This model is used as an illustration in the book

Gilbert, Nigel (2019). *Agent-Based Models (Quantitative Applications in the Social Sciences)*. 2nd edition. Thousand Oakes, London, Delhi, Singapore: Sage Publications, Inc.

and the book provides more information and context. See also the 'Info' tab of the NetLogo model.

The research topic

Several related social phenomena are difficult to model, or even to describe, because their boundaries are fluid, the people involved are constantly changing, and there is no single characteristic shared by all those involved. Examples include the following:

- Youth subcultures such as punks (Widdicombe & Wooffitt, 1990) or goths (Hodkinson, 2002)
- Scientific research areas or specialties such as astrobiology (Gilbert, 1997)
- Art movements such as the pre-Raphaelites or the vorticists (Mulkay & Turner, 1971)
- Neighborhoods such as Notting Hill in London or the Bronx in New York (van Ham, Manley, Bailey, Simpson, & Maclennan, 2012)
- Members of armed revolutionary or terrorist movements such as the Red Brigades in Germany (Goolsby, 2006)
- Industrial sectors such as biotechnology (Gilbert et al., 2014)

Although one can easily point to familiar examples, and although they are very common and easily identified, it is difficult to put one's intuitions about them on a firmer footing. For a start, there is no commonly accepted word with which to name the phenomenon. The terms "subculture," "area," "neighborhood," "specialty," and "movement" are used for particular types, but none of these terms is appropriate for describing all of them. A closely related concept is the term "figuration" (Elias, 1939), although strictly speaking this should be applied only to individuals, and not to organizations or other types of actors. In this section we use "collectivity" as the generic term, for lack of a better one. Note that the units making up the collectivity may be people (as in most of the examples above) or organizations (e.g., biotechnology firms).

A second barrier to gaining a better understanding of collectivities is that, by definition, there is no definite boundary around them. This means that it is impossible to count their members and therefore to engage in the more common kinds of quantitative analysis of their development over time, their incidence, and so on.

Third, the way in which collectivities arise from the actions of their members is not easily understood. It is the purpose of the model to be developed here to suggest how some plausible assumptions about individual action (micro foundations) could yield the collectivities that are observable at a macro level. The research question is, therefore, is it possible to generate collectivities from the individual actions of agents, given just these assumptions.

Macrolevel Features and Patterns

In all collectivities, the following seem to hold, to a greater or lesser extent:

- Although instances of collectivities are usually easily named and described at the aggregate level, precise definitions can prove to be rather slippery and open to negotiation or argument (e.g., there are many slightly different areas that can be described as Notting Hill, from the official local government area to the locality within which the film of the same name was shot).
- There is no accepted consensual definition that can be used to sort those who are in from those who are out (or members from nonmembers). For example, whereas some might think that someone is a punk because of the way that he or she dresses, this assignment might be contested by others (including the person him- or herself) by pointing to the person's beliefs, behavior, or acquaintances, all of which could alternatively be relevant to decide on membership. In particular, there is no one observable feature that all those who are in and none of those who are out possess. Collectivities are not, for example, formal organizations, where being an employee with a written or verbal contract distinguishes those who are members from those who are not; political parties, where, at a minimum, a formal declaration of support is required and defines membership; or social classes, where externally specified objective criteria are used to sort people (typically based on one's occupation).

- Nevertheless, many of the members will share characteristics in common (e.g., the scientists in a research area may have similar educations, have carried out similar previous research, and be known to each other, even if there is no technique, theory, or object of research with which all of those without exception in the research area are involved).
- Membership of the collectivity entails possessing some related knowledge (e.g., the science of the specialty, or whatever is accepted as cool in a youth culture, or the local geography of Notting Hill). However, no member possesses all the knowledge: Knowledge is socially distributed.
- The features that are thought to be relevant to the collectivity change. For example, researchers do not continue to work on the same problems indefinitely; once they have solved some, they move on to new ones, but still within the same research area. Most political movements change their manifestos over time to reflect their current thinking and the social problems that they observe, although they remain the same movements, with many of the same adherents. Youth cultures are constantly changing the items that are in fashion.
- Some of the people involved are widely considered (e.g., by the others) as being more central, more influential, of greater status, or as leaders compared with others. For example, some scientists are considered to be more eminent than others, some members of subcultures are cooler than the rest, and so on. (Compare the idea of optimal distinctiveness in social psychology [Brewer, 1991].)

Microlevel Behavior

One of the features common to collectivities is that the actors (i.e., the people or organizations that make up the collectivity) have some special knowledge or belief. For example, scientists have knowledge about their research area, and youth subcultures have knowledge about what is currently fashionable. Even though this knowledge is socially distributed among the members of the collectivity so that not every member has the same knowledge, possession of it is often a major feature of the collectivity (Bourdieu, 1986). In the model, we assume that all individuals, both members and nonmembers, have some knowledge, but what this knowledge is varies both among actors and over time. We use this knowledge to locate the actors: The position of

the actor at a moment in time in an abstract knowledge space represents the knowledge that he or she possesses at that time.

A second assumption is that some actors are of higher status than others and that all actors are motivated to try to gain status by imitating high-status actors (by copying their knowledge). For example, in a collectivity driven by fashion, all actors will want to be as fashionable as they can, which means adopting the clothing styles, musical tastes, or whatever of those whom they perceive to be of the highest status (Simmel, 1907). However, status is also a function of rarity: An actor cannot remain of high status if there are many other actors with very similar knowledge. For example, a fashion icon must always be ahead of the hoi polloi; a scientist will be heavily cited only if his or her research is distinctive; a revolutionary will earn the respect of colleagues only if he or she stands out in comparison with the foot soldiers.

Third, we assume that actors with the highest status want to preserve this status, which they cannot do if they start to be crowded out by followers who have been attracted to them. In this situation, we assume that high-status actors are motivated to make innovations—that is, to search out nearby locations in knowledge space where there are not yet crowds.

There are thus two countervailing tendencies for actors—on the one hand, they want to get close to the action; on the other hand, they want to be exclusive and can do so by changing the locations that represent the heights of status. As we will see, working out this tension yields patterns at the macro level that are typical of collectivities.

Designing a Model

Related Models

There are several generic models that deal with similar issues:

1. *Boid models* (Reynolds, 1987) have agents that try to maintain a desired distance away from all other agents and thus appear to move with coordinated motion. Agents have three steering behaviors: separation, to avoid nearby agents; alignment, to move in the same direction as the average of nearby agents; and cohesion, to move toward the average position of nearby agents. The effect is that agents move as if they were a flock of sheep or a school of fish. These models illustrate the effect of having agents carrying

out actions that are in tension: The separation behavior is in tension with the cohesion behavior, for instance. However, there are no notions of seeking status or innovation in these models.

2. *Innovation models* (Watts & Gilbert, 2014a) have agents that can learn and act according to their current knowledge. Agents also exchange knowledge and create new knowledge. However, there is no specific idea of collectivity in these models. The set of agents involved in innovation is predetermined.
3. *The minority game* (Challet, Marsili, & Zhang, 2013) is one example from a large literature. This model, also called the El Farol Bar model, has agents who wish to go to the bar, but only when a minority of the other agents also choose to go there. The agents decide based on their own past experience of the number they previously encountered at the bar. Each agent has several strategies that he or she uses in combination with his or her memory of the outcome of recent trips to the bar to decide whether to visit the bar at the current time step. The strategies are scored according to their success (such as whether the bar is overcrowded when the agent arrives), and unsuccessful strategies are dropped. Over time a dynamic equilibrium can be established, with the number of agents at the bar matching the threshold that agents use to judge that there are too many agents there. This model has some features of the problem addressed here, but there is no representation of a collectivity.

The Model

The collectivities model consists of a surface over which agents are able to move. The surface is a toroid with each point representing one particular body of knowledge or set of beliefs. The agents thus move, not in a representation of physical space, but rather in knowledge space. Although it may be oversimplifying to represent a knowledge space in two dimensions (more exactly, on the surface of a toroid), it makes for easier visualization.

An agent's movement in the knowledge space represents its change in knowledge. Thus, if an agent imitates another agent, it would move toward that agent in the knowledge space, whereas if it innovates and discovers knowledge that other agents do not have, it would move away from other agents into previously empty areas.

Agents are initially distributed at random on the surface. Agents have no memory of their own or other agents' previous positions. Each agent does the following:

1. It counts how many other agents there are in its immediate neighborhood.
2. If the number of agents is above a threshold, the agent turns to the direction opposite to the average direction of travel of other nearby agents and then moves a random distance.
3. If the number of agents is equal to or below the threshold, the agent looks around the locality to find a relatively full area and then moves a random distance from its present location in the direction of the center of that area.

Each agent acts asynchronously, repeating this sequence of actions indefinitely. There are four parameters required by this algorithm (see Figure 1):

1. The radius of the circular area surrounding an agent within which the number of agents is counted to determine whether the agent is crowded or lonely (*local-radius*).
2. The threshold number of agents below which the agent is lonely and above which the agent is crowded (*threshold*).
3. The radius of the circular area surrounding an agent in which the agent, if lonely, counts the number of agents to find where there is a maximum or, if crowded, finds the average direction of agent movement in order to determine the direction in which it is to move (*visible-radius*).
4. The distance that an agent moves; the distance is chosen randomly from a uniform distribution with this parameter as the maximum (*speed*).

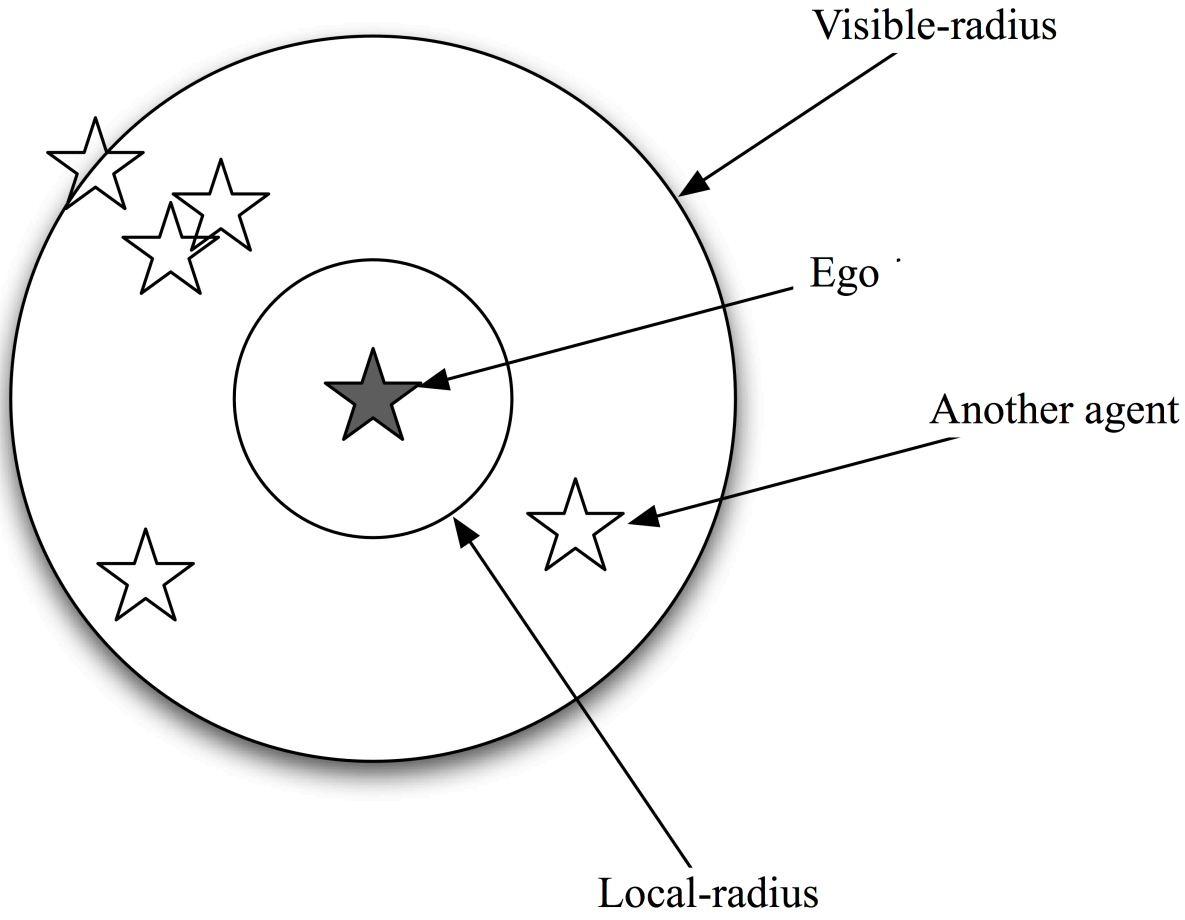

Figure 1 Local-radius and visible-radius in the Collectivities Model

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