Introduction to Agent-Based Modelling: Session 2

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Outline of session 2

Session 1 Recap (10 min) – Leandro

Translating conceptual models to agent-based models (15 min) – Sophie

Q & A (5 min)

Practical demonstration using NetLogo (15 min) – Sophie

Q & A (10 min)

Comfort break (5 min)

Hands on NetLogo (15 min) – Leandro

Q & A (5 min)

Using data to inform agent-based models (15 min) – Sophie

How to obtain, analyse, and use the outputs (15 min) – Leandro

Q & A (15 min)

COMPLEX SYSTEMS AND NETWORK SCIENCE FOR PREVENTION AND CONTROL OF NONCOMMUNICABLE DISEASES

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Recap session 1

Foundations of systems thinking

Foundations of agent-based modelling

Planning for an agent-based model

Steps for building an agent-based model

What is systems thinking?

- Way of thinking and doing based on systems concepts and methods
- **Core principle:** breaking the system down to its parts does not allow us to fully understand the whole system
- Active focus on structures, interconnections, processes, mechanisms, and context
- It is about seeing the ‘bigger picture’

The system's structure determines its behaviour
(system as cause)

Why use systems thinking?

- Investigate systems problems
- Identify ways to address systems problems
- Broadening perspectives

What is agent-based modelling?

Computational modelling technique for simulating the actions and interactions of autonomous entities to understand the behaviour of a system

Key tenet: *agent-centric perspective*, i.e., causal mechanisms of the system's behaviour are expressed by rules representing processes by which the simulated entities make decisions and act

Agent-centric perspective

"I, the agent, have certain characteristics and beliefs of my own as well as information about the world around me, and therefore will do some action."

↓

How do agents make decisions and behave to enact the process of interest?

↓

Set of programable rules defined by the modeller

Badham J et al. Health Place. 2018;54:170-7.

Elements of an agent-based model

- Agents
  - E.g., persons, families, businesses
  - Numerous, heterogenous, and autonomous
  - Interdependent and reactive
  - Governed by a set of rules (defined by the modeller)
    - Sometimes can learn and adapt rules
- Space where the agents exist
- Set of rules that define how:
  - Agents evolve over time (“take decisions” and “behave”)
  - Environment changes over time
  - Agents and environment interact with, and react to, each other

The main shift in thinking

Regression-based models	Agent-based models
Focus on dependent and independent variables	Focus on dynamic processes
What variables do I need to consider?	What processes do I need to consider?

Planning an ABM

1. Which processes should be simulated?
2. How to identify the characteristics and relationships relevant to each process: observations, literature, experiments, interviews…?
3. What agents are needed to implement the process?
4. What characteristics of agents are relevant to the process? (this includes characteristics that affect decisions, actions, and state indicators)
5. What form does the environment take: abstract space, realistic space, social network…?
6. What environmental characteristics influence the processes or are affected by the processes?
7. How do agents and the environment interact? (this includes inputs for actions and consequences of actions)
8. How to operationalize the processes? (details of the model rules that must be translated into code)

What a work plan (normally) looks like

Conceptual model of the interlinked processes

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Operationalization as a computer simulation model

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Parametrization and calibration

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Investigation of how behaviour of micro-level entities generate emergent macro behaviour and structures

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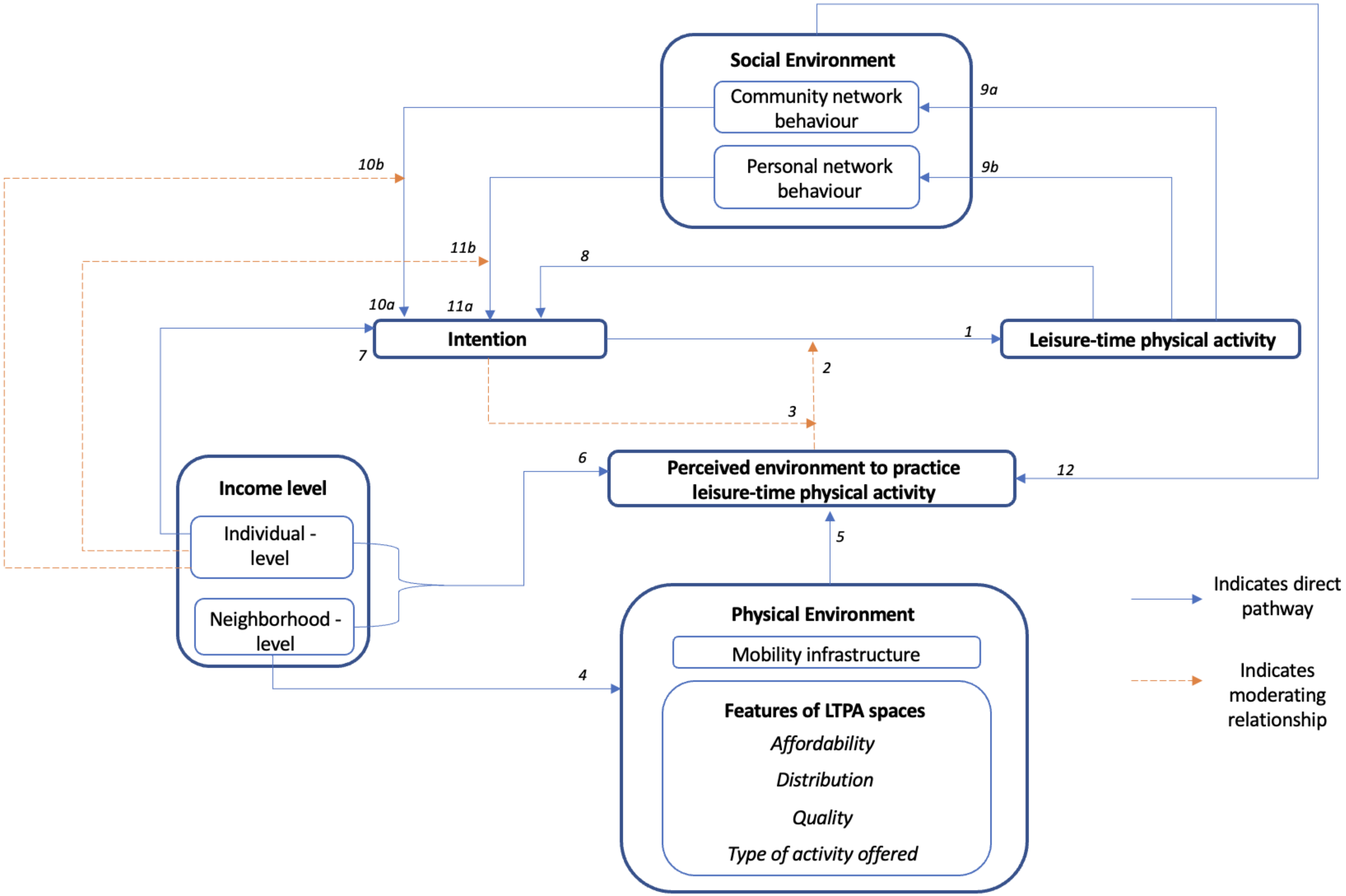
“What if” experiments

Session 2 training objectives

1. To understand how to design and develop an agent-based model.

2. To understand how data from agent-based models can be analysed.

Translating conceptual models to agent-based models



A conceptual model demonstrating an adult's decision to practice leisure time physical activity (LTPA)

[Jones, SM, Hunter, RF, Garcia, L. 2025. Developing a Conceptual Model for Collective Patterns and Leisure-Time Physical Activity Inequalities Among Adults]

‘pseudo code’ for main decision-making process

```
If people perceive >0 spaces in their perception radius
        set ‘potentially active’
    ask ‘potentially active’ people to calculate the utility of each LTPA space in their perception radius
     {utility = quality, distance, LTPA activity offered, and area level of income}
    select the space with the highest utility ‘x’
    set ‘x’ as ‘best space’

If people perceive 0 spaces in their perception radius
        set LTPA-behaviour -1 (do not practice LTPA)

For people who are ‘potentially active’
    update intention for LTPA
     {updated intention for LTPA = individual’s past behaviour + behaviour of their personal network + behaviour of their
     observed community + the utility of ‘best space’}

If random-generated number <= updated intention
    set ltpa-behaviour 1 (practice LTPA)
If random-generated number > updated intention
    set ltpa-behaviour -1 (do not practice LTPA)
```

LTPA: Leisure time physical activity

Practical demonstration using NetLogo

Introduction to NetLogo

ABM specialist program:

- Own language
- Windows, Mac OS X, and Linux
- Open source and access

Download: https://ccl.northwestern.edu/netlogo/

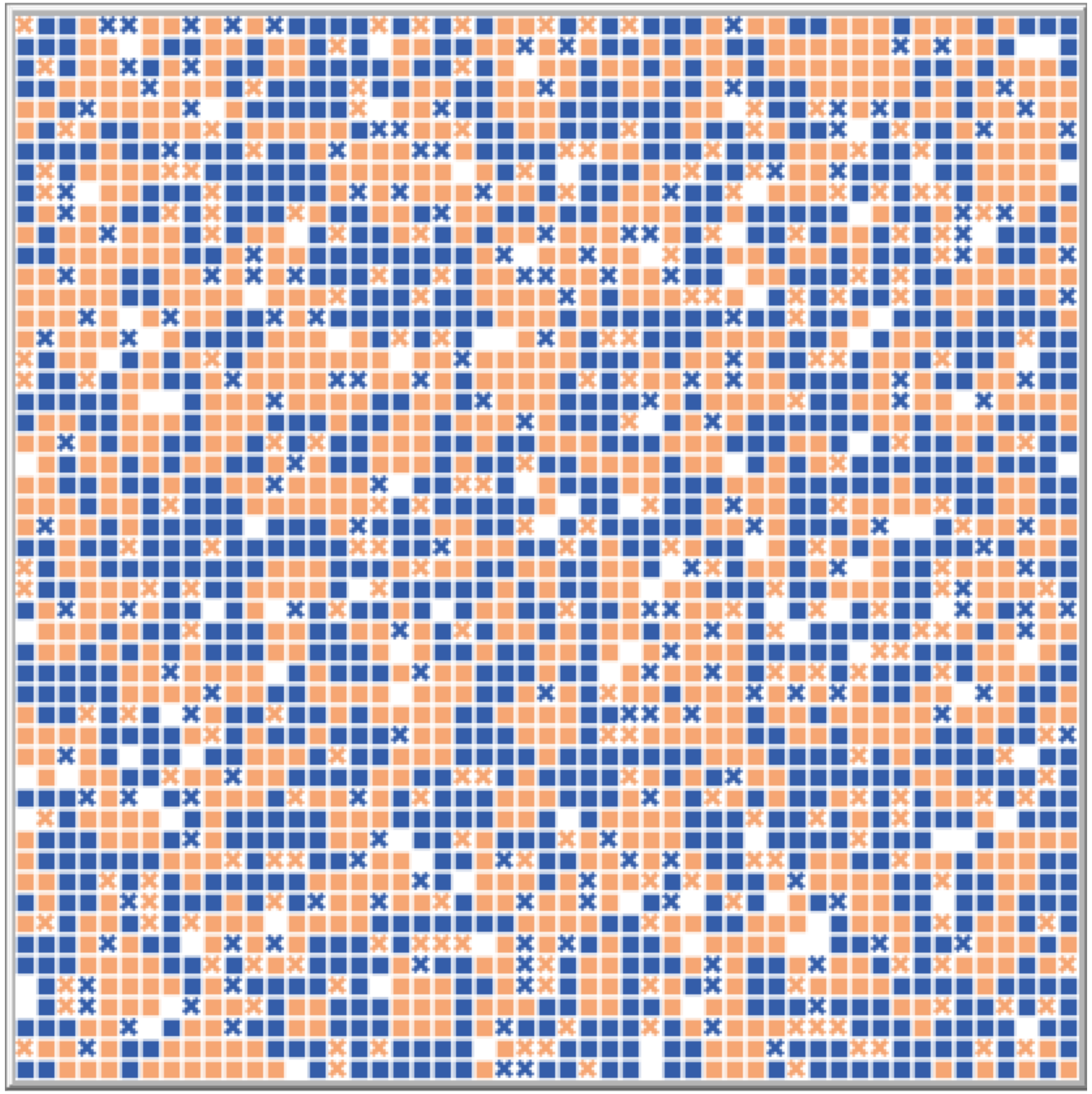
Web version: https://www.netlogoweb.org/

Alternatives:

- List on Wikipedia
- Python, Java, C++, Julia…

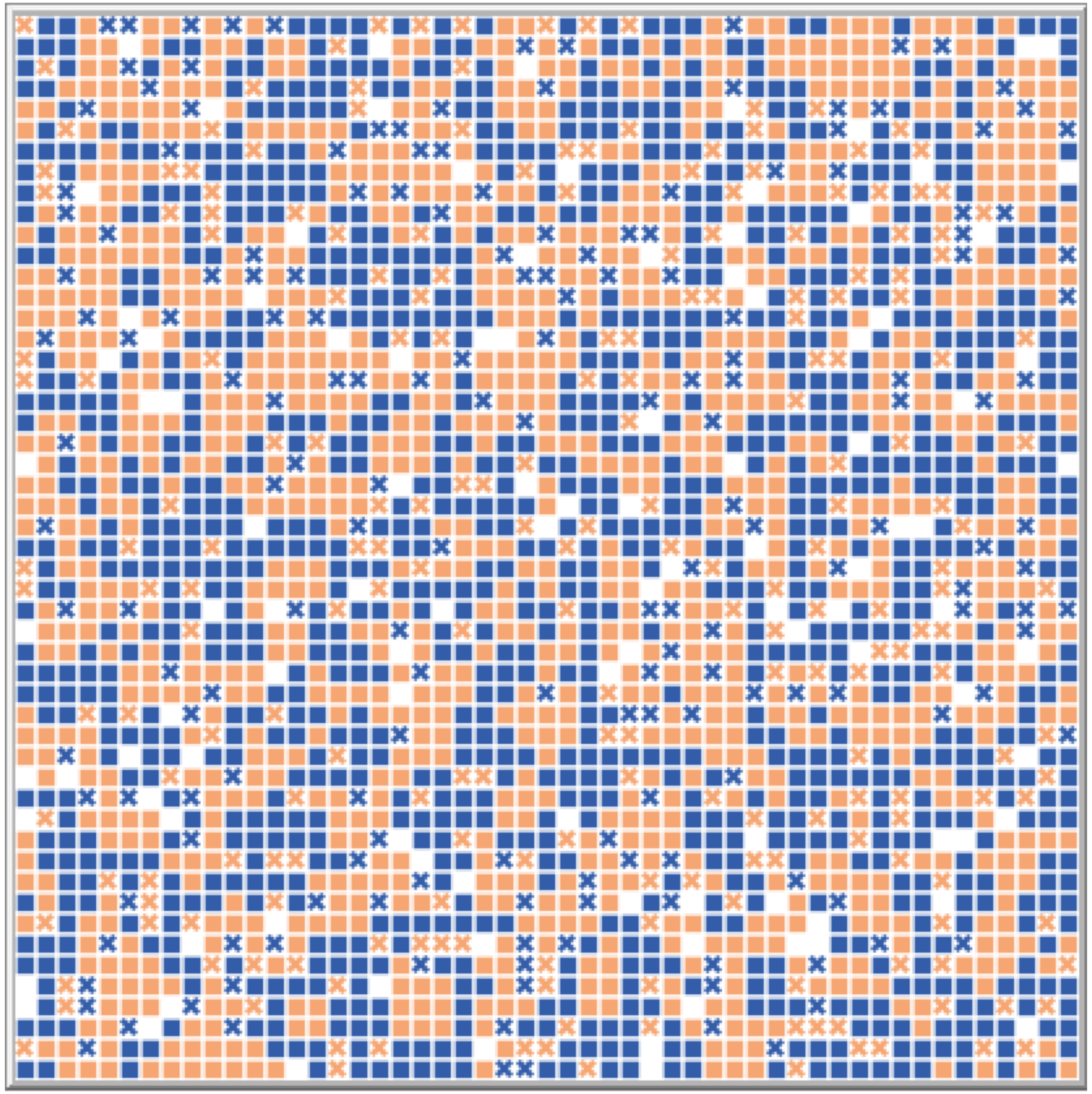
Segregation model

- Models the behavior of two types of agents in a neighbourhood.
- The orange agents and blue agents get along with one another. But each agent wants to make sure that it lives near some of "its own." That is, each orange agent wants to live near at least some orange agents, and each blue agent wants to live near at least some blue agents.
- The simulation shows how these individual preferences ripple through the neighbourhood, leading to large-scale patterns.

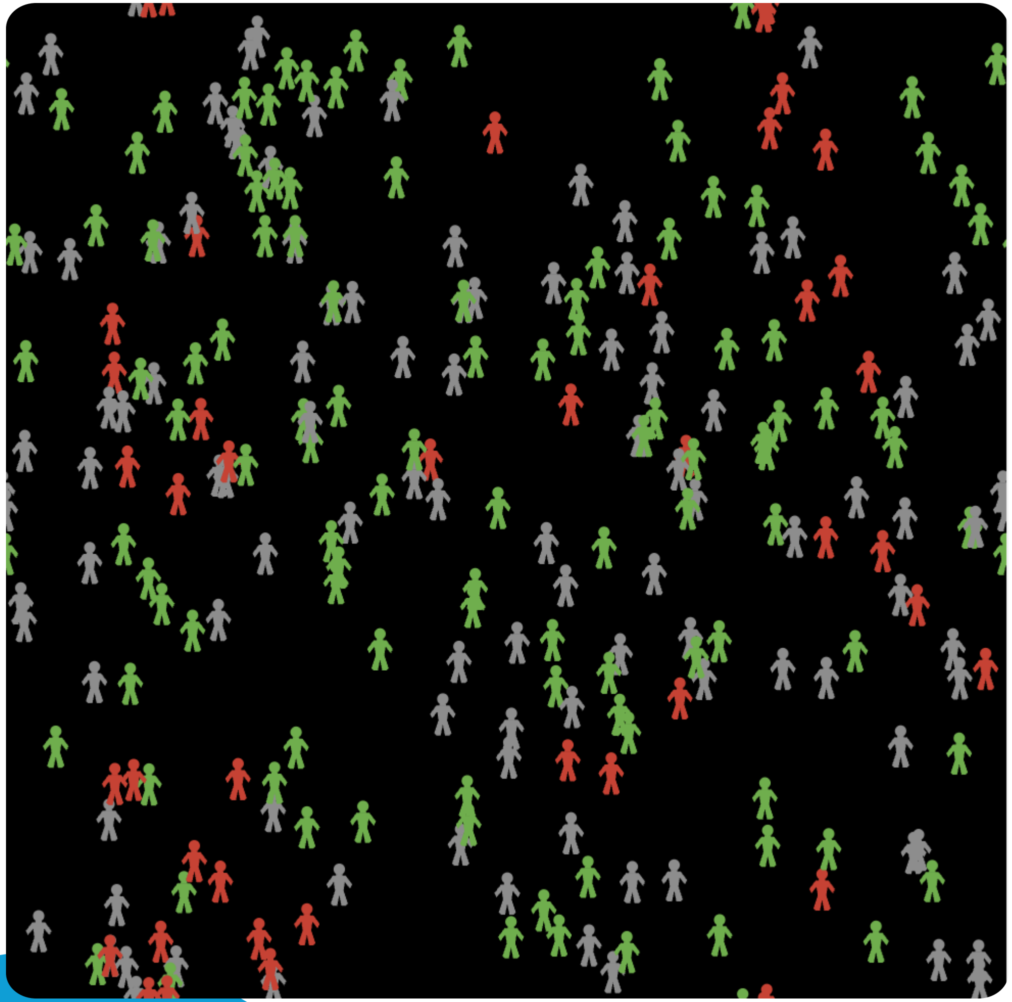


Segregation model

- NetLogo Web: https://tinyurl.com/2fjnft24
- NetLogo Desktop: File > Models Library > Sample Models > Social Science > Segregation



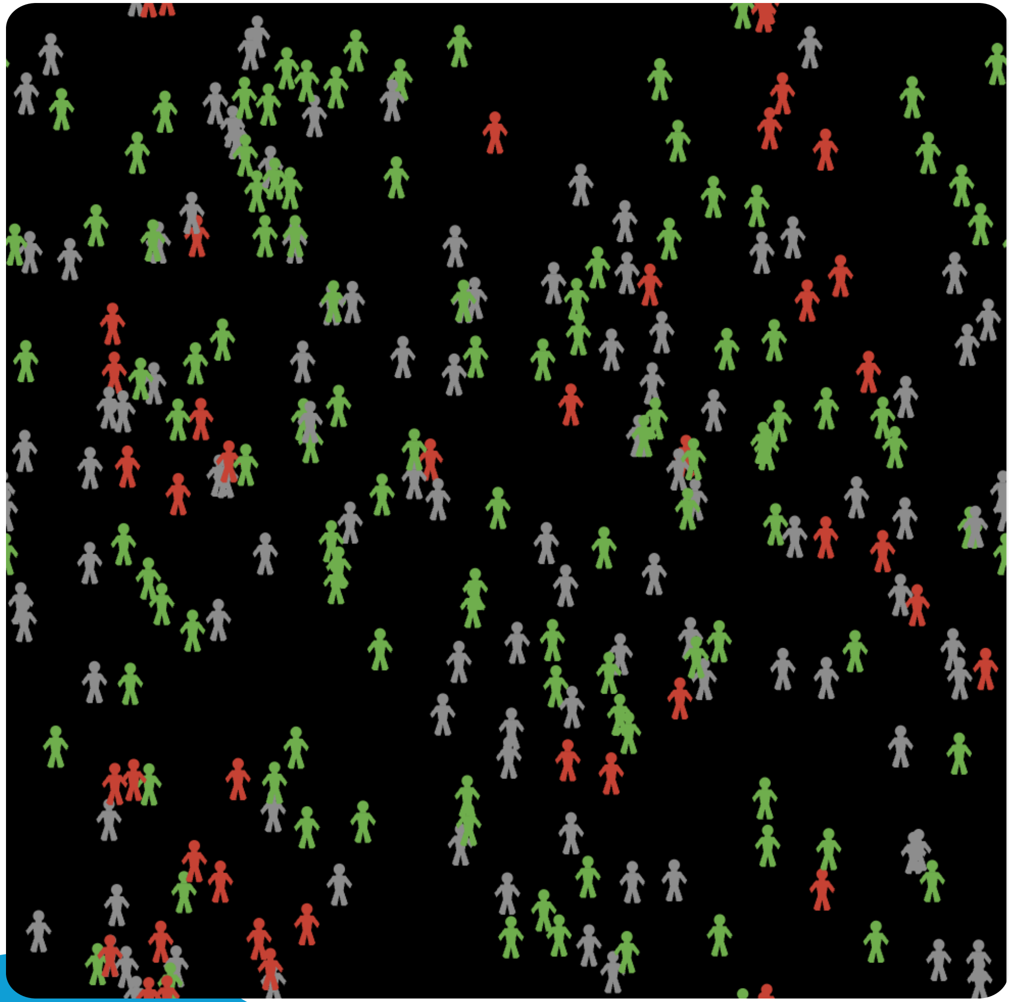
Hands on NetLogo



Now it's your turn!

Virus model

- NetLogo Web: https://tinyurl.com/54jrwcky
- NetLogo Desktop: File > Models Library > Sample Models > Biology > Virus



Virus model

Explore basic understanding

- What do the colours of the agents represent (green, red, blue)?
- What does each parameter (e.g. infectiousness, chance-recover) control?
- What happens if you run the model with infectiousness = 0 or chance-recover = 100?

Explore epidemic dynamics

- How do different parameters affect outcomes?
- How does changing infectiousness affect how fast the disease spreads?
- What happens to the peak number of infected individuals when chance-recover increases?
- Is there a threshold value of infectiousness where the disease starts to spread rapidly? (hint: epidemic threshold)
- Try running the model several times with the same settings — do you always get the same result? Why?

Using data to inform agent-based models

What is the purpose of data in ABMs?

- Ground the model in real-world context
- Parameterize agent behavior (infection, recovery, mobility)
- Calibrate and validate model outcomes
- Explore realistic policy or intervention scenarios

Common data sources used

Type of Data	Example Use in ABMs	Example Dataset
Demographic data	Define population (age, sex, household structure)	Census data
Behavioural data	How often people interact / move	Surveys, mobility data
Epidemiological data	Infection, recovery, immunity rates	Public health databases (e.g., WHO, CDC)
Spatial/geographic data	Map of movement and clustering	GIS datasets
Social network data	Who interacts with whom	Contact tracing or social network studies

Calibration

What if it is not possible to determine the value for one or more parameters?

Or the values obtained are not all about the location of interest?

Calibration: special type of parametrization through which we estimate the value of parameters, observing which values make the model to reproduce the real-world patterns

But how to seek for the most adequate set of calibrated parameter values?

Optimization – BehaviourSearch (https://behaviorsearch.org/index.html)

Railsback S, Grimm V. Agent-based and individual-based modeling: a practical introduction 2019.

Pattern-oriented modelling

Use of multiple patterns observed in the real system as information to make the ABM more structurally realistic

Steps:

1. Identify the set of real-world patterns to use as comparators
   - One or multiple
   - Qualitative or quantitative
2. Define criteria to check whether simulated and real-world patterns match
3. Refine model formulation (if necessary)

Railsback S, Grimm V. Agent-based and individual-based modeling: a practical introduction 2019.

How to use output data from agent-based models?

3 main uses

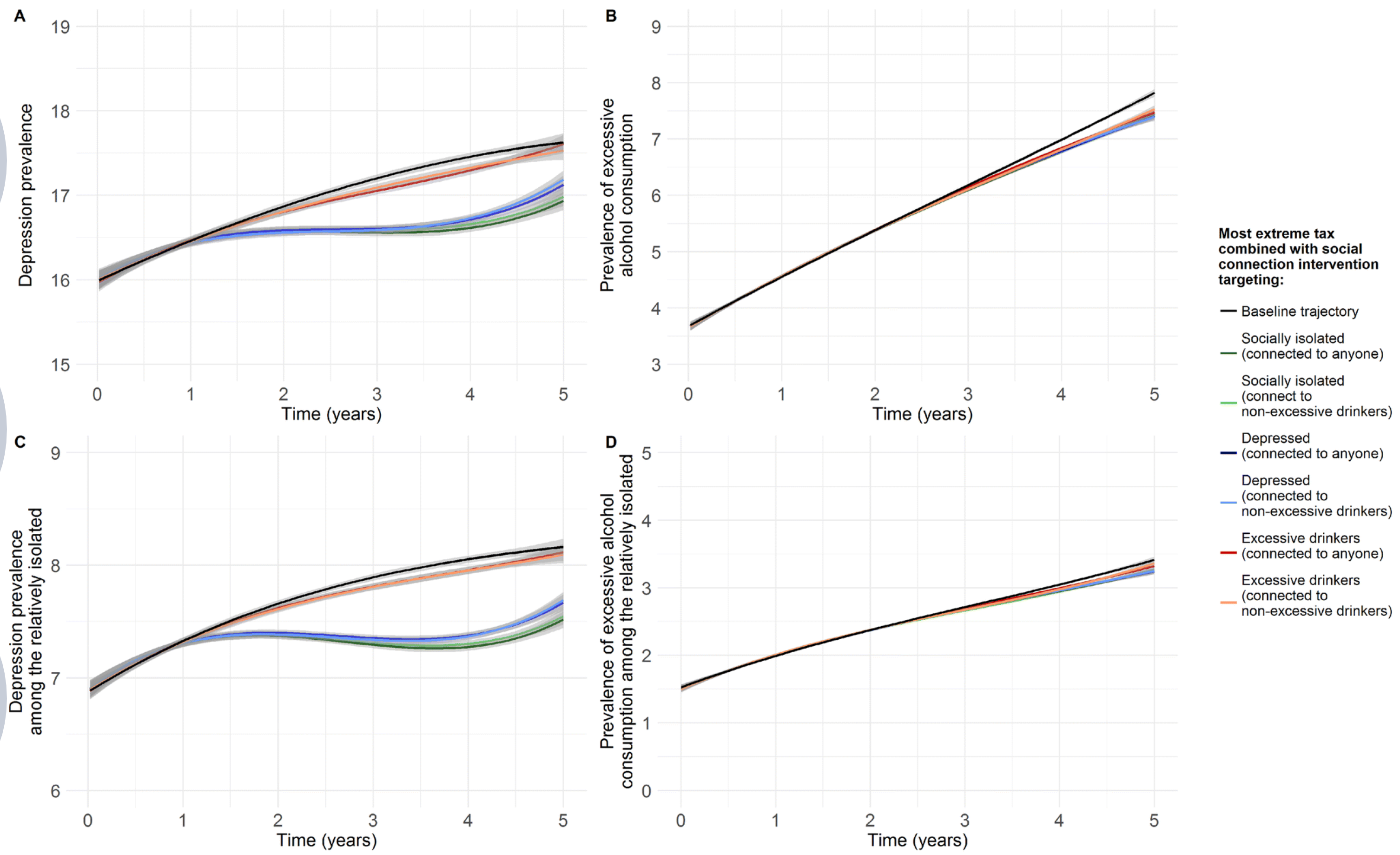
1. Learn about the (conceptual) model
2. Learn about the system of interest
3. Investigate the potential impacts of public health interventions

Stankov I et al. Depression and alcohol misuse among older adults: exploring mechanisms and policy impacts using agent-based modelling. Soc Psychiatry Psychiatr Epidemiol. 2019;54(10):1243-53.

Modelled process: Older adults making decisions about alcohol consumption

- Used to explore the social, environmental, and policy mechanisms that may underpin the relation between depression and alcohol misuse

- Older adults' attributes included income, social ties, likelihood of alcohol misuse, and predisposition towards developing depression. Environment included alcohol outlet density and cohabitant's excessive alcohol consumption status

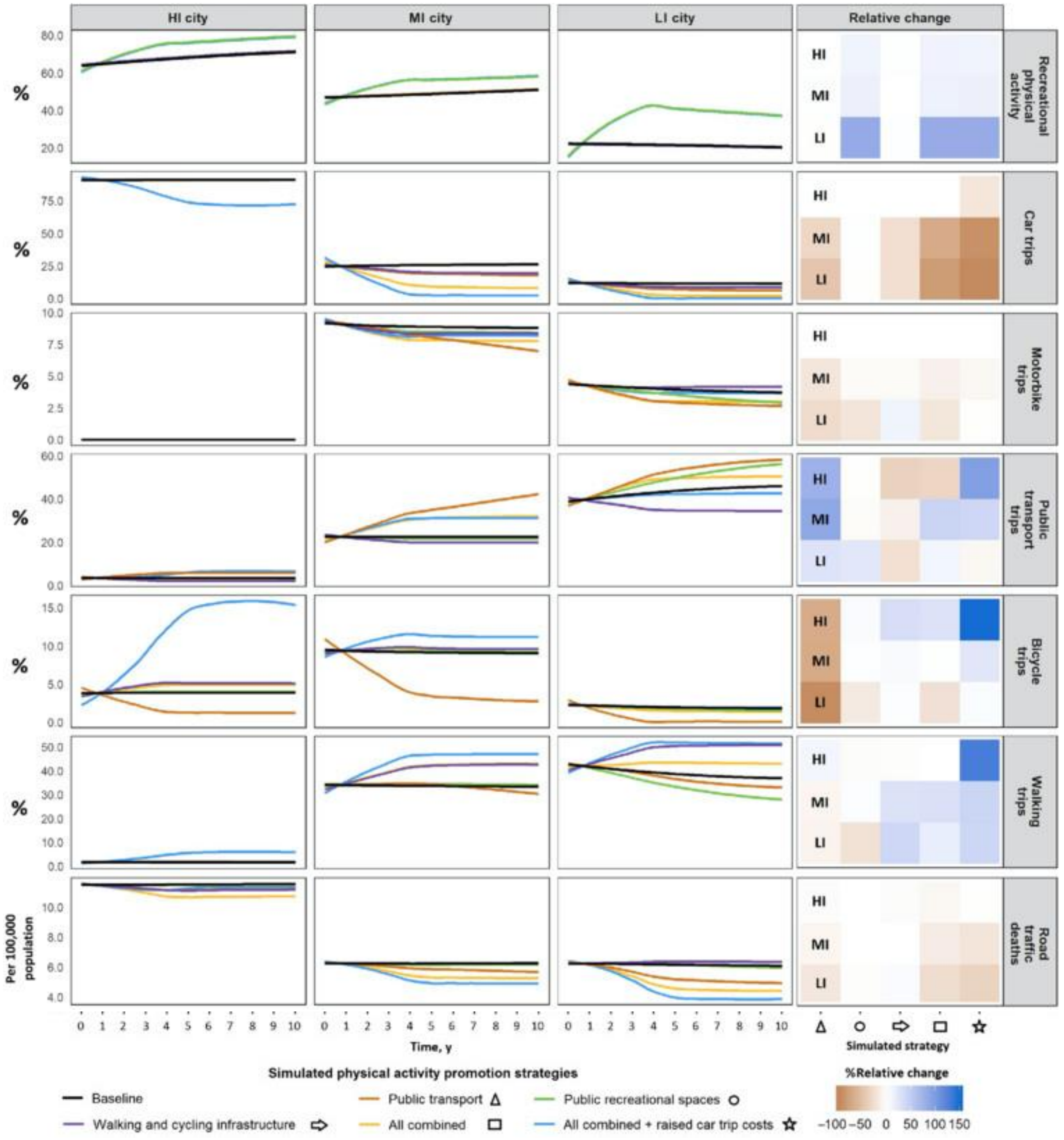


Salvo D et al. Physical activity promotion and the United Nations Sustainable Development Goals: building synergies to maximize impact. J Phys Act Health. 2021;18(10):1163-80.

Modelled process: Adults making decisions about their recreational physical activity and active travel behaviour

- Used to explore how physical activity promotion strategies can impact SDG indicators

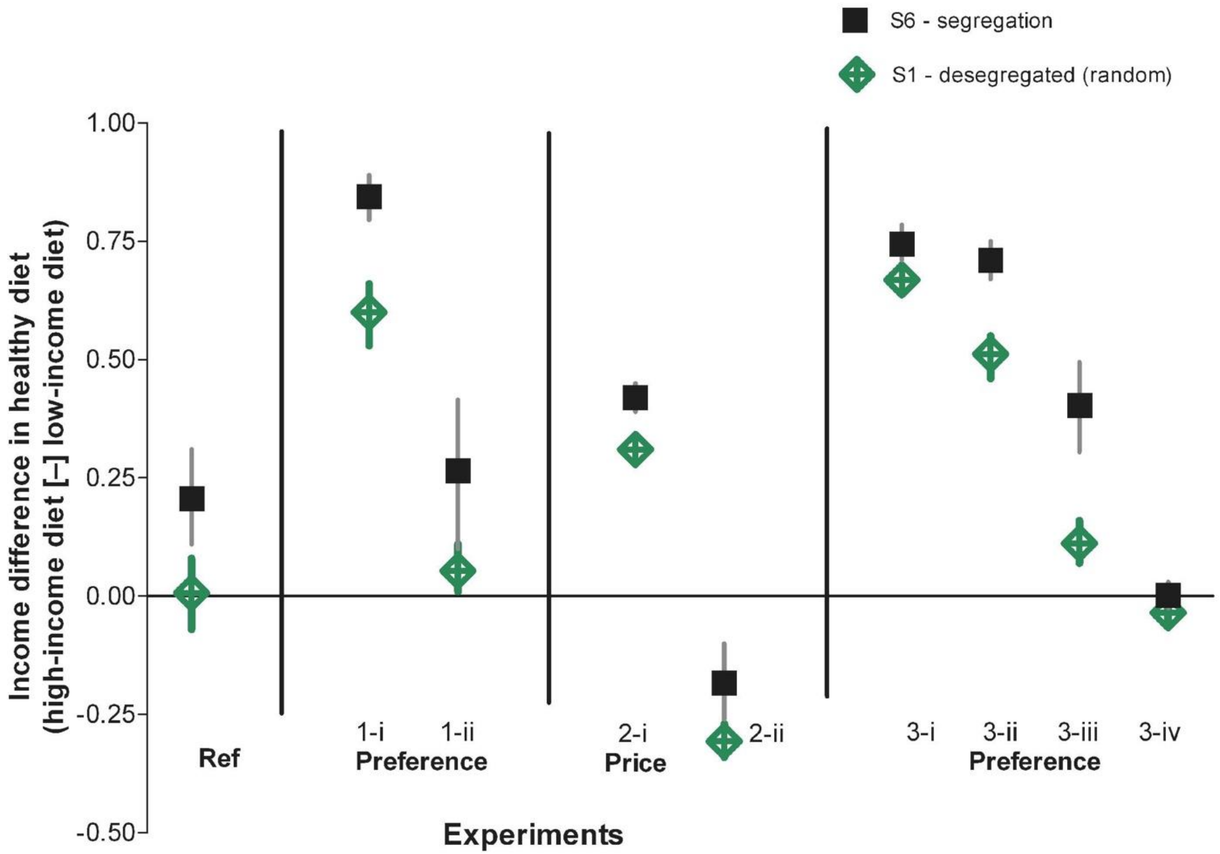
- Adults' attributes included intention to perform recreational physical activity, preferred mode of transport, number of trips per week, social ties, and perceptions about the environment. Built environment included spaces for physical activity, transport infrastructure and places to visit



Auchincloss AH et al. An agent-based model of income inequalities in diet in the context of residential segregation. Am J Prev Med. 2011;40(3):303-11.

Modelled process: Households making decisions about healthy food consumption

- Used to explore how urban segregation patterns generate income disparities in diet
- Two types of agents: households and food stores. Households' income, distance to stores, and food preferences would define which stores they visit. Stores seek to increase the number of customers by moving location or changing the type of food they sell



Ref, The referent experiment, index scenario 6 (S6 from Figure 1). No income differences in preference or prices; healthy food preference and price of food are randomly assigned.

1-i High income prefers healthy food, low income prefers unhealthy food
1-ii High income prefers healthy food, low income prefers healthy food

2-i Healthy food stores are expensive; unhealthy food stores cheap
2-ii Healthy food stores are cheap; unhealthy food stores expensive

3-i High income prefers (expensive) healthy food, low income prefers (cheap) unhealthy food
3-ii High income prefers (expensive) healthy food, low income prefers (expensive) healthy food
3-iii High income prefers (cheap) healthy food, low income prefers (expensive) unhealthy food
3-iv High income prefers (cheap) healthy food, low income prefers (cheap) healthy food

Session 2 training objectives (review)

1. To understand how to design and develop an agent-based model.

2. To understand how data from agent-based models can be analysed.

Short feedback survey

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WHO Collaborating Centre for Research and Training on Complex Systems and Network Science for NCDs

A WHO Collaborating Centre to build capacity in systems science skills, and to formulate innovate ways to address NCDs.

[Host LinkedIn page]

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Join us for a series of online short courses designed to build skills in a range of systems thinking methods for NCD prevention and control. Further details and registration links will be advertised 6 weeks in advance of the training sessions.

Introduction to Systems Dynamics Modelling:
Wednesday 15 & 22 October 2025 10:30 – 12:30 (BST)

Introduction to Agent-based Modelling:
Wednesday 5 & 12 November 2025 10:30 – 12:30 (GMT)

Introduction to Soft Systems Modelling:
Wednesday 21 & 28 January 2026 10:30 – 12:30 (GMT)

Introduction to Viable Systems Modelling:
Wednesday 18 & 25 February 2026 10:30 – 12:30 (GMT)

Introduction to Systems Maps and Causal Loop Diagrams:
Wednesday 25 March & Wed 1 April 2026 10:30 – 12:30 (GMT)

Introduction to Stakeholder Network Analysis:
Wednesday 22 & 29 April 2026 10:30 – 12:30 (BST)

SCAN ME

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Further information

https://www.qub.ac.uk/sites/who/

Thank you!

For any questions, contact whocc@qub.ac.uk.

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