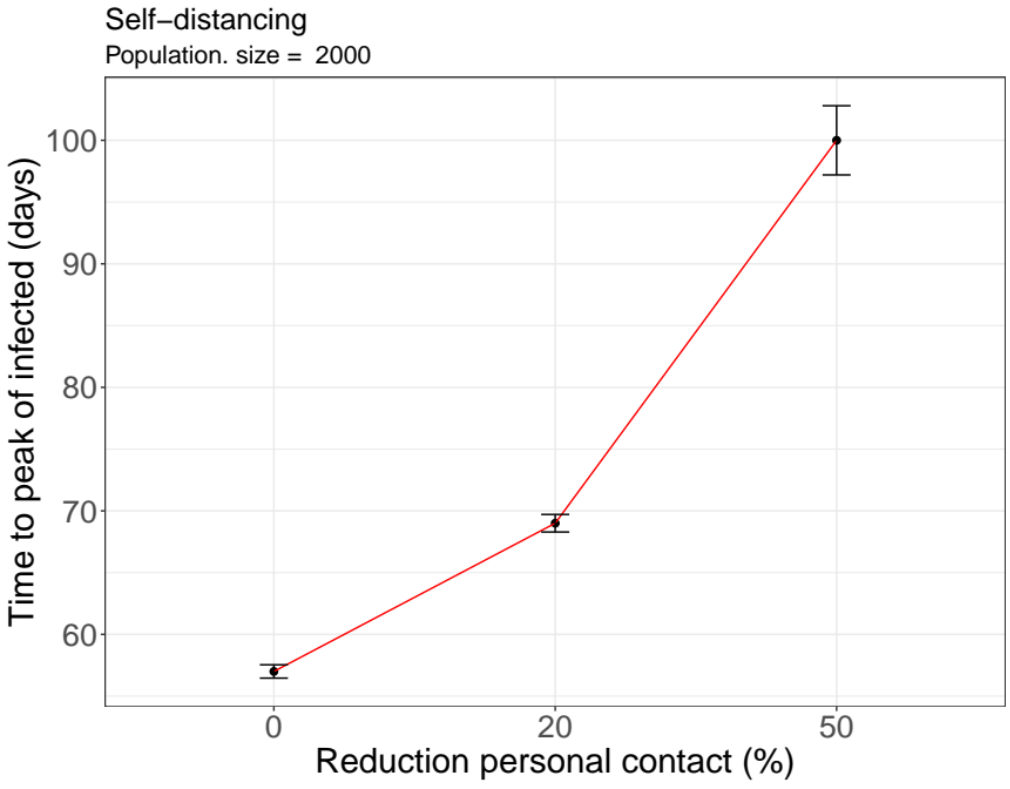
Strategy 1: Self-distancing





Strategy 1: Self-distancing





Up to 40% reduction in the the death tolls

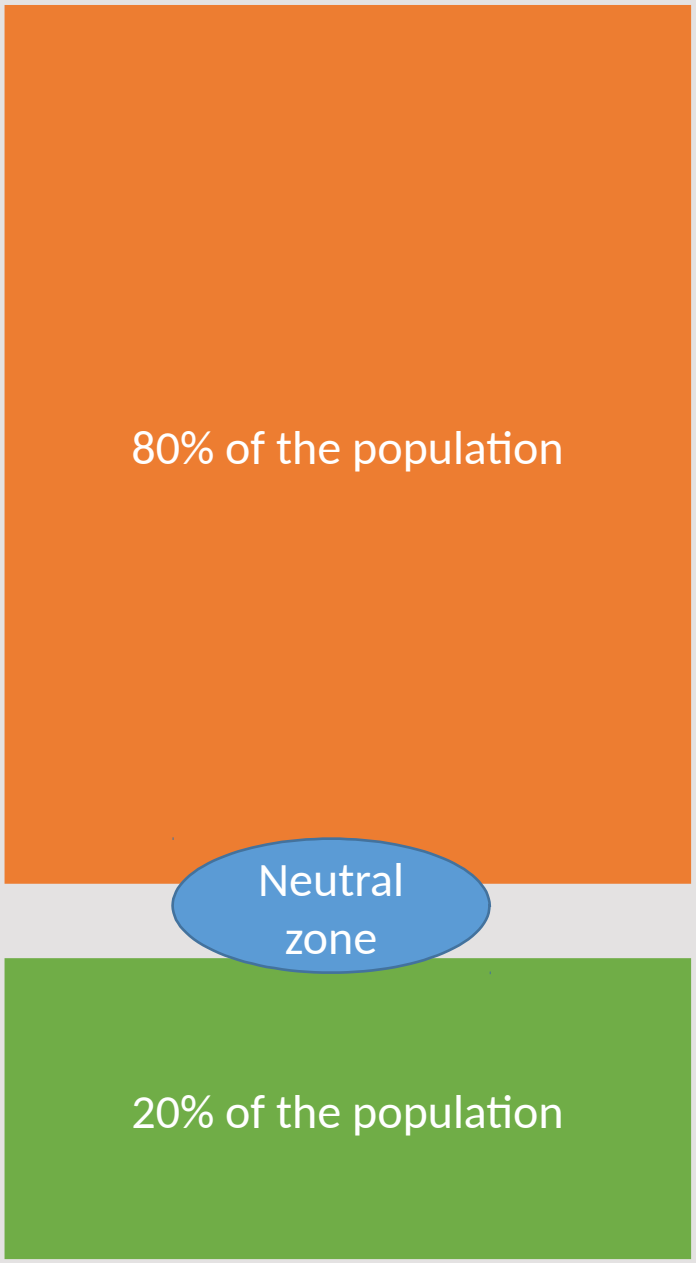
Up to 40% delay in the peak of infected population

Strategy 2: Shielding and Lockdown

Description

- Shield of vulnerable population.
- Similar conditions in terms of tents occupancy and distance between tents were considered.
- Vulnerable:
  - Elderly.
  - People with co-morbidities.
  - Carers/family.
- Lockdown when first symptom is detected.

Shielding vulnerable population within a “green” zone



For a total population of 100 persons

- 45 kids (0-18 yo)
- 35 adults
- Meetings between orange and green in « **neutral zone** » (open tent), no more than 4 people at a time (mixed orange/green). No physical contact (mask and gloves, 1.5 meter distance).

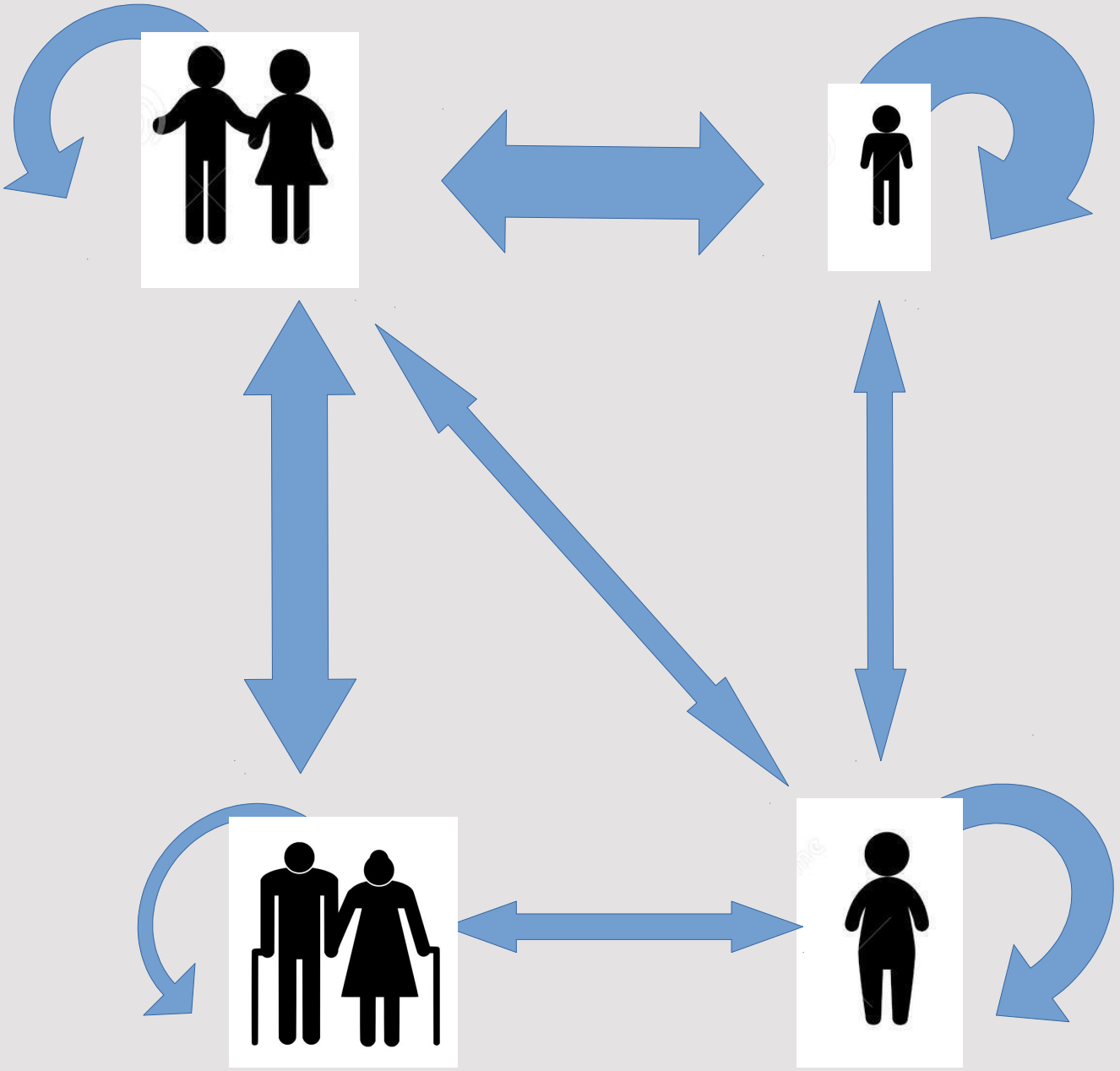
- 5 elderly (60+)
- 10 middle-aged NCD affected (mainly people 40-60 years old)
- 5 kids (<13 yrs)
- Intra-green zone carers are among the 10 non-elderly NCD
- No unprotected contact with orange zone or external world
- In average, meeting in neutral zone once per week (2 to 10 contacts per week with orange zone)

Shielding vulnerable population within a “green” zone

80% of the population

Neutral zone

20% of the population



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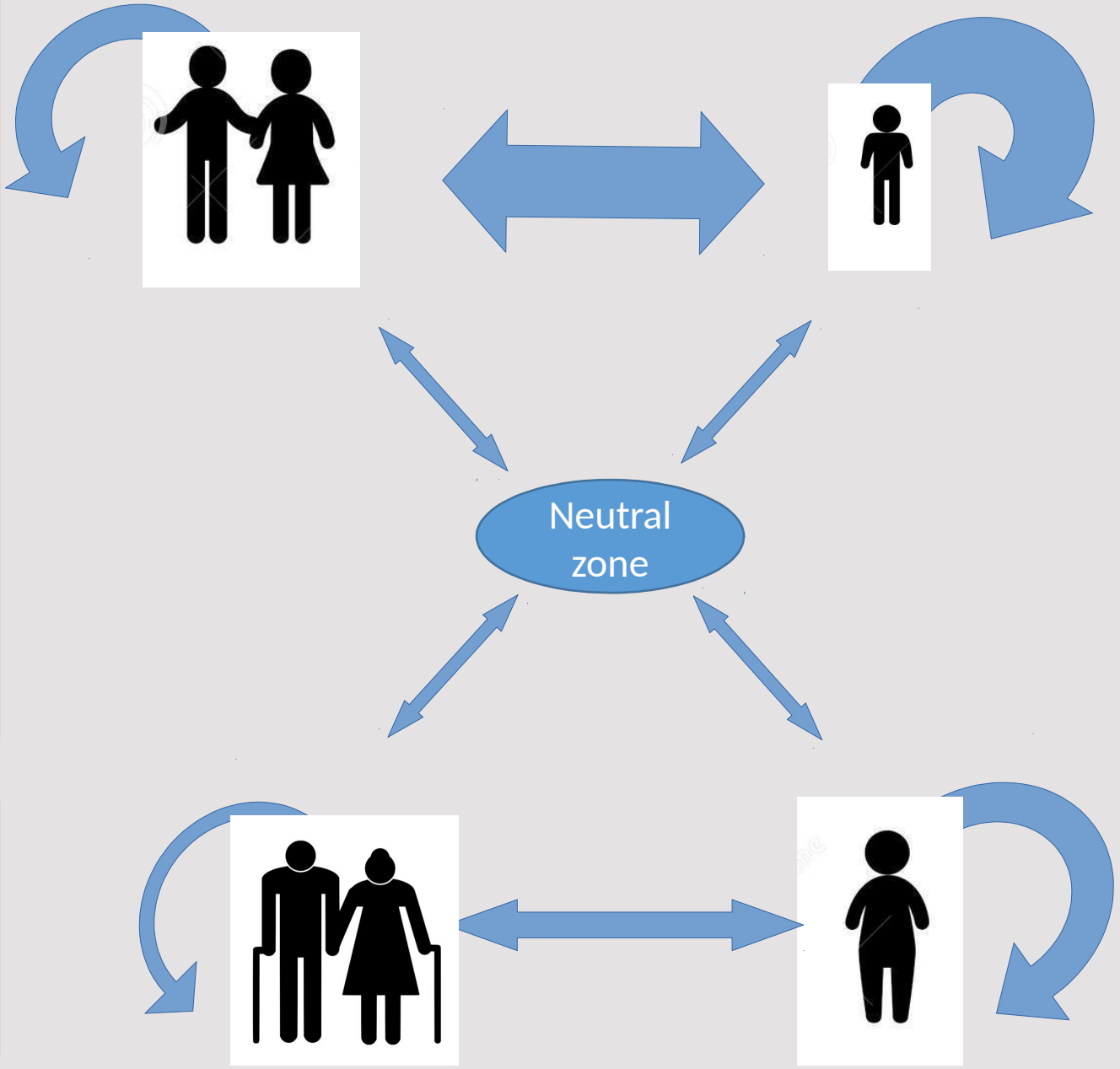

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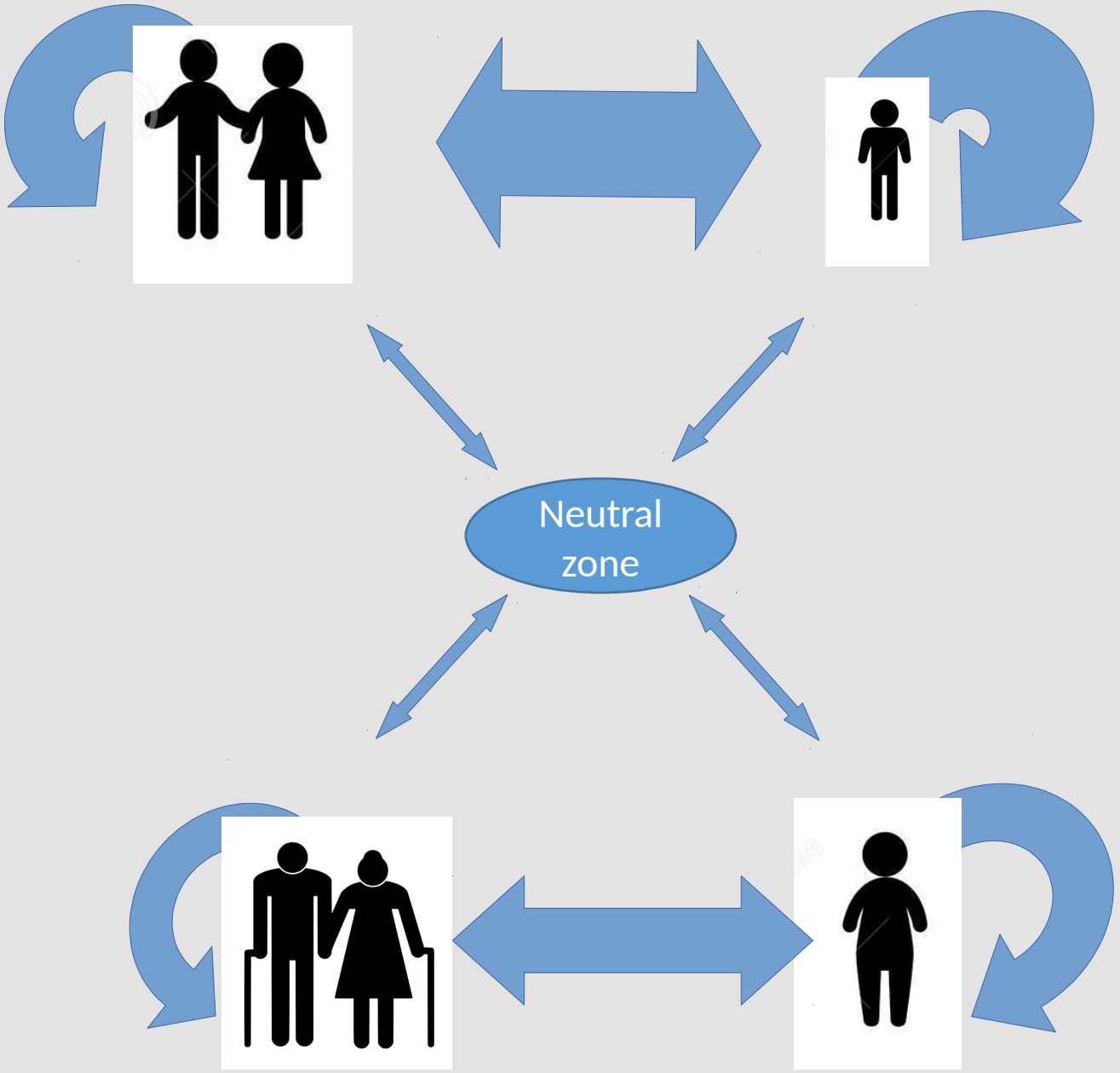
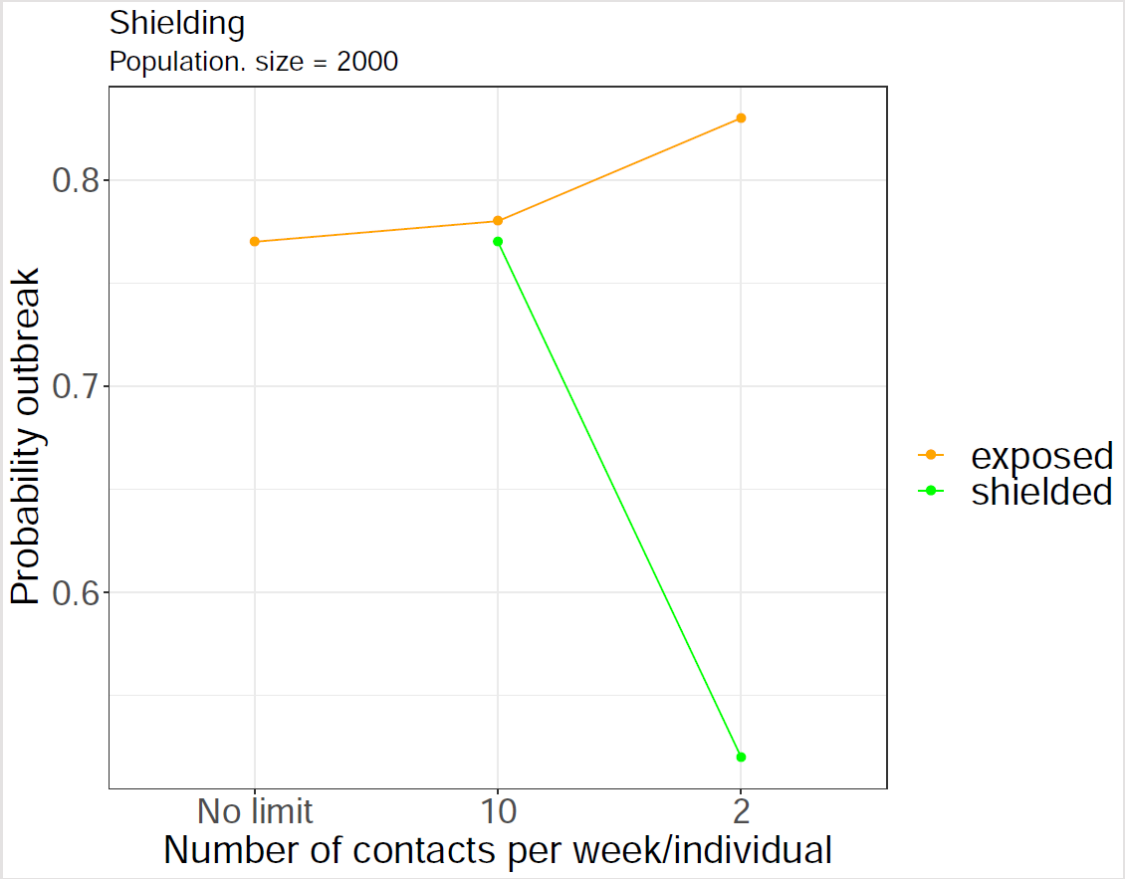
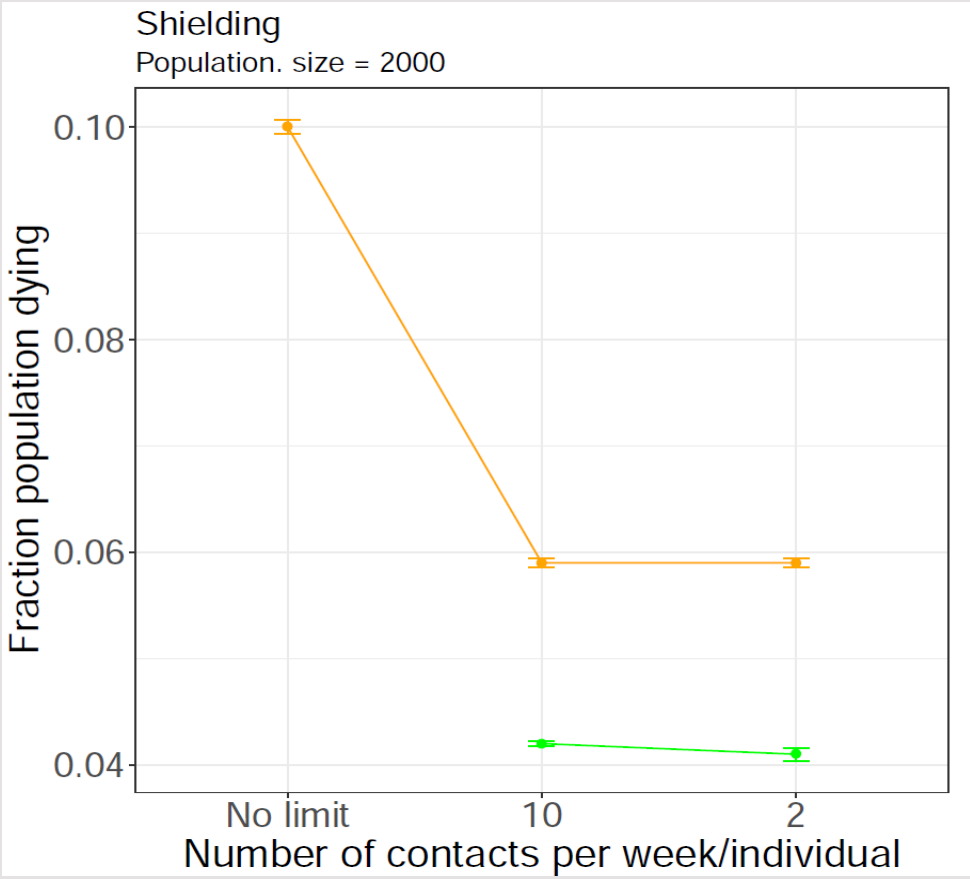


Strategy 2: Shielding only



Strategy 2: Shielding only



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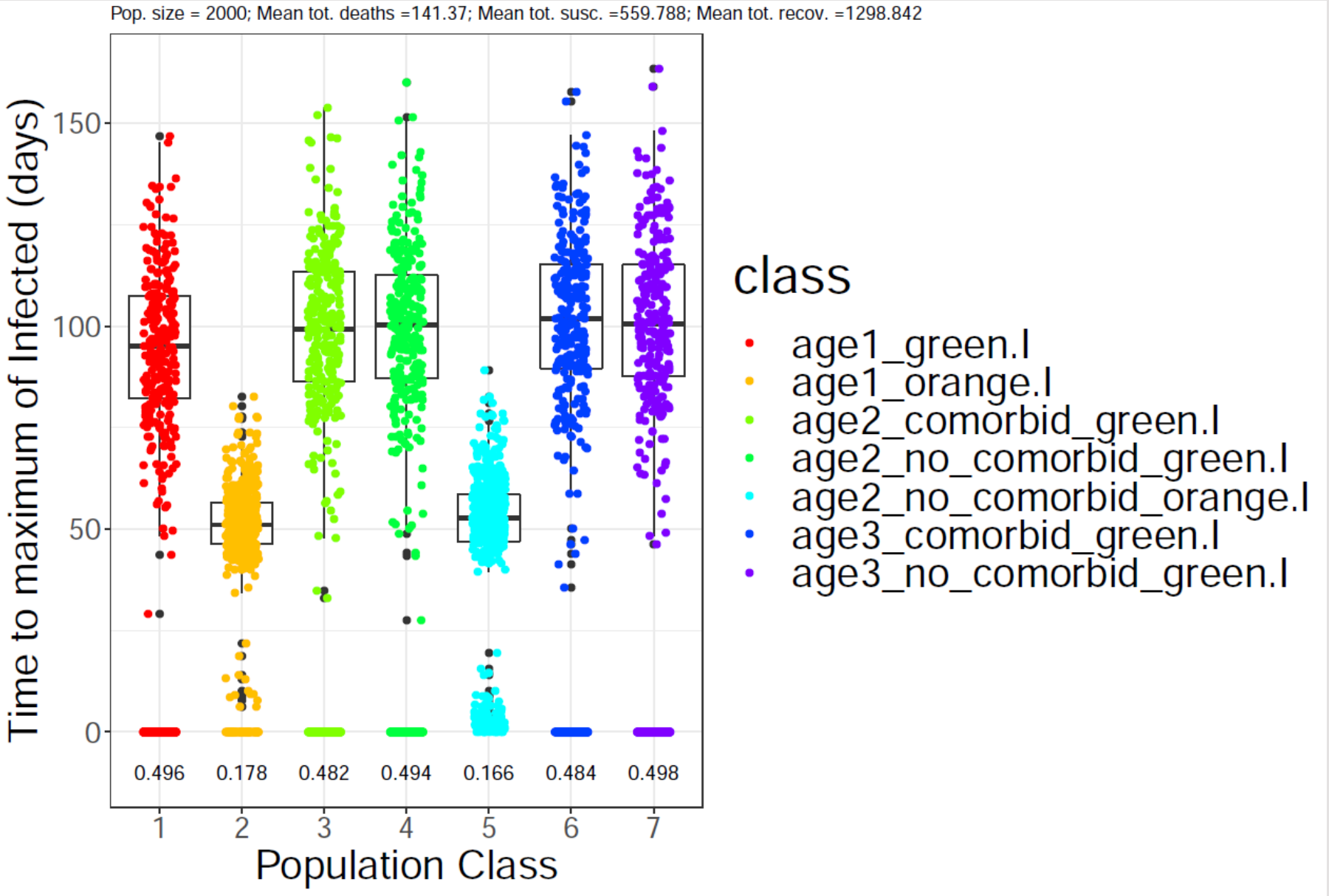
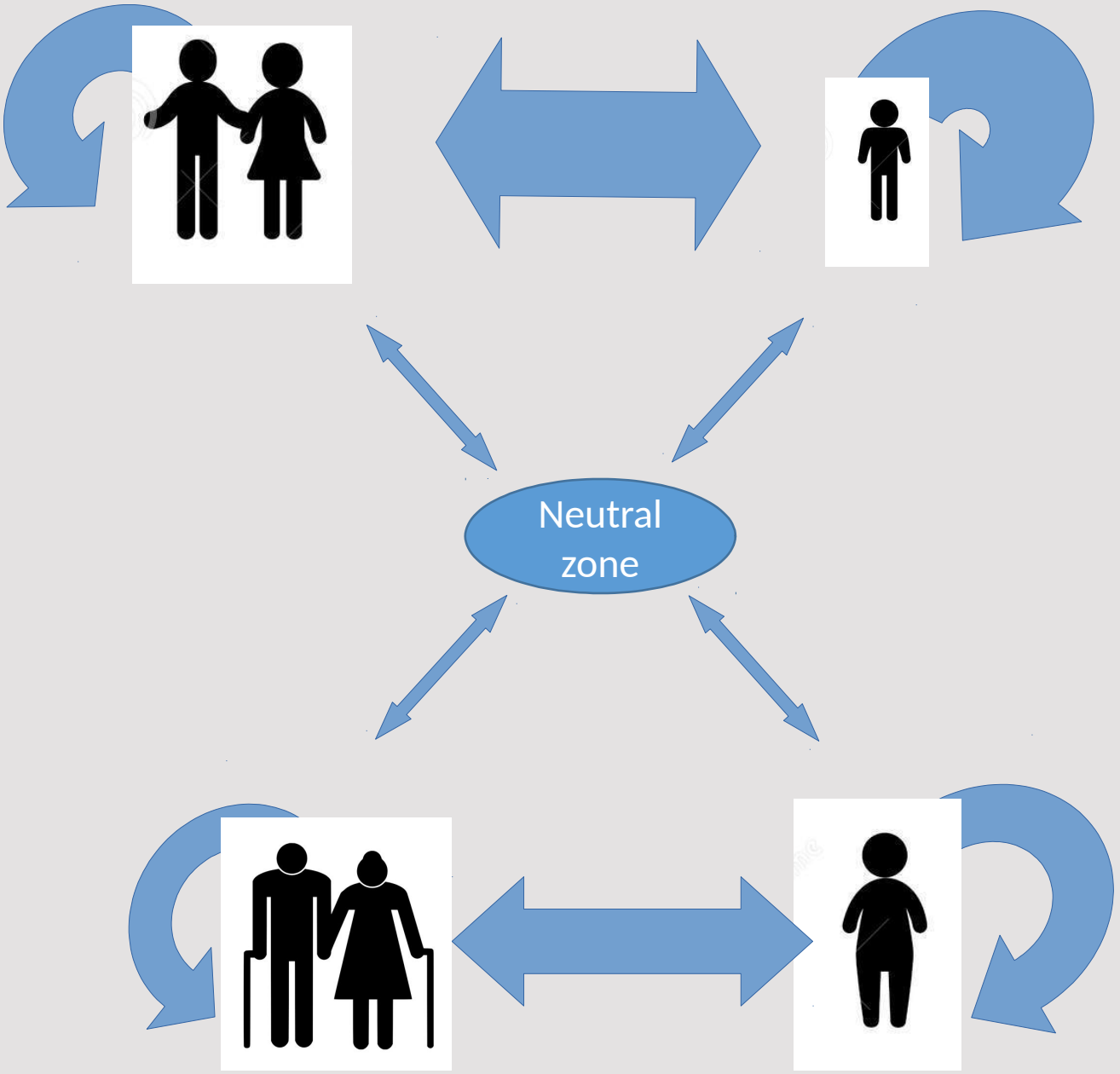


Lockdown of the “green” zone after first symptomatic case

80% of the population

Neutral zone

20% of the population



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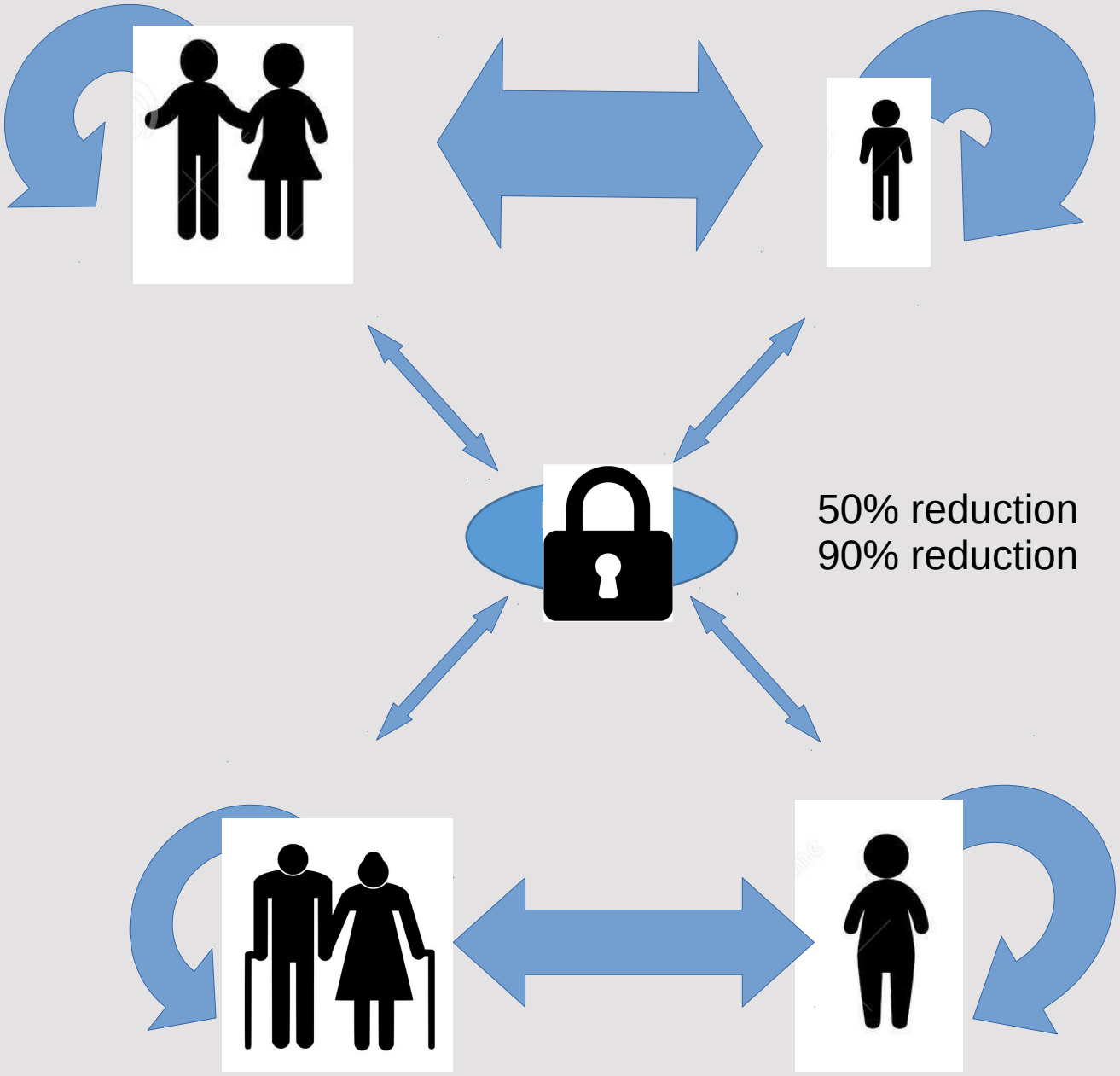
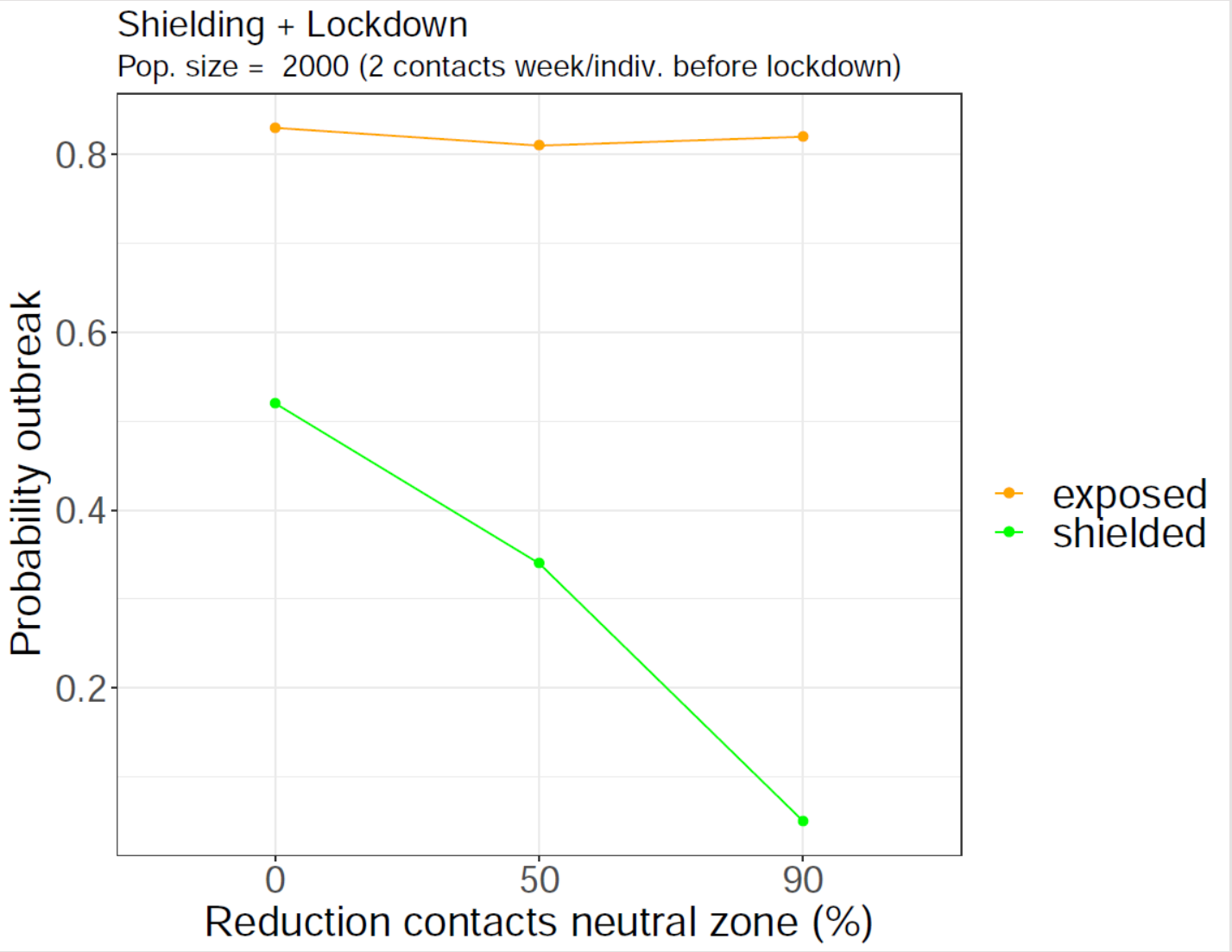
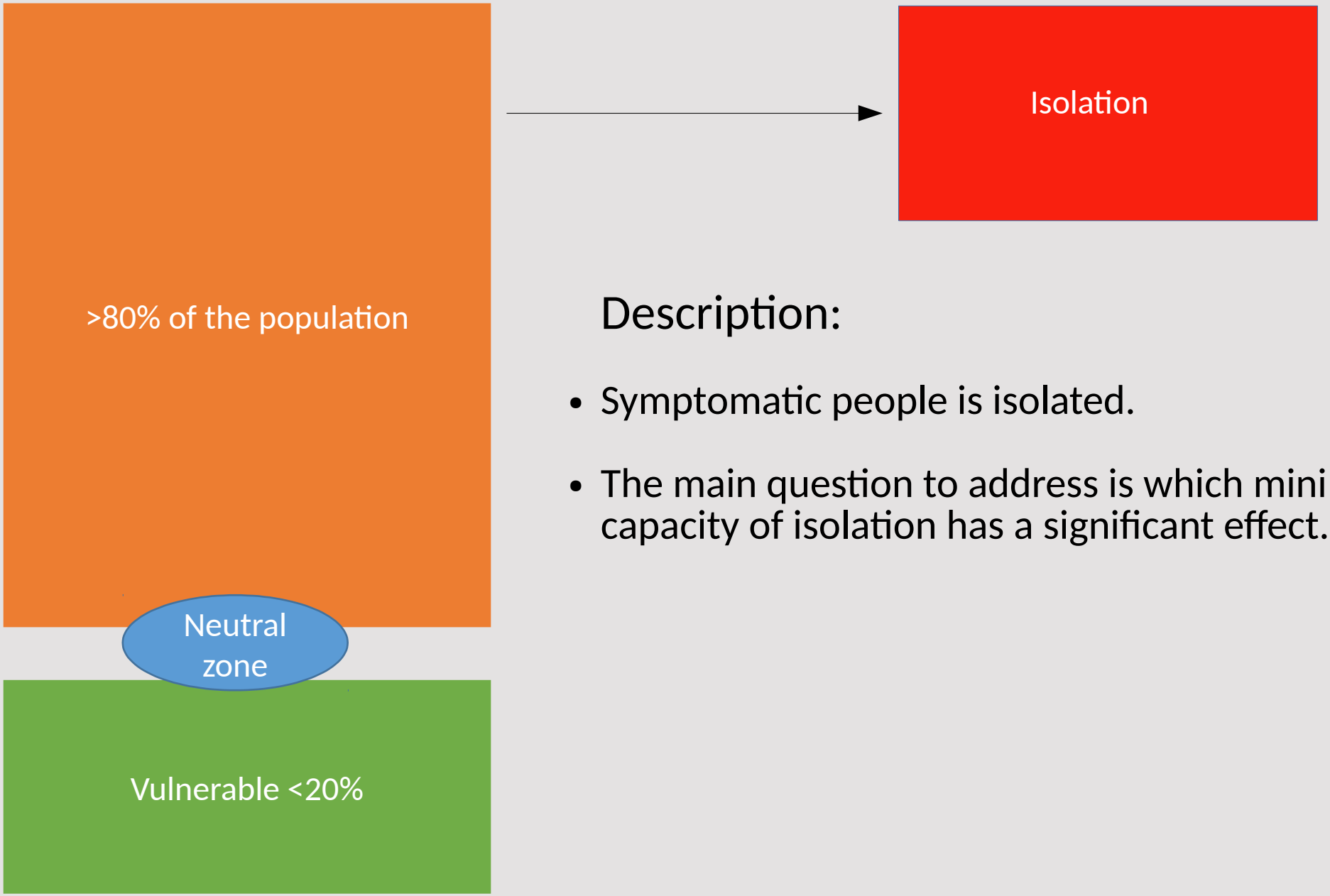


50% reduction
90% reduction

Strategy 2: Shielding and Lockdown



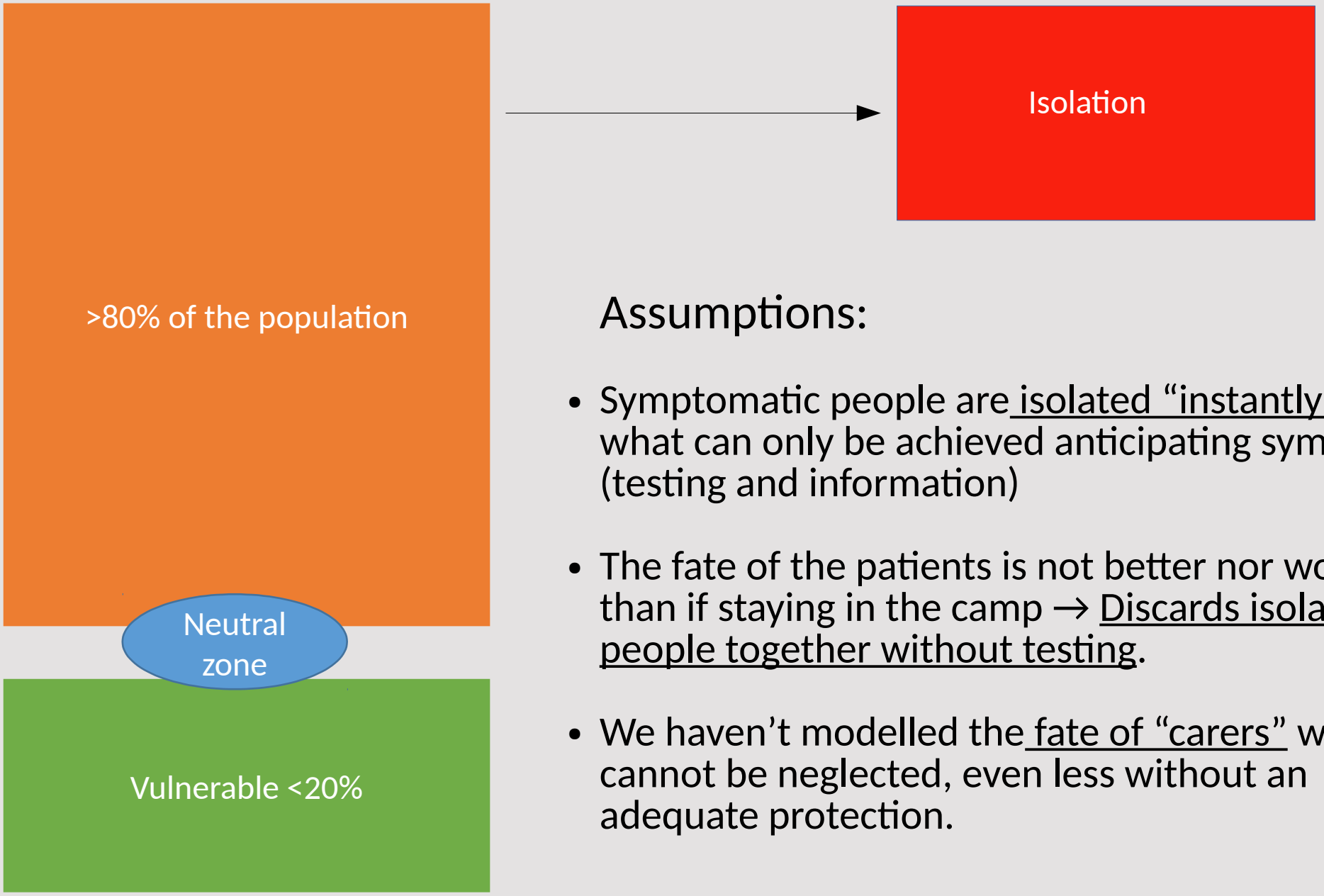
Strategy 3: Isolation



Description:

- Symptomatic people is isolated.
- The main question to address is which minimum capacity of isolation has a significant effect.

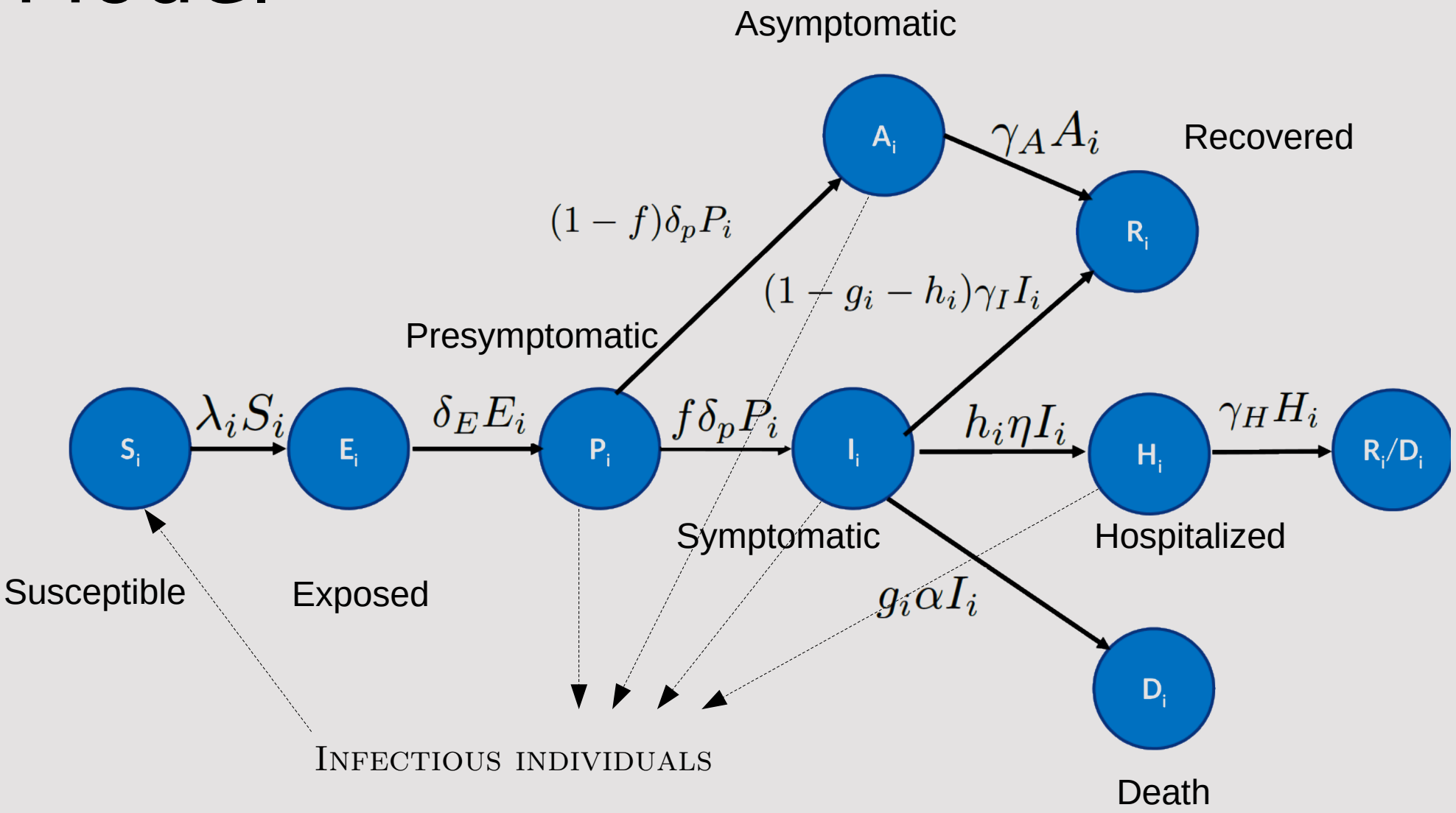
Strategy 3: Isolation



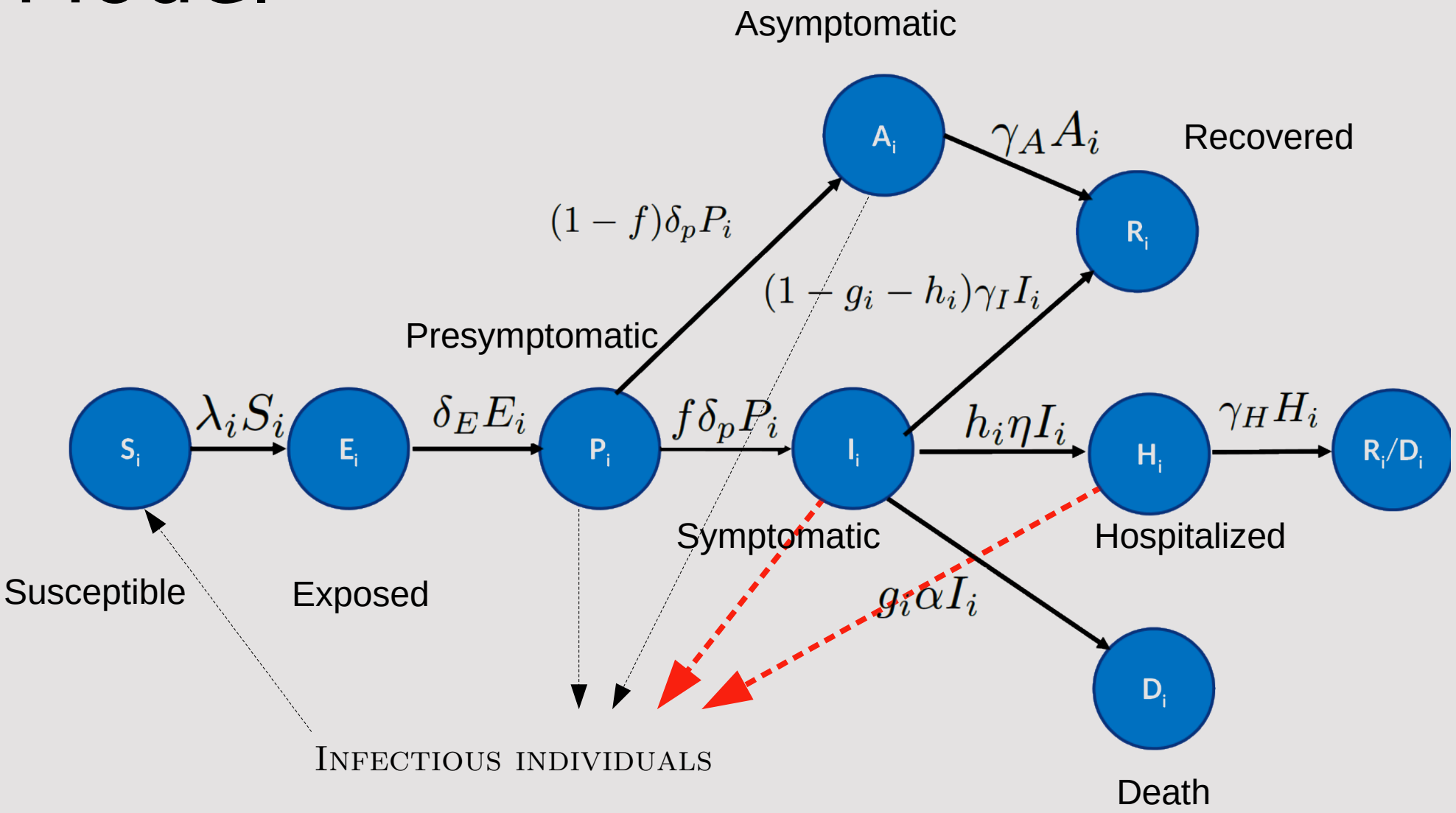
Assumptions:

- Symptomatic people are isolated “instantly”, what can only be achieved anticipating symptoms (testing and information)
- The fate of the patients is not better nor worse than if staying in the camp → Discards isolating people together without testing.
- We haven’t modelled the fate of “carers” which cannot be neglected, even less without an adequate protection.

Model


Asymptomatic
A_i
$\gamma_A A_i$
Recovered
R_i
$(1-f)\delta_p P_i$
$(1-g_i-h_i)\gamma_I I_i$
Presymptomatic
S_i
$\lambda_i S_i$
E_i
$\delta_E E_i$
P_i
$f\delta_p P_i$
I_i
$h_i \eta I_i$
H_i
$\gamma_H H_i$
R_i/D_i
Symptomatic
Hospitalized
Susceptible
Exposed
$g_i \alpha I_i$
D_i
Death
Infectious individuals

Model


Asymptomatic
A_i
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E_i
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I_i
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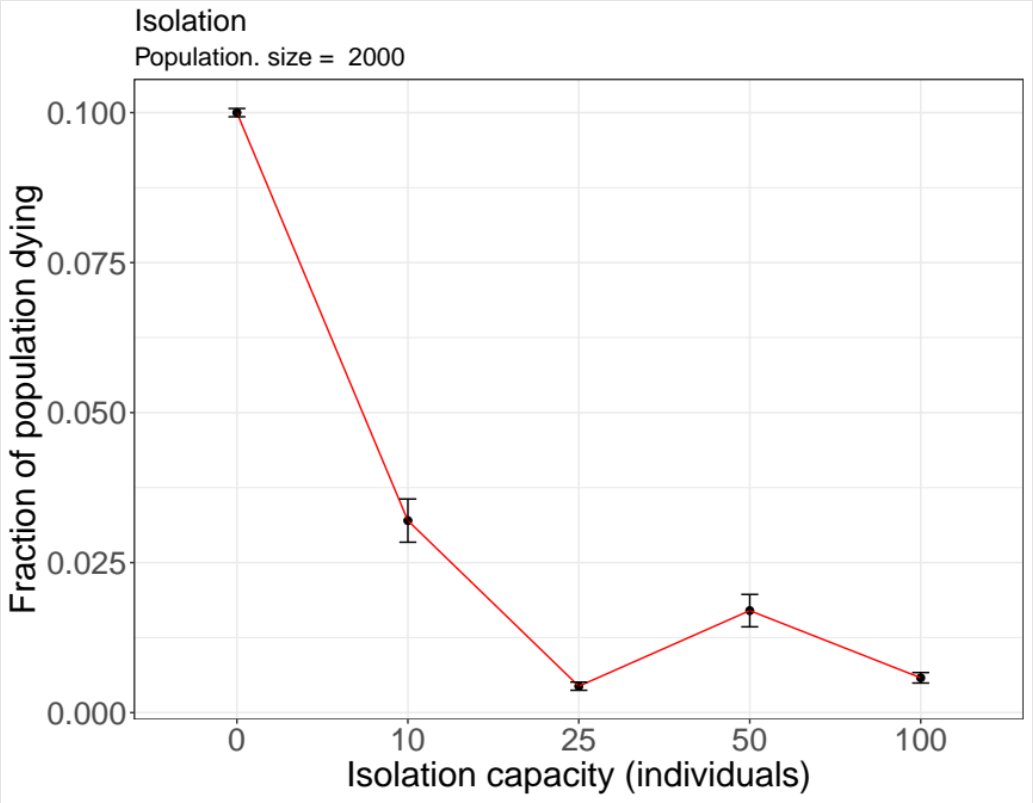
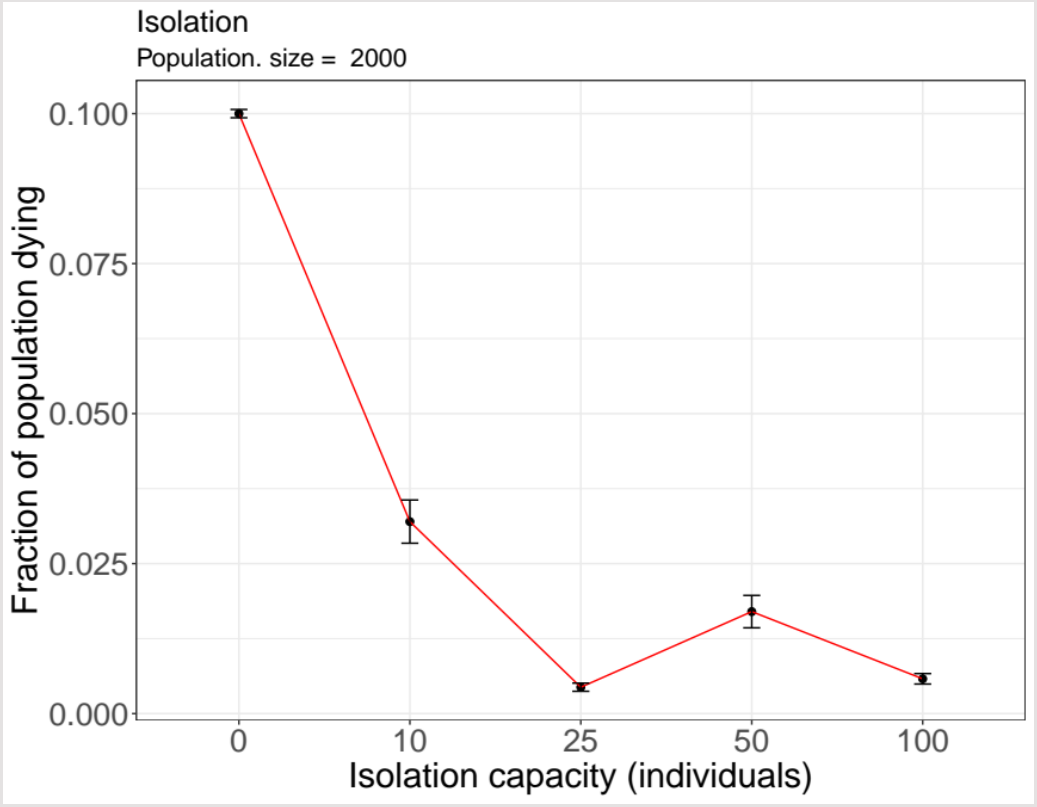
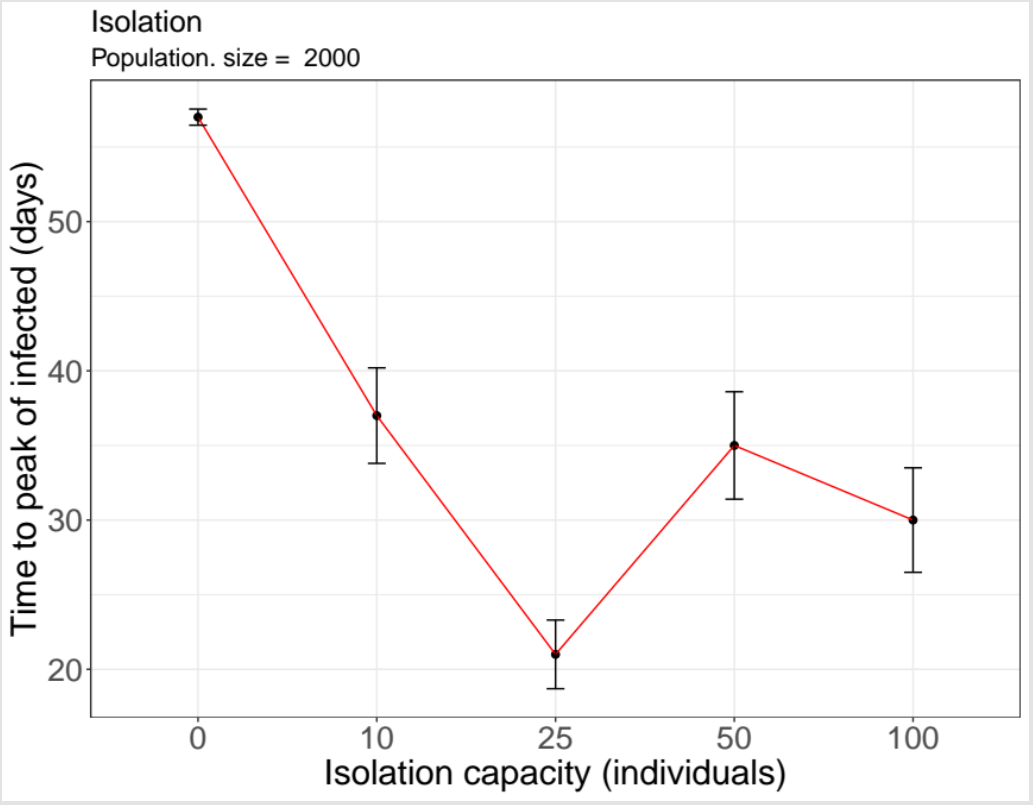


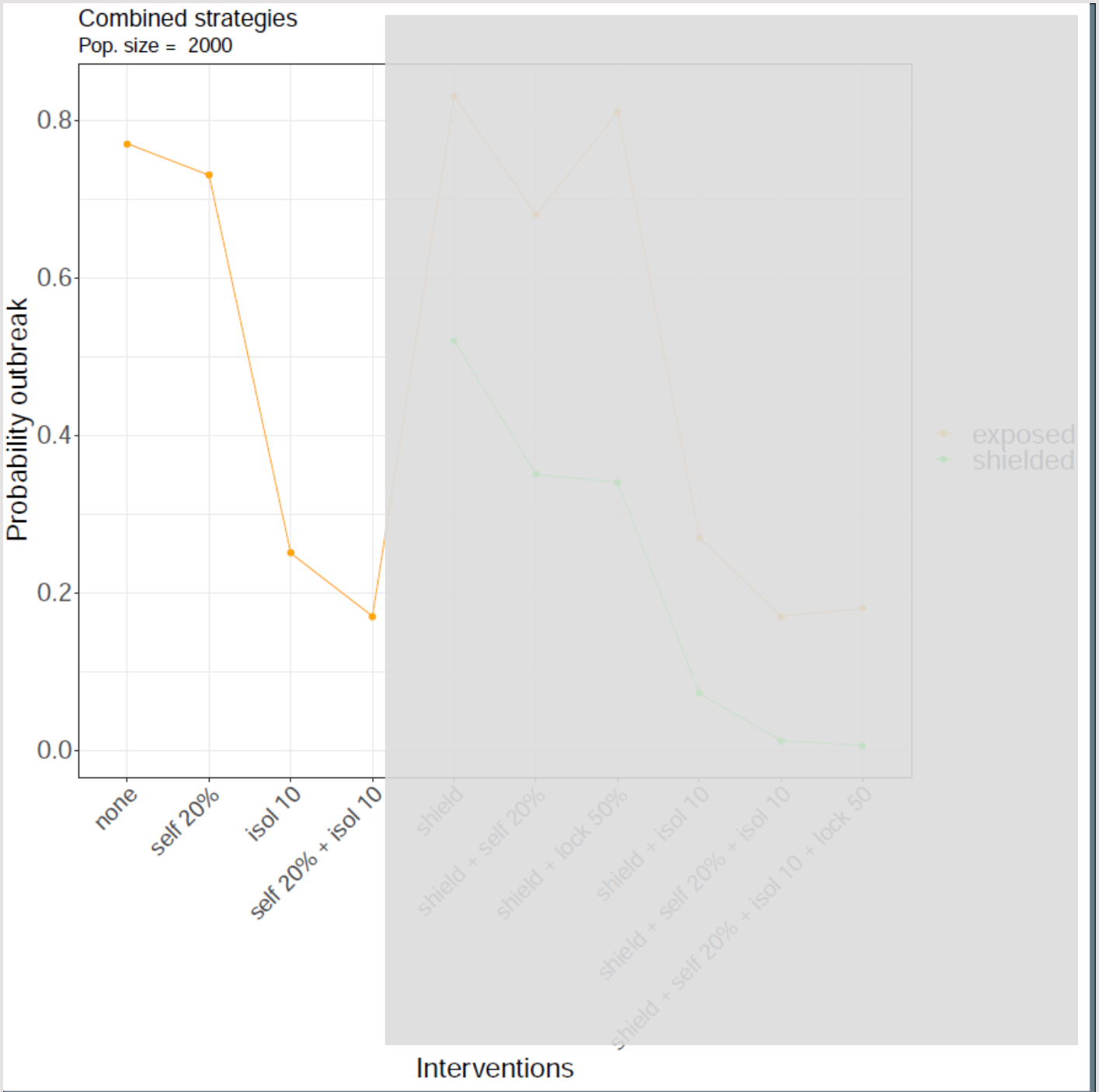
Strategy 3: Isolation



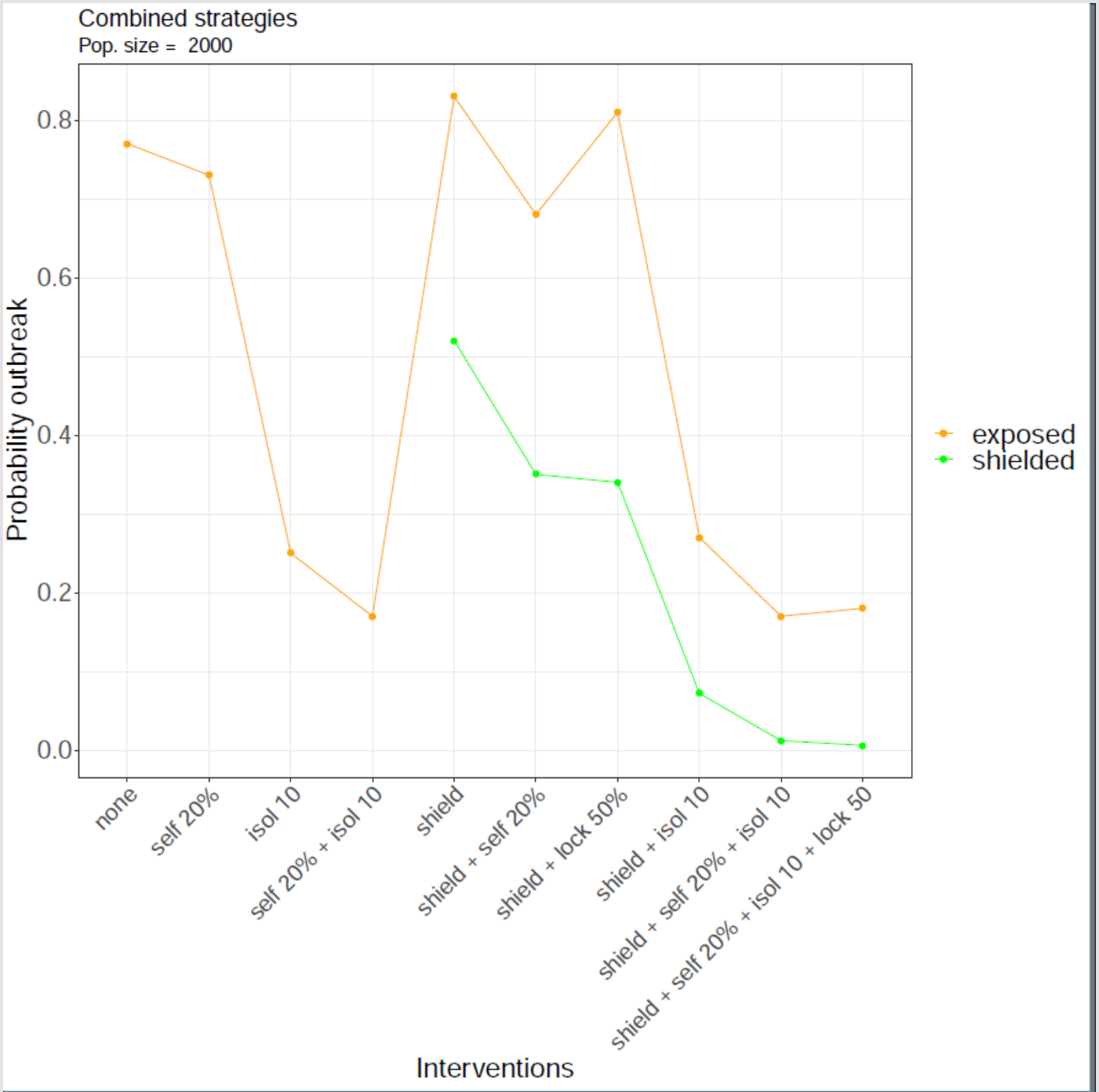


Combined strategies

Combined strategies



Combined strategies



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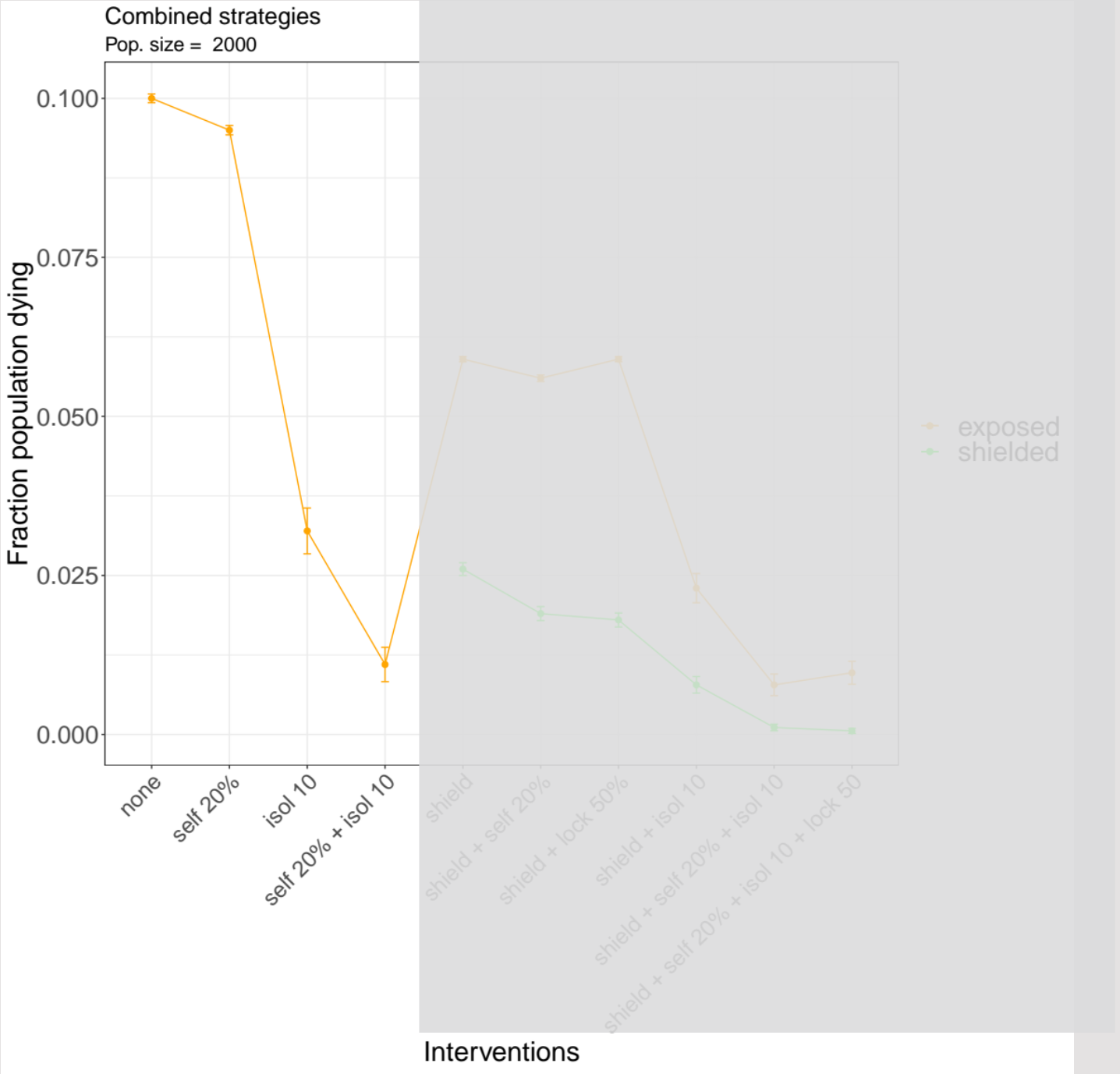

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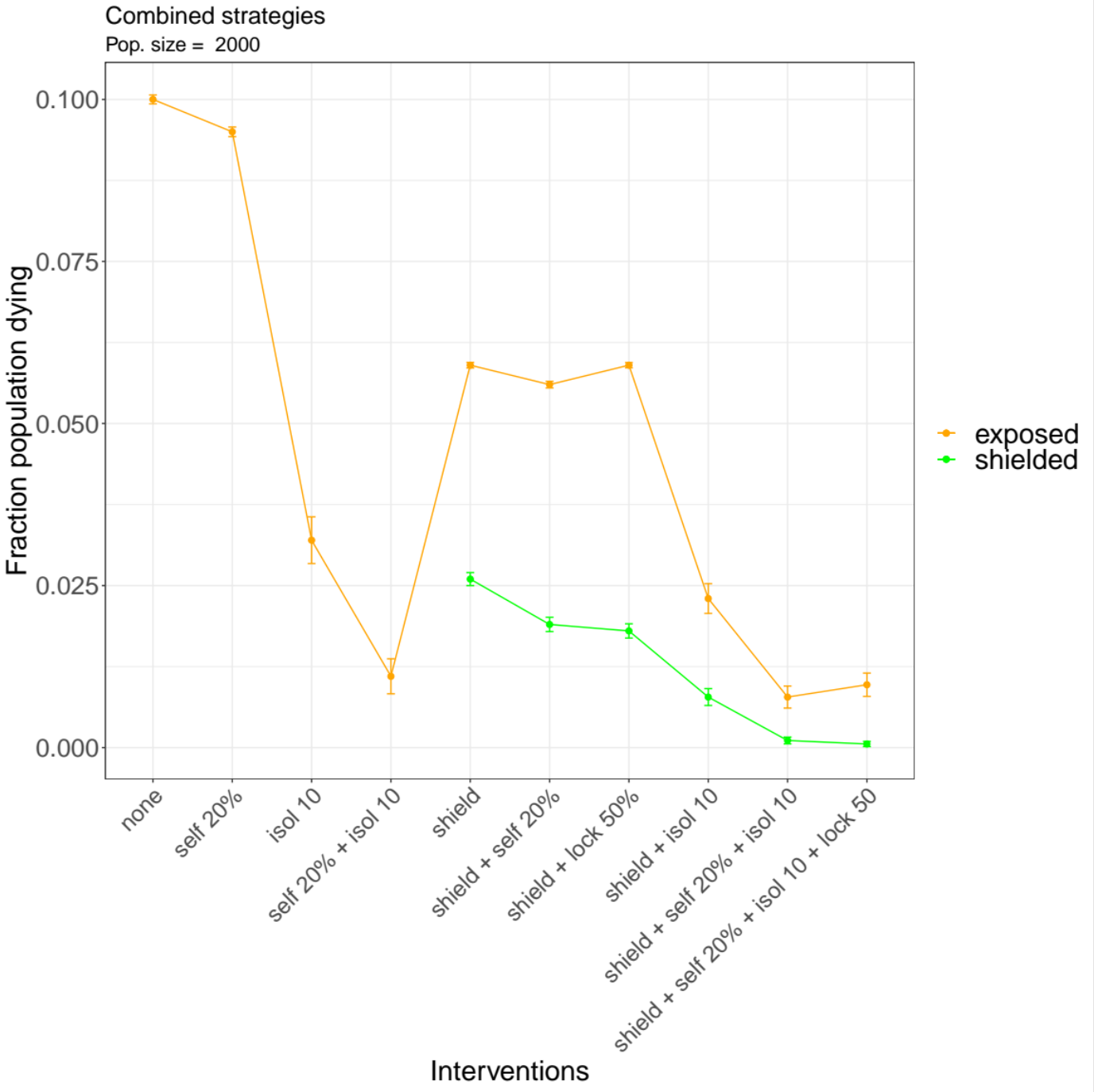

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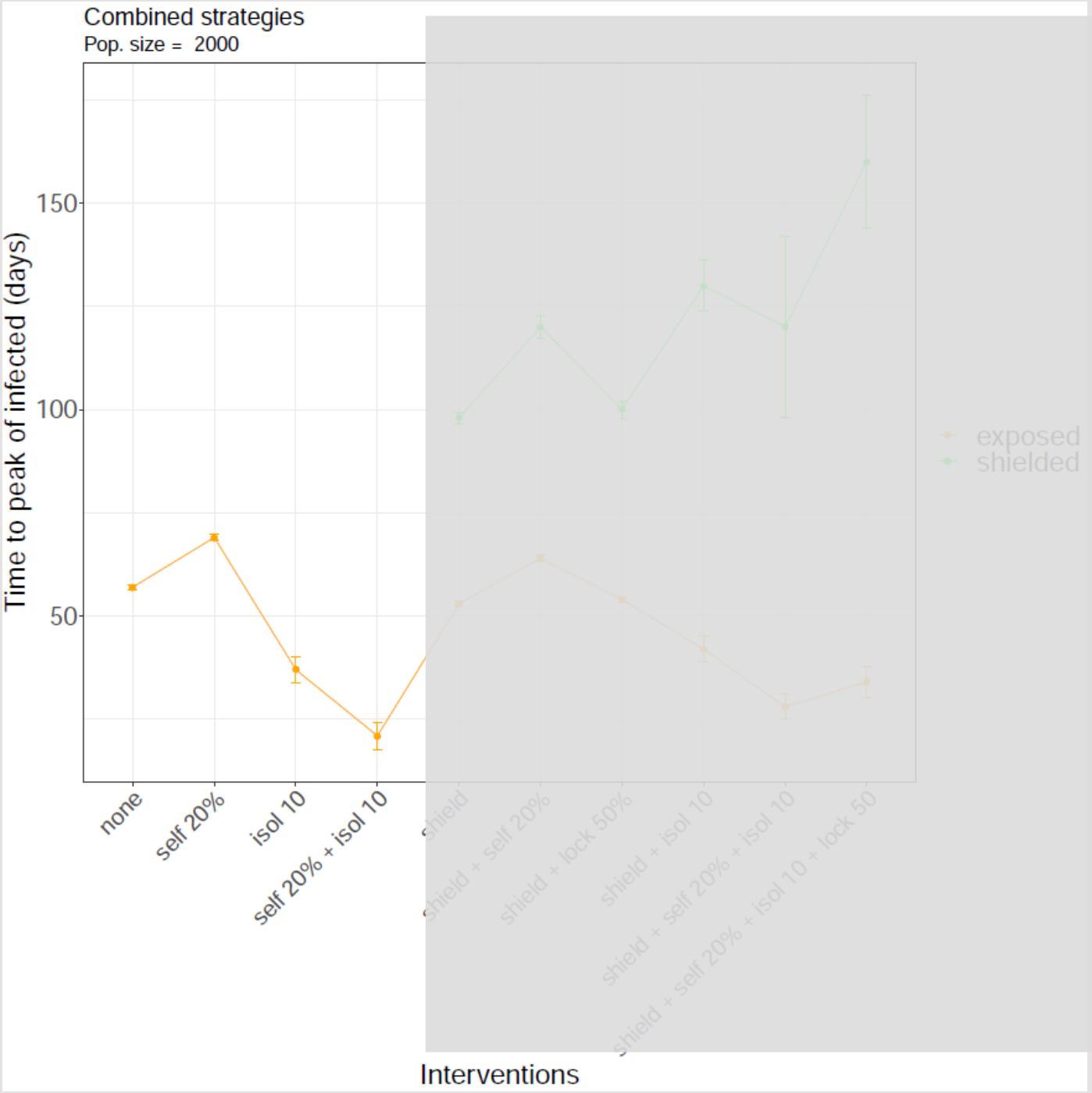

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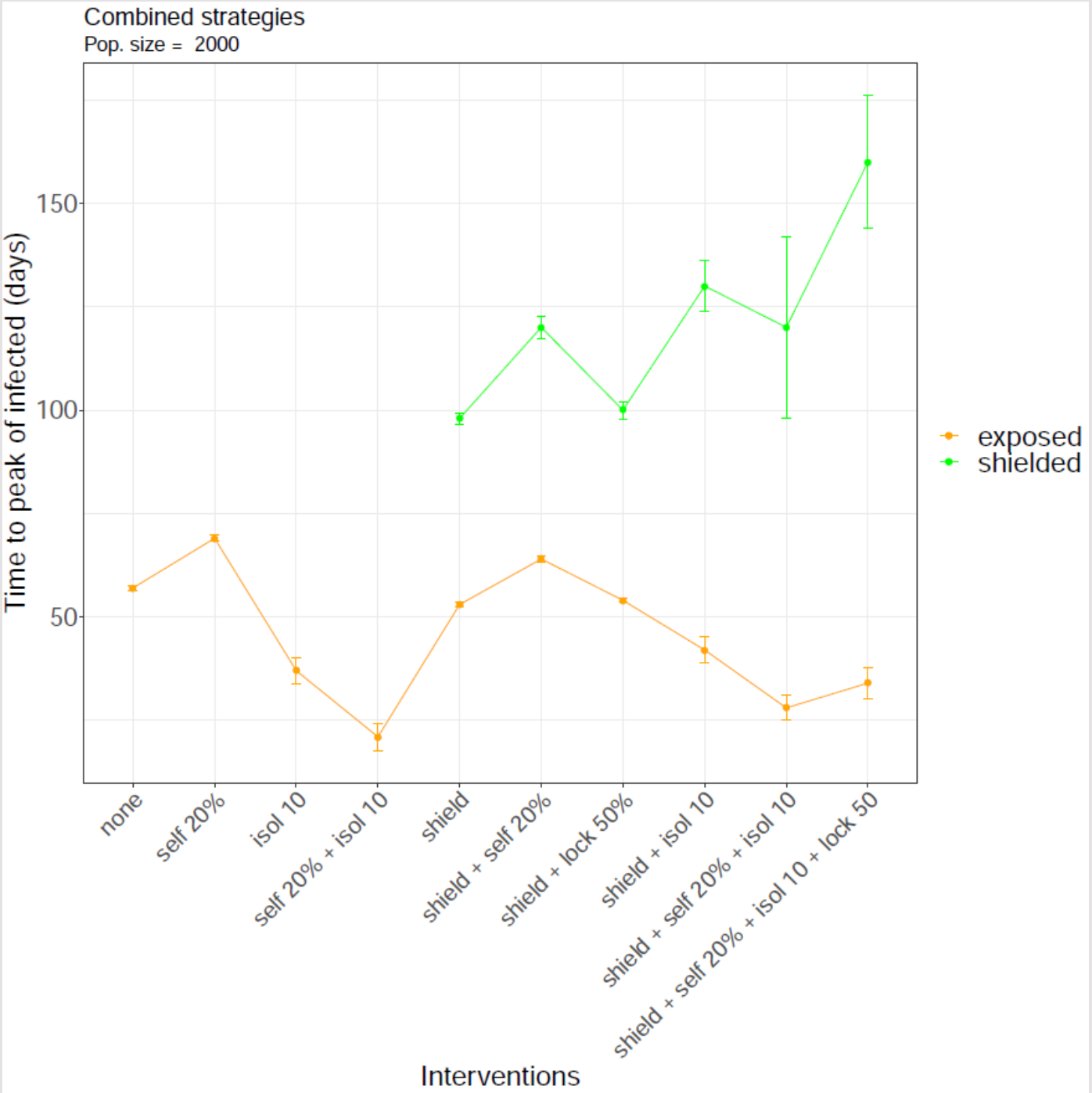

Conclusions

- Simple interventions can reduce the probability of outbreak and death tolls.
- **Shielding** under appropriate conditions has an overall positive effect. An increase in the probability of outbreak can be mitigated by self-distancing.
- **Isolation** brings the stronger reduction in death tolls. However, it may accelerate the spread of the virus among the vulnerable population. Several technical caveats should be considered in its implementation.
- The **combination of interventions** are very effective against the spread of the virus and its potential impact in the population.

Future work

- Determine the optimal population fraction that should be shielded (simulations done, analysis required).
- What can we expect in terms of herd immunity depending on the intervention, and estimate accurate times for e.g. lockdown.
- More accurate extrapolation of the spread of the infection at a regional scale.
- More realistic modelling of some interventions, e.g. introduction of carers if isolation.

Acknowledgements

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