Minding Norms in an Epidemic Does Matter

Klaus G. Troitzsch[1*]

[1*]Institute of Information System Research, retired from Universität Koblenz-Landau, Germany.

Corresponding author. E-mail: klaus.g.troitzsch@bluewin.ch;

Abstract

This paper tries to shed some light on the mutual influence of citizen behaviour and the spread of a virus in an epidemic. While the spread of a virus from infectious to susceptible persons and the outbreak of an infection leading to more or less severe illness and, finally, to recovery and immunity or death has been modelled with different kinds of models in the past, the influence of certain behaviours to keep the epidemic low and to follow recommendations of others to apply these behaviours has rarely been modelled. The model introduced here uses a theory of the effect of norm invocations among persons to find out the effect of spreading norms interacts with the progress of an epidemic. Results show that norm invocations matter. The model replicates the histories of the COVID-19 epidemic in various region, including "second waves", and shows that the calculation of the reproduction numbers from current reported infections usually overestimates the "real" but in practice unobservable reproduction number.

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Appendix A Minding Norms in a Nutshell

The model presented in this paper uses the theory developed in the EU projects EMIL and GLODERS and explicated in in Conte, Andrighetto, and Campennì (2013) and Elsenbroich, Anzola, and Gilbert (2016) which partly go back to Cialdini, Reno, and Kallgren (1990). The main idea behind this theory is that humans can be modelled as using an architecture (called the "EMIL-I-A architecture" (Conte et al., 2013, p. 162–166)) in which norm invocations, compliances, violations, sanctions and punishments are stored. To this end, the agents use a memory in which for each norm the number of

- their own compliances and violations (C and V, respectively),
- compliances and violations observed with neighbours (O_C and O_V, respectively),
- sanctions and punishments received (S and P, respectively) and
- explicit norm invocations (when agent A observes a compliance of violation of a norm by agent B and communicates this to the latter for instance in the form of praise or blame, E_C and E_V, respectively)

is stored. These numbers are decremented by a certain percentage now and then and computed to generate the *salience* of the respective norm according to the following formula:

$$\sigma = \alpha\left(\beta + \frac{C-V}{C+V}w_c + \frac{O_c-O_v}{O_c+O_v}w_o + \frac{\max(0,(O_v+V)-P-S)}{O_v+V}w_{npv} + \frac{Pw_p+Sw_s}{\max(P+S,O_v+V)} + \frac{E_c-E_v}{E_c+E_v}w_e\right) \tag{A1}$$

where the capital letters have the meaning explained above. The coefficients w_c, w_o, w_{npv}, w_p, w_s and w_e are the weights for the six factors ("norm cues") derived from Cialdini et al. (1990) and defined in Andrighetto et al. (2013) (see also Andrighetto and Castelfranchi (2013) and Troitzsch (2018)). α and β have to be chosen dependent on the weights w_c, w_o, w_{npv}, w_p, w_s and w_e in a way that $0 \leq \sigma \leq 1$. The weights used in the literature cited above are $w_c = w_s = w_e = 0.99, w_{npv} = 0.66, w_o = w_p = 0.33$.

The model described in this paper uses only C, V, O_C and O_V. The other four kinds of "norm cues" could be added in future extensions of the model.

Appendix B ODD+D Description of the Model

This section describes the model along the lines of ODD+D Grimm et al. (2006, 2010); Müller et al. (2013).

I. **Overview**

I.i. ***Purpose***

I.i.A *What is the purpose of the study?* The purpose of this study is to find out how the course of an epidemic is determined by heterogeneities of population density and of certein behavioural features, among them the propensity to abide by norms invocated by others or to violate them.

I.i.B *For whom is the model designed?* For researchers and students of epidemiology as well as for social scientists at large.

I.ii. ***Entities, state variables and scales***

I.ii.A *What kinds of entities are in the model?* There is only one class of active entities in the model, namely the `people`. For technical reasons, there is also the entity type `county` which is used to allow for different population densities all over the simulated world; `counties` also collect information on all `people` in the `ill` state.

I.ii.B *By what attributes (i.e. state variables and parameters are these entities characterised?*

- `people` keep a number of initialised constants:
  - `conviviality` and
  - `carelessness`

  which determine their persional risk aversion, and of instance variables
  - `state`: suspensive, infected, ill, recovered, immune, dead,
  - `infectious?`: for some of the infected, all ill and some of the recovered person agents (infectiosity starts only some time after being infected and ends some time after recovering),
  - their place in the topography of the simulated world,
  - `wears-a-mask?`: and
  - `stays-at-home?`: modifying the probability of being infected by another agent in its neighbourhood,
  - `perceived-infection-risk`: the current risk of being infected as the proportion of infectious neighbours among all neighbours (in times of increasing daily new infcetions) or as the proportion of all infectious agents among all agents (in times of decreasing daily new infections),
  - — in the normative mode — the salience of four norms and the propensity to abide by them or to violate them (see the discussion in III.iv.A.4).

- `counties` keep a number of initialised constants (area, population, colour) andstate variables for counting their people with respect to their state. These are output at the end of each run for further analysis.

I.ii.C *What are the exogenous drivers of the model?* There are no exogenous drivers of the model except the possibility that a user can interrupt a run and set or unset the global variable `lockdown?` which reduces the mobility of all agents (see below III.iv.B.14–III.iv.B.16). The chooser `infectious-from-abroad` is not an exogenous driver proper, as it is set before the start of the model, but has an effect similar to the effect of an exogenous driver (see below III.iv.B.8).

I.ii.D *If applicable, how is space included in the model?* Space plays a prominent role in the model as the distribution of agents over the simulated world can have three different modes (see III.iv.B.6) with increasing heterogeneity of the population density of the `counties`: nearly equal, linearly or hyperbolically increasing with decreasing area.

I.iii. ***Process overview and scheduling***

I.iii.A *What entity does what, and in what order?* The only active entities are the `people` agents which are scheduled at the start of the simulation to move to another patch. The time when they will move is random. When the move is executed they will not only move but schedule their next move at a random time in the future, and if they meet an infectious agent at or near the new patch they get infected, get the time scheduled when they become infectious and ill, respectively, and when they fall ill, they are moved to a central patch in their `county` (the "hospital") where they stay until the scheduled time for recovery or death. In both cases they return to their start patch ("`home`"), and the loss of infectiosity as well as the start and end of their immunity period are scheduled for those which recovered. The time between movements is hard coded as a uniformly distributed random number of 0 to 4 simulated days, whereas the uniform distributions of the other period lengths can be set via the GUI (see below III.iv.B.22–III.iv.B.26).

II. **Design Concepts**

II.i. ***Theoretical and Empirical Background***

II.i.A *Which general concepts, theories or hypotheses are underlying the model's design at the system level or at the level(s) of the submodel(s) . . . ?* The model draws on standard epidemiological models and extends them in two directions as it wants to give answers to the questions:

II.i.A.1 What is the consequence of the violation of the assumption that a population is homogeneous with respect to population density in different parts of the world and of the assumption that every person is able to infect any other person regardless of the distance between them (see III.iv.B.6)?

II.i.A.2 What is the consequence of the violation of the assumption that a population is homogeneous with respect to the personal risk aversion of its members (see III.iv.B.31)?

II.i.A.3 Does communication among people about infection risks and measures taken against infection make a difference (see III.iv.A.4 and III.iv.B.31)?

II.i.B *On what assumptions are the agents' decision models based?* In the non-normative version of the model, agents do not make decisions proper but just move around and are exposed to the risk of infection and of falling ill. Only in the normative version, they learn from others how they should behave and make a normative decision of taking one of the actions of putting a mask on or off or of staying at home whenever possible or moving around without any necessity. Their decisions are controlled by the personal salience of the four norms to take one of the four actions. For more details see Andrighetto et al. (2013); Andrighetto and Castelfranchi (2013); Troitzsch (2018) and Section A where the formula for the calculation of the salience of a norm together with the values of the weights of the memory contents are given. The term β in this formula is represented by the variable `beta` in the NetLogo code, whereas the variable `one-divided-by-alpha` in the code correspond to the inverse of the term α of the formula. The calculation of `one-divided-by-alpha` and `beta` in the code of the procedure `calculate-a-salience` makes sure that, with any values of the weights w_c, w_o, w_{npv}, w_p, w_s and w_e of the formula, the resulting value of a salience is always $0 \leq \sigma \leq 1$.

II.i.C *Why are certain decision models chosen?* See again Andrighetto et al. (2013); Andrighetto and Castelfranchi (2013); Troitzsch (2018).

II.i.D *If the model ... is based on empirical data, where does the data come from?* The parameters of the model are taken from the current discussion about the parameters of the Covid-19 pandemic. As such they are currently not reliable and save only as a starting point for sensitivity analysis and calibration of the non-epidemiological input parameters.

II.i.E *At which level of aggregation were the data available?* Only at the aggregate level, as information about the length of periods between infection, infectiosity, illness, recovery and death are still only roughly estimated, and the estimates differ from study to study.

II.ii. ***Individual Decision Making***

II.ii.A *What are the subjects and objects of decision making? On which level of aggregation is decision making modelled?* Objects of decision making in the normative mode are the actions of putting a mask on or off and of staying at home or of leaving one's home even if unnecessary.

II.ii.B *What is the basic rationality behind agents' decision making in the model? Do agents pursue an explicit objective or have other success criteria?* There is a certain rationality behind agents' decision making in the normative mode, namely to behave like the neighbours expect them to do.

II.ii.C *How do agents make their decisions?* Both by estimating an objective risk of being infected and by deriving a propensity of action from the current saliences of norms which in turn depend on the contents of their memories of earlier norm compliances, violations, invocations, sanctions or punishments. For details see Andrighetto et al. (2013); Andrighetto and Castelfranchi (2013); Troitzsch (2018) and Section A.

II.ii.D *Do the agents adapt their behaviour to changing endogenous and exogenous state variables?* Yes, but only in the normative mode. In the non-normative mode it is the probability of being infected that determines their future fate.

II.ii.E *Do social norms or cultural values play a role in the decision making process?* Yes, in the normative mode, explained in the previous items.

II.ii.F *Do spatial aspects play a role in the decision process?* Yes, norm saliences depend only on invocations from near neighbours.

II.ii.G *Do temporal aspects play a role in the decision process?* No.

II.ii.H *To which extent and how is uncertainty included in the agents' decision rules?* The decision making process ends in a propensity to act this way or that way, and this propensity is taken as the probability with which an action is taken.

II.iii. ***Learning***

II.iii.A *Is individual learning included in the decision process?* Only in terms of norm learning, see above.

II.iii.B *Is collective learning implemented in the model?* No.

II.iv. ***Individual Sensing***

II.iv.A *What endogenous and exogenous state variables are individuals assumed to sense and consider in their decisions? Is the sensing process erroneous?* Agents sense which neighbour is infectious (from which they calculate their personal risk which is only used as the probability that they are infected). Risk perception does not affect the decision where to move next.

II.iv.B *What state variables of which other individuals can an individual perceive? Is the sensing process erroneous?* The only state variable of this kind is `infectious?`. Norm invocations are transmitted as simple messages written directly into the memory of the recipients.

II.iv.C *What is the spatial scale of sensing?* Sensing is only possible in the neighbourhood which is defined by `distance-for-infection`; other information can come from within a radius of five patches.

II.iv.D *Are the mechanisms by which agents obtain information modelled explicitly, or are individuals simply assumed to know these variables?* As for infectiosity, they just know, norm invocations are transmitted in simple messages.

II.iv.E *Are costs for cognition and costs for gathering information included in the model?* No.

II.v. ***Individual Prediction*** There are no predictions.

II.vi. ***Interaction***

II.vi.A *Are interactions among agents and entities assumed as direct or indirect?* Direct.

II.vi.B *On what do the interactions depend?* Interactions depend on vicinity.

II.vi.C *If the interactions involve communication, how are such communications represented?* The sender of a norm invocation writes directly into the memory of the recipient agent.

II.vi.D *If a coordination network exists, how does it affect the agent behaviour? Is the structure of the network imposed or emergent?* There is no network.

II.vii. ***Collectives*** There are no collectives or other aggregations.

II.viii. ***Heterogeneity*** Both `people` and `county` agents are homogeneous as they have the same structure, processes are equal among them, but some state variables are randomly assigned during the initialisation and change over time. Heterogeneity with respect of the initial values of these state variables can be switched on and off (see III.iv.B.31).

II.ix. ***Stochasticity*** Periods between events are stochastic, actions are taken according to a propensity which is turned into a probability to take this action.

II.x. ***Observation***

II.x.A *What data are collected from the ABM for testing, understanding and analysing it, and how and when are they collected?* Two agents (`witnesses`) write whatever they do into a log file, at the end all current information about the state of the model and all its agents is stored for inspection. The logfile contains some additional information about distribution parameters at the end of the run.

II.x.B *What key results, outputs or characteristics of the model are emerging from the individuals? (Emergence)* As there is no emerging structure beside the frequency distributions of the state of the people, nothing important can be observed in this respect. The form of the time series of daily infections and death can, however, be seen as an emergent phenomenon, as this form deviates considerably from the results of the classical SIR compartment models.

III. **Details**

III.i.B ***Implementation Details***

III.i.A *How has the model been implemented?* The model is implemented with NetLogo 5.3.1[1]. The buttons, sliders, switches etc. with which global parameters (see below III.iv.B) have the following meaning (from top left to bottom right, left of the view):

III.i.A.1 `setup` and `go` have the usual meaning, but in an event-oriented model `go` is a *go forever* and can either be stopped with `Tools->Halt` (but then at the risk of loss of all final output except the logging file and the PNG files of the view output every simulated day) or via an interruption mechanism explained below (see III.iv.B.30).

III.i.A.2 `Date and time` gives the simulated time which starts at the beginning of the year 2020.

III.i.A.3 `stop date` shows how long the simulation can run (namely for `max-months` months, if it is not interrupted before or ends when no infectious agents are left.

III.i.B The monitors and plots are more or less self-explanatory:

III.i.B.1 (left of the view, these and the following plots have little monitors attached that inform about the median and maximum of the respective distributions) the two plots `conviv*careless...` show the distribution and the median of the product of the two individual constant attributes `conviviality` and `carelessness` separately for the susceptible and for all other agents and the individual variable attribute `perceived-risk`.

III.i.B.2 the plot `conviv*carel*perc...` shows the distribution and the median of the product of the two individual constant attributes `conviviality` and `carelessness` and the individual variable attribute `perceived-risk` which is at the same time the probability of being infected once an infectious contact happened.

III.i.B.3 `perc inf risk` shows the distribution and the mean of the individual variable attribute `perceived-risk` which while the moving-average of the daily number of newly infected agents rises (`pandemic-grows?` is true) is the percentage of

[1]This version was used instead of NetLogo 6 as the more recent version skipped the `task` primitive which was used in earlier applications of the normative mode; replacing `task` with the anonymous procedures of NetLogo 6 is a task for the future. This is also the reason why the 5.3.1 version of the time extension has to be used.

infectious agents within a radius of 5, otherwise it is the overall percentage of infectious agents.

III.i.B.4 `med perc risk` represents the maximum and the median of the distribution of the `perceived-risk` attribute over time.

III.i.B.5 (right of the view) `current state of the population`: these two plots represent several global percentages,
- the upper plot containing the number of susceptible agents and of all who were ever infected (per 1,000),
- the second plot containing the numbers of currently infected, infectious, ill, recovered, immune and deceased persons (per 1,000),

separated for better legibility.

III.i.B.6 `infectious in last 24 hours` represents the number of newly infected, those whose test was reported and a 7-day moving average of the former (per 1,000).

III.i.B.7 `deaths in past 24 hours` represents the number of newly deceased, those which were reported and a moving average of the former (per 1,000).

III.i.B.8 The `R0 real / est` plot keeps track of three variants of the *basic reproduction number* R_0; the "real" reproduction number is calculated as the mean of the length of the list `whom-I-infected` of all currently infectious agents, the two others are calculated according to the rules published by the German Robert Koch Institute, in two variants, one using 4-day moving averages, the other uses 7-day moving averages of daily new infections, R_0 being calculated as the quotient of the current moving average and the moving average four days earlier, hence $\mathrm{MA}_t/\mathrm{MA}_{t-4}$. See an der Heiden and Hamouda (2020). Moreover, it keeps track of a dispersion parameter which for this model is defined as $0 \leq (\sigma^2 - \mu)/\mu^2 + 1 \leq N - 2$ and called $1/k+1$ with k as in the formula for a negative binomial distribution of Lloyd-Smith (2007). The dispersion parameter defined here is 0 when there is no variance at all (all infectors infected the same number of agents), it is 1 when there is neither underdispersion nor overdispersion ($\sigma^2 = \mu$ as in the Poisson distribution), and it is $N - 2$ when only one agent infected all others in the population.

III.i.B.9 The `test positivity rate` plot keeps track of two variants of the *test positivity ratio*, one calculated from a five per cent random sample of the overall population and one calculated from a sample of equal size containing all infectious agents and their nearest neighbours.

III.i.B.10 The `whom-I-infected_t` plot tries to visualise the time dependent distribution of the number of the infections directly caused by the currently infectious agents.

III.i.B.11 (below the view) `max daily infected` and `max daily dead` contain two numbers: the number of the day when the maximum of daily new infections and deaths, respectively, was reached, and the number of these events.

III.i.B.12 `incidence rate` the number of new infections per 100,000 during the past seven days[2].

III.i.C In each run, the model creates a directory into which four files are written (the final state of the world and a profile[3] — except in behaviour space —, a logging file with details about interesting events, a result file with details about the epidemic histories in the individual counties, and the data generated for all plots). At the end of every simulated day — except in behaviour space —, a PNG file is written, and these PNG files can be converted to an AVI file using (on Unix systems) `mencoder` (NetLogo's movie feature is not used as not all video programmes can work with MOV files).

Which events are logged can be determined in the code by changing the first parameter of the util-flog procedure and/or by setting the respective switch.

III.ii.C ***Initialisation***

III.ii.A *What is the initial state of the model world, i.e. at time* $t = 0$ *of a simulation run?* During model setup global variables (mainly counters and file names for output) are initialised and the entities are generated according to the input parameters. `people` agents are generated by the `counties` and placed on patches belonging to each `county` according to the settings of the global parameters `density-mode` and `total-population` (see III.iv.B.7). In the normative mode, `people` agents get their normative memories initialised according to III.iv.A.4.

III.ii.B *Is the initialisation always the same, or is it allowed to vary among simulations?* The initialisation is equal for equal random number generator seeds. This seed is different for each run of the model provided that the global parameter `constant-seed?` is switched off.

III.iii.B ***Input Data***

III.iii.A *Does the model use input from external sources such as data files or other models to represent processes that change over time?* No.

III.iv.A ***Submodels***

[2]Germany, Switzerland and Austria use this definition for the incidence rate, others use the number of infections per 100,000 or per million and/or during the past fourteen days and call it *14-day notification rate*, e.g. in https://www.ecdc.europa.eu/en/publications-data/weekly-subnational-14-day-notification-rate-covid-19 with fourteen days per 100,000.

[3]This is a means of finding out how time-consuming the procedures of the model are.

III.iv.A *What, in detail, are the submodels that represent processes listed in 'Process overview and scheduling'?* Four submodels can be identified (although they are not explicitly separated in the code as this is not possible in NetLogo):

III.iv.A.1 A calendar makes sure that at the end of a simulated day all changes in the epidemiological state of the population are collected and sent to the respective plots and monitors of the user interface. This also includes an update done by all `people` with respect to their actual neighbourhood.

III.iv.A.2 `people` schedule their own movements around their `home` which was assigned to them and to which they return every simulated Saturday. These movements happen at discrete events, they are scheduled at the time of current movement for some random time in the future. The following events can be scheduled by the model:

- `move-around`: the agent moves to another place,
- `set-infectious`: the agent is infected and becomes infectious,
- `report-a-positive-test`: the agents is reported to the observer as infected,
- `fall-ill`: the agent shows symptoms and is brought to hospital,
- `recover-or-die`: the agent either recovers or dies and is returned to its original patch,
- `report-a-death`: the death of the agent is reported to the observer,
- `become-immune`: the agent is no longer infectious nor susceptible,
- `lose-immunity`: the agent loses its immunity and is susceptible again.

III.iv.A.3 When as a consequence of their movements they approach other `people` agents which are infectious they take the risk of being infected. This risk depends on the values of their `conviviality` and `carelessness` instance variables (which are initialised to constant values at the simulation start and remain constant) and on their currently `perceived-risk` as well as — in the normative mode — on their earlier decision to wear a mask and to stay at home (stored in the instance variables `wears-a-mask?` and `stays-at-home?`). The event of being infected happens immediately, the events of becoming infectious, of having first symptoms, of having to be hospitaiised, of recovering, becoming immune or losing immunity as well as death are scheduled for random times in the future whose distribution is a uniform distribution with the parameters noted below in III.iv.B.22–III.iv.B.26.

III.iv.A.4 In the normative mode, `people` process the norm invocations they have stored in their memories, calculate their actual saliences (see Section A) and decide whether they change their behaviour with respect to wearing a mask and staying at home[4] and whether they let their neighbourhood know about their decision, encouraging them to behave the same.

III.iv.B *What are the model parameters, their dimension and reference values?* The following list informs about all the global parameters of the model (standard values in paranthese):

III.iv.B.1 `total-population` determines the number of `people` in the simulated world. Usually there will be several agents per patch in the initialisation (except for borderline patches which are inhabited by a single agent), according to the `density-mode`; the algorithm in the setup procedure makes sure that the population densities with the `counties` are in line with the selected `density-mode` and that the total population is as determined with this input parameter.

III.iv.B.2 `normative-mode?` decides whether agents use their normative mode (see III.iv.A.4).

III.iv.B.3 `BACKGROUND` sets the normative predisposition, i.e. the number of norm invocation which agents have in their memories when the simulation starts. With `heterogeneity` set to `none` or `wrt risk`, all agents have the same number of norm invocation in their memories. `BACKGROUND > 0` sets the initial number of invocations of risk-aversive norms to `BACKROUND`, `BACKGROUND < 0` sets it to `-BACKGROUND`. With `heterogeneity` set to `wrt norm` or `both`, the initial number of invocations of risk-aversive norms is set to a beta distributed random number with its mean as in the previous sentence (see also III.iv.B.31).

III.iv.B.4 `NDW` is the weight of the normative drive as opposed to the individual drive, the former being calculated from the saliences of each norm and the resulting propensity to take one of the possible actions, the individual drive being the calculated risk.

III.iv.B.5 `initial-counties` (13) determines how many subregions (`counties`) are displayed.

III.iv.B.6 `density-mode` allows for three different modes of populating the `counties`: all with the same population density, with linearly decreasing density and with inversely (hyperbolically) decreasing as a function of the number of patches; a patch can sprout one or four or nine agents (except on

[4] In a real world scenario this would mean: wearing a mask whenever near other people and staying at home except for going to work or meeting a doctor or to do the most necessary shopping as in mild phases of lockdown.

the boundary of a neighbouring `county` where there is one or no agent per patch).

III.iv.B.7 The combination of `constant-seed`, `density-mode`, `initial-counties` and `total-population` allows for different topographies.

III.iv.B.8 `infected-from-abroad` (none) determines whether it is possible that some agents are infected from abroad (as if they had just returned from holidays abroad); in this case about two percent of the population become infected and infectious from the second to the eleventh simulated month (alternatively: in months 7 to 8 or in months 9 to 11; such an event is logged in the output area).

III.iv.B.9 `period` shows whether the model is in lockdown mode or in normal mode; this can be switched automatically or by the user.

III.iv.B.10 `max-months` (24) determines the maximum duration of the simulation run.

III.iv.B.11 `far-commuter` (0.20) determines the ratio of agents which can move up to `long-distance` patches at a time.

III.iv.B.12 `short-distance` (2) determines how far (at most) the ordinary agents can walk at a time (in units of patches).

III.iv.B.13 `long-distance` (50) determines how far (at most) the far-commuting agents can travel at a time (in units of patches).

III.iv.B.14 `auto-lockdown?` (off) determines whether the model can enter the lockdown mode automatically. "Lockdown" means that the distances up to which agents may move are lowered to one half of its normal value.

III.iv.B.15 `lockdown-at` (50) determines the limit for entering the lockdown: when the number of new infectious agents per 100,000 during the paast seven days (the *incidence rate*, see also III.i.B.12) becomes greater than this limit, lockdown starts at the next midnight.

III.iv.B.16 `lockdown-end-at` (25) determines the limit for exiting the automatic lockdown: when the *incidence rate* becomes less than this limit, lockdown ends at the next midnight.

III.iv.B.17 `distance-for-infection` (2.25) is the maximum distance within which infections are possible. This distance is measured as a multiple of the mean distance between an agent and its nearest neighbour, not in patch size (see III.iv.B.7).

III.iv.B.18 `infections-per-contact` (0.25) is the ratio between successful infections and contacts.

III.iv.B.19 `tested-per-infected` (1.0) is the ratio between tested (and, hence, reportable) infections and all infections.

III.iv.B.20 `asymptomatic-per-infected` (0.15) is the ratio between the number of agents which do not show symptoms resulting in being hospitalised and the number of all agents.

III.iv.B.21 `case-fatality-rate` (0.03) is the ratio between all deceased and all infected.

III.iv.B.22 `time-to-infectiosity-min` (1) and `-max` (4) is the range of a uniform distribution for the time between being infected and being infectious (in days).

III.iv.B.23 `incubation-time-min` (5) and `-max` (10) is the range of a uniform distribution for the time between between being infected and showing symptoms of illness that lead to hospitalisation (in days).

III.iv.B.24 `illness-duration-min` (12) and `-max` (17) is the range of a uniform distribution for the time between falling ill and recovering or death (in days).

III.iv.B.25 `time-till-immunity-min` (0) and `-max` (2) is the range of a uniform distribution for the time between recovery and immunity (in days),

III.iv.B.26 `immunity-duration-min` (24) and `-max` (30) is the range of a uniform distribution for the time between recovering and becoming susceptible after loss of immunity (in months).

III.iv.B.27 `reporting-delay` (0.0) is the upper end of the range of a uniform distribution determining when a test result is reported; over the weekend further delays are programmed (see code).

III.iv.B.28 `random-seed?` provides a standard random number generator seed when it is `on` (the seed is then 118866472), otherwise each run starts with a different seed provided by NetLogo (dependent on the current date and time down to the millisecond).

III.iv.B.29 `zero-person` determines whether `person-zero` occurs in the `densest` (standard), `sparsest` or a `random county`.

III.iv.B.30 `interruptible?` (off) determines whether the simulation run can be interrupted at the end of each simulated day. The switch can be changed at any time, and at midnight of the next simulated day a chooser opens which allows the user to determine how the simulation should go on. The options are

- `continue` until next midnight;
- `go on forever`: continue forever;
- `print profile and continue forever`: (only for debugging purposes) print a profile (duration of all procedures) and continue;
- `halt and print profile and result!`: end the simulation run and output all collected information;

- `spread`: call the procedure `move-an-infectious-far-away`, i.e. select an infectious agent randomly and put it on a random patch;
- `normal time`: exit from a user-defined lockdown;
- `lockdown`: start a user-defined lockdown;
- `inspect` a randomly selected infectious agent.

III.iv.B.31 `heterogeneity` determines whether personal risk aversion (`conviviality * carelessness`) and/or normative background (`BACKGROUND` and `individual-LNP`) are equal for all agents (alternative `none`) or are beta distributed individual variables (alternative `wrt risk` between 0 and 1 for both instance variables, alternative `wrt norm` between `BACKGROUND - 10` and `BACKGROUND + 10`); for the alternative `both` (the standard) all three instance variables are random.

III.iv.C *How were submodels designed or chosen, and how were they parameterised and then tested?* The calendar submodel just organises a discrete-event model with the help of the `time` extension. The events scheduled by the `people` agents generalise a SEIRS model.

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