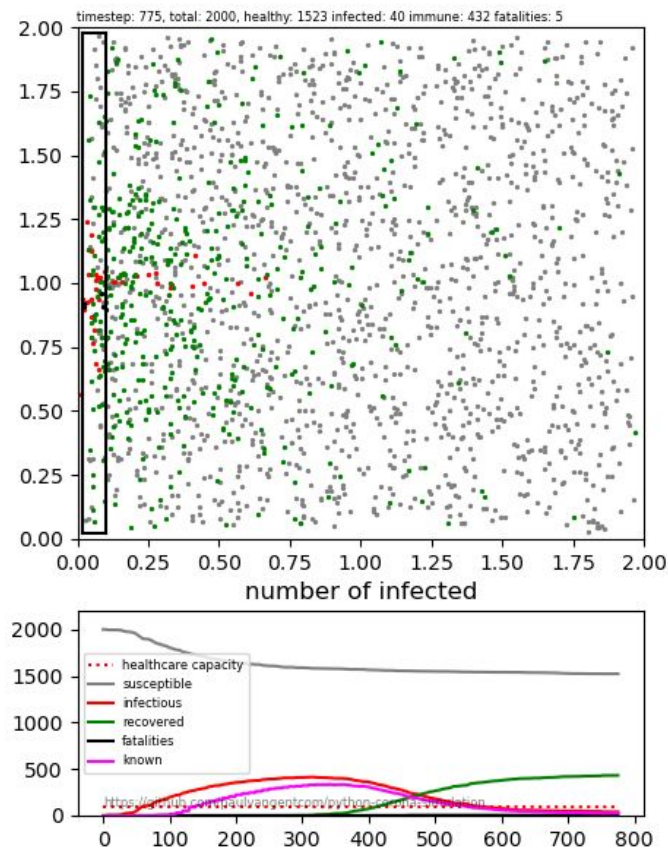


Complex Systems 2020/21 - Epidemic Agents - Final Report

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https://github.com/kaskadz/python_corona_simulation

Simulation visualisation



Improvements over the original code

1. Symptoms severity

We introduced three levels of severity: asymptomatic (0), mild (1), severe (2)

Target severity is sampled from an age-dependent probability distribution. Severity progresses according to 'infection_progression_duration' = [20, 70, 140] (steps after infection, 10 steps = 1 day)

Severity influences:

- Probability of self-isolation based on symptoms
- Priority of getting a test
- Chance of infecting others (multiplied by 0.5, 1 and 2 respectively for increasing levels of severity)
- Agent may die only at severity = 2

2. Custom age distribution

Age distribution is defined with probabilities for each 10-year period between 0 and 90 years of age. We used the age distribution of Lombardy.

3. Correlating parameters with age

Probabilities of increased symptoms severity and speed are correlated with age.

4. Wearing masks

The formula for infecting other agents in proximity has been changed to:

infection_chance_1 * infection_chance_2 * severity_infection_chances[severity]

Infection_chance_1 and infection_chance_2 are lower when agents wear masks.

5. Testing

- Performed every day (every 10 ticks)
- Starts when at least 'test_proportion_to_start' (5%) of population is sick (the time at which the epidemic is noticed)
- The possible number of tests each day is limited by 'min_tests_daily_proportion' and 'max_tests_daily_proportion' (fraction of population, e.g. 0.5% and 5% for 2000 agents will be between 10 and 100 tests daily)
- The desired number of tests for the day is computed as:
(1 / desired_positive_proportion * rolling_avg(last_positive))
and then clipped with min-max values.
- Strategy of allocation of the daily test pool: test untested agents with severity = 2, the reminder goes to agents with severity = 1, and the rest to severity = 0 and healthy agents (without discrimination)

6. Self-isolating

Probability of self-isolating has been changed to:

max(1, tested + self_isolate_severity_proportion[severity]) * self_isolate_proportion

7. Other

We changed the start of the epidemic from one agent to 5 agents to make the results more repeatable (with one agent the epidemic would often not develop)

Important parameters

pop_size = 2000
speed = 0.01
world_size = [2,2]

infection_range = 0.04
infection_chance = 0.4
infection_chance_with_mask = 0.1
proportion_wearing_masks = 0.5
recovery_duration = [200, 500]
severity_infection_chances = [0.5, 1, 2]
infection_progression_duration = [20, 70, 140]
mortality_chance = 0.2 (*when severity = 2*)

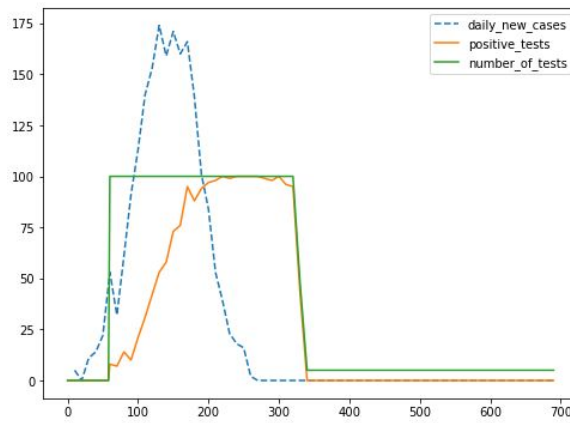
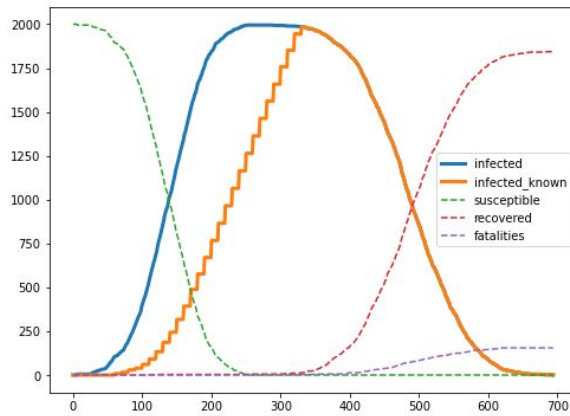
healthcare_capacity = 100
treatment_factor = 0.5 (multiplier of mortality_chance when in treatment)
no_treatment_factor = 3 (multiplier of mortality_chance when not in treatment)

self_isolate_proportion = 0.7 (*final multiplier, fraction of population who will self-isolate*)
self_isolate_severity_proportion = [0.0, 0.2, 0.7] (*fraction of population who will self-isolate based on severity*)

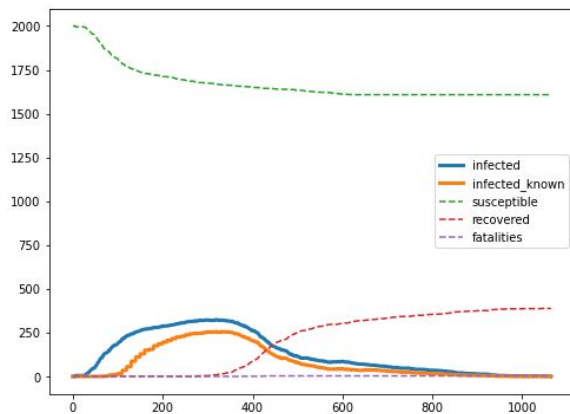
test_proportion_to_start = 0.05
min_tests_daily_proportion = 0.005
max_tests_daily_proportion = 0.05
desired_positive_proportion = 0.1

Interesting findings

1. When self-isolation is based only on test results, the epidemic spreads to the whole population.

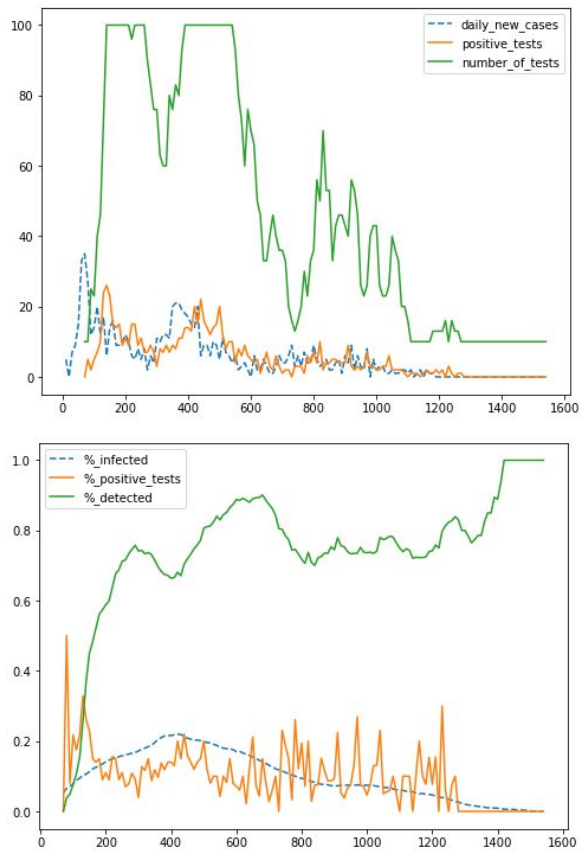


Compared to self-isolation based on test results or symptoms:

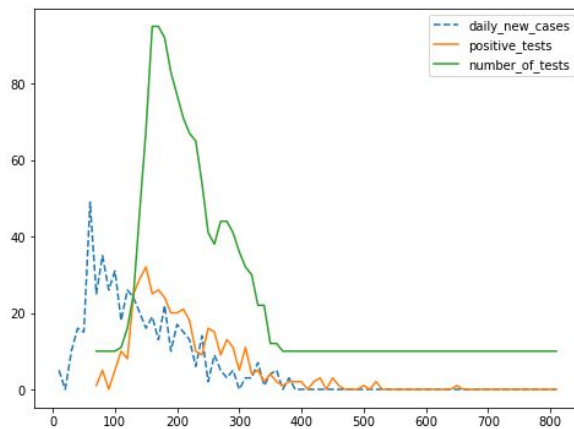


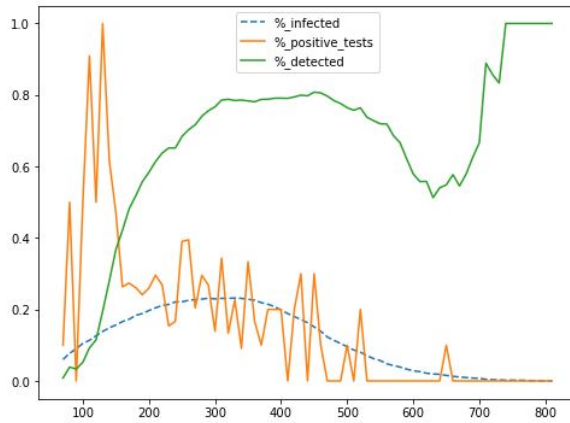
- It's important to keep the fraction of positive tests low. Otherwise the percentage of positive tests blows up in the initial phase resulting in low detectability.

Desired positive tests at 10%:



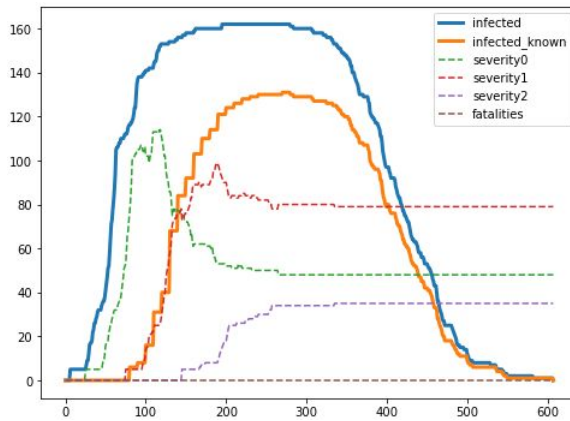
Desired positive tests at 30%:



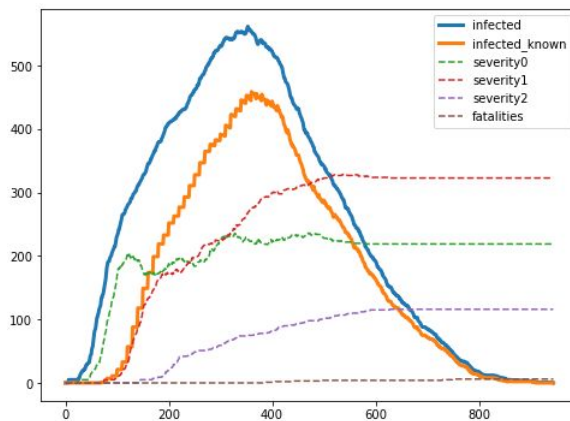


3. Wearing masks is highly effective in reducing the spread of the epidemic.

80% wearing masks:



50% wearing masks:



Sensitivity analysis

Sensitivity analysis of the model was performed. SALib library was used: <https://salib.readthedocs.io/en/latest/>. After several approaches to the analysis, Morris method was used to measure influence of the parameters and prioritize them.

Three input parameters have been chosen:

1. min_tests_daily_proportion - minimal daily tests proportion (values from 0.001 to 0.01)
2. max_tests_daily_proportion - maximal daily tests proportion (values from 0.02 to 0.1)
3. desired_positive_proportion - desired infections discover rate (values from 0.01 to 0.5)

Influence on 7 output metrics was measured:

- A. Number of fatalities at the end of the simulation
- B. Number of unaffected people at the end of the simulation
- C. Total number of people with the highest severity through the simulation
- D. Discover rate at the peak of infections (at max of infections)
- E. Discover rate at the peak of known infections (at maks of known infections)
- F. Minimal discover rate through 75% of time
- G. Minimal discover rate through 50% of time

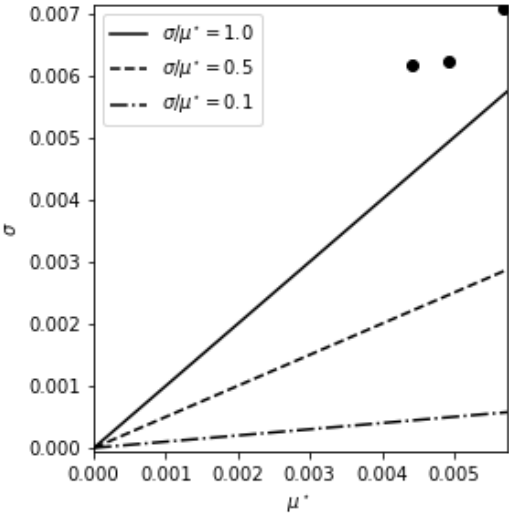
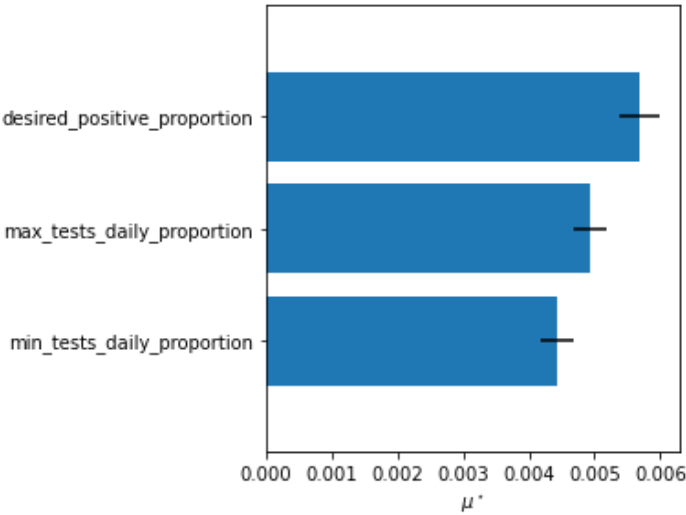
Description of output variables from the library, described in the documentation:

- mu - the mean elementary effect
- mu_star - the absolute of the mean elementary effect
- sigma - the standard deviation of the elementary effect
- mu_star_conf - the bootstrapped confidence interval
- names - the names of the parameters

Most of the SA results do not provide a strong information on which parameters are the most influential. In most cases the deviation of influence (sigma) is very big. That tells us that the model is very sensitive to the input values.

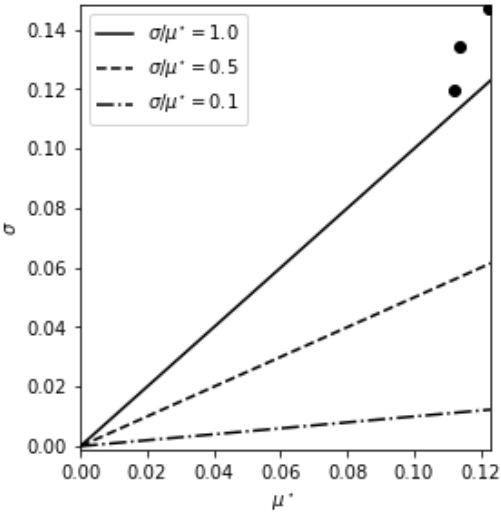
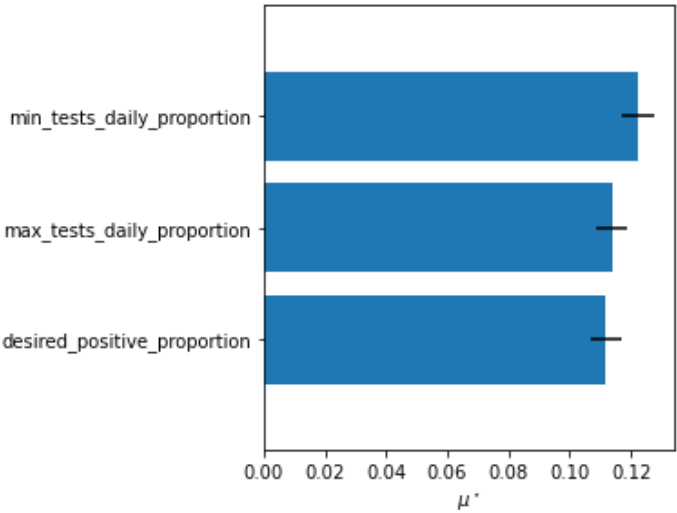
A Number of fatalities at the end of the simulation

names	mu	mu_star	sigma	mu_star_conf
min_tests_daily_proportion	-0.000497	0.004429	0.006159	0.000261
max_tests_daily_proportion	0.000421	0.004924	0.006233	0.000247
desired_positive_proportion	-0.001712	0.005687	0.007091	0.000315



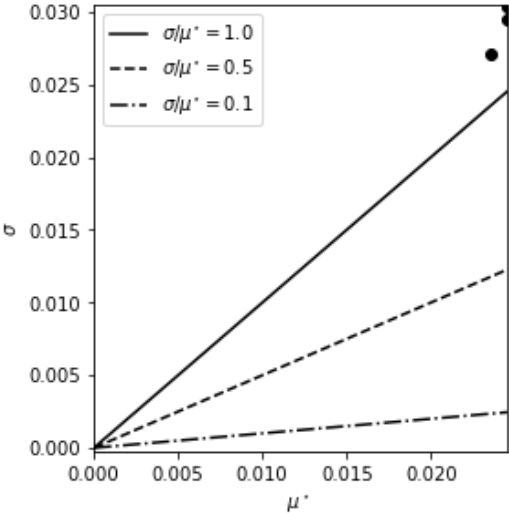
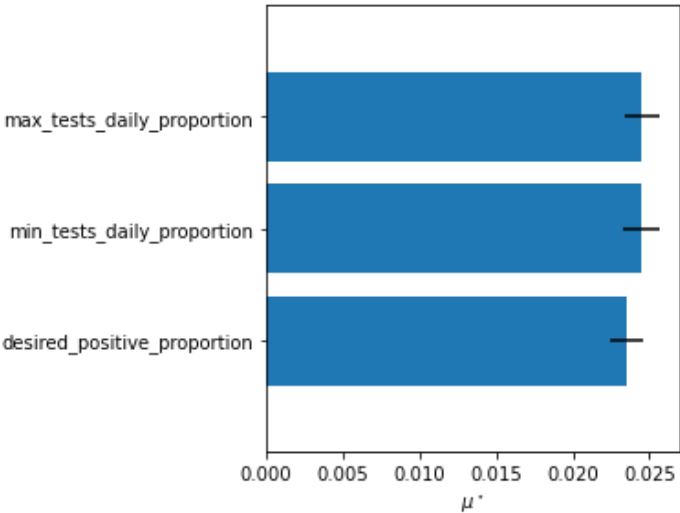
B Number of unaffected people at the end of the simulation

names	mu	mu_star	sigma	mu_star_conf
min_tests_daily_proportion	0.004118	0.122480	0.146953	0.005369
max_tests_daily_proportion	-0.003903	0.113842	0.134328	0.005071
desired_positive_proportion	0.063240	0.111831	0.119559	0.004998



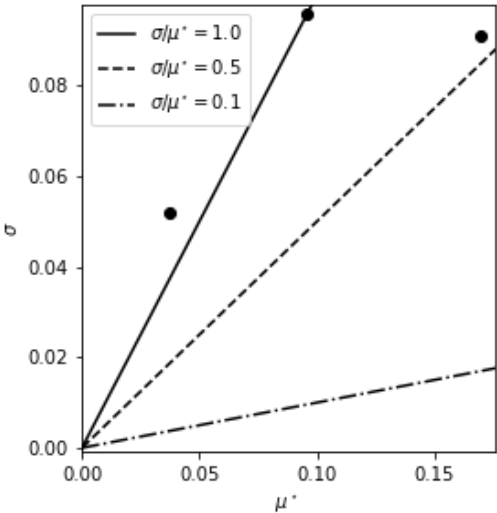
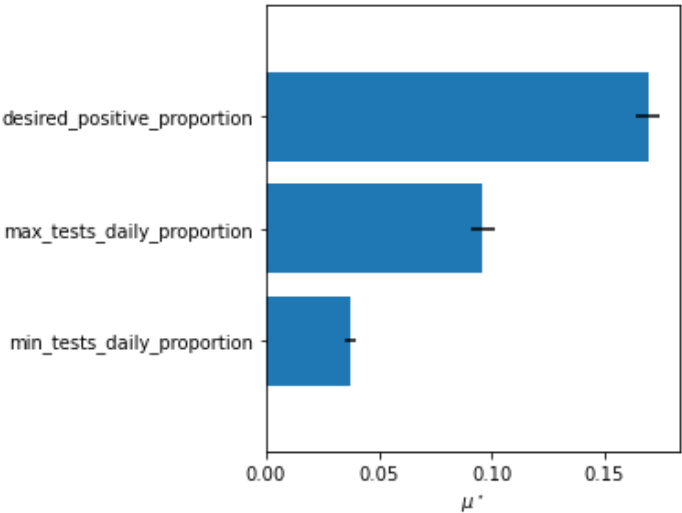
C Total number of people with the highest severity through the simulation

names	mu	mu_star	sigma	mu_star_conf
min_tests_daily_proportion	-0.000559	0.024499	0.030324	0.001215
max_tests_daily_proportion	-0.000210	0.024512	0.029429	0.001129
desired_positive_proportion	-0.008193	0.023525	0.027101	0.001023



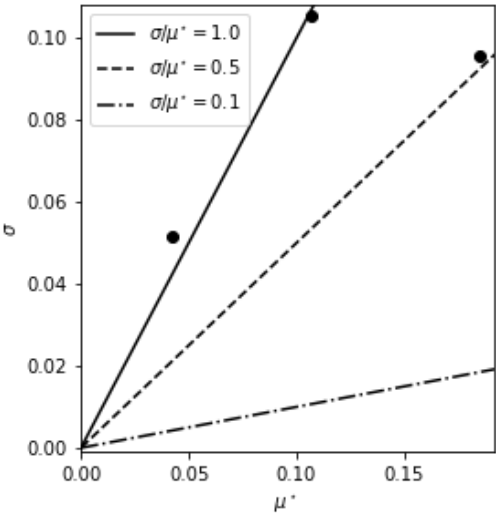
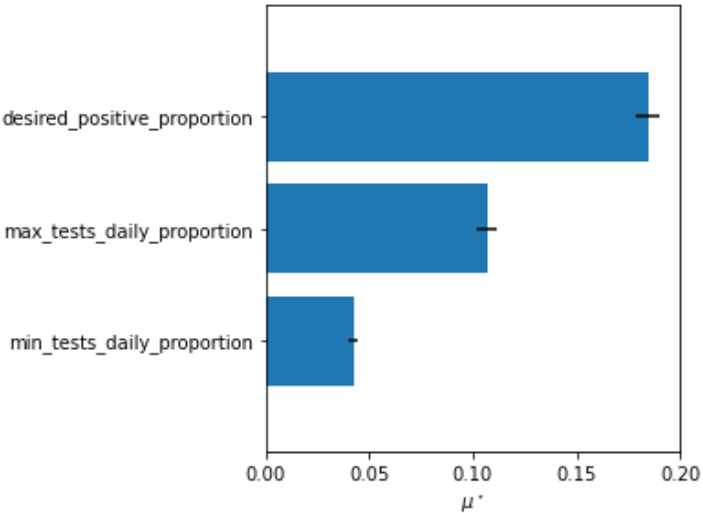
D Discover rate at the peak of infections (at max of infections)

names	mu	mu_star	sigma	mu_star_conf
min_tests_daily_proportion	-0.010141	0.037062	0.051833	0.002551
max_tests_daily_proportion	0.088304	0.095899	0.095569	0.005287
desired_positive_proportion	-0.164755	0.169370	0.090755	0.005336



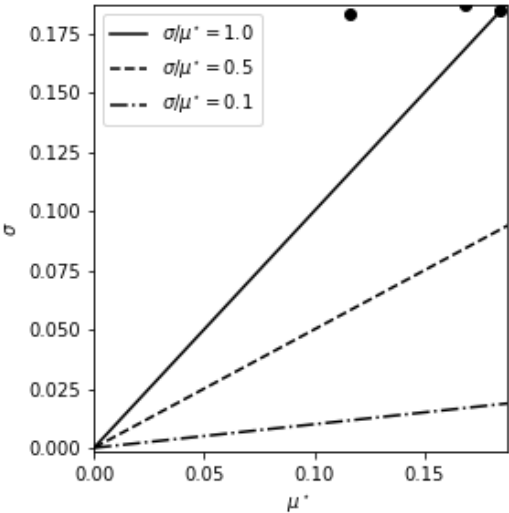
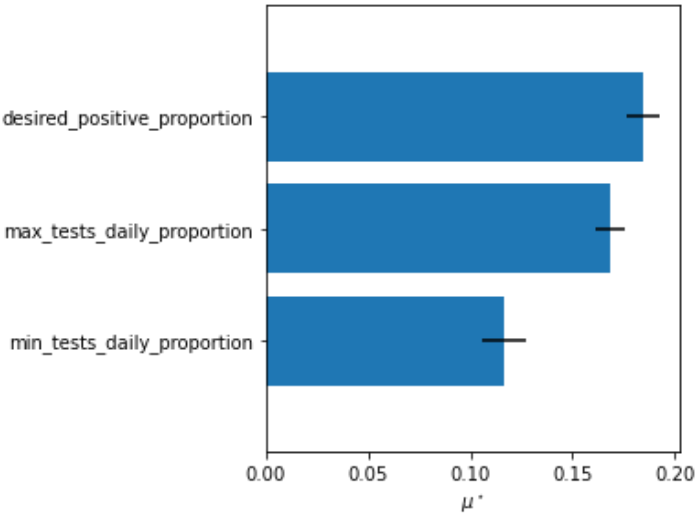
E Discover rate at the peak of known infections (at max of known infections)

names	mu	mu_star	sigma	mu_star_conf
min_tests_daily_proportion	-0.012392	0.042116	0.051626	0.002172
max_tests_daily_proportion	0.086556	0.106812	0.105334	0.005069
desired_positive_proportion	-0.179533	0.184715	0.095376	0.005784



F Minimal discover rate through 75% of time

names	mu	mu_star	sigma	mu_star_conf
min_tests_daily_proportion	-0.050476	0.116600	0.183302	0.010491
max_tests_daily_proportion	-0.087374	0.168232	0.187019	0.007360
desired_positive_proportion	0.145514	0.184549	0.185069	0.008395



G Minimal discover rate through 50% of time

names	mu	mu_star	sigma	mu_star_conf
min_tests_daily_proportion	-0.015858	0.064516	0.077305	0.002993
max_tests_daily_proportion	-0.078570	0.112651	0.105411	0.004004
desired_positive_proportion	0.188803	0.193864	0.122076	0.007952

