General Comments

Can you make all models so that you need to hit start and they don't run automatically – I found it a bit intimidating opening the page and watching it run before I understood what I was looking at.

I quite like what you did with the Bhar and Gorman models, giving a couple of things to try with the settings and explaining what people will see. Could you add this for some of the others as well? Might work well if you split 'how does the model work' into 'what are the key components' and 'how does the model work' for each, and add some stuff to try in how it works?

My preference is for the drop down text next to the model, but happy with either format – whatever is easiest for you.

Do we have more text for the Gorman model somewhere for when you redo the model in Java? I think we had it drafted somewhere already?

Brief [introductory guide to agent-based modeling and an illustration from urban health research]

Model notes:

- Food preference
- Unsegregated
- Mouse

Is it possible to show the key as well as the shop id information?

What are low / high customers? Add income? Change high/low-end to high/low-cost foods.

Is it possible to add some headings above the sliders/radio buttons to say what these are?

Why is this a good example?

This is an excellent example of using an agent-based model (ABM) to ask "what if" questiona about aspects of individual behaviour that would be very difficult to replicate within a real population. In this case the positioning of different types of food outlets within neighbourhoods.

This is a model of the inequalities in diet in the context of urban residential segregation. Auchincloss and Garcia use this model as an example of how to create an ABM to address complex non-communicable disease(NCD) problems. The model is used as an introductory guide to the philosophy and practices of ABMs and is used to illustrate why ABMs are a good fit for investigating NCD prevention. The paper describes very clearly how to take descriptions of individual behaviour and incorporate them into an ABM framework and run "what if " experiments with the model.

What is the NCD prevention challenge being addressed?

This model investigates the inequalities in diet in the context of urban residential segregation

One of the contributory factors to obesity and obesity-related health conditions and illness is the high consumption of nutrient-poor energy-dense foods. Numerous population studies have shown that there is a higher prevalence of nutrient-poor energy-dense foods in the diets of lower income families compared with higher income families. One of the contributing factors to this difference in diet quality is access to healthy food outlets. It has long been recognised that urban landscapes are influenced by residential segregation based on both economic and ethnic factors and that there is a marked difference in resources and services between these areas. (See the model by Thomas Schelling included in this series for an ABM of segregation). Lower income neighbourhoods usually have far fewer outlets that provide healthy foods compared to higher income neighbourhoods. Auchincloss and Garcia's model looks at the role of economic segregation on food outlet distribution and looks at possible "policy levers" that may be used to counteract this.

How is ABM suited to address this challenge?

As is demonstrated by the Schelling model segregation and an individual's response to it is a function of the spatial location of populations. The nature of the spatial location of the individuals is governed by local factors and tends to be heterogeneous. By that we mean that the spatial pattern of the population tends not to a smooth gradation but tends to be a more patchy pattern. This type of spatial distribution is very hard to be incorporated in traditional mathematical or statistical models but is very easy to implement with an Agent Based Model (ABM). In this model we are mainly looking at the decisions that outlets make on their location, and food and price. The rule based nature of ABMs makes construction of a shop based model both simpler and transparent.

What are the key components of the model?

Here we present a simplified version of Auchinclosss model that concentrates on just the effect that segregation has on the success and type of food outlets within a neighbourhood.

The model has two entities, people and shops. Each person is represented as an arrowhead. The colour of the arrowhead indicates their economic status: high income is blue;low income is red. Each person has a home. This is a square of the same colour. The homes are presented as a grid. People go to shops to buy food. The shops also occupy the same grid and are represented as circles. The shops are of one of four types: High-cost convenience food ●, Low-cost convenience food ●, High cost healthy food ●, Low cost healthy food ●.

Each person chooses a shop to go to. They choose the shop based on sensitivity to three factors: 1) price; 2)the distance they have to travel; 3) individual preference for healthy food. When a person has chosen a shop they move to that shop. The proportion of each economic status at each shop is indicated by the size of the solid colour surrounding the shop circle. The exact information on the type of food sold and number of customers with high or low income for each shop can be accessed by clicking your mouse on the shop circle.

Each economic class has different underlying preferences. For example, it is assumed that distance from shops has less influence for high income people. The overall effect of each of the three factors can be altered.

The model simulates the effect of economic segregation. This is done by either randomly allocating a home (select unsegregated model) or placing each economic group in a separate half of the grid (select segregated model).

How does the model work?

The model will run automatically when the page is opened. The overall effect of each of the three factors influencing an individual's preference for a specific type of shop (price, distance, food preference) can be altered with the sliders on the right of the display. The type of population distribution (segregated or unsegregated) can be chosen from the radio buttons. The model can be restarted with the new values using the reset button. The customers visiting each shop can be seen within the shop circle. More detailed information on shop type and the number of customers can be seen by clicking on a shop circle.

Alter the three factors influencing individual's shopping preferences and the segregation to see the effect it has on which shops are successful and what type of customers they attract.

This is a simplified version of the model constructed by Auchincloss [1]. In the paper you read about how ABMs can be applied to complex social systems, and see how they constructed their more complex model and how it compares to this simplified example.

What are the implications of these findings for policy or practice?
In a follow-up paper in which Auchincloss's uses this model of residential segregation to look at the impact of income inequalities on diet in more detail, [2] the author concludes: "*The model underscores the challenges of fostering favorable behavior change when people and resources are residentially segregated and behaviors are motivated or constrained by multiple factors. Simulation modeling can be a useful tool for proposing and testing policies or interventions that will ultimately be implemented in a complex system where the consequences of multidimensional interactions are difficult to predict.*"

[1]Auchincloss, Amy H., and Leandro Martin Totaro Garcia. "Brief introductory guide to agent-based modeling and an illustration from urban health research." Cadernos de saude publica 31 (2015): 65-78.

[2]Auchincloss, Amy H., et al. "An agent-based model of income inequalities in diet in the context of residential segregation." American journal of preventive medicine 40.3 (2011): 303-311.

Schelling Segregation Model

Why is this a good example?

Schelling's segregation model can be said to be the first sociology agent-based model (ABM). Schelling took the complex social behaviour of racial segregation and asked whether this behaviour could be captured in a model by using some simple rules. What makes the model exceptional are the range and types of behaviours that this simple model exhibits. These types of behaviours are known as emergent behaviours (i.e., population level patterns of behaviour that can’t be predicted by looking the behaviour of each individual seperately) and this is one of the first models of its type to exhibit this. Many sociological ABMs can trace their lineage back to this model. If you are interested in ABMs for simulating non-communicable disease (NCD) is well worth your while getting to know Schelling's segregation model first.

What is the NCD prevention challenge being addressed?

Schelling's segregation model does not directly address a NCD but social segregation does play a part in a number of NCD issues. For example, take a look at the Auchincloss model example that investigates inequalities in diet in the context of urban residential segregation.

How is ABM suited to address this challenge?

What sets ABMsapart from other modelling methods is population-level behaviour patterns emerging from rules that apply across the whole model but are enacted by individuals based on local information. In this case we are looking at individuals' choice of home based on just the racial makeup of their very local neighbourhood. The model asks the simple question of what happens to the global level of segregation if individuals make their housing choice based on how many people are like them in the local neighbourhood. ABMs can model systems and ask questions of systems like these because ABMs model each of the different individuals that make up the population.

How does the model work?

This is a very simple model. In this version of the model the world is divided into a 40 by 40 grid. Each cell of the grid can either be empty or be occupied by a blue agent or a red agent. Each agent represents a person. Each agent’s neighbourhood consists of the adjacent 8 cells on the grid. At each iteration every agent counts the number of agents in the adjacent 8 other cells on the grid and notes the percentage that are the same colour as themselves. If that percentage is less than globally set level (the person’s preference to live next to people who are similar to themselves) then the agent randomly picks an empty cell and moves there.

These are the only rules, and are so simple that Schelling originally did the first models by hand using a paper grid. In the version of the model here the total number of agents in the model is set with the population density slider. The global acceptance value is set with the alike slider. You can change these values and re-run the model with the reset button. Run the model with differing levels of global acceptance. Not how the behaviour changes around 30%.

This is such an important model that along with this web-based javascript version we have added links to a NetLogo and a Python version.

What are the implications of these findings for policy or practice?

This model demonstrates the effect of local individual decisions on global measurable attributes, like the segregation of a community. These global patterns of behaviour are not immediately obvious from just analysing an individual's behaviour in isolation, and demonstrate the importance of looking at how policies that aim to change to individual behaviours may influence global patterns, including both positive effects or potentially unintended harms.

[1] Schelling, T. 1971. "Dynamic Models of Segregation." Journal of Mathematical Sociology 1:143-86.

Netlogo version of the Schelling Segregation Model

Python (Google colab) version of the Schelling Segregation Model

The dissemination of culture

Axelrod, Robert. "The dissemination of culture: A model with local convergence and global polarization." Journal of conflict resolution 41.2 (1997): 203-226.

Why is this a good example?

Like Schelling (see Schelling segrataion model example), Axelrod is a pioneer in the use of agent-based models (ABM) in social sciences. The Axelrod model looks at the influence of a person's social network on the behaviour of an individual agent (person). In this model each agent's ideas or culture can change depending on the influences from it's neighbours or "social networks". Like the Shelling model, the Axelrod model is a theoretical model that illuminates the emergent complex behaviours of social networks.

What is the NCD prevention challenge being addressed?

This model does not directly address a non-communicable disease (NCD) challenge, but provides a basis for understanding more complex models of behaviour. As illustrated in our other examples based on the Bhar model (social influence on eating) and the Gorman model (social influence on drinking) understanding how people's behaviours are influenced by their social networks is key to many NCDs.

How is ABM suited to address this challenge?

What sets ABMs apart from other modelling methods is global behaviour emerging from rules that apply across the whole model but are enacted by individuals based on who they are linked to, their social network. Influence flows across the network altering each agent's culture in an iterative manner to produce both local and global consensus. This dynamic spatially heterogeneous behaviour of the global culture would be very hard to model with other methodologies.

How does the model work?

The Axelrod model is a model of social influence where a person becomes more like a person they are linked to. It models the social convergence of culture.

Each agent, or person, is static in its own cell within a two dimensional matrix. Each agent has four neighbours/contacts within their social network: those directly above, below, to the left and right of the agent within the grid matrix. Note that an agent does not share any other contacts with each of its four contacts.

Each agent's culture is represented as a set of 5 features. Each feature is described by a trait, that is a single value between XX and XX.. An agent's similarity to any of its contacts is measured by how many features that each has that have the same trait. For example if agent A has a feature set [5,2,7,4,6] and the agent it contacts above it has the feature set [2,8,7,7,3] then the two agents share the same trait at feature 3 (both are trait 7) so have a similarity of ⅕ or 20%.

An agent will influence another agent in direct proportion to their similarity. When one agent does influence the other a random feature is chosen and the traits of both the agents for that feature are made equal. So for agent A and agent B above there is a 20% chance they will interact. A's feature set will change from [5,2,7,4,6] to [5,2,7,7,6], a change in feature 2 to match the trait of its neighbour (both now trait 7). Note that there is now a 40% similarity.

In this simulation the different sets of features are represented by a single colour. Similar feature sets have similar colours. Over a number of iterations the random patchwork of colours converges on blocks of similar colours as groups of agents converge on similar cultures.

What is interesting is to see what effect changing the population size the number of iterations and the number of features has on the spatial heterogeneity. This can be done by moving the sliders on the right of the model and re-running the model with the "Reset" button. The patterns formed by the model can be quite mesmeric.

What are the implications of these findings for policy or practice?

Two interesting outcomes from the model are: the move to a common culture in smaller populations and the occurrence of lockout groups when the number of features that constitute a culture are small. While this is only a simple theoretical model it does highlight some possible obstacles that may occur in both addressing diversity and in changing mindsets.

[1] Axelrod, Robert. "The dissemination of culture: A model with local convergence and global polarization." Journal of conflict resolution 41.2 (1997): 203-226.

Infections on a "Small World" Model

Watts, Duncan J., and Steven H. Strogatz. "Collective dynamics of ‘small-world’networks." nature 393.6684 (1998): 440-442.

Why is this a good example?

One of the other modelling methods in complex systems science is network models. Two of the pioneers of modern network modelling were Duncan Watts and Steven Strogatz. Among their contributions to modelling was the small world network. This model gives one possible explanation for the famous six degrees of separation. In the 1960’s the social psychologist Stanley Milgram tried to get letters sent to random people in the USA by people passing on the letter to people they personally knew who may be closer to the target then they were. The results showed that on average it took just six intermediate people to pass on the letter. If our connections to other people were just random then the number of intermediates required for people to pass on the letter would be much higher. Watts and Strogatz small world model posited that connections are locally made but with the occasional link to someone more distant would account for the behaviour seen by Milgram. The connections between agents (people) are important to understanding emergent social behaviour. We have all recently experienced this with the spread of COVID19. In this demonstration we use a simple agent-based model (ABM) combined with the small world model to show the effect of long distance links to the spread of an infectious disease.

What is the NCD prevention challenge being addressed?

The same model that can be used to model disease spread can be applied to the spread of influence. This is seen in our example of the Bhar model of the social influence on diet: the behaviour presented at the population level is dependent on the nature of the interactions at the individual level. Networks are found throughout nature and society. Despite their apparent random appearance network theory can be applied to these networks to identify common patterns and behaviours. Using network theory, artificial networks of social interactions can be constructed that have the same important characteristics of real social networks. These artificial networks can then be used in models with the assurance that they will behave in the same way as real social networks found in society

How is ABM suited to address this challenge?

As previously stated network models are another modelling type used in complex systems science. Adding an ABM to a network model makes it easier to incorporate geographical position and allows individual agent’s (people’s) behaviour rules to be included in the model. This is particularly important when modelling emergent social behaviour.

How does the model work?

Each agent can be in one of three states: susceptible to disease (green ●), infectious(red ●) ,recovered and not susceptible (orange ●) Each agent is connected to eight other agents, the members of its social network. Initially each agent is linked to its eight immediate neighbours on the grid. A random agent is chosen to develop the disease and it then potentially infects the other agents it is linked to with a given probability. This is the now famous “R” number. The agent remains ill and infectious for a set number of days at which point it recovers. In this state the agent will not catch the disease again. This recovered state lasts for a set time. At the end of that time the agent is then susceptible again.

When the model has only local links the disease spreads as a single wave across the population. Most of the time there is only a single wave. You can alter this behaviour by creating a “small world”. Here you add links between random agents with the links slider. The number on the links slider represents the probability that a single local link will be replaced by a random link to another part of the grid. These links are shown as a blue line. When the model is reset using the reset button you will see that the disease now has multiple spatial and temporal waves.

What are the implications of these findings for policy or practice?

The influence of social networks has been seen in a number of models focussed on NCD prevention, For example, in the Framingham heart study the relationships described by Christakis and Fowler are friends, family and coworkers and an individual propensity to obesity is seen to be influenced by the nature of these connections. This is also seen in our Bhar diet model example. Investigators such as Giabbanelli and Shi have also used this knowledge of networks to test out different intervention strategies targeting the most connected individuals.

Christakis, Nicholas A., and James H. Fowler. "The spread of obesity in a large social network over 32 years." New England journal of medicine 357.4 (2007): 370-379

Giabbanelli, Philippe J., et al. "Modeling the influence of social networks and environment on energy balance and obesity." Journal of Computational Science 3.1-2 (2012): 17-27.

Shi, Liuyan, Liang Zhang, and Yun Lu. "Evaluating social network-based weight loss interventions in Chinese population: An agent-based simulation."Plos one 15.8 (2020): e0236716.

Watts, Duncan J., and Steven H. Strogatz. "Collective dynamics of ‘small-world’networks." nature 393.6684 (1998): 440-442.