

MODEL SOCIAL SYSTEM DESIGN, ODD PROTOCOL, DATA SET AND SIMULATION CODE

In information is related to this paper:

THE CATASTROPHE OF SOCIAL EXCLUSION IN DEAFBLIND PEOPLE: AN AGENT-BASED SIMULATION ANALYSIS

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Design of the modelled social system

The modelling universe is a defined space (from -16 to 16 on the x and y coordinates). Within this universe, the social exclusion of a given population consisting of 1,000 agents is analysed. To this end, various individual and collective factors are established.

First, the global (independent) variables representing the aggregate characteristics (collective factors) of the social model are determined. These include the general level of social risk (*social risk*), the threshold above which a person is considered to be at risk (*risk threshold*), and other indicators such as the total number of excluded or non-excluded persons, and the averages of key variables such as education, income, access to health care, social power and social exclusion. The *risk-threshold* variable represents a limit or probabilistic tolerance to situations of vulnerability or social danger affecting agents. In contrast, *social risk* is the probability with which agents face negative social factors.

Secondly, the social variables specific to each turtle (*turtles-own*) are defined, representing the characteristics of the agents within the social model. In this regard, it should be emphasised that we are talking about social characteristics and, therefore, not subjective characteristics. In this sense, each agent has attributes that aim to reflect their particular situation: their level of risk, their education, their income, their access to

healthcare, their social power (agency), their level of social exclusion and also a Boolean indicator that indicates whether they are socially excluded. These characteristics of each agent served as dependent variables.

First, the so-called *average-health-access* was established, which represents the measure of each agent's access to the healthcare system. This variable reflects the level of access based on their social status, income, illnesses, and social interactions. Secondly, the *average social exclusion* variable was determined as the one that represents the average social exclusion of the agents. This information complements access, as it measures how many agents end up on the margins of the social system. Therefore, *social exclusion* refers to the situation in which agents are marginalised from the other variables (education, income, and health). In the modelling, relationships were established between the variables such that the greater the exclusion, the less access to the other variables, and likewise, the healthier and greater the access, the less exclusion there will be. For all these reasons, the model simulates an unequal society where parameters such as social risk generate non-linear effects on well-being (education, income, exclusion, and health).

The simulation design consists of a population of agents with different characteristics in four key dimensions, considered to be axes of structural exclusion: 1) education; 2) income; 3) health; and 4) social power. Each agent has an assigned value in these dimensions, which when combined generate an aggregate value called social risk. On the other hand, an exogenous and adjustable parameter called the risk threshold was established, which operates in the system as a normative criterion. Agents in the model whose social risk exceeds the risk threshold will be considered excluded.

The analysis procedure consisted of multiple runs of the system, systematically varying the values of the dependent variables. In this regard, several runs of the model were performed, systematically varying the values of the independent variables. In the case of the "risk threshold" variable, the variations took the following values: 0.2, 0.4, 0.6, and 0.8. In relation to the other independent variable, "social risk," the modifications took the following values: 0.1, 0.3, 0.5, 0.7, and 0.9. For each combination, the number of excluded agents was recorded.

Each run of the model starts from a random distribution of agents, allowing the effects of changes in parameters to be observed without initial biases. However, any agent that exceeded the defined risk threshold and had deficiencies in two or more structural dimensions was considered to be excluded from the system.

In order for the modelling to be credible and considered to provide epistemologically relevant information, previously published data were obtained. To this end, the Global Report of the World Federation of the Deafblind (2018) was used. As there was no data adjusted to the MESOC—especially on the risk threshold and social risk—an estimate as realistic as possible was made to operationalise the model (Table 1), and once this was done, the experiment was carried out.

Table 1 – Social risk and risk threshold values used as the basis for the model developed.

Indicator	Overall value (%)	Value in deafblind people (%)	Risk threshold (%)
Employment	80	8	< 10%
Schooling	90	5.3	< 10%
Poverty	20	40	< 35%
Disability	10	50	< 40%
Social participation	60	30	< 35%

Notes: The general values are approximate based on international and contextual data for comparison purposes. The values for deafblind people come from the 2018 global report of the World Federation of the Deafblind. Risk thresholds are defined based on relevant differences to indicate significant vulnerability. Social risk data indicate the extent of exclusion or vulnerability compared to the general population.

Source: Prepared internally based on data from the World Federation of the Deafblind Global Report (2018).

ODD Protocol

The ODD (*Overview, Design Concepts, Details*) protocol of Grimm et al. (2010; 2020) was followed to provide greater robustness and technical transparency to the MESOC.

1. Overview.

1.1. Objective.

To analyse how the regulatory risk threshold (U) and individual social risk (R) generate exclusion in deafblind people. The agents represent deafblind people with characteristics in four social dimensions: education, income, health, and social power.

1.2. Entities, Variables, and Scale.

1.2.1. Agents:

1.2.1.1. Attributes: ‘social-risk-level’, ‘social-health-access’, ‘individual-education-level’, ‘individual-income-level’, ‘social-power’ and ‘social-exclusion’.

1.2.1.2. States: defined by: ‘is-excluded?’ (Boolean) and ‘social-health-status’ (‘healthy’/‘sick’).

1.2.2. Environment: Continuous 2D space (coordinates [-16, 16] in x and y).

1.2.3. Time scale: 500 ticks (simulated months).

1.3. Processes and programming.

1.3.1. Initialisation: Random distribution of agents (N=1000) with random initial values in attributes.

1.3.2. Dynamics:

1.3.2.1. Random movement: fd 2 and rt random 90.

1.3.2.2. Local interaction: nearby agents (neighbours) influence ‘social-health-access’, ‘individual-education-level’, etc.

1.3.2.3. Status update: If the following occurs: ‘social-risk-level > risk-threshold’, then the agent is marked as excluded.

1.3.3. Stopping criterion: after 500 ticks or stabilisation of variables.

2. Design Concepts.

2.1. Theoretical principles.

2.1.1. Theoretical foundations:

2.1.1.1. Intersectionality (Bourdieu, 1984), referring to exclusion as a result of accumulated social capital.

2.1.1.2. Biopolitics (Foucault, 1979), relating to the normative threshold as a control device.

2.1.2. Emerging hypotheses: Stepwise exclusion pattern (Heaviside function) when $R > U$.

2.2. Emergence.

2.2.1. Observed patterns:

2.2.1.1. Abrupt exclusion when exceeding U (Table 2).

2.2.1.2. Negative correlations between education/access to health and exclusion (Table 3).

2.3. Adaptation.

2.3.1. Social learning: Agents adjust the variables ‘individual education level’ and ‘individual income level’ according to the averages of their neighbours.

2.4. Objectives:

2.4.1. Agents will seek to maximise ‘social-health-access’ and minimise ‘social-exclusion’, but they do not have complex objectives.

2.5. Observation

2.5.1. Fundamental metrics:

2.5.1.1. ‘total-excluded’, ‘average-social-exclusion’, ‘average-social-health-access’.

2.5.1.2. Correlations between variables (Table 3).

3. Details (Technical Details).

3.1. Implementation.

3.1.1. Language/Platform: NetLogo 6.2.2 software.

3.1.2. Code: Available in Annex II.

3.1.3. Parameters and Initial Values.

3.1.3.1. “risk-threshold”: takes the following values in the designed experiments: 0.2; 0.4; 0.6; 0.8. The values are based on differences in vulnerability (Table 1).

3.1.3.2. ‘social-risk’: takes values between 0.1 and 0.9.

3.1.3.3. ‘initial-population’: 1,000 agents.

3.2. Submodels.

3.2.1. Access to healthcare:

3.2.1.1. ‘social-health-access-set’:

Calculated as $\text{social-health-access} + \text{average-neighbour-access} / 2 + (\text{random-float } 0.1 - 0.05)$.

Simulates inequalities based on the social network.

3.2.2. Exclusion:

3.2.2.1. “is-excluded set”:

Calculated as $\text{social-health-access} < 0.3$ and $\text{individual-income-level} < 0.2$.

RAW DATA FROM THE EXPERIMENT

"BehaviorSpace results (NetLogo 6.2.2)"

"21/05/2025 11:28:52:567 +0200"

"risk threshold" - "0.1","0.2","0.3","0.4","0.5","0.6","0.7","0.8","0.9","1",

"[reporter]" - "average-health-access","average-social-exclusion","total-excluded","total-not-excluded","average-income","average-education","average-social-power","social-risk",

"[final]",

1. "0.04035075493205768","0.9596492450679422","3","1008","0.2506678875948609","0.7676243974698495","0.19241839942849973","0.3",
2. "0.04192216985052405","0.9580778301494763","4","1004","0.25666903528114526","0.7966197261764737","0.20446761660364643","0.3",
3. "0.046436125209643006","0.9535638747903575","0","1009","0.2719974964207547","0.7766612958737719","0.2112500360310587","0.3",
4. "0.042015536054113324","0.9579844639458851","8","1004","0.23753663655412727","0.7859045468522687","0.1866802650597982","0.3",
5. "0.042552063360418314","0.9574479366395805","3","1007","0.24862659919133223","0.783414262431683","0.19477719850830524","0.3",
6. "0.04258178724097565","0.9574182127590248","20","997","0.2369134486398244","0.7747910235674104","0.18355839349629877","0.3",
7. "0.043941558824176795","0.956058441175824","2","1005","0.24776812389410693","0.7853872005267463","0.19459406000787638","0.3",
8. "0.04458718083415285","0.9554128191658479","14","994","0.24158232463485135","0.7779464740617232","0.18793803802211126","0.3",
9. "0.04356045748741589","0.9564395425125847","2","1010","0.25494853142294216","0.774406776652921","0.19743388620012642","0.3",
10. "0.04232299919283805","0.9576770008071617","6","1000","0.24364923391277482","0.76983358353976","0.18756936293764048","0.3"

"[min]",

11. "0.03815150102863296","0.4964008736473823","0","920","0.2467185907330125","0.2396275651799067","0.059257215953769315","0.3",
12. "0.03814394823708815","0.5042507085008758","0","905","0.24364522067107575","0.2608524562703584","0.06473351012917994","0.3",
13. "0.03879571180920653","0.5142302494191796","0","888","0.2552595181660527","0.24444787939238807","0.0642145439681113","0.3",
14. "0.03833370468782732","0.48522647045732786","0","918","0.23522064624377492","0.25598177971683195","0.062072969896504925","0.3",
15. "0.037955003499836534","0.48731199314281015","0","913","0.241866685896459","0.2514223233153944","0.06276720701836552","0.3",
16. "0.038569962971942755","0.5060607723949534","0","890","0.23393501136707232","0.2518622535485739","0.06113620698319576","0.3",
17. "0.039586570264781656","0.5063882361265377","0","906","0.2409461043095106","0.25083988421426656","0.062270364625333904","0.3",
18. "0.037455308532232216","0.49161488832820927","0","926","0.24044238674860624","0.2533733544817127","0.06340111339874524","0.3",
19. "0.03823544909461797","0.4959725161652187","0","903","0.24676491615550517","0.24728744683971385","0.06264961729341285","0.3",
20. "0.03882324780476865","0.484169226204995","0","916","0.2431885743135433","0.23611501206818555","0.059183717091248866","0.3"

"[max]",

21. "0.5035991263526173","0.9618484989713659","80","1011","0.2527822480677452","0.7738852725263654","0.19524807425735236","0.3",
22. "0.4957492914991242","0.961856051762911","95","1008","0.25780382639795335","0.7993645333898498","0.20537161359238984","0.3",
23. "0.48576975058082034","0.9612042881907944","112","1009","0.27333741832062564","0.7795199334387025","0.21254415740059776","0.3",
24. "0.5147735295426719","0.9616662953121721","82","1006","0.24424279856201186","0.792175449698808","0.19265750260577869","0.3",
25. "0.5126880068571905","0.962044996500163","87","1009","0.2509708370835939","0.7882565342759997","0.1967232772277477","0.3",

26. "0.4939392276050466","0.9614300370280585","110","1011","0.242768512798
69513","0.785028551147207","0.18909277180062653","0.3",
27. "0.4936117638734624","0.9604134297352186","94","1005","0.2512359282170
7474","0.7888717557901073","0.19813650014505388","0.3",
28. "0.5083851116717916","0.962544691467767","74","1004","0.25796106535183
39","0.7830993341841624","0.20198839158590873","0.3",
29. "0.5040274838347814","0.9617645509053833","97","1012","0.2619482000974
43","0.7808031189108857","0.2032749944237901","0.3",
30. "0.5158307737950054","0.9611767521952328","84","1005","0.2545051065275
3644","0.7727960933731461","0.19660976911858102","0.3"

"[mean]",

31. "0.05626073466877026","0.9437392653312296","4.383233532934132","1000.
38123752495","0.2496803012211398","0.7567588399481494","0.1889291245982
667","0.3",
32. "0.055899187303967854","0.9441008126960334","5.105788423153693","1000
.3592814371258","0.24953358446356552","0.7830744966831705","0.195472164
760434","0.3",
33. "0.057488810234503356","0.9425111897654961","1.2075848303393213","100
2.8942115768463","0.2643235470417916","0.7636105683718324","0.201955496
49305278","0.3",
34. "0.057196718090194235","0.942803281909805","14.151696606786427","990.
7005988023952","0.23913281713693688","0.7752249280818655","0.1853753036
6285304","0.3",
35. "0.05826762010903076","0.941732379890969","6.7624750499002","998.0918
163672654","0.24670938145455457","0.771615691141371","0.190364614946223
78","0.3",
36. "0.0555581032750125","0.9444418967249877","15.007984031936127","996.2
914171656687","0.2387989001274606","0.7638590378852801","0.182382695294
28153","0.3",
37. "0.05633227597935353","0.9436677240206469","6.906187624750499","996.1
117764471057","0.24691080918798983","0.7729712999099704","0.19081886677
383644","0.3",

38. "0.05671955721364825","0.943280442786352","4.568862275449102","997.86
42714570858","0.2506867319095827","0.7668684659513674","0.1922390550634
3636","0.3",
39. "0.05589415665599413","0.9441058433440062","2.588822355289421","1002.
9321357285429","0.255074588310072","0.7634593062171096","0.194835682043
61987","0.3",
40. "0.05766148674961413","0.9423385132503843","5.1836327345309385","997.
7325349301398","0.24912149847271078","0.7568712761560038","0.1884892487
225777","0.3"

"[steps]","500",

SIMULATION CODE

```
globals [  
  social-risk  
  risk-threshold  
  total-excluded  
  total-non-excluded  
  average-risk  
  average-education  
  average-income  
  average-access-health-social  
  average-social-power  
  average-social-exclusion  
]  
  
turtles-own [  
  level-of-social-risk  
  social-health-status  
  individual-education-level  
  individual income level  
  access-to-social-health  
  social power  
  social exclusion  
  is-excluded?  
]  
  
; Initial configuration  
to setup  
  clear-all  
  set social-risk 0.3  
  set risk-threshold 0.4  
  create-turtles 1000 [  
    set xy random xcor random ycor  
    initialise-turtle
```

```
]
reset-ticks
update-counters
end
```

```
; Initialise turtle properties
```

```
to initialise-turtle
```

```
set social-risk-level random-float 0.5
```

```
set social-health-status "healthy"
```

```
set individual-education-level random-float 0.5
```

```
set individual-income-level random-float 0.5
```

```
set social-health-access random-float 1
```

```
set social-power individual-education-level * individual-income-level
```

```
set social-exclusion 1 - access-to-health-and-social-care
```

```
set is-excluded? false
```

```
if social-risk-level > risk-threshold [
```

```
set social-health-status "ill"
```

```
]
```

```
end
```

```
; Simulation evolution month by month
```

```
to go
```

```
if ticks >= 500 [ stop ]
```

```
ask turtles [
```

```
fd 2
```

```
rt random 90
```

```
; Update health access
```

```
let neighbours turtles in-radius 1
```

```
let average-access-neighbours mean [health-social-access] of neighbours
```

```
set social-health-access (social-health-access + average-neighbour-access) / 2 +  
(random-float 0.1 - 0.05)
```

```
if social-health-access > 1 [ set social-health-access 1 ]
```

```
if social-health-access < 0 [ set social-health-access 0 ]
```

; Evaluate exclusion

let excluded? social-health-access < 0.3 and individual-income-level < 0.2

set is-excluded? excluded?

; Grouping by similarities

let neighbours-influence turtles in-radius 1

let average-risk-neighbours mean [social-risk-level] of influence-neighbours

let average-education-neighbours mean [individual-education-level] of neighbours-influence

let average-neighbour-income mean [individual-income-level] of neighbours-influence

; Update characteristics according to similarities

set social-risk-level (social-risk-level + average-neighbour-risk) / 2

set individual-education-level (individual-education-level + average-neighbourhood-education) / 2

set individual-income-level (individual-income-level + average-neighbour-income) / 2

; Evolution of education

if ticks < 30 [

if social-health-status = "healthy" [

set individual-education-level individual-education-level + random-float 0.05

]

if social-health-status != "healthy" [

set individual-education-level individual-education-level + random-float 0.025

]

]

; Random income change

if random-float 1 < 0.1 [

set individual-income-level individual-income-level + random-float 0.1 - 0.05

]

; Re-evaluate health according to social risk level

```
if social-risk-level > risk-threshold [  
  set social-health-status "ill"  
]  
if social-risk-level <= risk-threshold [  
  set social-health-status "healthy"  
]
```

```
; Update colour according to health status
```

```
if social-health-status = "unhealthy" [  
  set colour red  
]  
if social-health-status != "ill" [  
  set colour green  
]  
]
```

```
; Random generation of new turtles (every so often)
```

```
if random-float 1 < 0.02 [  
  create-turtles 1 [  
    setxy random-xcor random-ycor  
    initialise-turtle  
  ]  
]
```

```
; Update averages
```

```
update-counters
```

```
tick
```

```
end
```

```
; Updating counters
```

```
to update-counters
```

```
set total-excluded count turtles with [is-excluded?]
```

```
set total-not-excluded count turtles with [not is-excluded?]
```

```
set average-risk mean [social-risk-level] of turtles
```

```
set average-education mean [individual-education-level] of turtles
set average-income mean [individual-income-level] of turtles
set average-access-to-social-health mean [access-to-social-health] of turtles
set average-social-power mean [social-power] of turtles
average social exclusion mean [social exclusion] of turtles
end
```