Simulating Contact Tracing in the Pandemic: TTI Explorer

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COVID-19

Does it really need an introduction?

What to do about COVID?

Would be great if we had a vaccine, but we don’t.

Need non-pharmaceutical interventions (NPIs) in their place to prevent transmission. E.g. masks, social distancing, lockdowns.

Test, Trace, Isolate (TTI) is one such NPI

What is TTI?

- Test people for disease
- Trace their contacts
- Isolate people

Many believe it is an effective tool to:

- Reduce transmission =>
- Smaller R =>
- Fewer cases

Kucharski, Adam J., et al. "Effectiveness of isolation, testing, contact tracing and physical distancing on reducing transmission of SARS-CoV-2 in different settings." *medRxiv* (2020).

TTI: a silver bullet!

> *And if we are to control this virus, then we must have a world-beating system for testing potential victims, and for tracing their contacts.*

Boris Johnson

May 10, 2020

Is it really a silver bullet?

How effective can it be?

What are resource requirements?

- Number of tests needed
- Application uptake
- Manual tracing

What are the most important success factors?

DELVE

DELVE

Data Evaluation and Learning for Viral Epidemics

Cross-disciplinary group

Convened by the Royal Society in March 2020

Feeds into SAGE

Publishes reports and other artifacts for general public

https://rs-delve.github.io

DELVE Test, Trace, Isolate report

Released: May 27, 2020

Covers compliance, surveillance, capacity constraints, public perception, etc.

Coverage: BBC, Channel 4, Financial Times, The Independent, The Times, The Guardian, Daily Mail, New Scientist

[Presumably] Influenced the overall policy

TTI Explorer

TTI Explorer: background

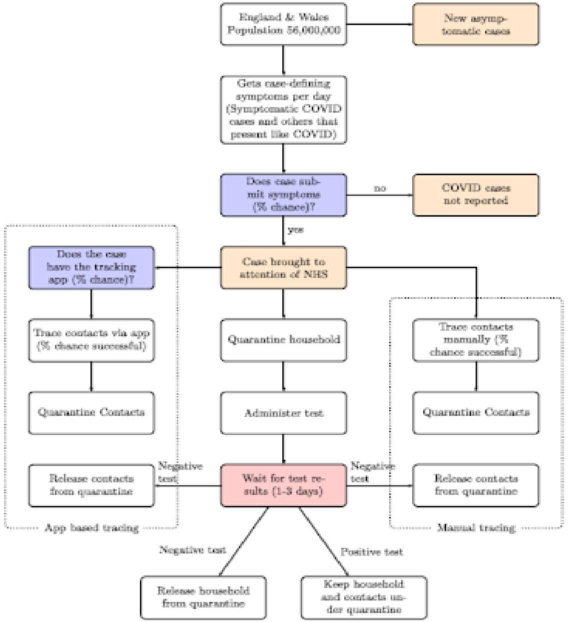
Explores the effectiveness and resource requirements of TTI strategies

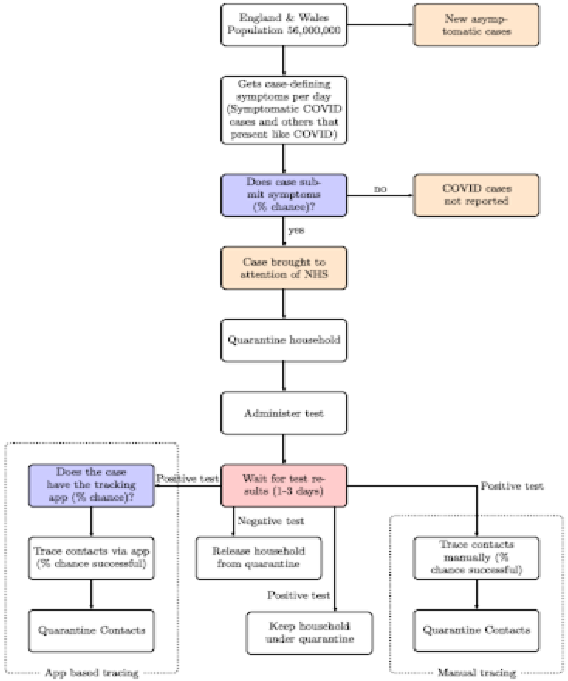
Builds upon Kucharski et al. 2020

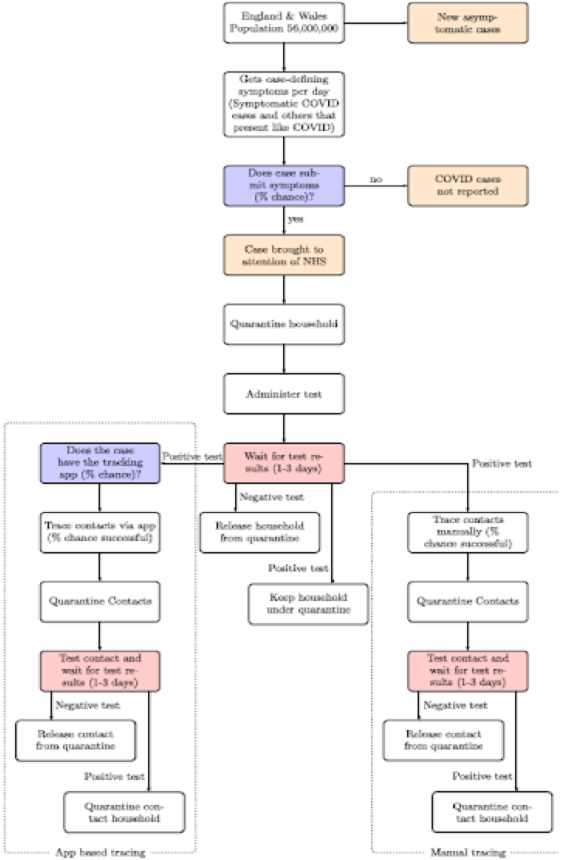
Takes into account logistics of real-world TTI

BBC Pandemic data for contacts

TTI flowchart







TTI Explorer: generate data

Generate primary cases

- Has COVID, has symptoms
- Has COVID, no symptoms
- No COVID, has symptoms

Generate contacts

- Household
- Work/school
- Other

TTI Explorer: simulation

5 levels of governmental measures (NPIs), S5 ≈ strict lockdown, S1 ≈ no control

4 TTI strategies

- No TTI (baseline)
- Trace on symptoms
- Trace on positive test
- Trace on positive test, test contacts

Account for

- Quarantine
- App and manual tracing
- Compliance

TTI Explorer: key results

TTI alone is not enough, other NPIs are needed

Prompt self-isolation is very effective

Key success factors:

- Test and (manual) trace times
- Compliance with guidance

TTI Explorer: key results

Resources:

- Manual tracing is essential to make up for low app installs
- Symptom-based TTI is very expensive
- Testing contacts doesn't impact R much, but reduces days in quarantine

Sensitivity Analysis

Why?

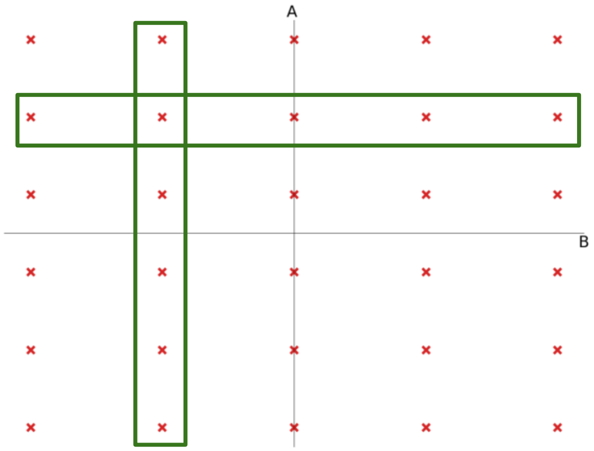
Two reasons we used sensitivity analysis:

1. Verify robustness to modelling assumptions
    - Example: What happens if we change our estimate of the proportion of asymptomatic positive cases?
2. Identify pinch points in TTI strategies and the magnitude of their effects
    - Example: How important is public compliance to the effectiveness of a TTI strategy?

How?

Params of interest assigned to one of two very simple strategies

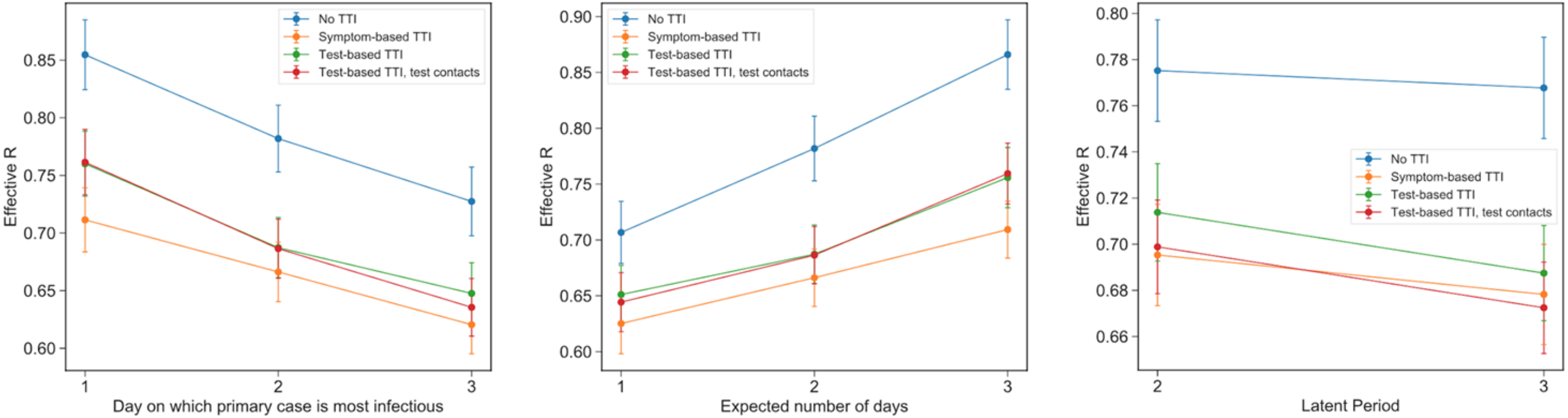
1. Grid Variation
    - Try all the combinations of all the parameters in this group



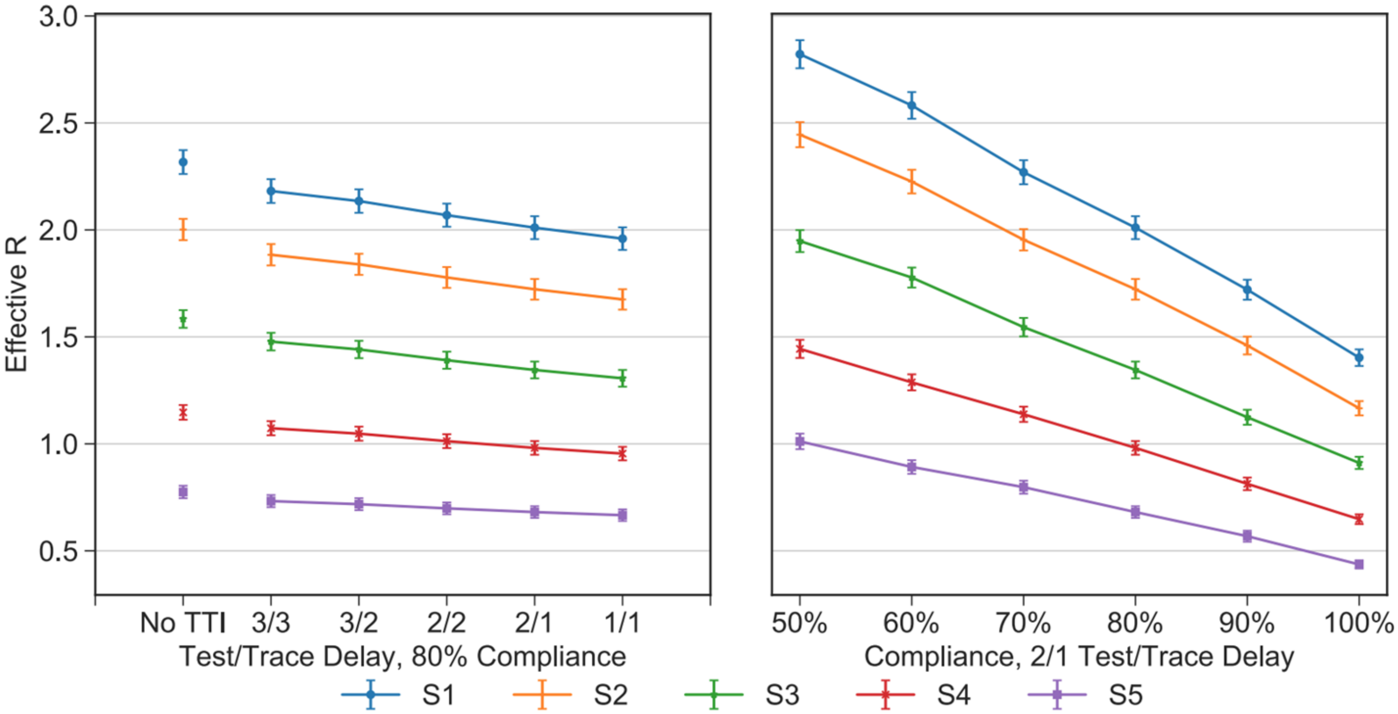
1. Axis Variation
    - Keep n-1 fixed at a default value, vary one at a time.

Measure e.g. reproduction number in each configuration

Results: Uncertainty



Results: Pinch Points



Extensions

Some ideas

- Parameter interactions in sensitivity analysis
- Inference: use the simulation “backwards”
- More ideas relevant to this course in Appendix

Parameter Interactions

In our sensitivity analysis, in particular when analysing pinch points such as public compliance, we did not study parameter interactions.

An extension could incorporate parameter interactions, possibly using one of the methods from your lectures.

Inference

Current simulation:

Parameters ⇒ # of new cases, R

Can you do this in reverse?

Real world R and cases ⇒ parameters (e.g. public compliance)

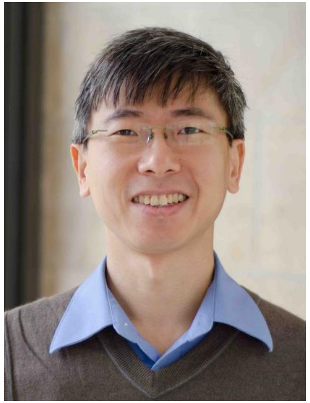
Using TTI Explorer Code

The technical report can be found here

All of our code is on GitHub at rs-delve/tti_explorer. Feel free to fork or contribute!

We made an introductory colab notebook to show how to use the code.

Team behind TTI Explorer (in no particular order)



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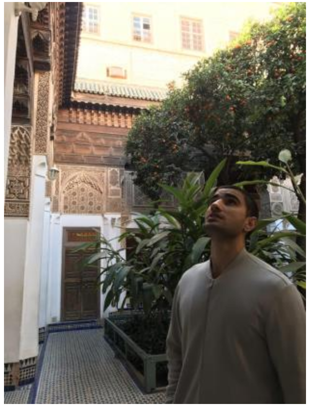

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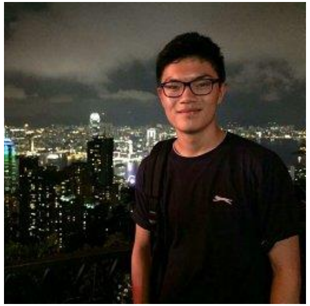

Bobby He

Sheheryar Zaidi

The End

Questions?

Appendix

NPI Severity Levels

1. S5 - Lockdown (up to 9th May 2020)
2. S4 - Slightly relaxed work and social restrictions
3. S3 - Moderately relaxed work and social restrictions
4. S2 - Strongly relaxed work and social restrictions
5. S1 - No social restrictions

Attribute	S5	S4	S3	S2	S1	Notes
`work_from_home_proportion`	65%	55%	45%	25%	0%	The proportion of the population not going into their regular workplace. 35% of people are not going into work as usual, and 45% are working from home (as of 07/05/2020, ONS [2020]).
`school_from_home_proportion`	100%	100%	50%	0%	0%	The proportion of school-aged children not going into schools
`max_other_contacts`	1	4	10	20	-	A hard limit placed on the number of non-home, non-work contacts a person has per day.
`work_met_before_proportion`	79%	79%	79%	79%	79%	The average proportion of work contacts a person has met before, allowing them to manually trace a contact. Taken from Klepac et al. [2018].
`school_met_before_proportion`	90%	90%	90%	90%	90%	The average proportion of school contacts a person has met before, allowing them to manually trace a contact. Taken from Klepac et al. [2018].
`other_met_before_proportion`	100%	100%	90%	75%	52%	The average proportion of other contacts a person has met before, allowing them to manually trace a contact. Taken proportion from Klepac et al. [2018], adjusted for lockdown.

TTI Strategies Considered

TTI Strategy	No TTI	Symptom-based TTI	Test-based TTI	Test-based TTI Test Contacts
Isolate Individual on Symptoms?	Yes	Yes	Yes	Yes
Quarantine Household on Symptoms?	Yes	Yes	Yes	Yes
Test Symptomatic Individuals?	No	Yes	Yes	Yes
Trace Contacts on Symptoms?	No	Yes	No	No
Trace Contacts on Positive Test?	No	No	Yes	Yes
Quarantine Traced Contacts?	No	Yes	Yes	Yes
Test Contacts?	No	No	No	Yes

Table 1: Main decisions points defining the TTI strategies considered.

Extension: Constrained BayesOpt

Can our model be used to find a strategy that results in the minimum possible reproduction number given a particular set of resource constraints (e.g. limited number of tests)?

Extension: Further Analysis

Consider the variation in the effective reproduction number (R), in the context of various levels of NPI stringency (i.e. various levels of lockdown), as we vary the uptake of a contact tracing app. (Figure 10, page 22 of report here.)

Why is R not monotonic in the level of app uptake in the more stringent lockdown scenarios?

Can you see anything else in our report that you think warrants further analysis?

Extension: Uncertainty Propagation

Many of the parameters of our model reflect properties of the disease or its dynamics about which we are uncertain, for instance: if you are infectious, how likely are you to infect someone in your household? How does your infectiousness change over time?

We attempted to quantify this uncertainty by measuring the variation in the outputs of our model as we vary these parameters. Can you do better? For instance, you might like to represent uncertainty in these parameters in terms of probability distributions, then propagate this uncertainty into a distribution over the outputs of the model.

Extension: Generative Model for Social Contacts

In our model we need, for each primary case, a number of social contacts of different types (eg people from home, work, school) who they have the potential to infect.

We used a very simple generate these contacts. The data from the BBC Pandemic Survey [1] contains data on the social contacts of 40162 participants. In short, each time we generate a primary case, we generate their social contacts by sampling a participant from this dataset and using their contact pattern.

Can you do better, for instance by constructing a generative model? Can you incorporate network effects?

1: Petra Klepac, Stephen Kissler, and Julia Gog. Contagion! The BBC Four Pandemic - The model behind the documentary. Epidemics, 24:49–59, March 2018. link.