Individual-level differences in symptomatic and asymptomatic transmission shape population-level dynamics of SARS-CoV-2 outbreaks

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Project Repository:
https://github.com/Jeremy-D-Harris/Asymptomatic_Transmission_COVID

Background

- Symptomatic vs. asymptomatic individuals may have different generation intervals (e.g., lack of isolation → longer generation intervals)
- Such time-scale differences can both shape outbreak dynamics and bias population-level estimates including: epidemic strength, speed, and controllability
- How do correlations between transmission and disease status impact dynamics?

Approach

- Here, we use a series of nonlinear epidemic models to study the impact of differences in time scales between asymptomatic and symptomatic transmission of SARS-CoV-2 on the relative contribution of asymptomatic infections to epidemic dynamics.
- We build on prior work [1] and show that differences in time scales of transmission may impact estimates of disease severity throughout the course of the epidemic due to changes in the effective proportion of asymptomatic transmission over time.
- We do so in two parts:
  1) We study dynamics when transmission outcomes and disease statuses are correlated: that is, transmission from asymptomatic (symptomatic) individuals is more likely to lead to new, asymptomatic (symptomatic) infections.
  2) We examine dynamics given age-dependent assortative mixing coupled with intrinsic differences in symptomaticity with age.

RESULTS

1) With longer time-scales of asymptomatic relative to symptomatic transmission, the effective proportion of asymptomatic transmission increases over time as total incidence decreases.
2) Coupled with correlations between transmission and disease status, the realized proportion of asymptomatic incidence increases over time as total incidence decreases.
3) When coupling differences in time scales with age-dependent assortative mixing, we find that the age distribution of infections shifts to younger ages as incidence decreases.

DISCUSSION

- These results demonstrate the need to explore the role of time-scale differences in transmission dynamics alongside behavioural changes to explain outbreak features.
- At early stages of an epidemic, time-scale differences can bias estimates of the basic reproduction number.
- Throughout an epidemic, time-scale differences can connect shifts in the age of infection to periods of changing incidence.

References

1. Park, S. W., Champredon, D., Weitz, J. S., & Dushoff, J. (2019). A practical generation-interval-based approach to inferring the strength of epidemics from their speed. *Epidemics*, *27*, 12-18.

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medRxiv

Time-scale differences between

asymptomatic vs. symptomatic infections

lead to changes in the relevance of

asymptomatic carriers

over the course of an epidemic.

Figure 1

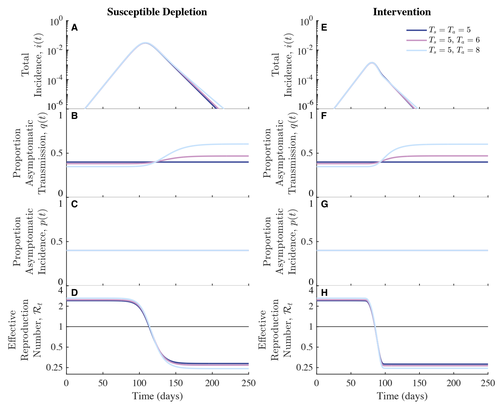


Figure 2

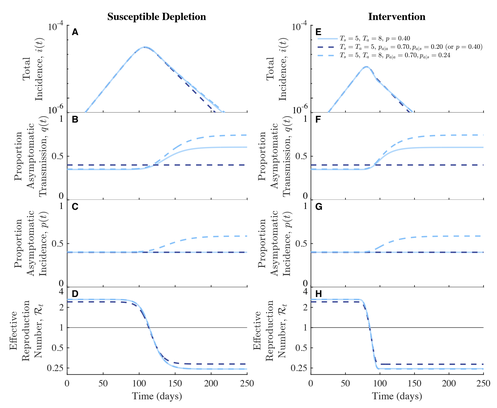
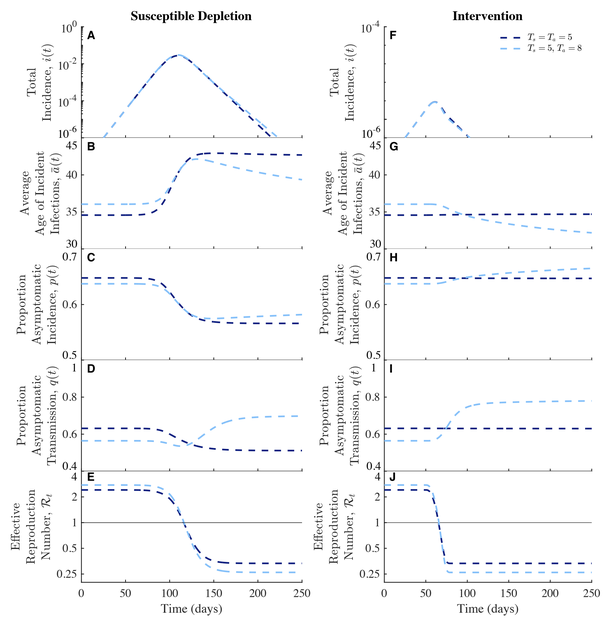
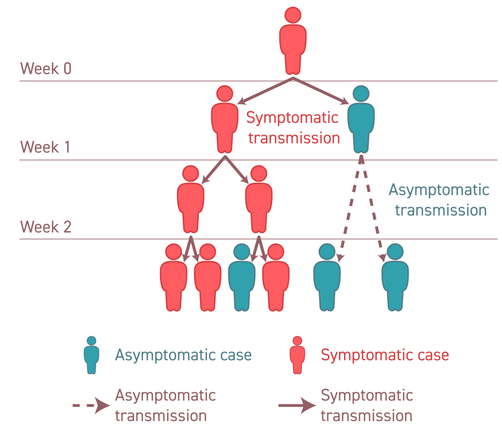


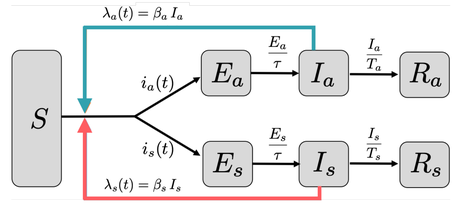
Figure 3





Created by: Audra Davidson, *Science Communication Specialist*, Weitz Group & Georgia Tech College of Sciences

Model Framework



Variables:

S : Susceptible Individuals
E : Exposed Individuals
I : Infected Individuals
R : Recovered Individuals

Parameters:

β : Transmission Rate
τ : Exposed Period
T : Infectious Period

a : Asymptomatic Individuals
s : Symptomatic Individuals

Figure 1. Effects of differences in asymptomatic and symptomatic generation-interval distributions on the population-level dynamics of asymptomatic infections. Setting the infectious period of symptomatic individuals to T_s = 5 days, we increase the infectious period of asymptomatic carriers from T_a = 5 days (dark blue), T_a = 6 days (purple), T_a = 8 days (light blue). **(A-D)** Without intervention the susceptible population is depleted. When the asymptomatic infectious period is longer, the proportion of asymptomatic transmission increases as new infections decrease. **(E-H)** Changes in the proportion of asymptomatic transmission are comparable with intervention when the reproduction number is reduced to similar levels as with susceptible depletion.

Figure 2. Effects of transmission correlations and generation-interval differences on the population-level dynamics of asymptomatic infections. Setting the symptomatic infectious period to T_s = 5 days, the dashed lines correspond to increasing assortative transmission such that the exponential growth rate and initial proportion of asymptomatic incidence match across simulations. The asymptomatic infectious period is T_a = 5 days (dark blue) and T_a = 8 days (light blue). For comparison, solid light blue curve is when T_a = 8 without correlations (same as in Figure 1). **(A-D)** With susceptible depletion. **(E-H)** With intervention, changes in the relevance of asymptomatic individuals over time are comparable when the reproduction number is reduced to the same level as in the susceptible depletion scenario.

Figure 3. Effects of age-dependent mixing and generation-interval differences on the population-level dynamics of asymptomatic infections. We fix the symptomatic infectious period to T_s = 5 days and compare when the asymptomatic infectious period is equal to ($T_a = T_s$ = 5 days) or longer than the symptomatic infectious period (T_a = 8 days). We show susceptible depletion **(A-E)** and intervention scenarios **(F-J)**. As the average age of an incident infection changes over time **(C,H)**, so do the realized proportions of asymptomatic incidence **(C,H)** and transmission **(D,I)**.

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