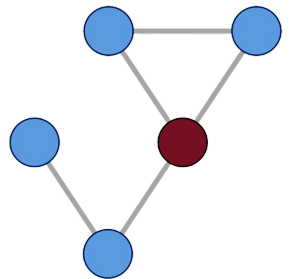


Putting network epidemiology theory to the test

Estimating contact structure across epidemic conditions with implications for control

Juliana Taube

NetSci 2026 Satellite



Bansal Lab



disease

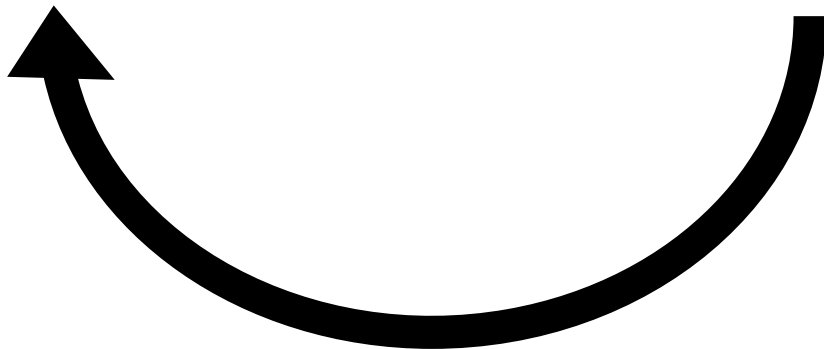
behavior





disease

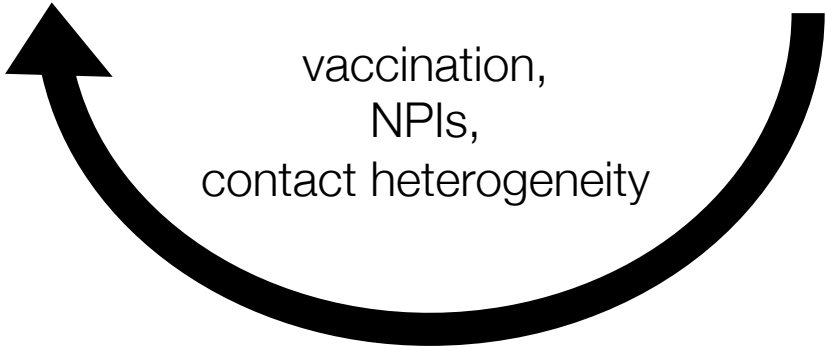
behavior





disease

behavior



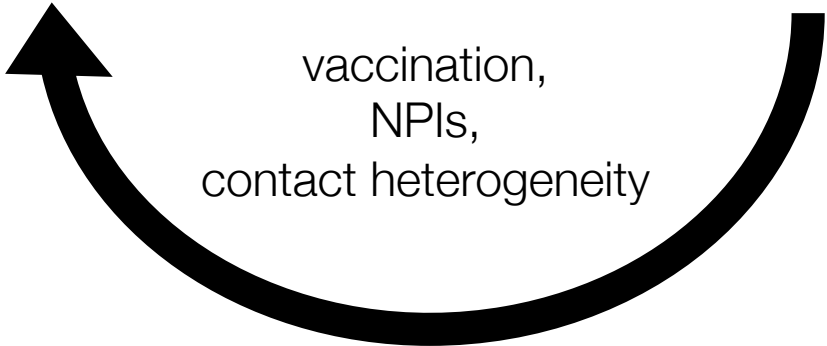
vaccination,
NPIs,
contact heterogeneity

well-characterized

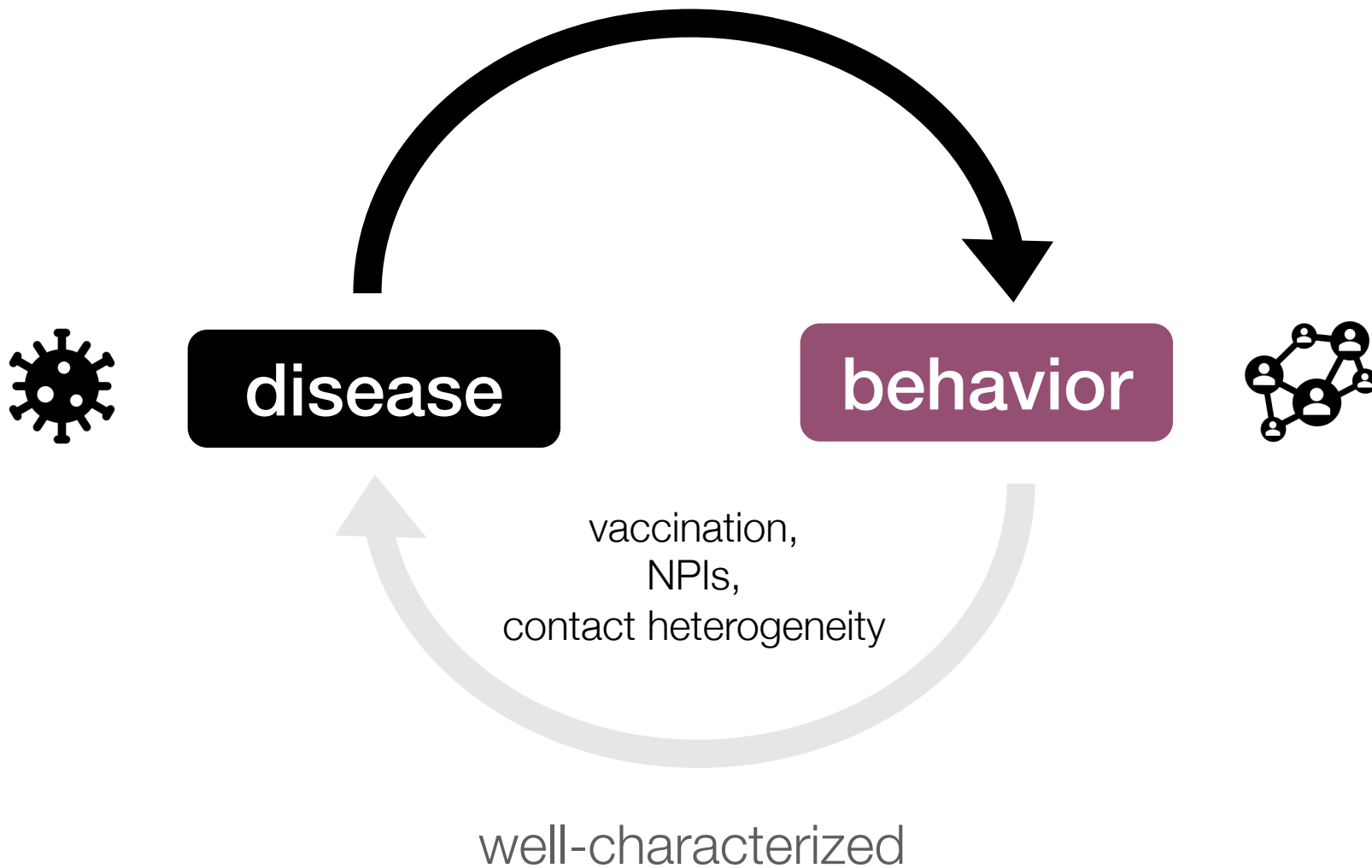


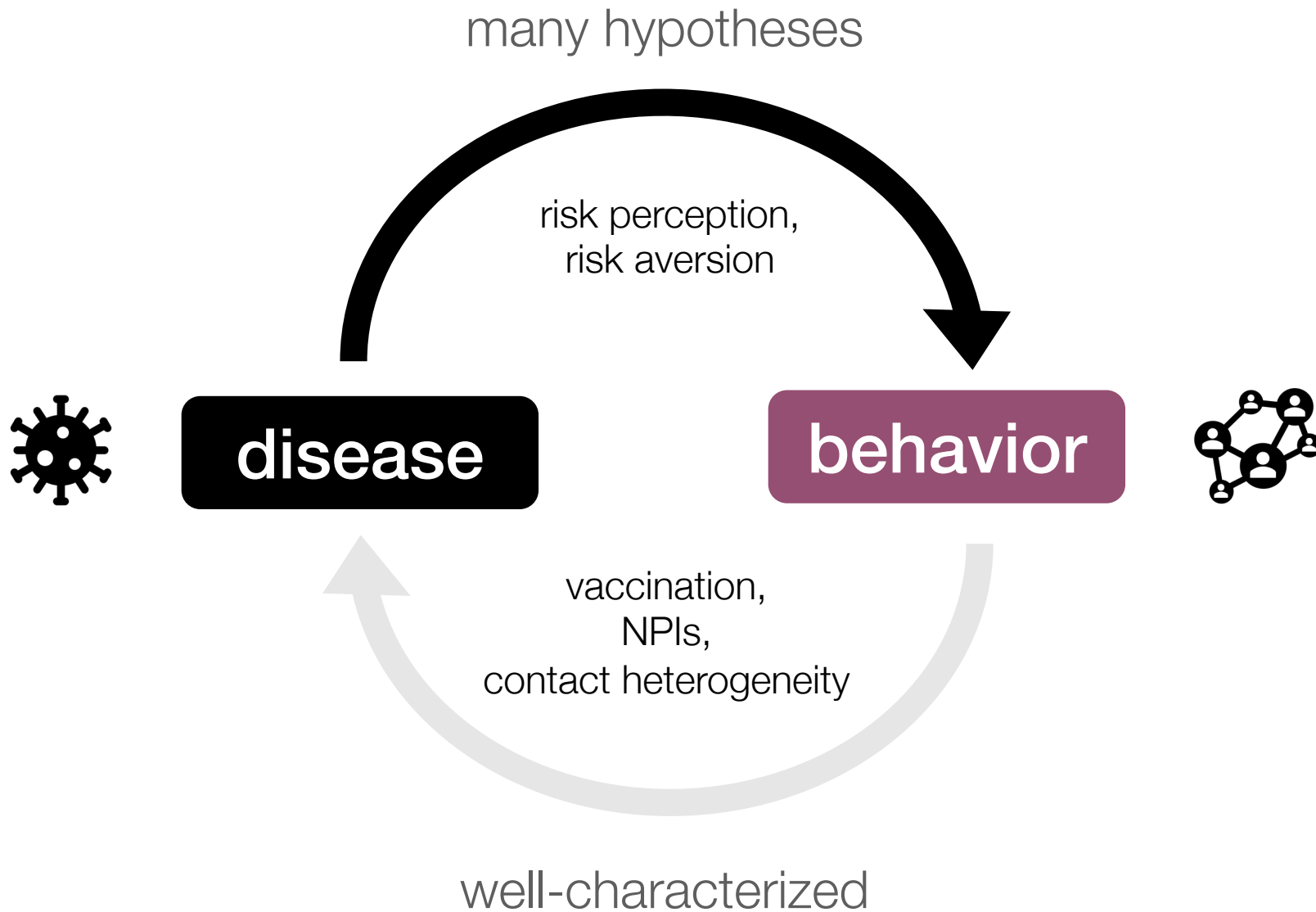
disease

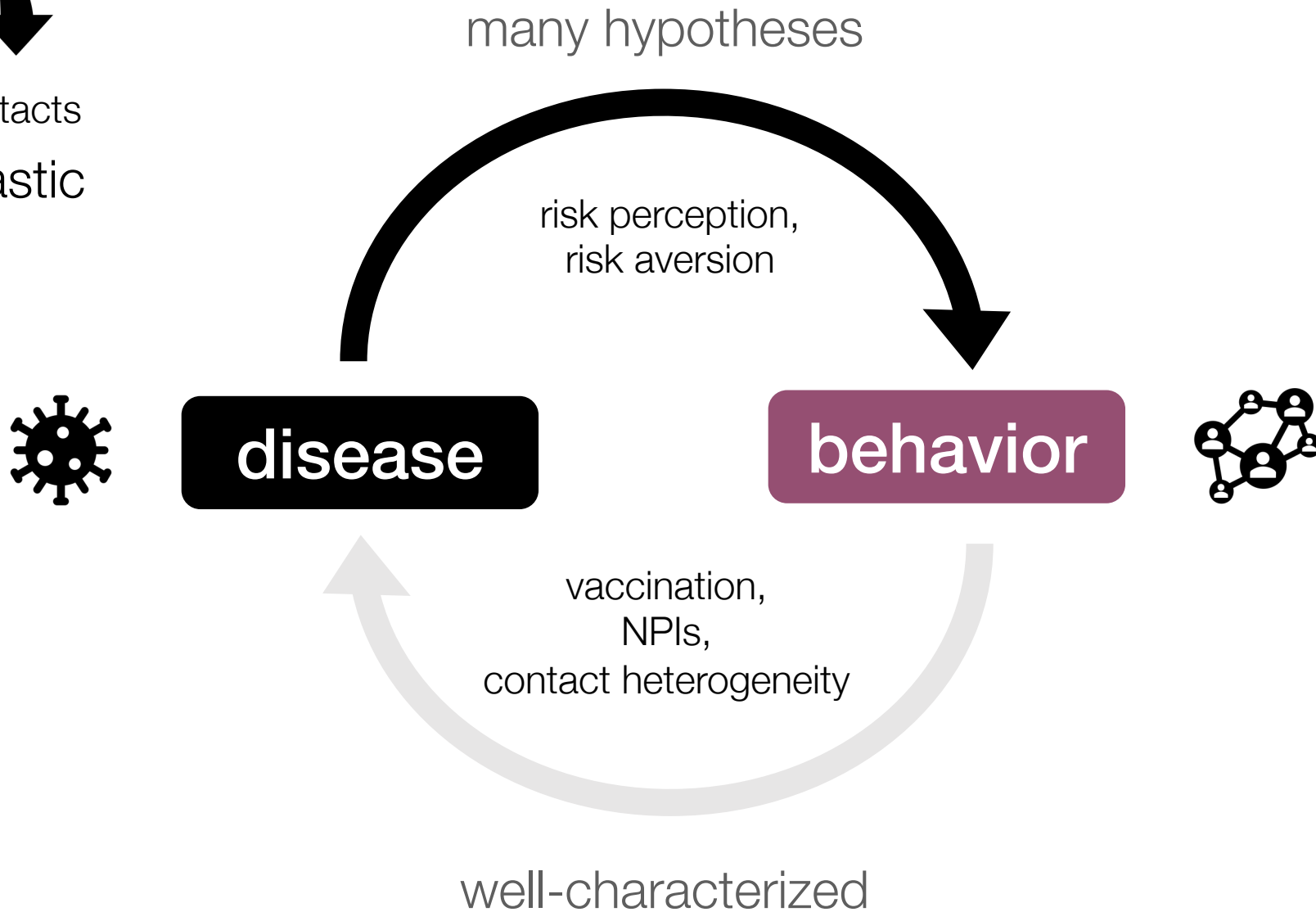
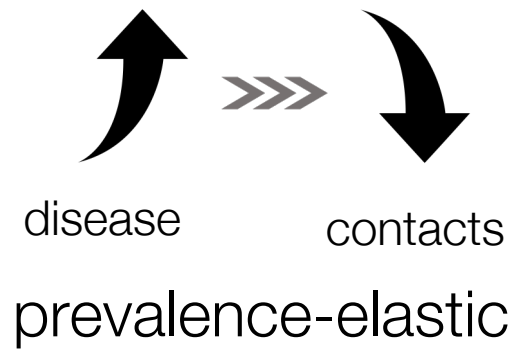
behavior

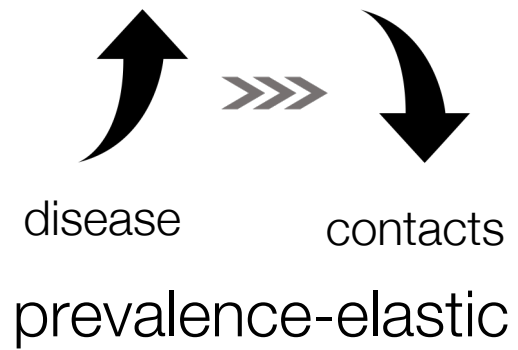


well-characterized

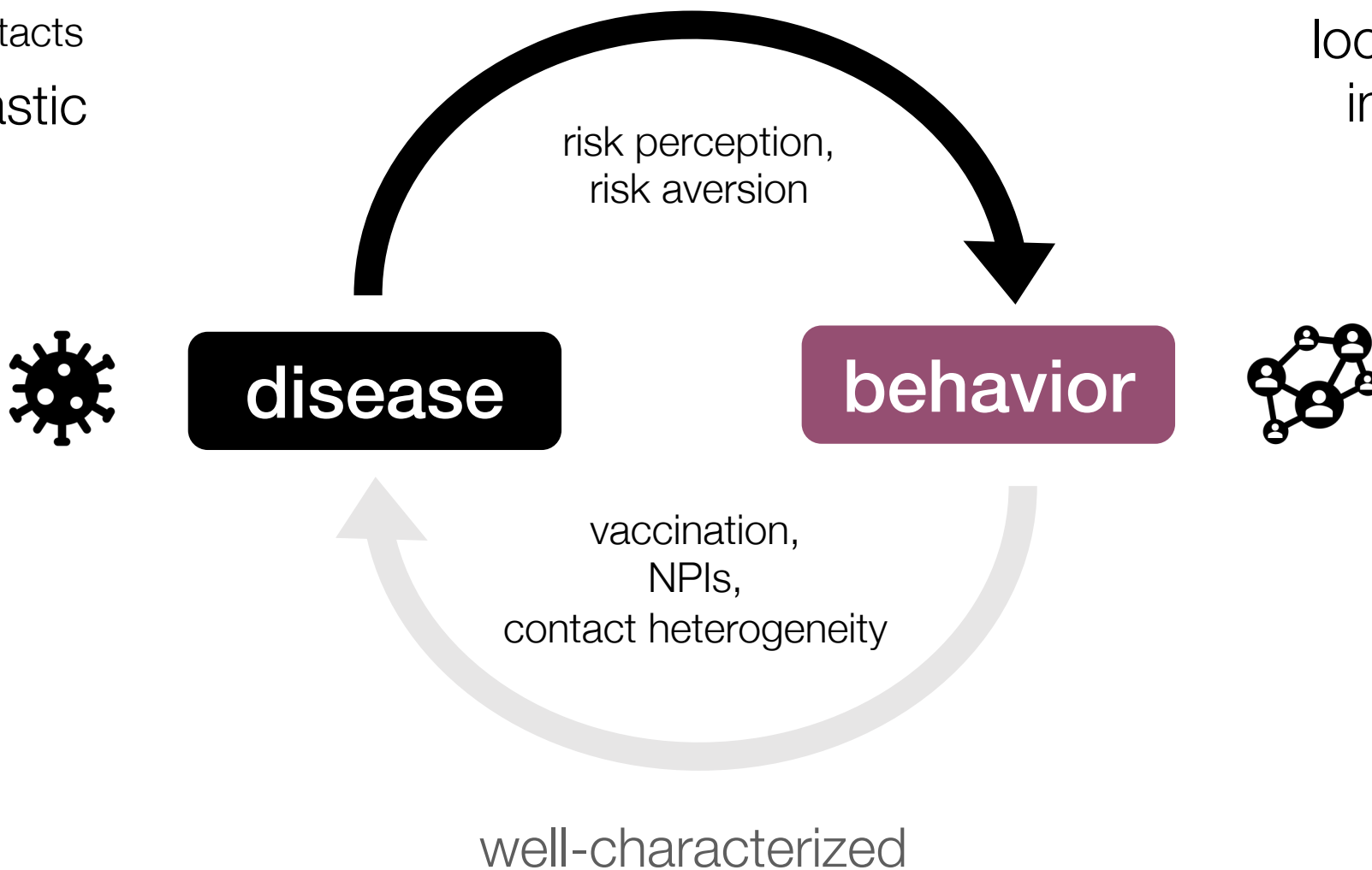


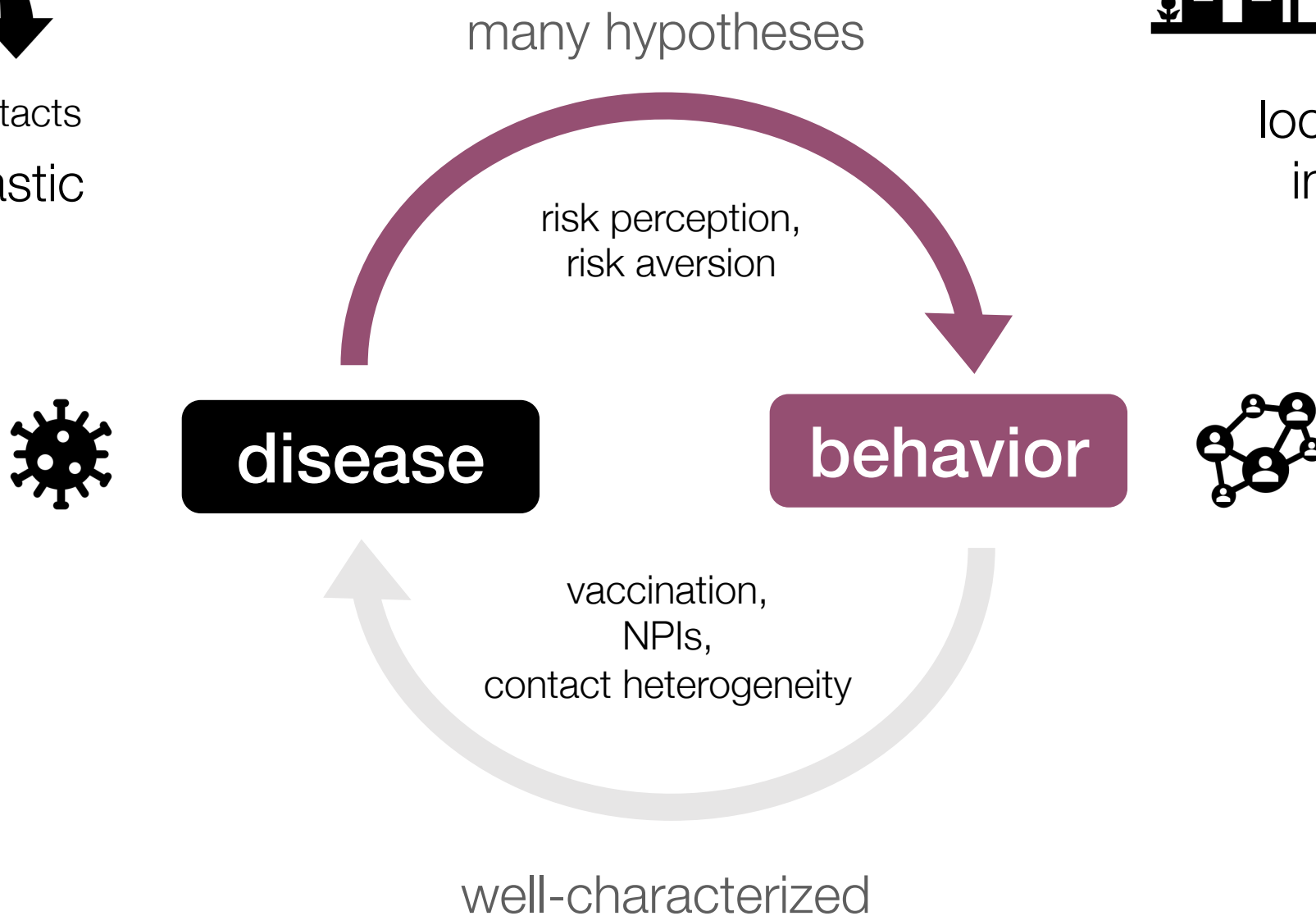
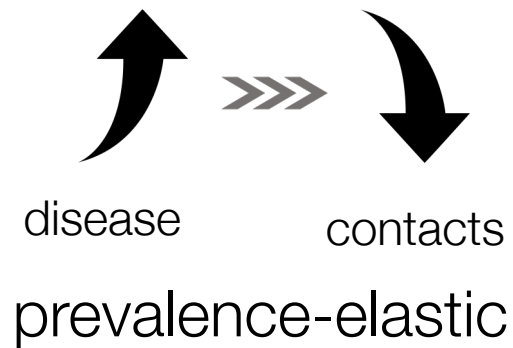






local vs global
information



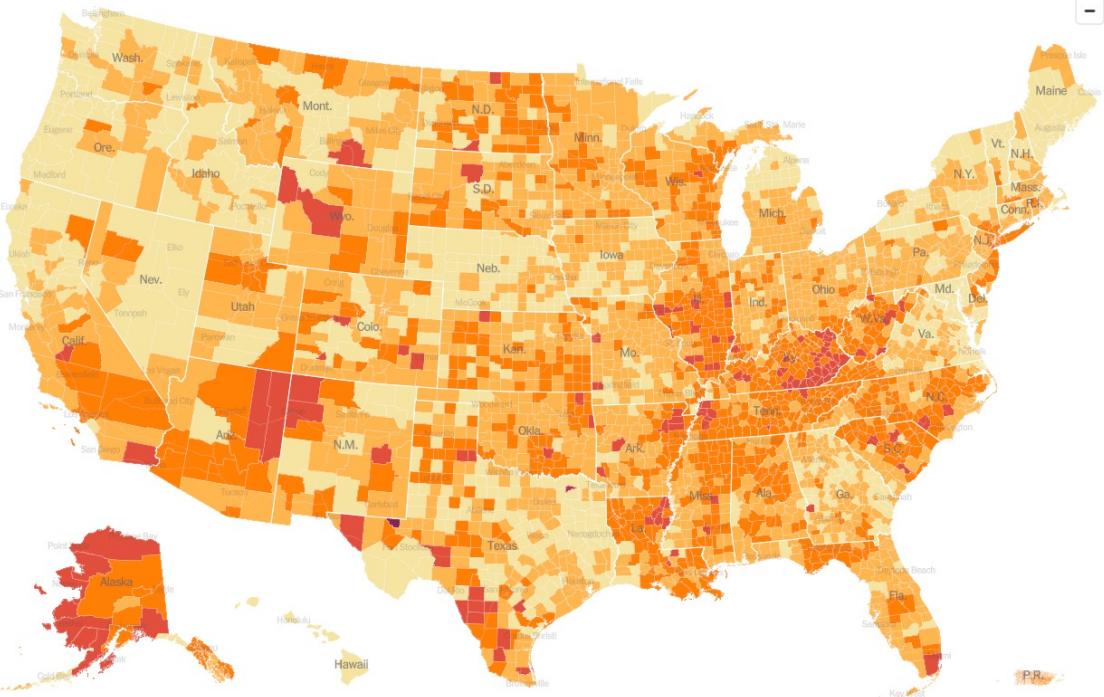


Heterogeneities in disease across space & time

Heterogeneities in disease across space & time

Spatial patterns of disease

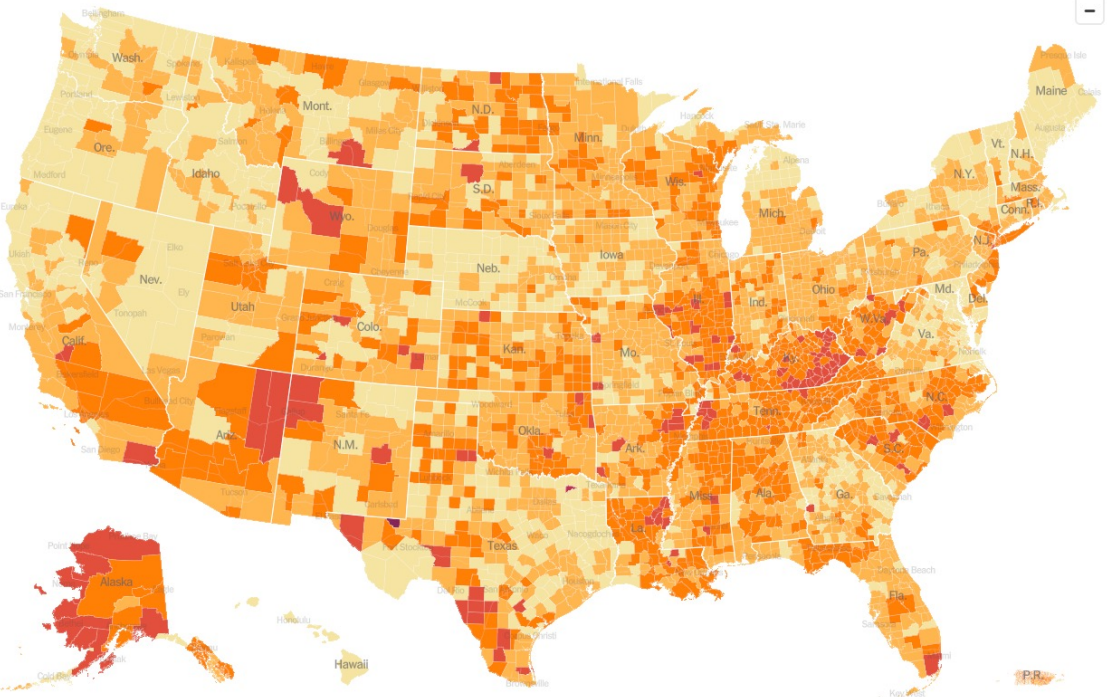
reported COVID cases/100k



Heterogeneities in disease across space & time

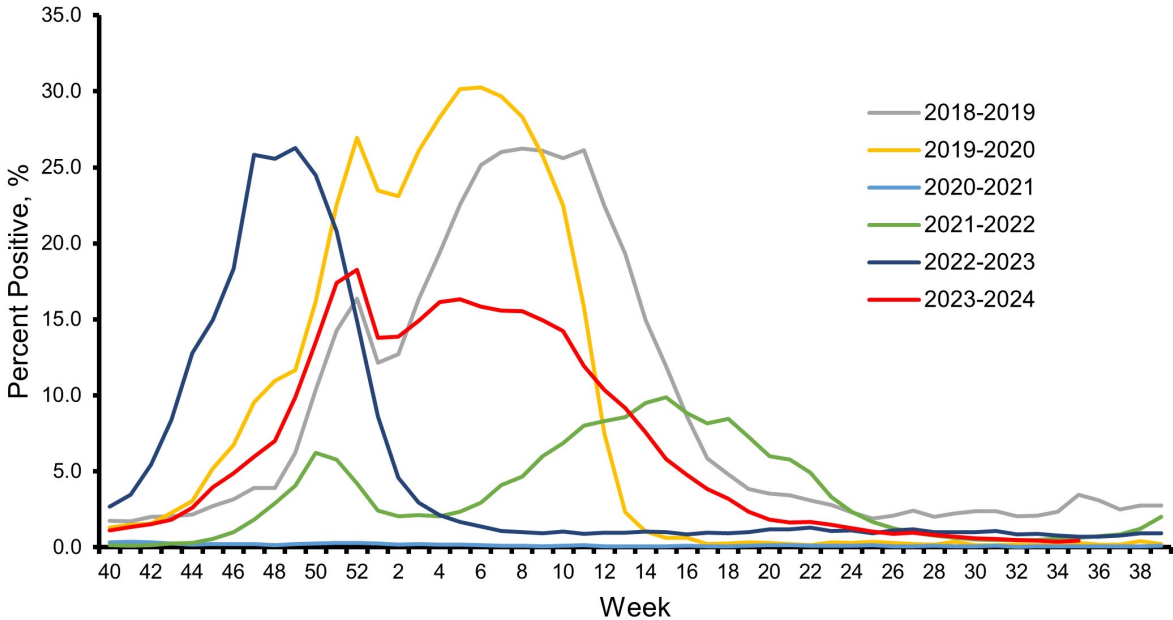
Spatial patterns of disease

reported COVID cases/100k



Seasonality of respiratory viruses

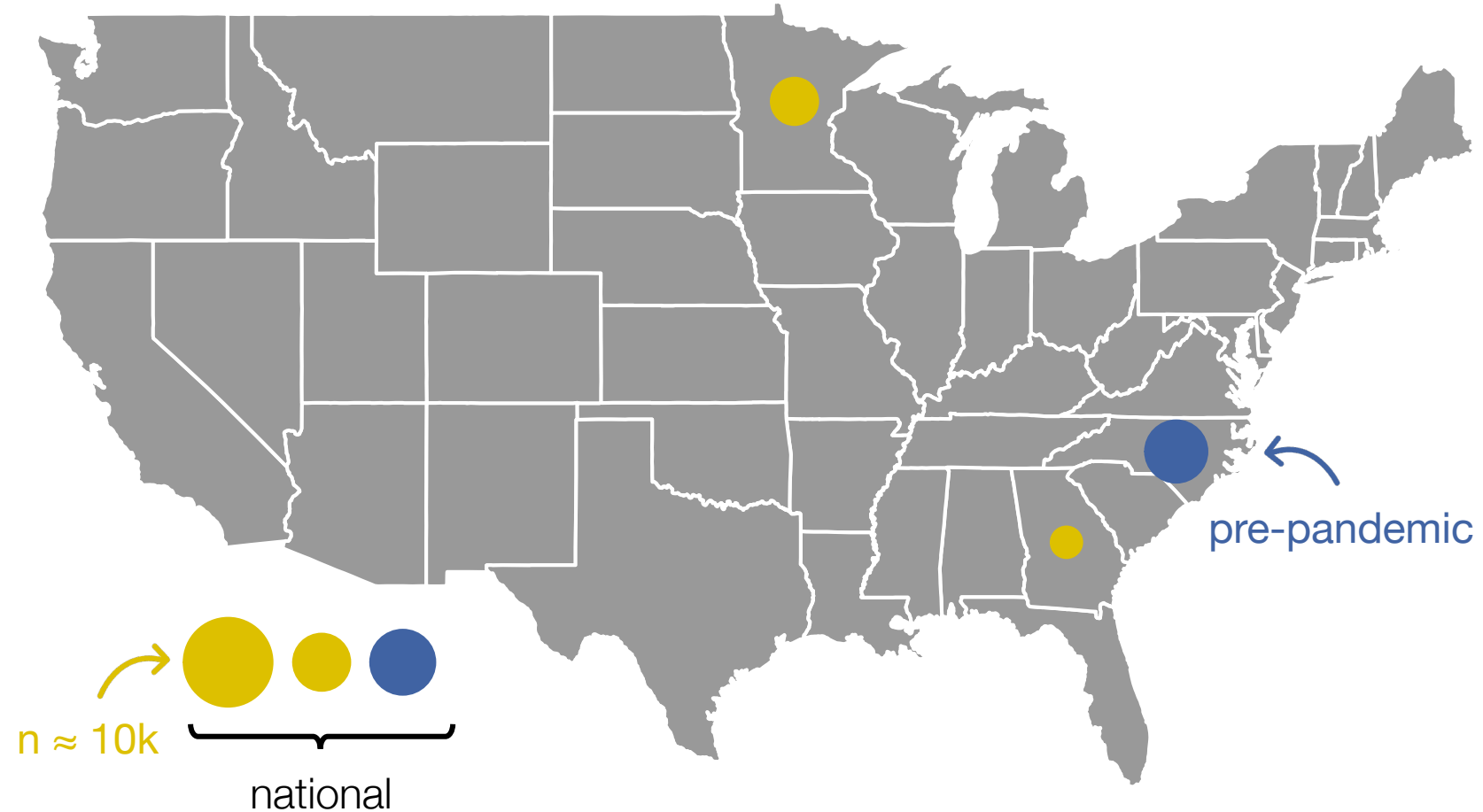
annual influenza activity



Data on contact network structure is limited

Studies that do exist are small and brief...

...which prohibits us from analyzing behavior at fine spatial and long temporal scales



each dot is a study & its location

CTIS non-household contact data

CTIS non-household contact data



COVID-19 Trends and Impact Survey



CTIS non-household contact data



COVID-19 Trends and Impact Survey



Number of direct **non-household** contacts in the last 24 hrs



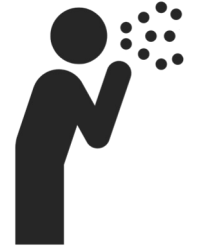
CTIS non-household contact data



COVID-19 Trends and Impact Survey



Number of direct **non-household** contacts in the last 24 hrs



11.2 million responses (Jun 2020 – Apr 2021)

CTIS non-household contact data



COVID-19 Trends and Impact Survey



Number of direct **non-household** contacts in the last 24 hrs



11.2 million responses (Jun 2020 – Apr 2021)



Estimate **mean degree** & population **degree heterogeneity** at fine spatial & temporal scales

Estimating mean degree across space & time



We want fine spatial & temporal estimates of contact rates

Estimating mean degree across space & time



We want fine spatial & temporal estimates of contact rates



But low sample sizes in some locations + temporal noise make this hard

Estimating mean degree across space & time



Zack Susswein



We want fine spatial & temporal estimates of contact rates

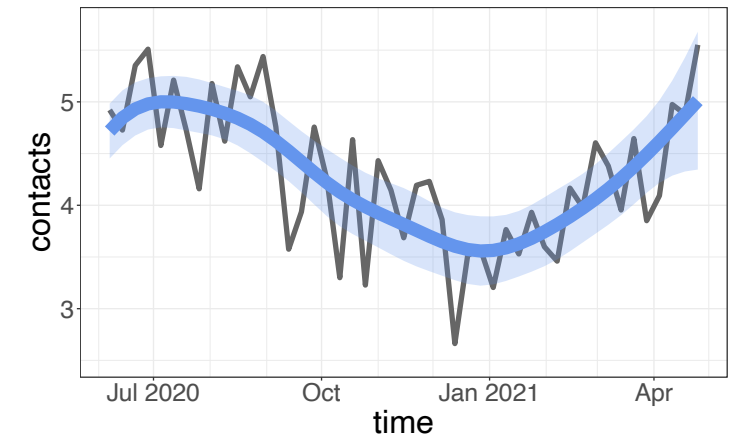


But low sample sizes in some locations + temporal noise make this hard

We use [Generalized Additive Models \(GAMs\)](#)



- Create smooth temporal trend
- Allow counties within a state to share information (hierarchical)



Estimating mean degree across space & time



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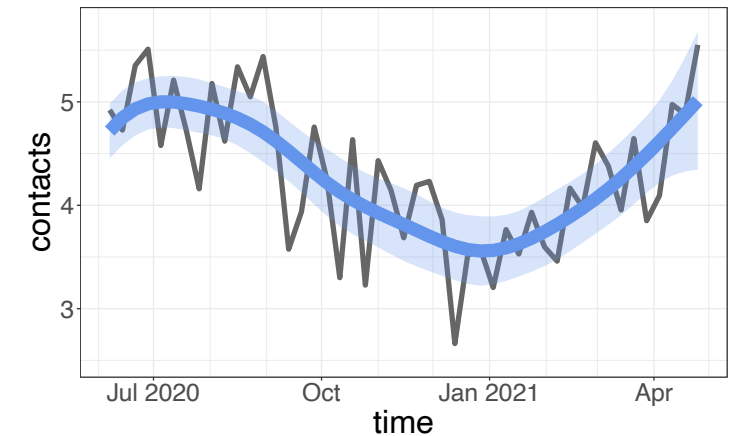


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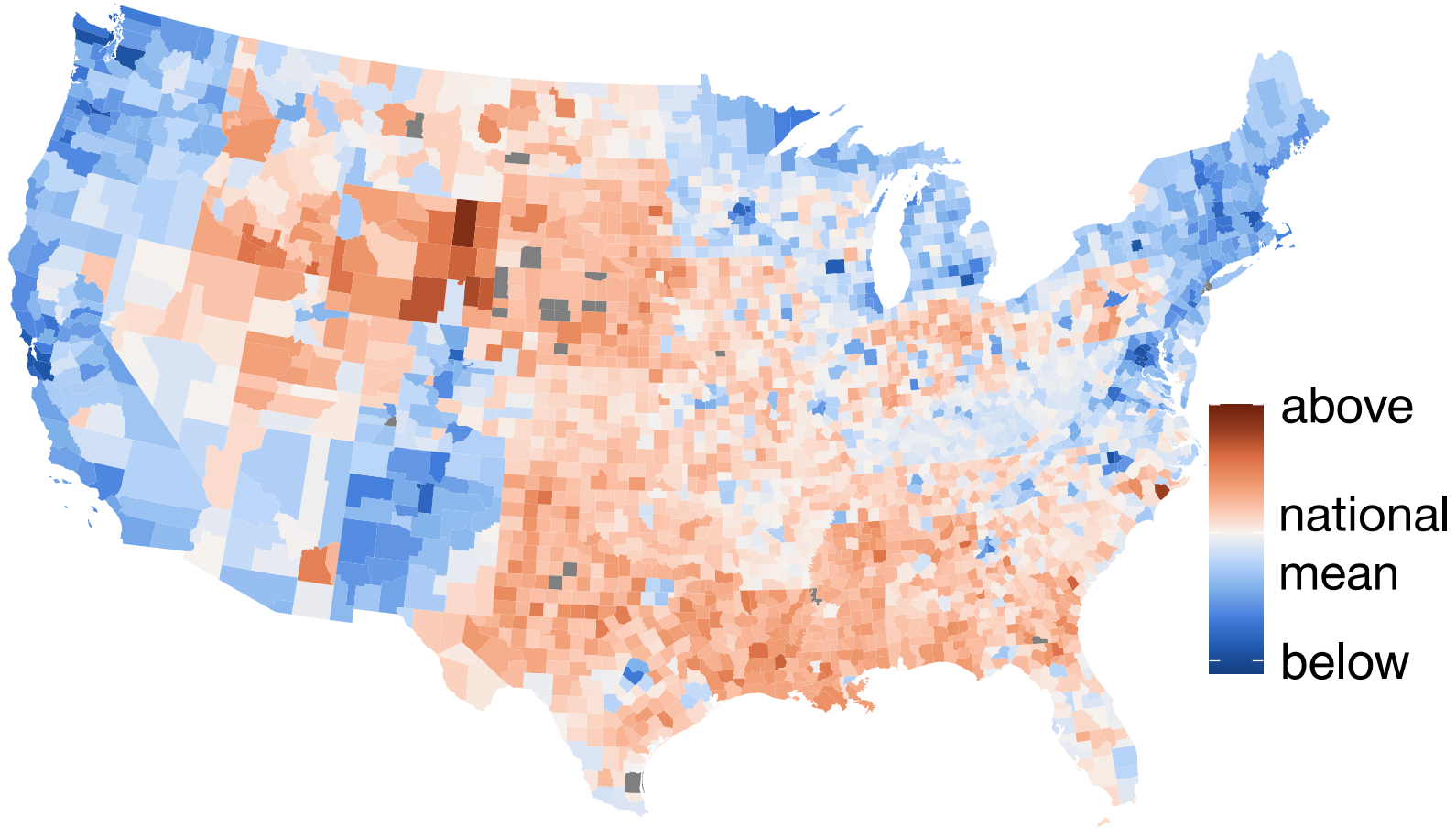
- Create smooth temporal trend
- Allow counties within a state to share information (hierarchical)



Output: county-week estimates of mean non-household degree

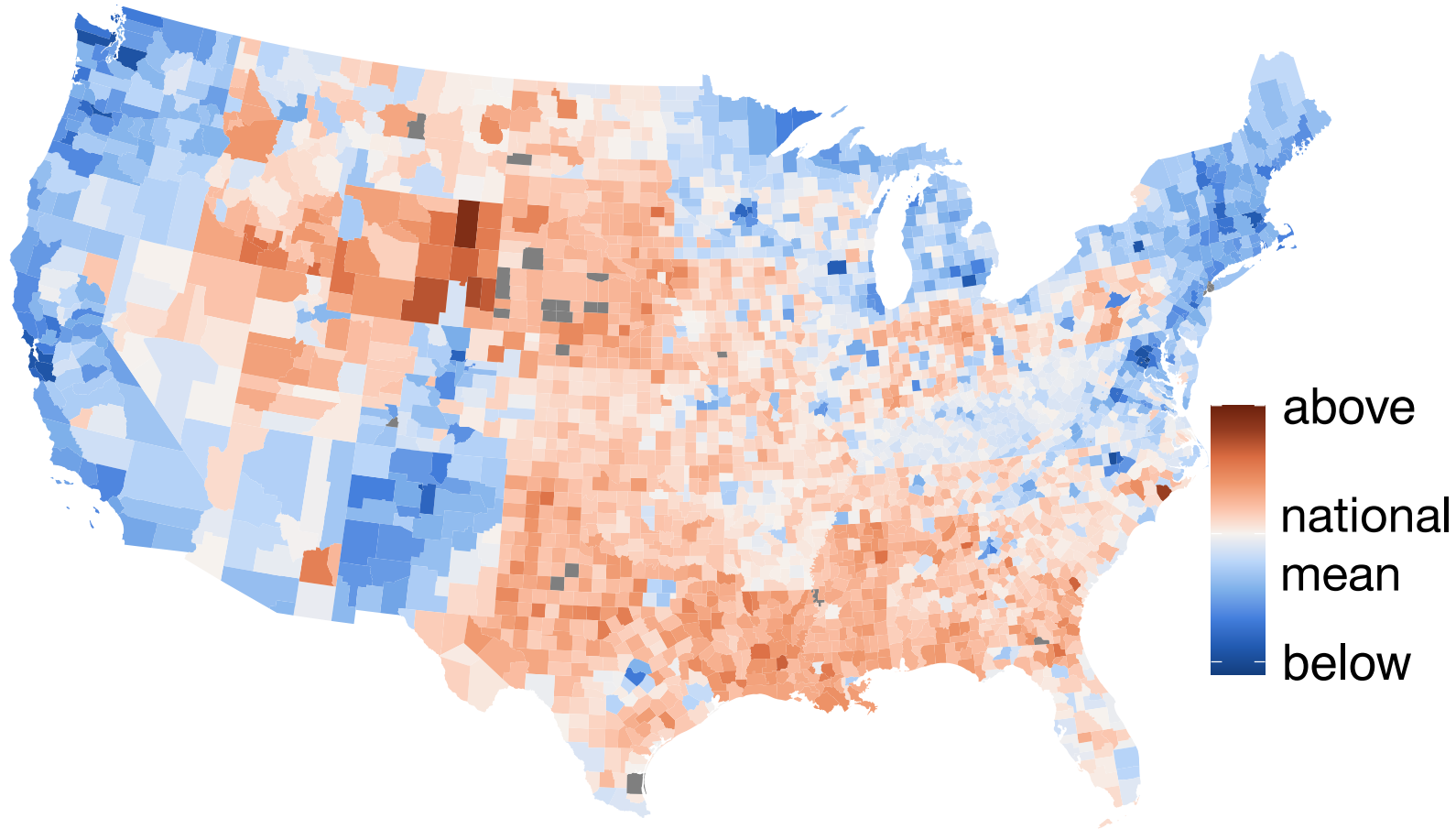
Degree varied spatially during the pandemic

Degree varied spatially during the pandemic

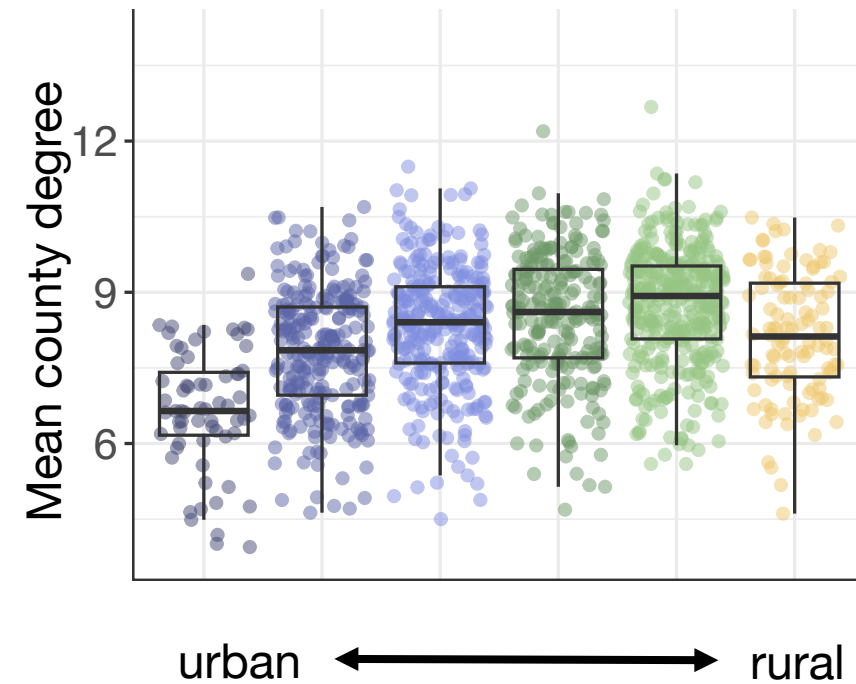


Mean county degree

Degree varied spatially during the pandemic

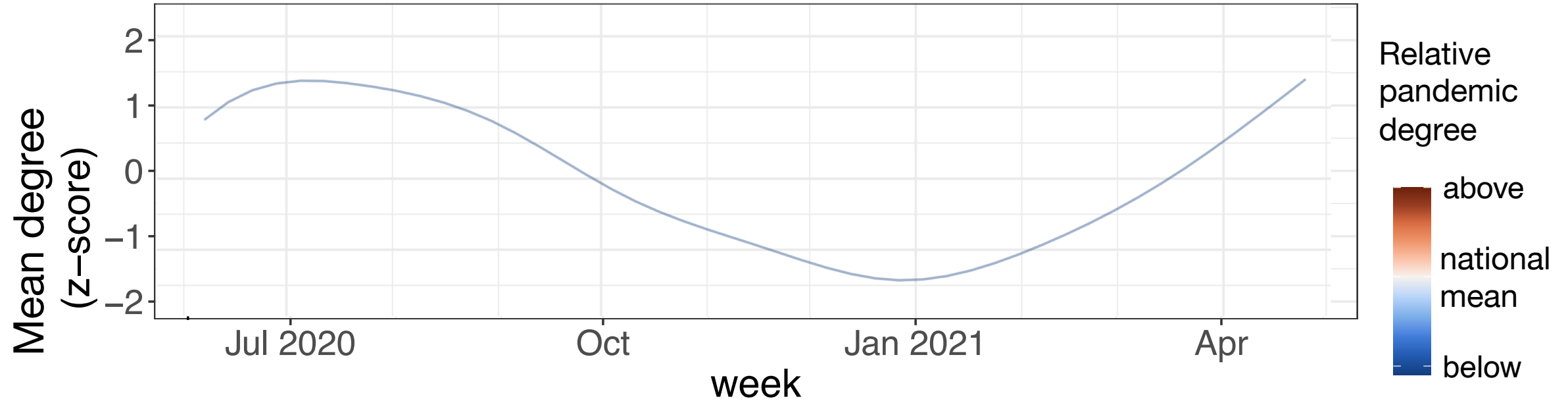


Mean county degree

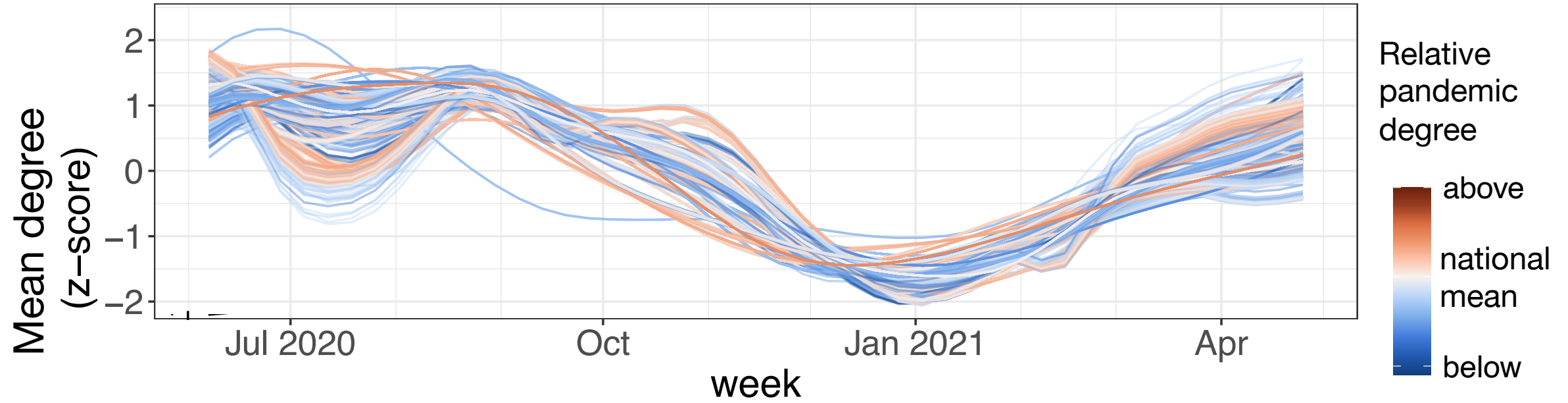


Degree varied temporally during the pandemic

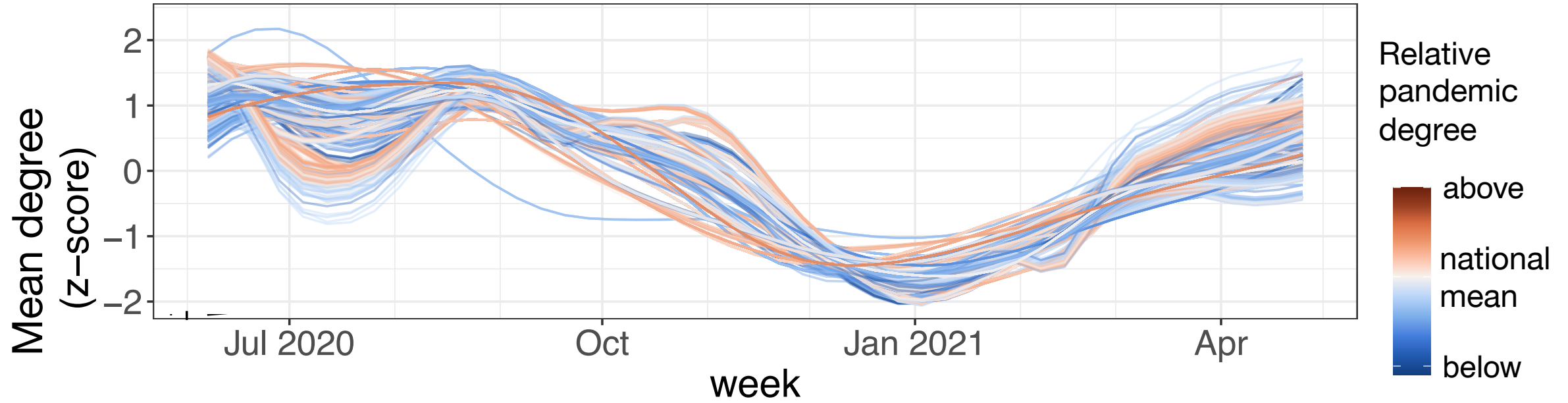
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Degree varied temporally during the pandemic

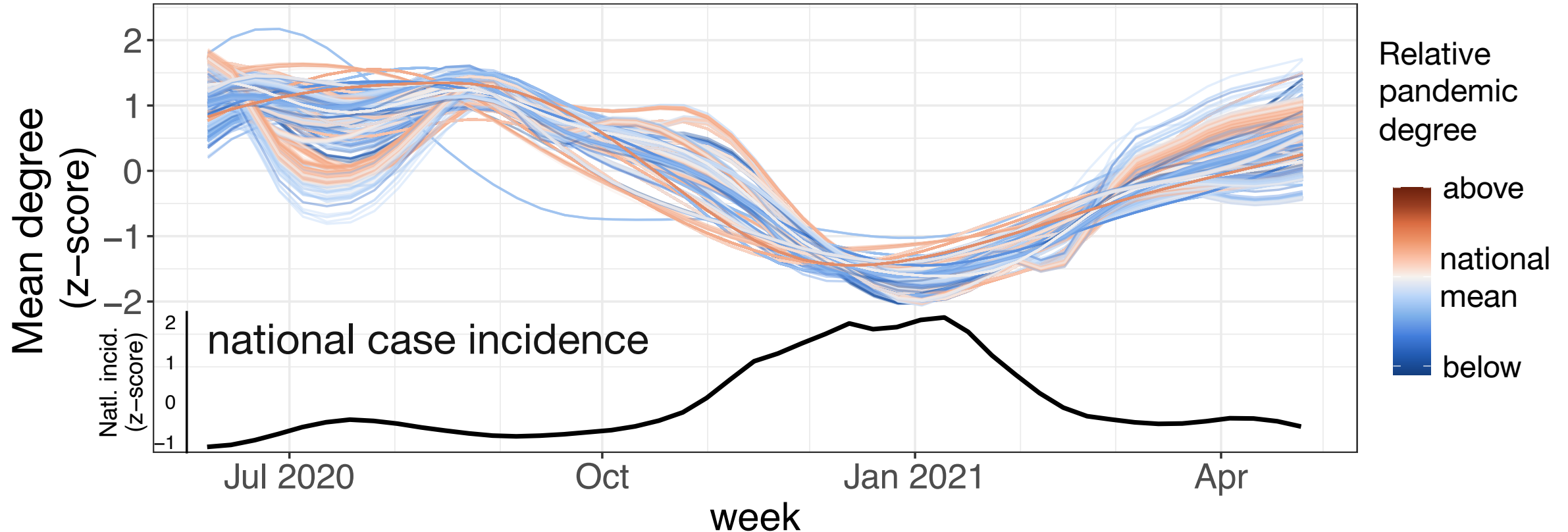


Degree varied temporally during the pandemic



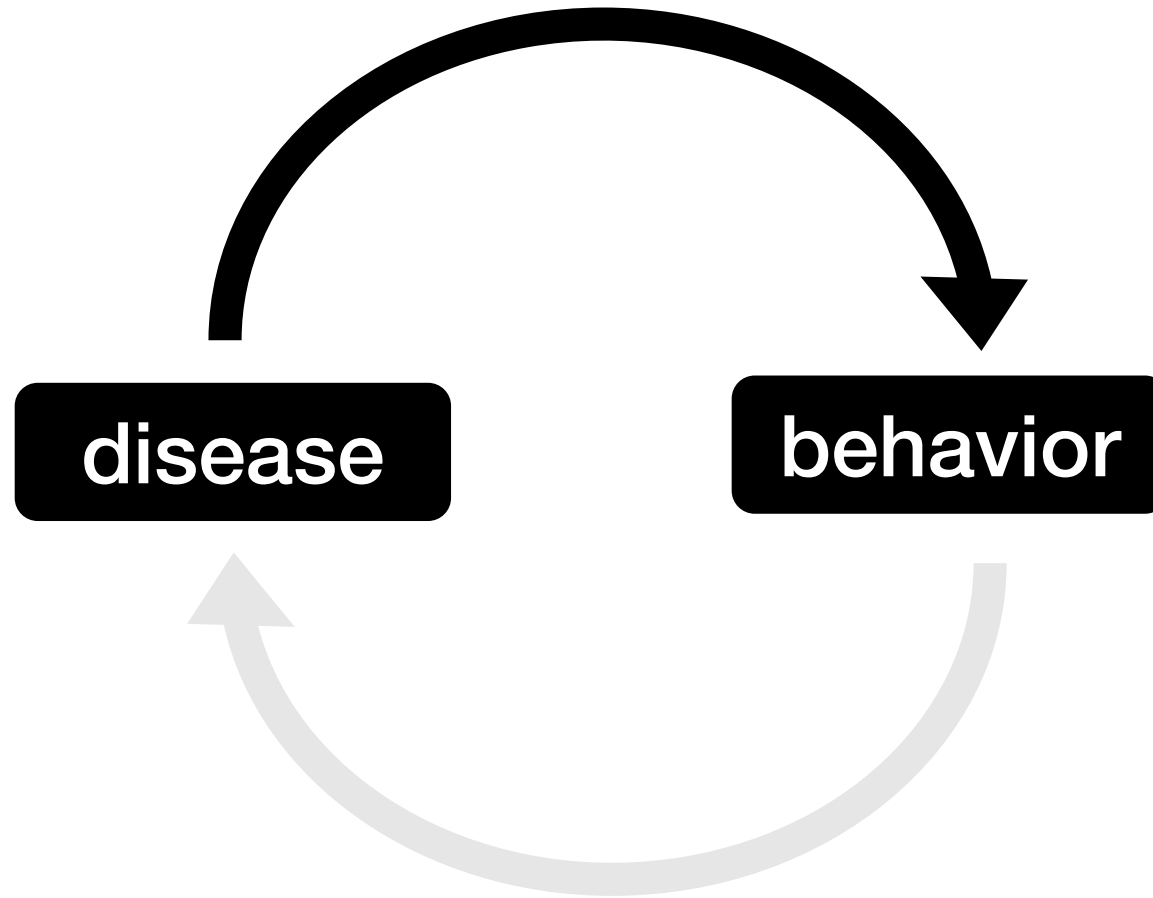
What is driving these spatial & temporal heterogeneities?

Degree varied temporally during the pandemic

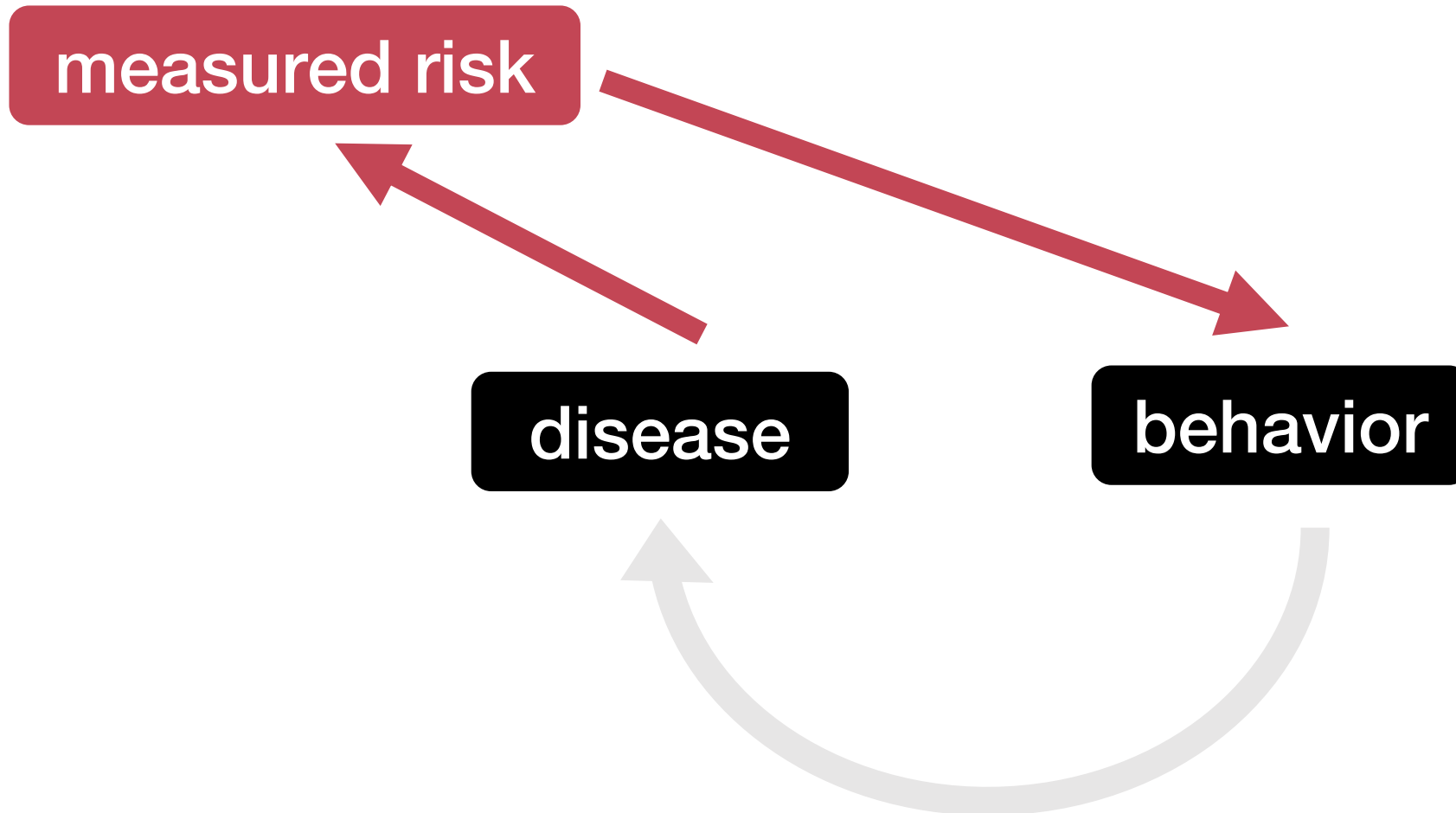


What is driving these spatial & temporal heterogeneities? Disease?

What factors are driving pandemic behavior change?



What factors are driving pandemic behavior change?



What factors are driving pandemic behavior change?



disease contacts

prevalence-elastic

What factors are driving pandemic behavior change?

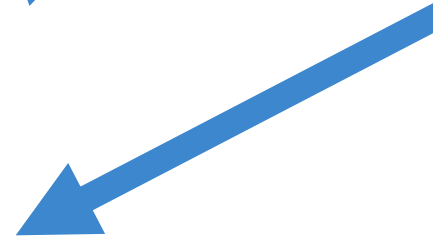
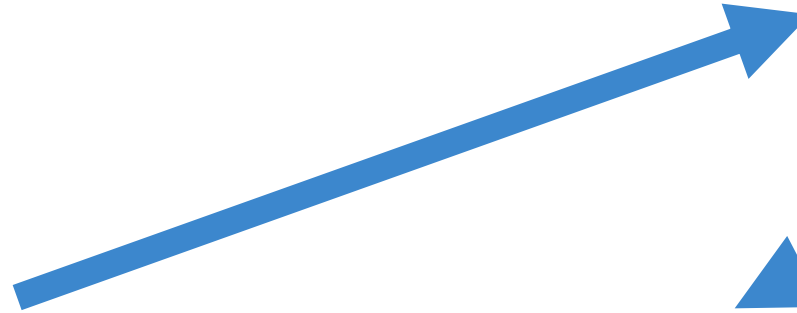


measured risk

perceived risk

disease

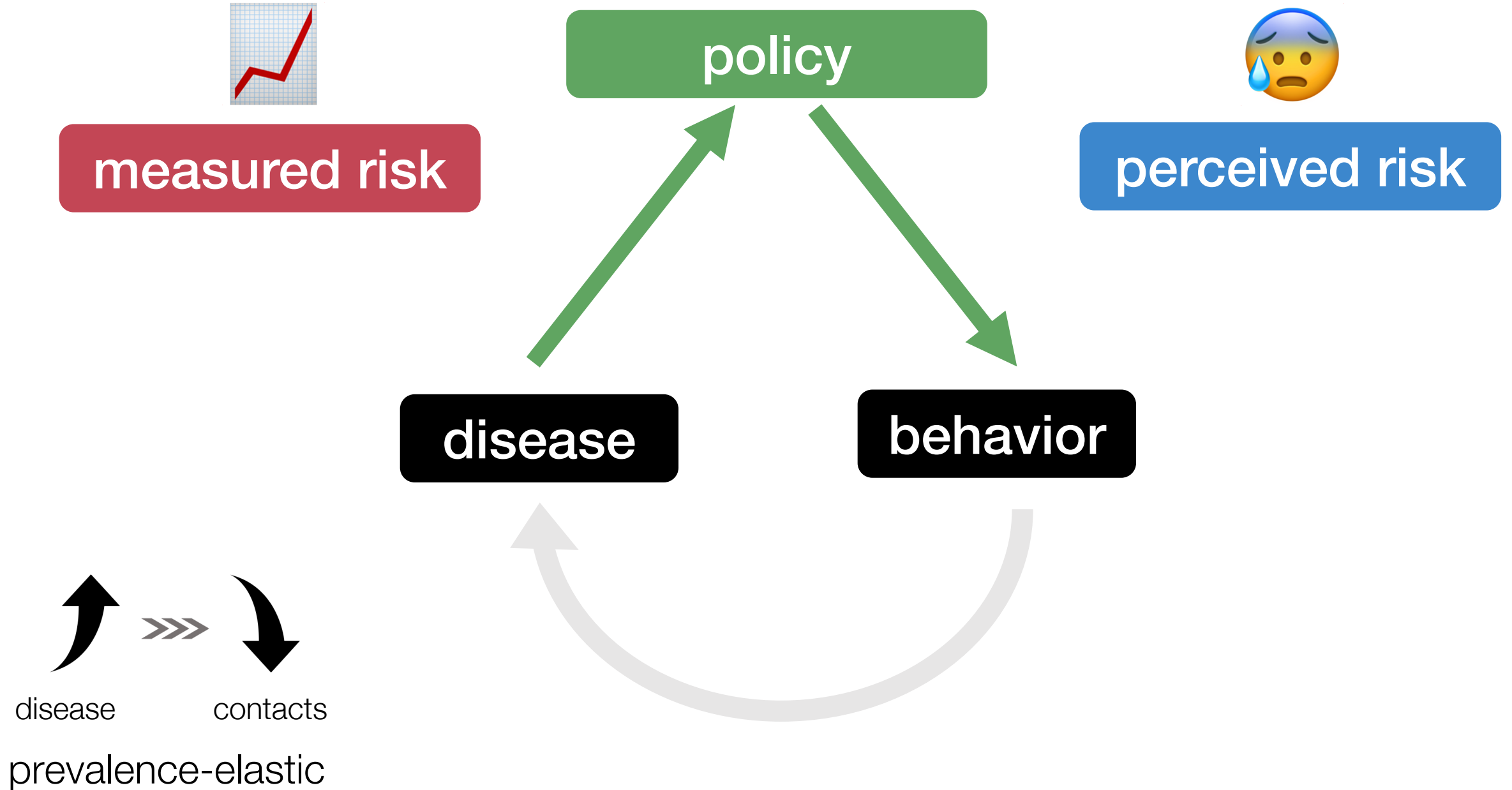
behavior



disease contacts

prevalence-elastic

What factors are driving pandemic behavior change?



What factors are driving pandemic behavior change?



measured risk

policy



perceived risk



disease

behavior



disease contacts

prevalence-elastic

What factors are driving pandemic behavior change?



measured risk

policy



perceived risk



disease

behavior



disease
prevalence-elastic

contacts



local vs global
information

What factors are driving pandemic behavior change?



measured risk

policy



perceived risk



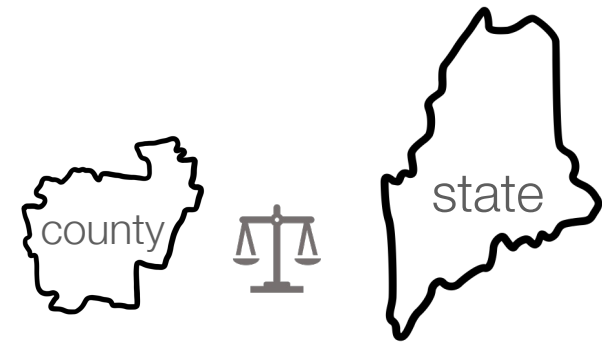
disease

behavior



disease
prevalence-elastic

contacts



local vs global
information

What factors are driving pandemic behavior change?

What factors are driving pandemic behavior change?



behavior ~ measured risk + perceived risk + policy + control variables



weather



popn. density



demography



essential workers



education



income

What factors are driving pandemic behavior change?

 behavior ~ measured risk + perceived risk + policy + control variables



weather



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demography



essential workers



education



income



We use **Integrated Nested Laplace Approximation** (INLA) models

- Can handle spatial and temporal autocorrelation



Casey Woika

What factors are driving pandemic behavior change?



behavior ~ measured risk + perceived risk + policy + control variables



weather



popn. density



demography



essential workers



education



income



We use **Integrated Nested Laplace Approximation** (INLA) models

- Can handle spatial and temporal autocorrelation



Output: estimated effects of each factor on county mean degree



Casey Woika

Measured risk



COVID-19 case incidence



Measured risk



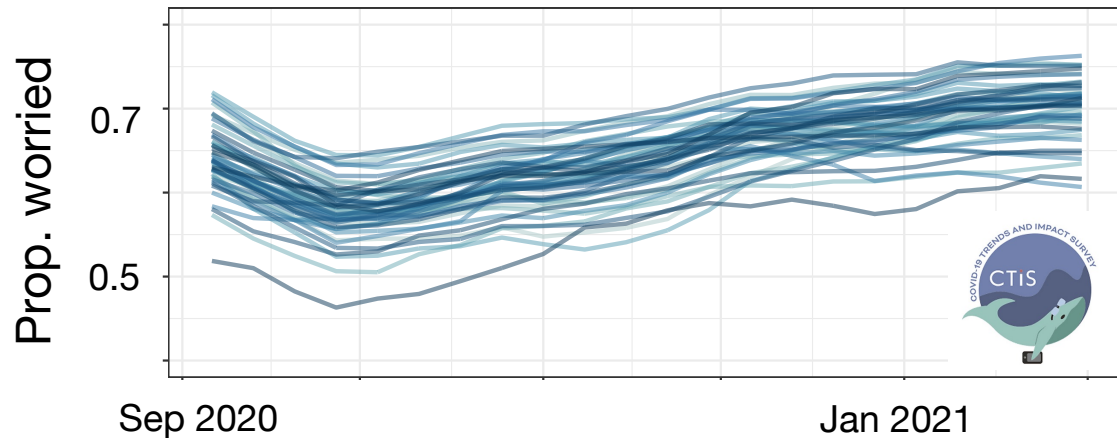
COVID-19 case incidence



Perceived risk



Prop. of respondents concerned about becoming seriously ill



Measured risk



Policy

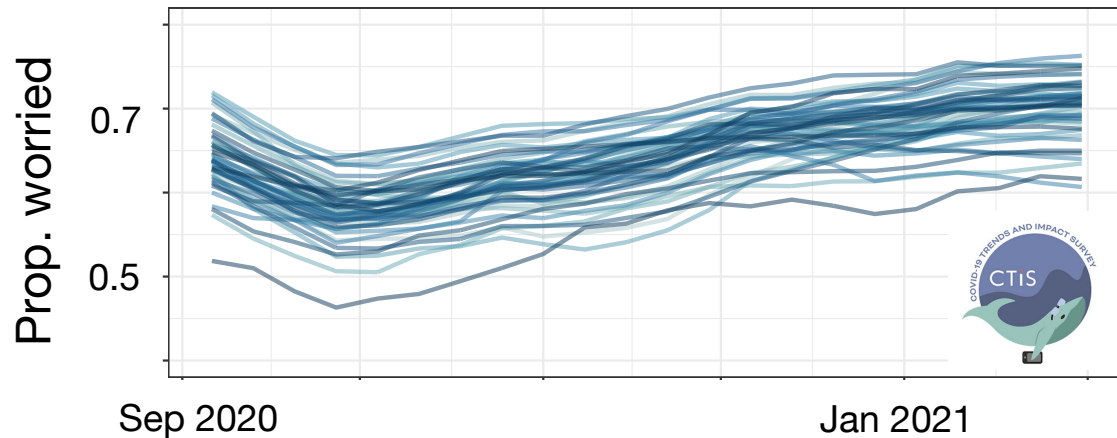
COVID-19 case incidence



Perceived risk



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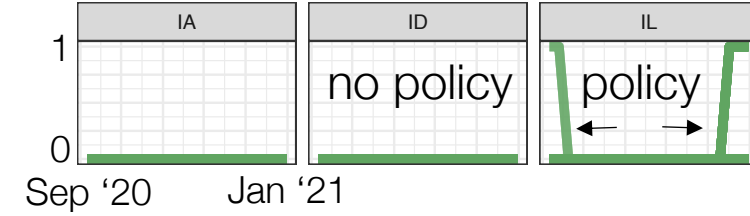


Measured risk



Policy

nonessential



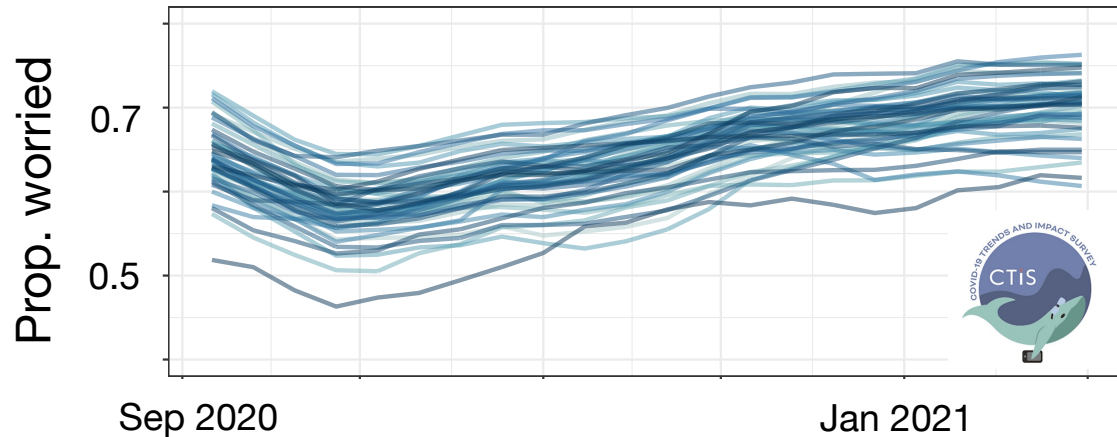
COVID-19 case incidence



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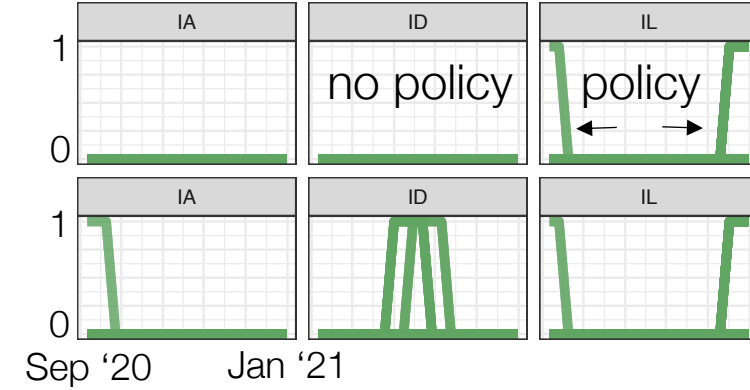


Policy

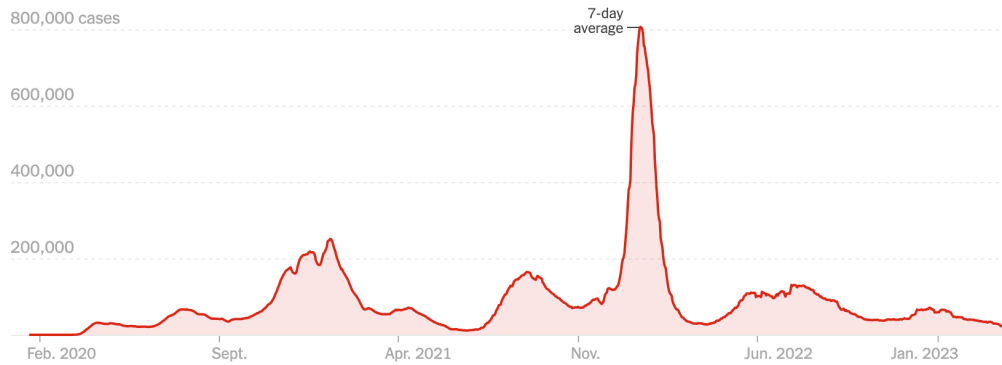
nonessential



food & drink



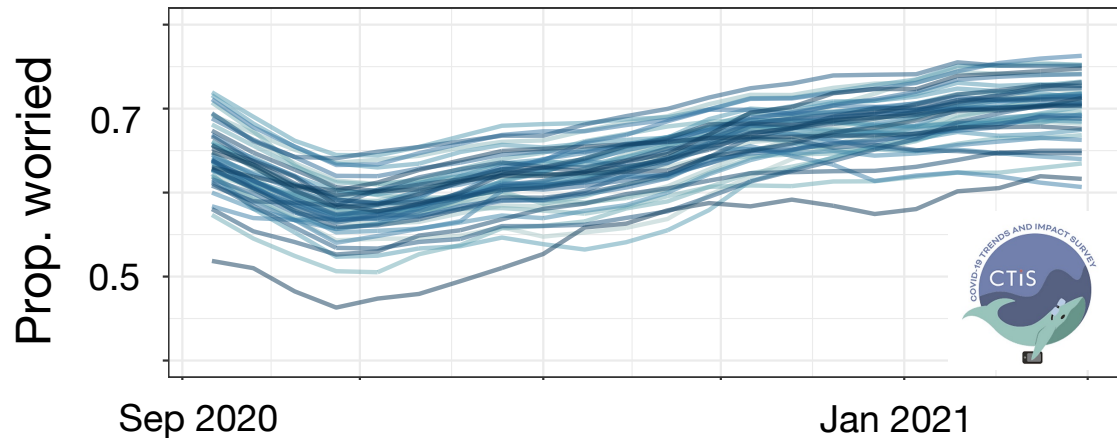
COVID-19 case incidence



Perceived risk



Prop. of respondents concerned about becoming seriously ill



Measured risk



Policy

nonessential



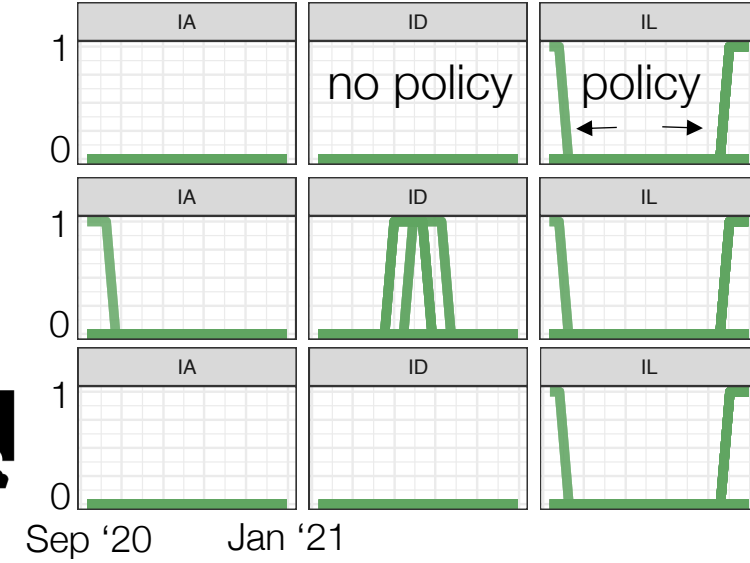
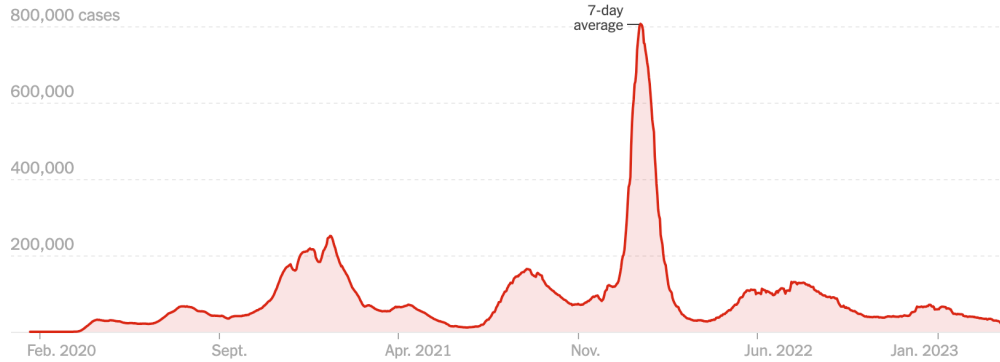
food & drink



entertainment



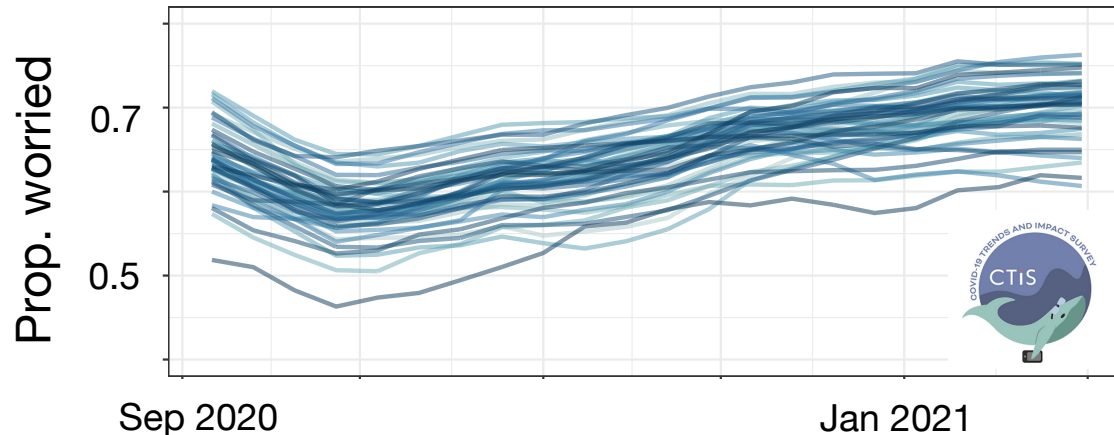
COVID-19 case incidence



Perceived risk



Prop. of respondents concerned about becoming seriously ill



Measured risk



Policy

nonessential



food & drink



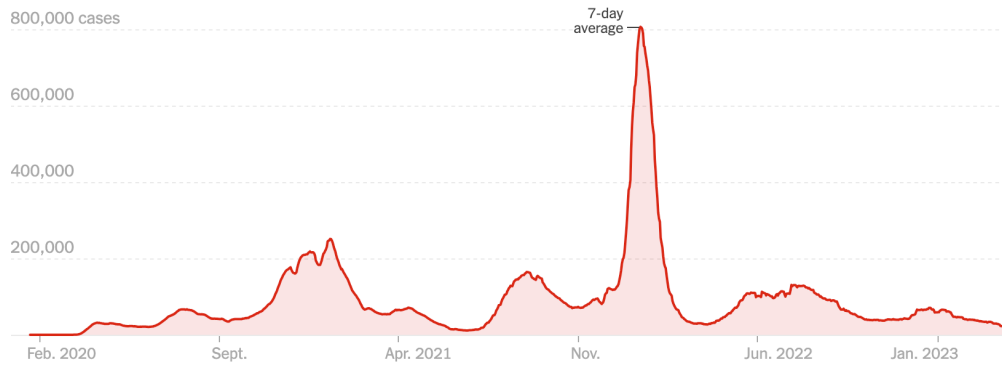
entertainment



outdoor recreation



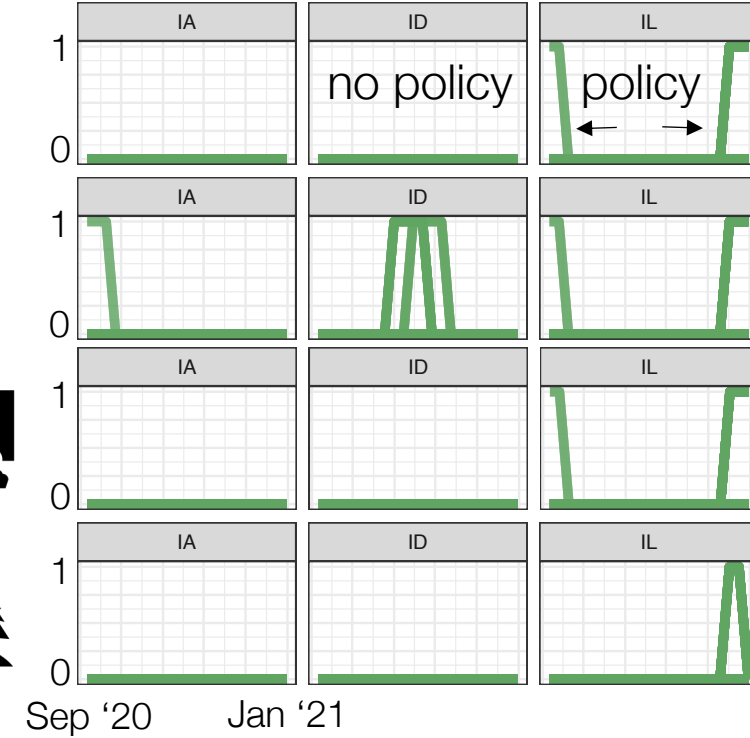
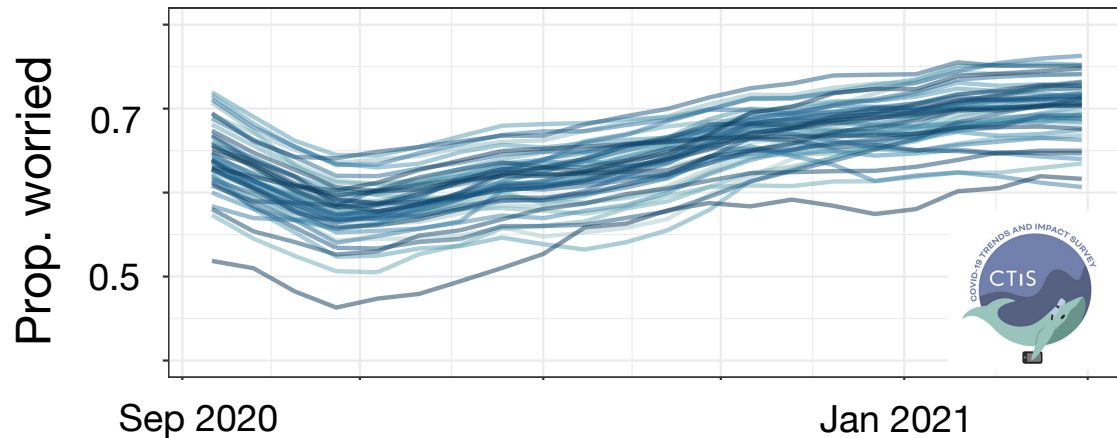
COVID-19 case incidence



Perceived risk



Prop. of respondents concerned about becoming seriously ill



Measured risk



COVID-19 case incidence



Policy

nonessential



food & drink



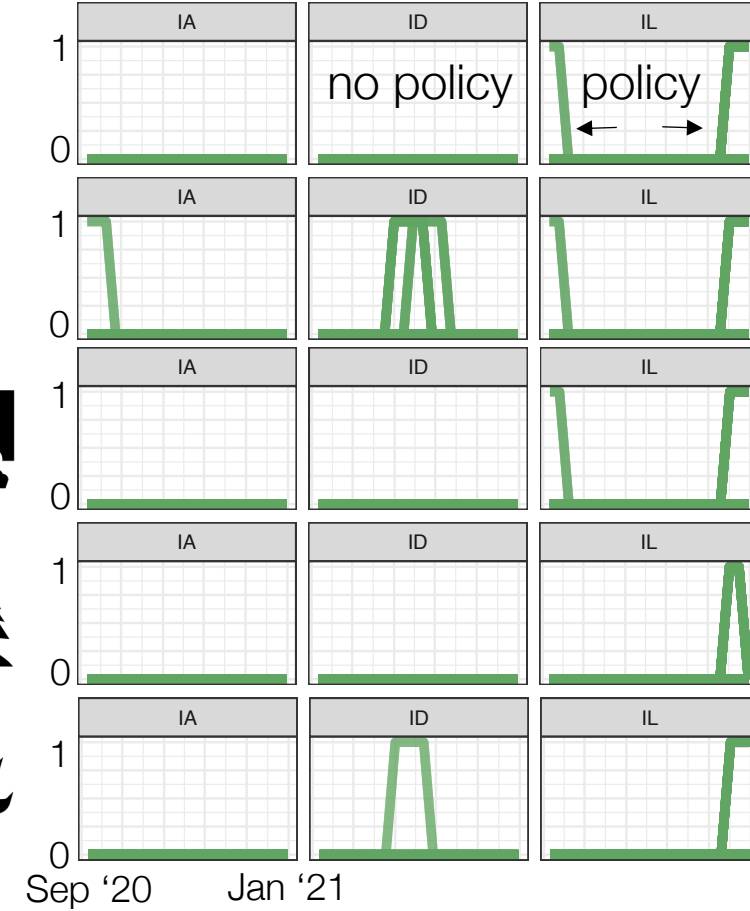
entertainment



outdoor recreation



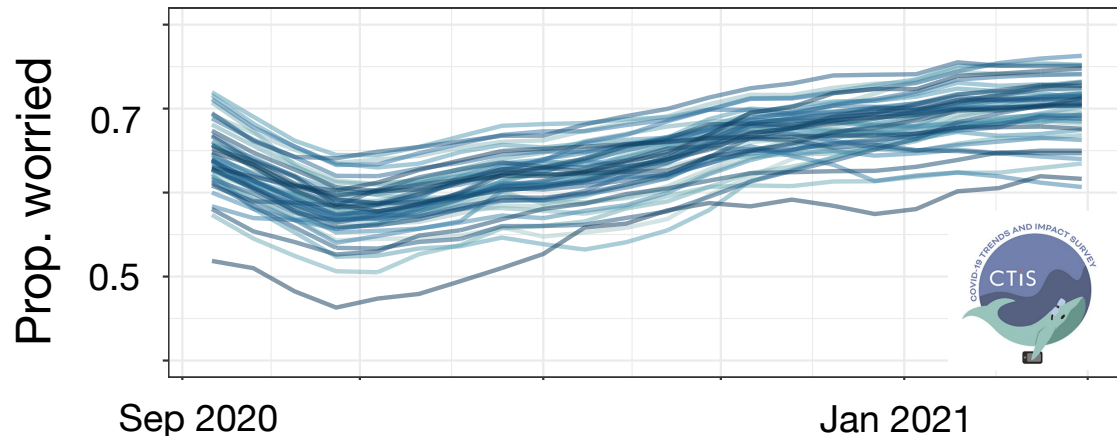
worship



Perceived risk



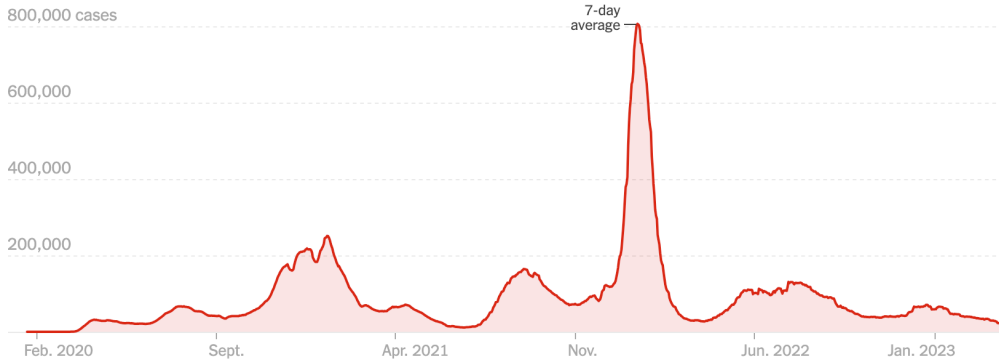
Prop. of respondents concerned about becoming seriously ill



Measured risk



COVID-19 case incidence



Policy

nonessential



food & drink



entertainment



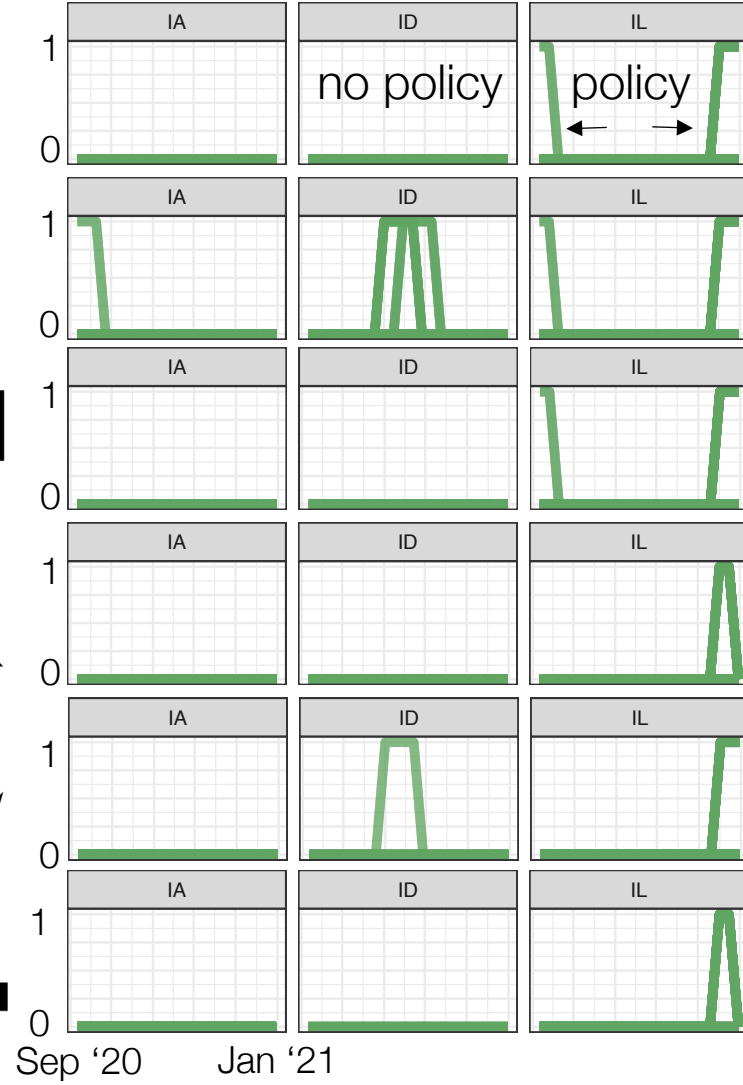
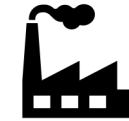
outdoor recreation



worship



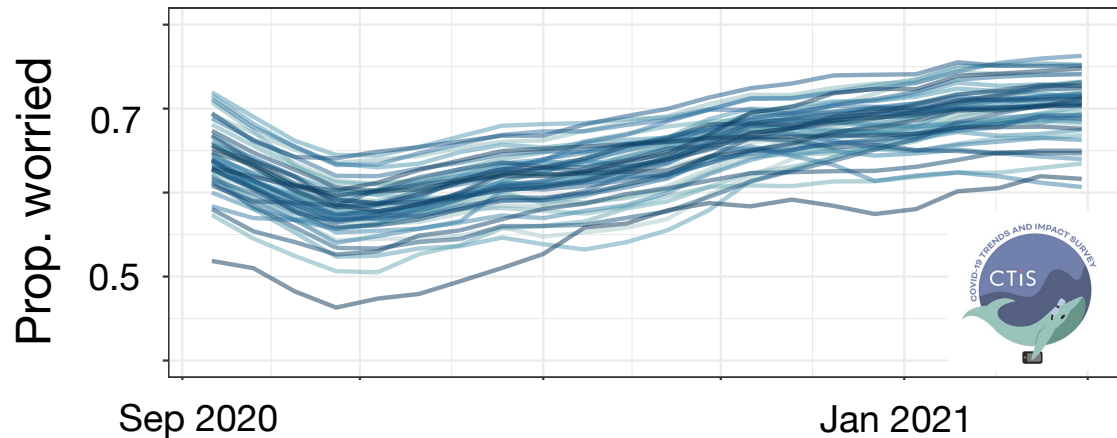
manufacturing



Perceived risk



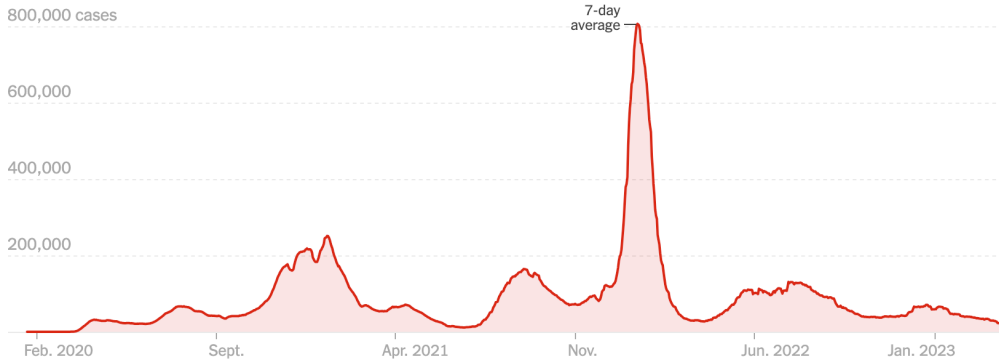
Prop. of respondents concerned about becoming seriously ill



Measured risk



COVID-19 case incidence



Policy

nonessential



food & drink



entertainment



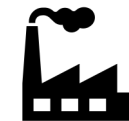
outdoor recreation



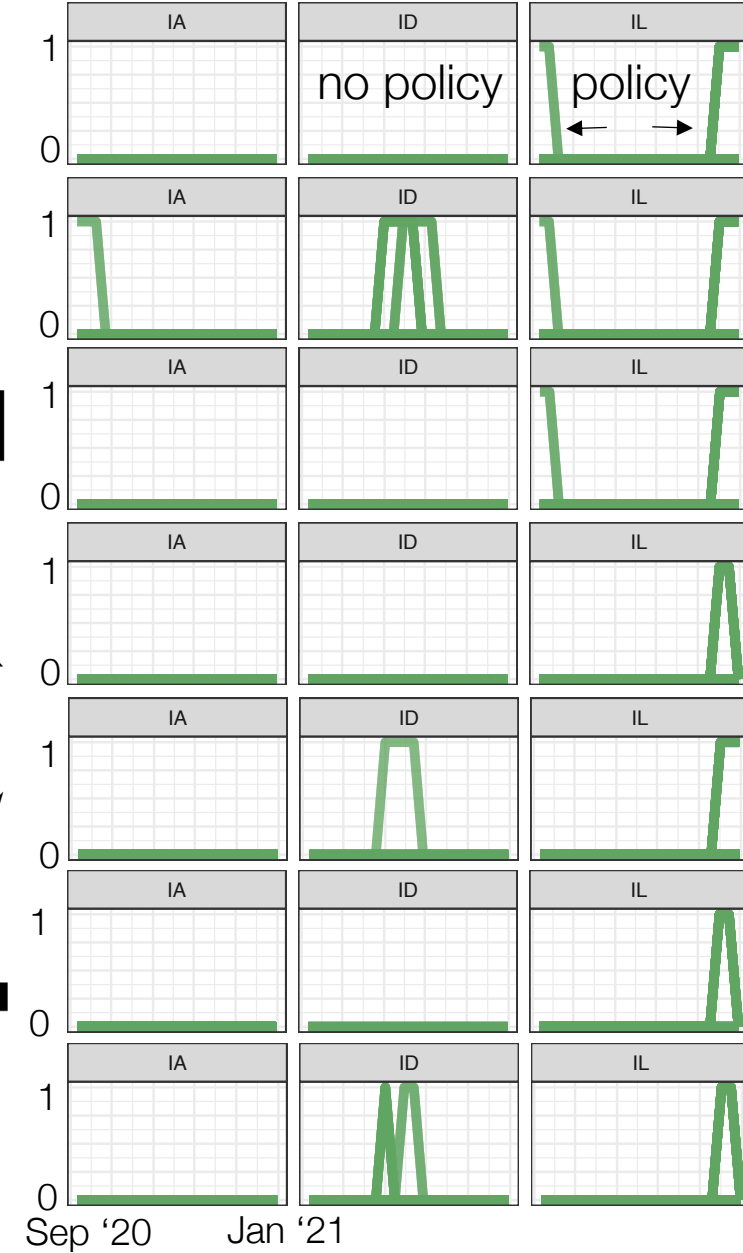
worship



manufacturing



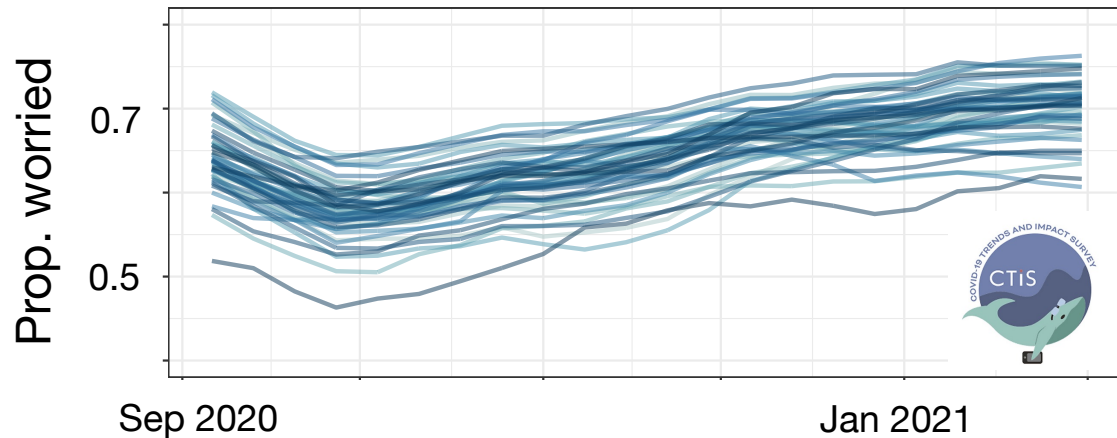
childcare
(county-level only)



Perceived risk



Prop. of respondents concerned about becoming seriously ill



Measured risk



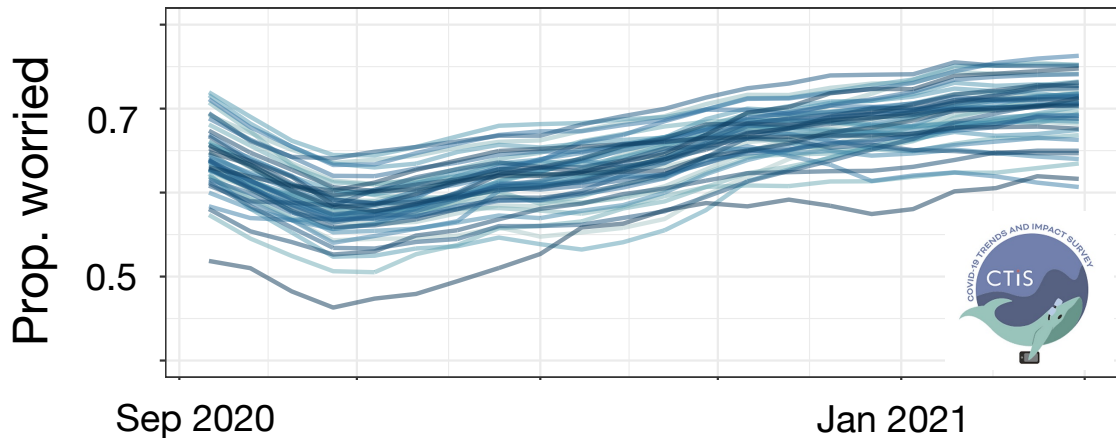
COVID-19 case incidence



Perceived risk



Prop. of respondents concerned about becoming seriously ill



Policy

nonessential



food & drink



entertainment



outdoor recreation



worship



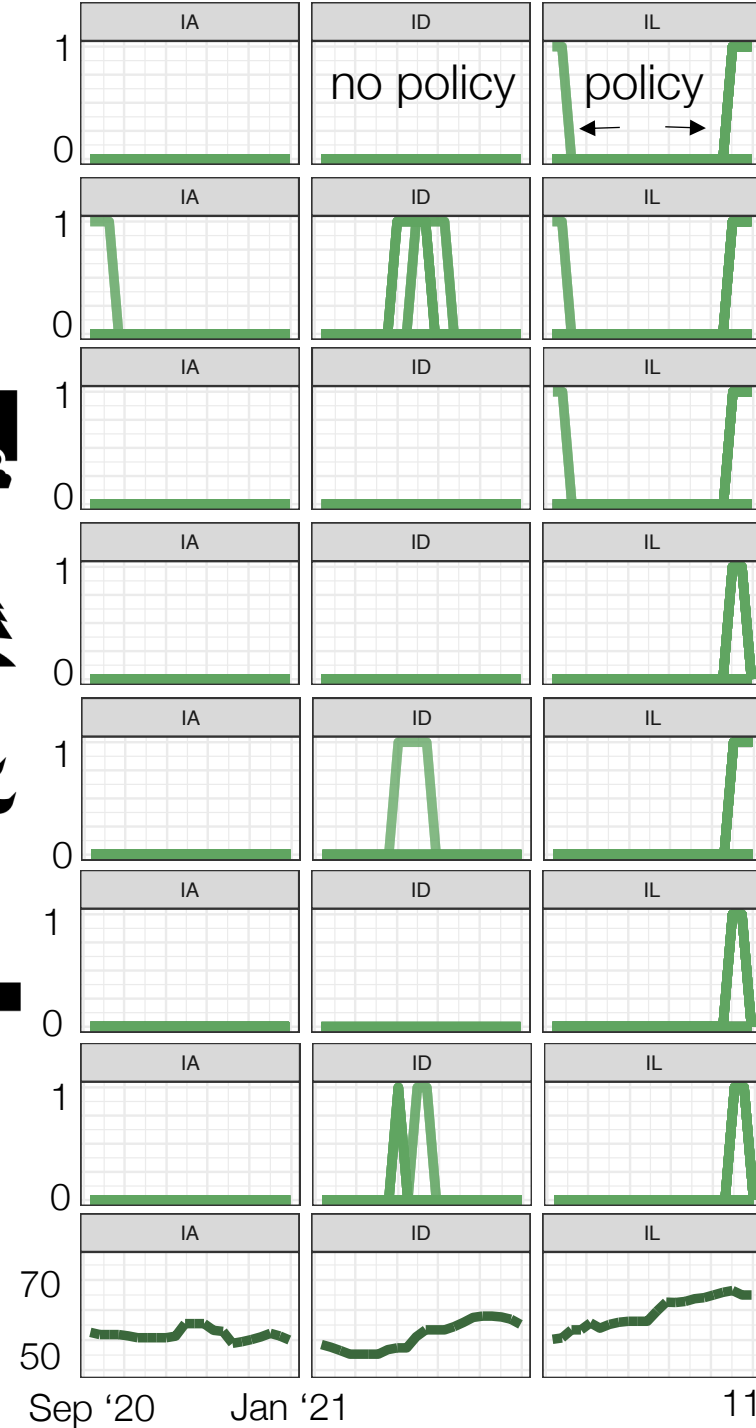
manufacturing



childcare
(county-level only)



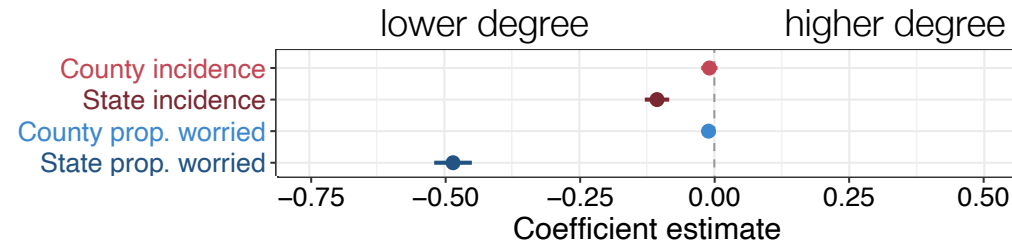
Oxford Stringency Index
(state-level only)



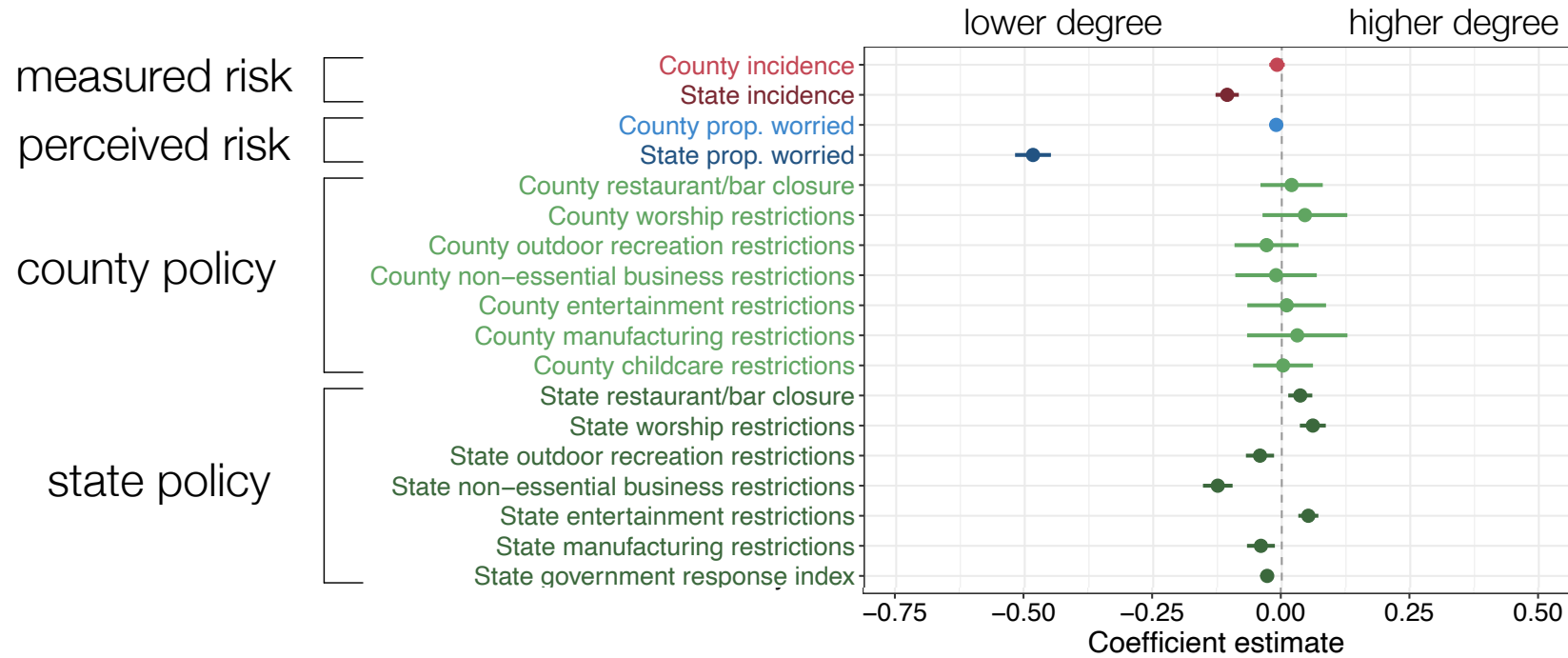
Behavior change is informed by **disease** & **perception**,
especially at larger spatial scales

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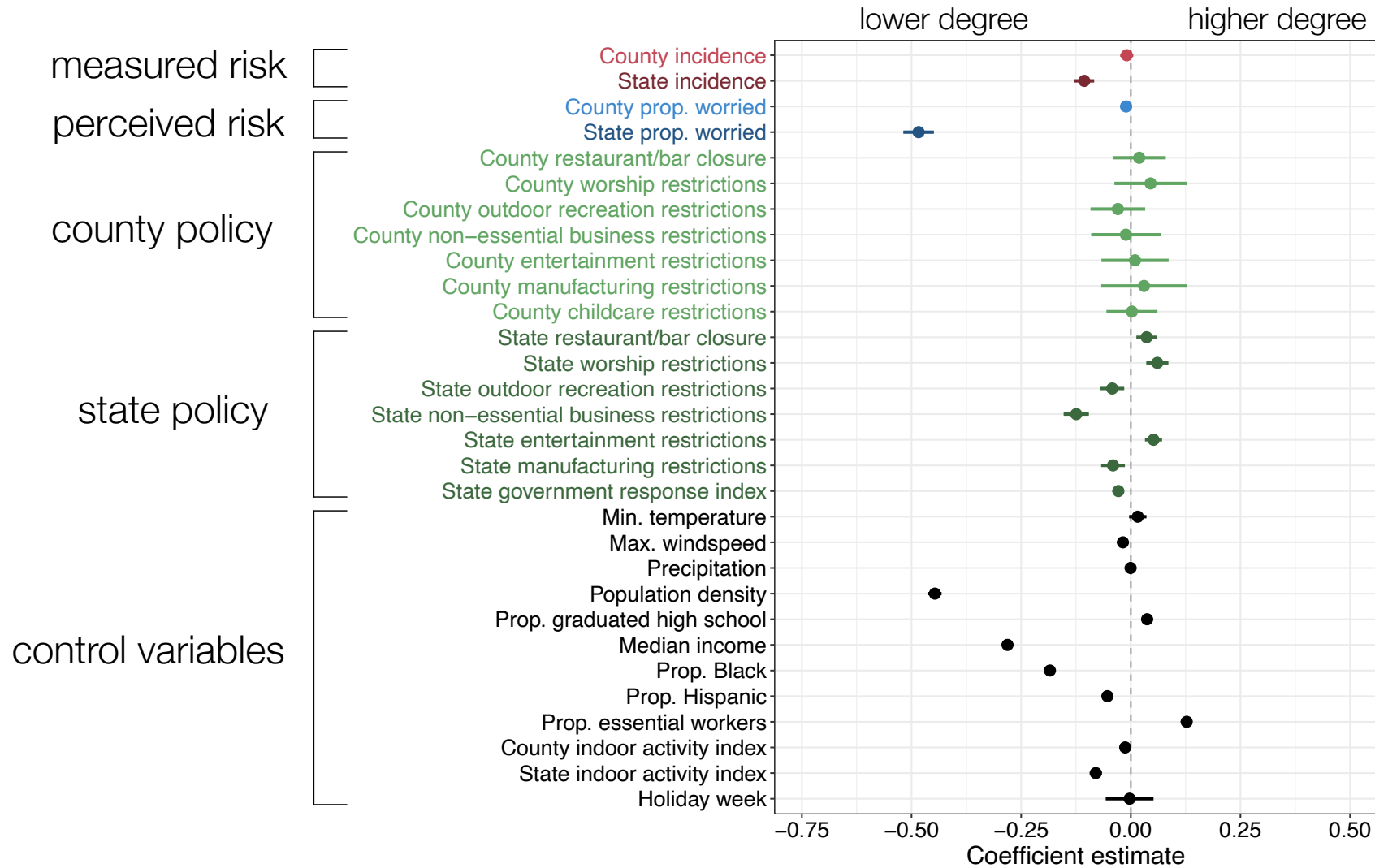
measured risk
perceived risk



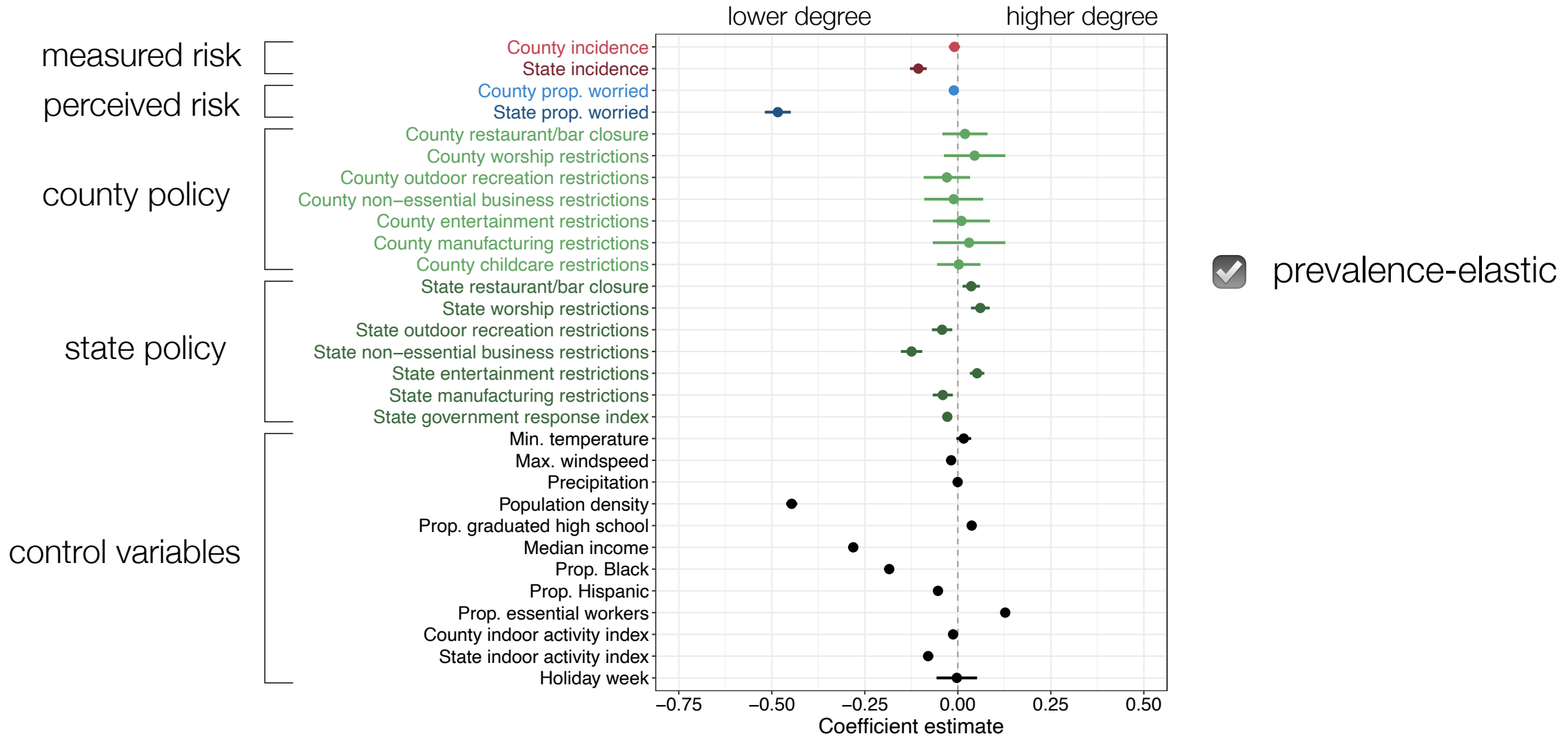
Behavior change is informed by **disease** & **perception**, especially at larger spatial scales



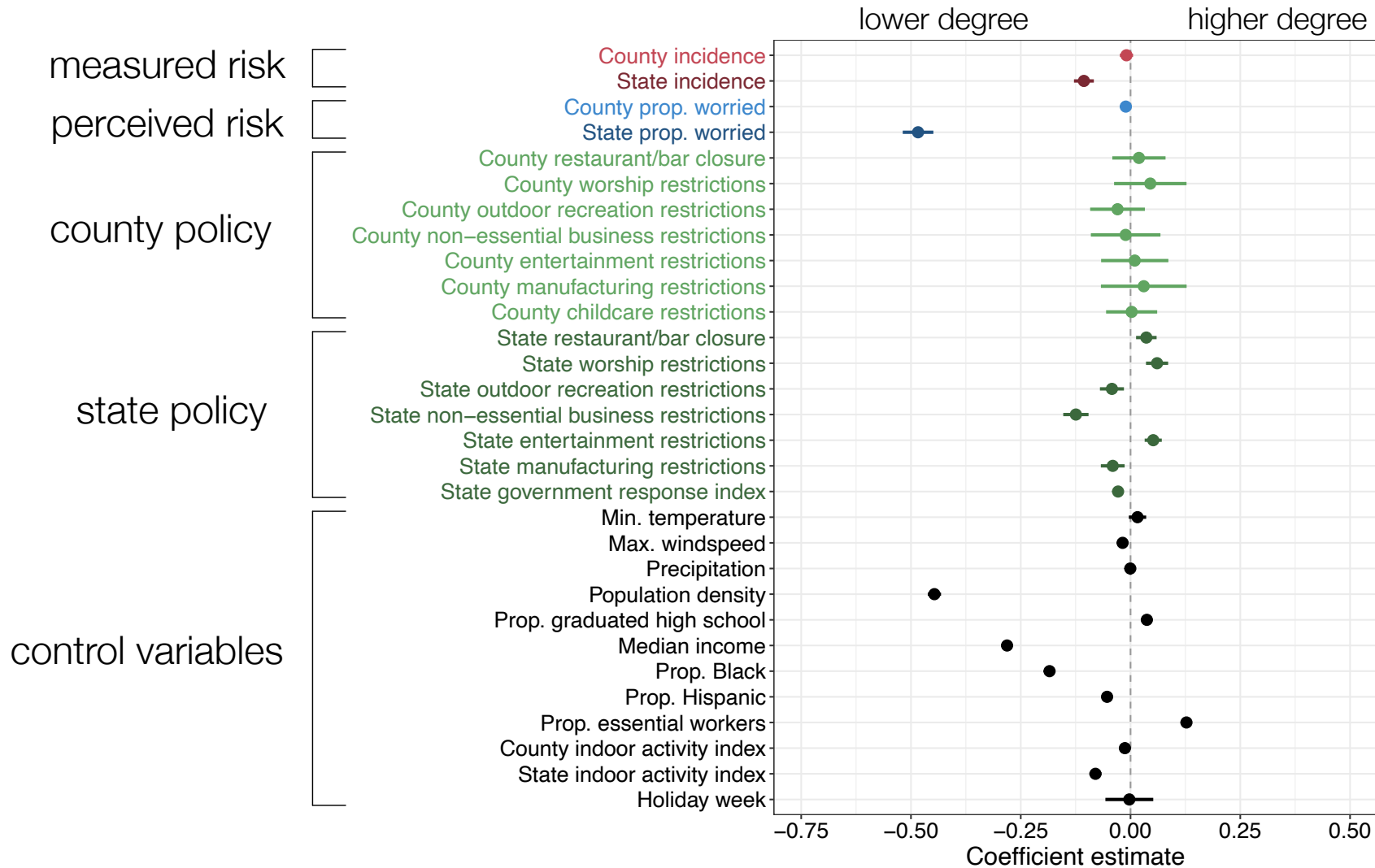
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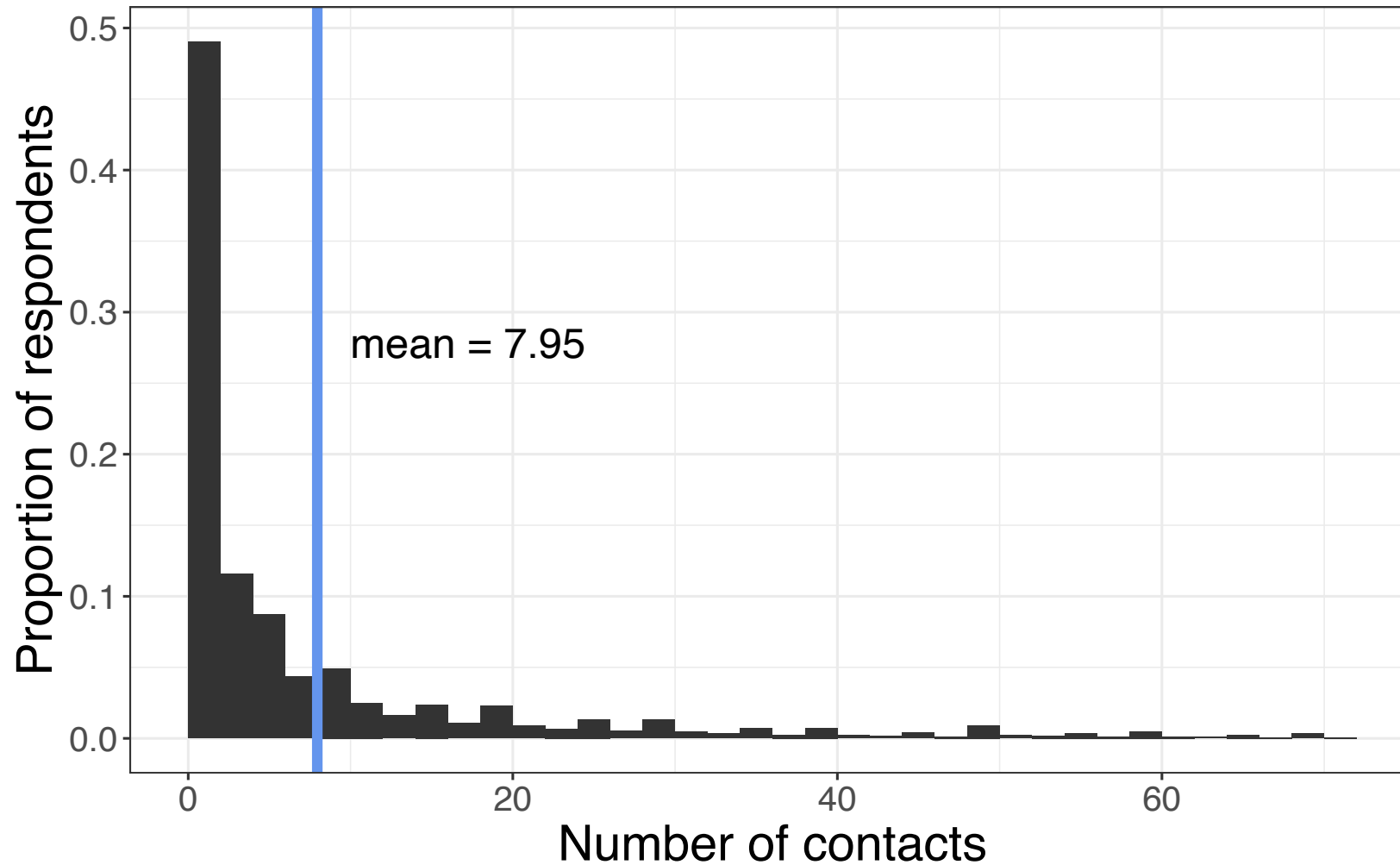
Behavior change is informed by **disease** & **perception**, especially at larger spatial scales



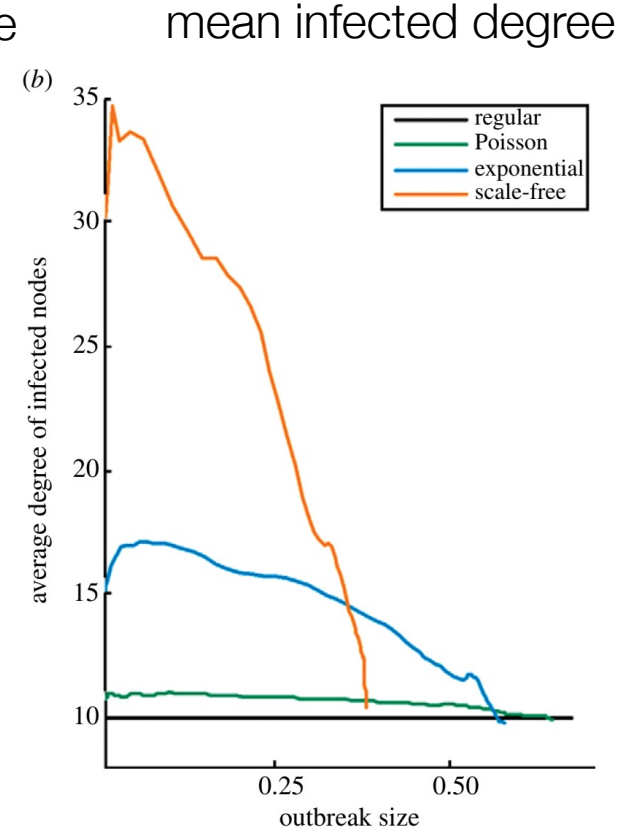
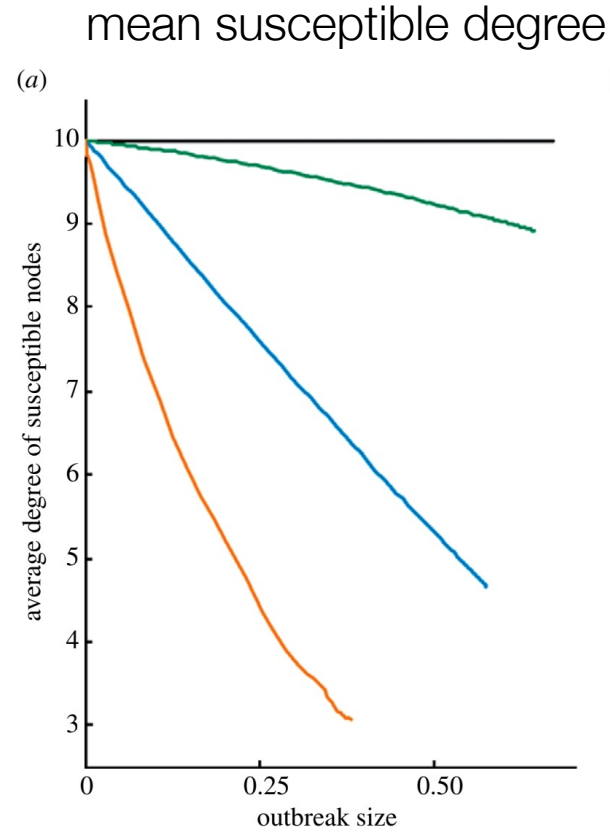
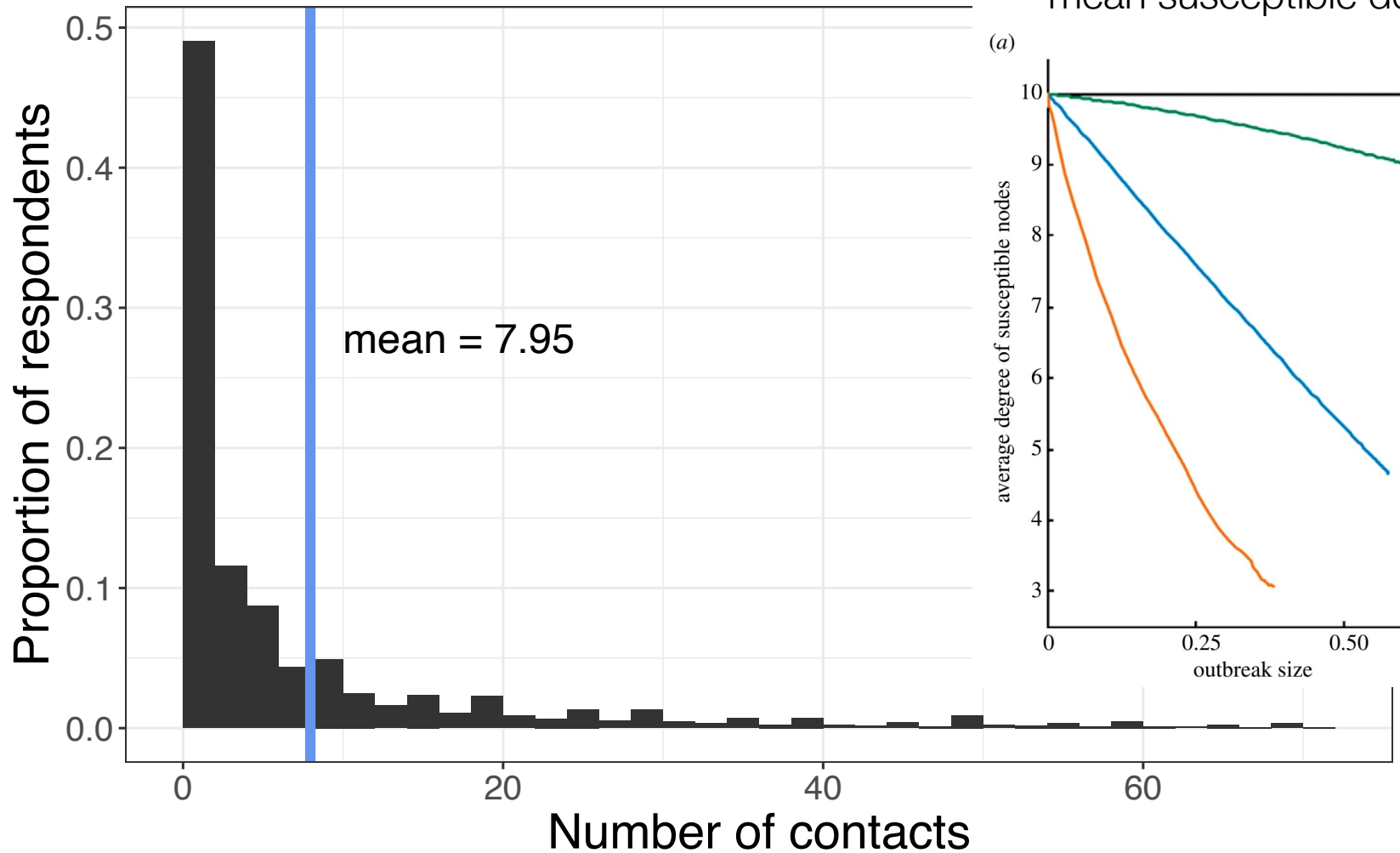
prevalence-elastic

global > local

Revisiting degree heterogeneity

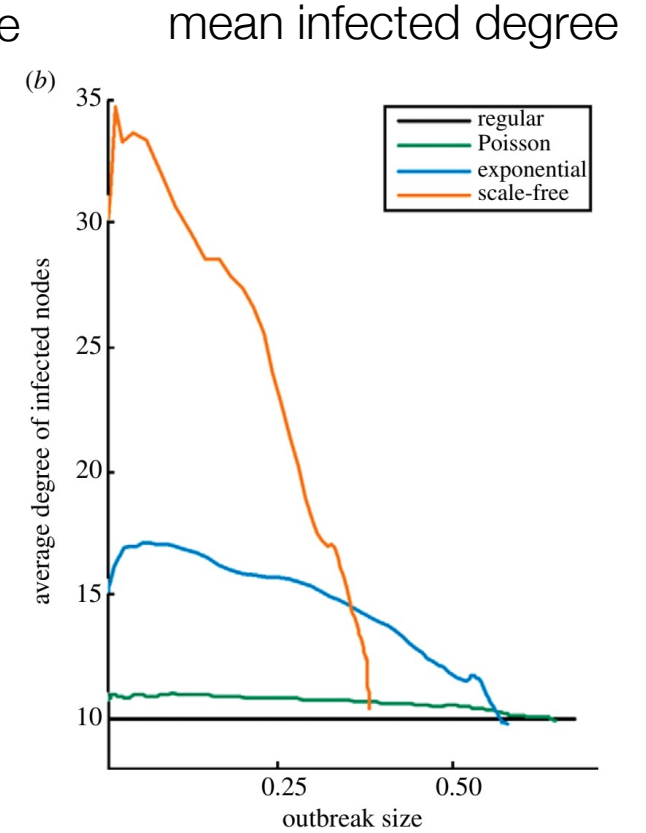
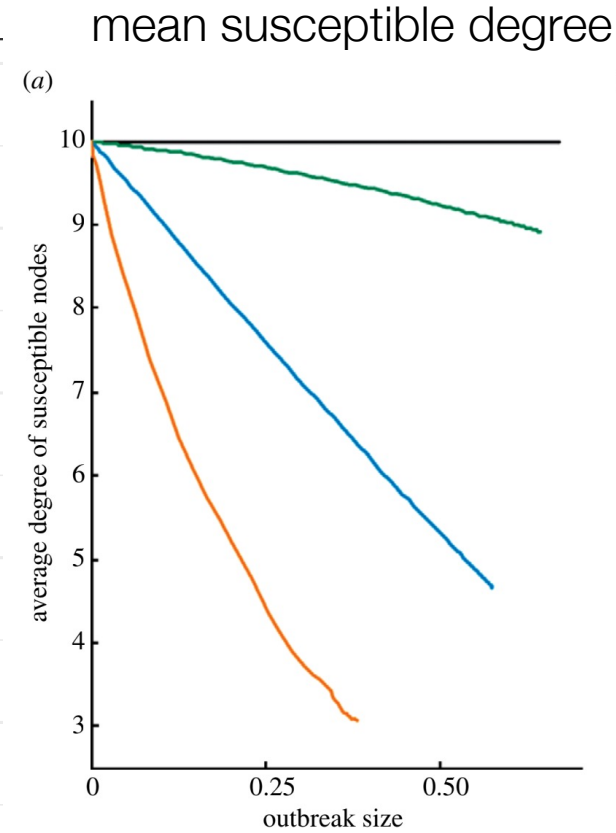
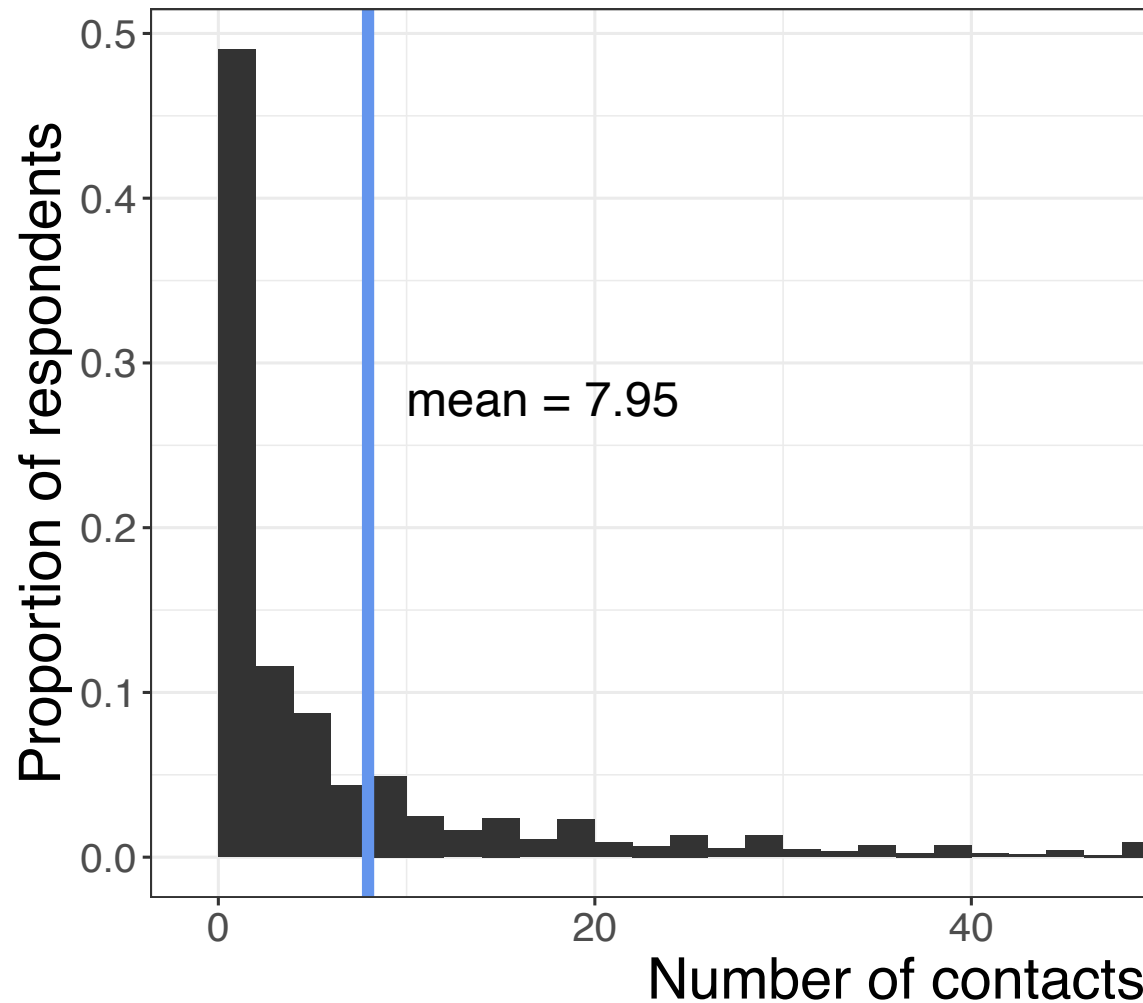


Revisiting degree heterogeneity



Bansal et al. (2007)

Revisiting degree heterogeneity



Bansal et al. (2007)

Do our data follow these predictions?

Degree varies by infection status

Degree varies by infection status

Asked whether (+) test:

- in the last 14 days
- ever



Classify as S, I, R

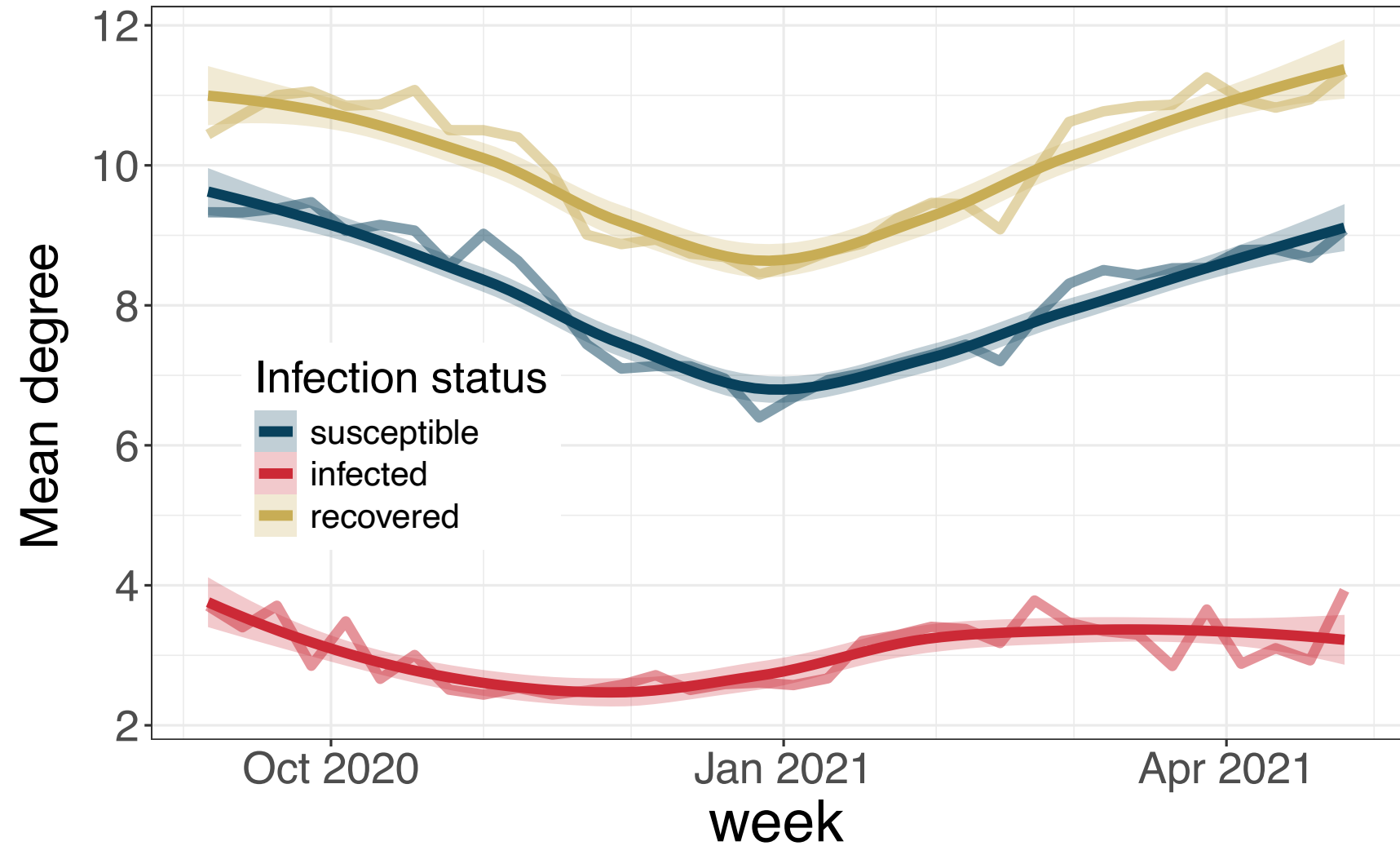
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Classify as S, I, R



Potential drivers of degree differences

Potential drivers of degree differences

Main hypothesis:

Infection process depletes high degree susceptibles

Potential drivers of degree differences

Main hypothesis:

Infection process depletes high degree susceptibles

Alternative hypotheses:

1. Post-recovery behavior change
2. Sickness behaviors & downstream effects

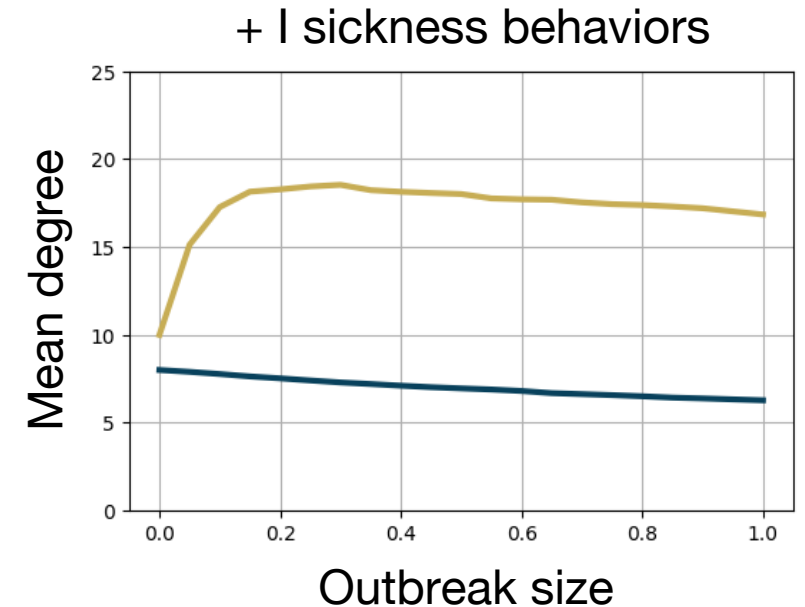
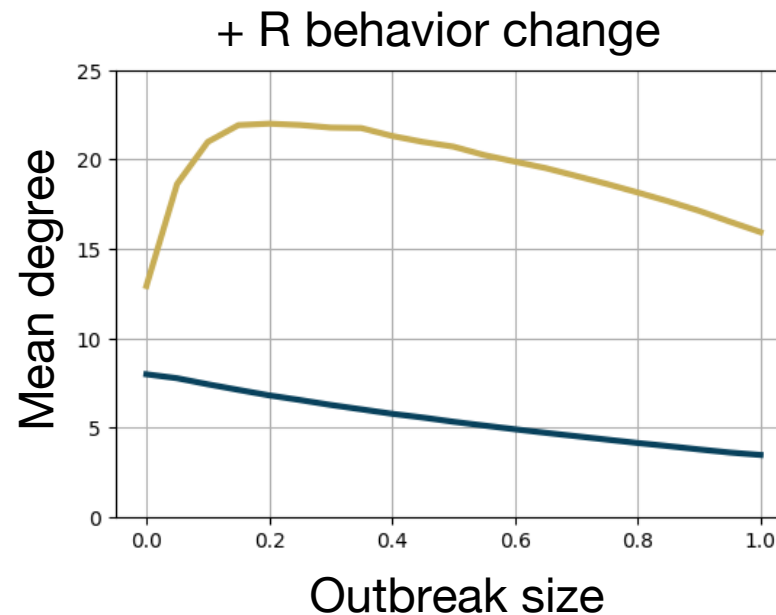
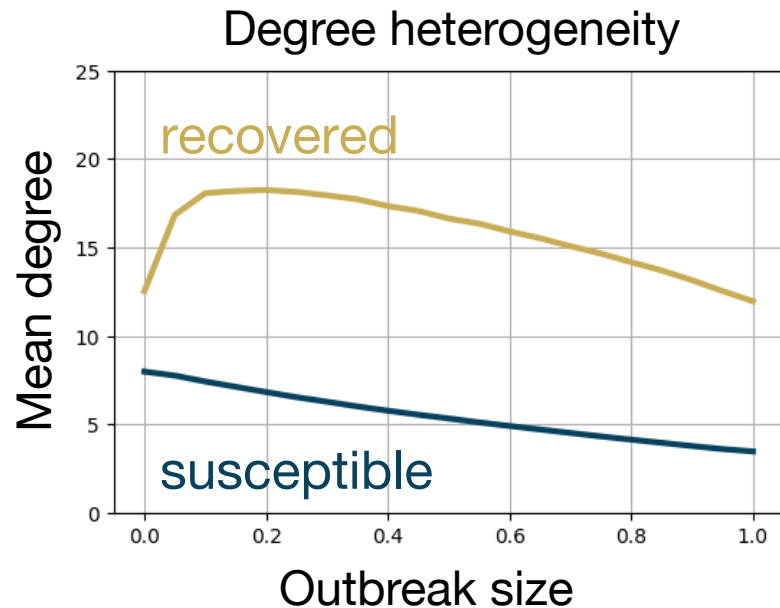
Potential drivers of degree differences

Main hypothesis:

Infection process depletes high degree susceptibles

Alternative hypotheses:

1. Post-recovery behavior change
2. Sickness behaviors & downstream effects



Potential drivers of degree differences

Main hypothesis:

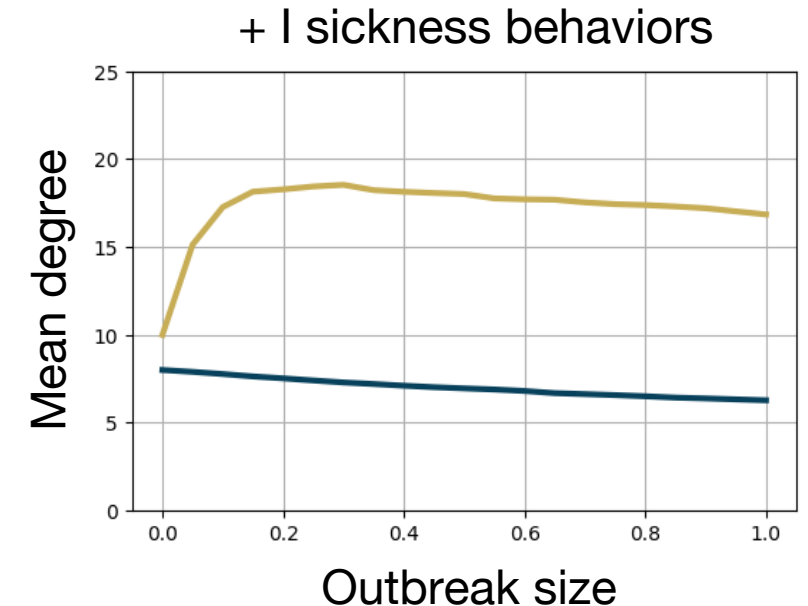
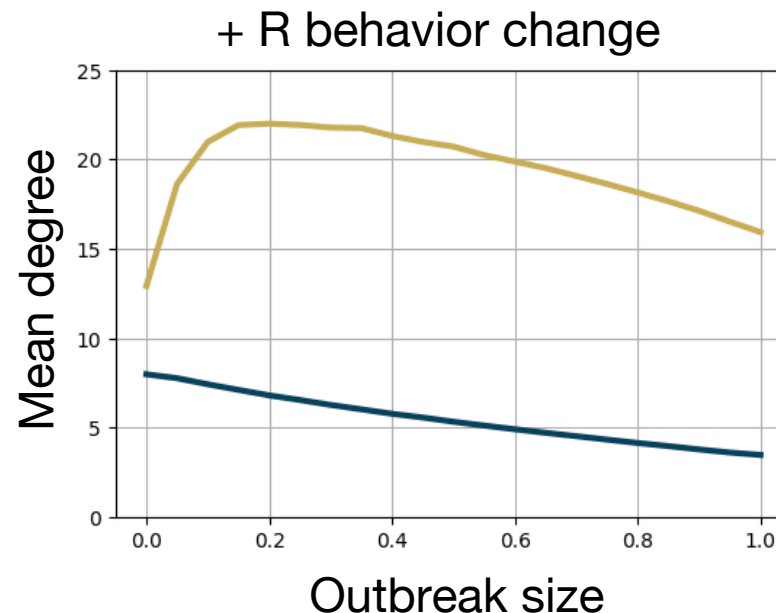
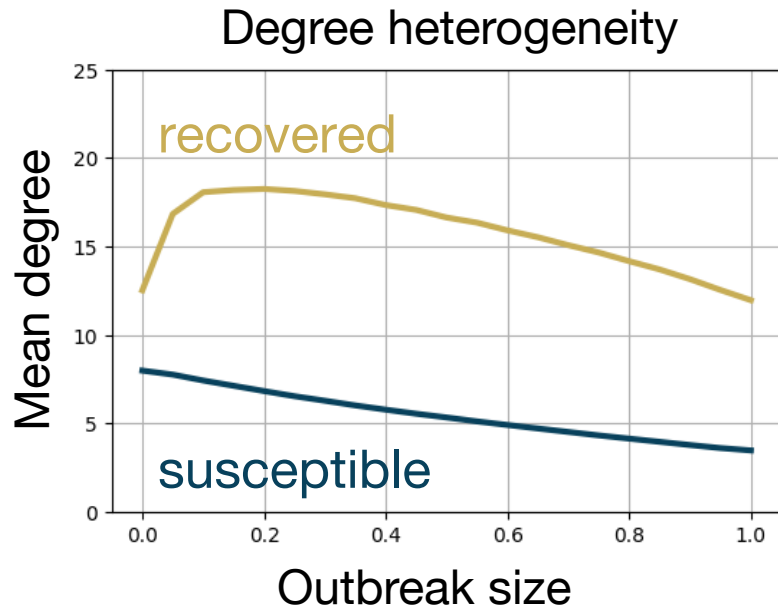
Infection process depletes high degree susceptibles

Alternative hypotheses:

1. Post-recovery behavior change
2. Sickness behaviors & downstream effects

Temporal change hypotheses:

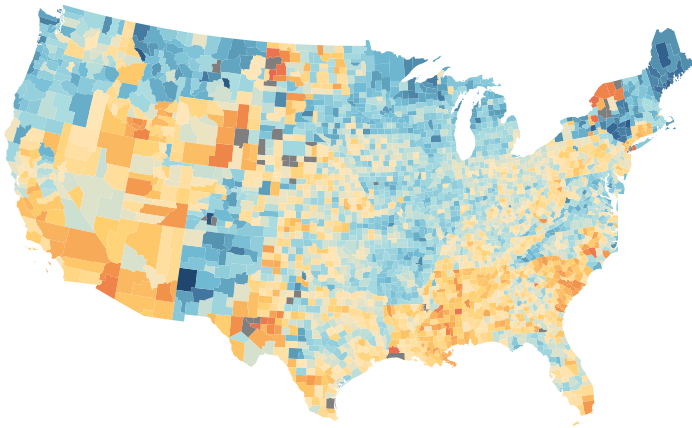
1. Social distancing
2. Local avoidance
3. Social desirability bias



Conclusions & future work

Conclusions & future work

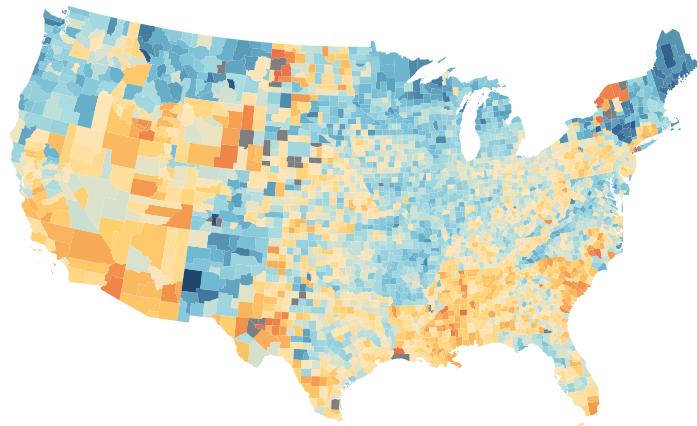
Degree varies spatially &
with disease dynamics



Design models, policies, &
surveillance accordingly

Conclusions & future work

Degree varies spatially & with disease dynamics



Design models, policies, & surveillance accordingly

Mesoscale disease information drives behavior change



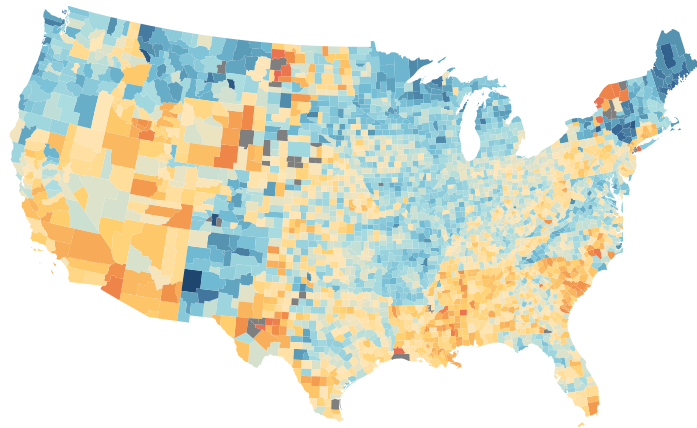
measured risk



perceived risk

Conclusions & future work

Degree varies spatially & with disease dynamics



Design models, policies, & surveillance accordingly

Mesoscale disease information drives behavior change



measured risk



perceived risk

Changes in degree across infection stages

