Model Description

This is a model description of a replication of the model described in Nowak and Sigmund (1998).
The model description follows the ODD protocol for describing individual- and agent-based models (Grimm et al. 2006) and consists of seven elements. The first three elements provide an overview, the fourth element explains general concepts underlying the model's design, and the remaining three elements provide details. Additionally, details of the software implementation are presented.

Purpose
The purpose of the model is to investigate the possibility of the evolution of cooperation due to indirect reciprocity when agents derive information about the past behavior of the opponent in one-shot dilemma games.

State variables and scales
There are n agents. Each agent can be drawn to be the receiver or the donor. A generation consists of m games after which the next generation is determined based on the relative values of the payoff of the agents.

Agents play the following games. A donor needs to decide to donate or not. A donor cooperate if the image score of the recipient is great than or equal to the donor's k value. Cooperation means that the donor pays a cost, c, and the recipient obtains a benefit, b. There is no payoff in the absence of cooperation.

The image scores range from-5 to +5, the strategy (k) values from -5 to +6. The strategy k = -5 represents unconditional cooperators, whereas the strategy k = +6 represents defectors.

Process overview and scheduling
At the beginning of each generation, all players have image score 0. Hence, strategies with $k \leq 0$ are termed 'cooperative', because individuals with these strategies cooperate with individuals that have not had an interaction. In each generation m donor–recipient pairs are chosen; each player has, on average, 2*m/n interactions. The chance that a given player meets the same player again, or that a chain of possible altruistic acts ever leads back to the original donor, is negligibly small. Therefore, direct reciprocity cannot work here.

Design concepts

Emergence. The values of k, when agents will cooperate, will emergence over time.

Fitness. The payoff derived by the agents playing the games.

Prediction. The image score provides information whether the randomly drawn agent will cooperate.

Sensing. Donors sense the image score of the recipients

Interaction. Two agents play one game at the time. Each generation agents with higher payoff values derive more offspring.

Stochasticity. Randomly matching agents to play games.

Initialization
The image scores are 0 at the start of the simulation. The values of k are randomly drawn between -5 and +6 at the start of the simulation.

Input
Parameter values: $b = 1$, $c = 0.1$ (to avoid negative payoffs we add 0.1 in each interaction).

Submodels

In the default model, it is assumed that the image score of each individual is known to every other member of the population. This should be seen as only an idealized scenario. It is more realistic to assume that an interaction between two individuals is observed by a subset of the population. Only the agents who observe the interaction, and the recipient, update the image score of the donor. The agents who can observe the interaction are chosen at random for each particular interaction. We implemented these modestly different in the replication, each participant has a probability to observe an interaction. Note that Nowak and Sigmund do not provide an indication of the level of uncertainty used for their published results
Each player has a specific perception of the image score of the other players. The same player can have different image scores in the eyes of different individuals. The information is contained in a matrix whose elements s_{ij} denote the image score of player i as seen by player j. In a donor–recipient interaction between j and i, player j will cooperate if $s_{ij} > k_j$. If j has no information on i, then $s_{ij} = 0$.

Another extension of the basic model is to include strategies that consider both the recipient's and the donor's image score. Two types of strategies are explored. 'And' strategies involve cooperation if the image score of the recipient is larger than a certain value *and* the image score of the donor is less than a certain value. The idea is that if an individual has already a high image score, it is not necessary to aim for a still higher image score (by helping others). On the other hand, 'or' strategies result in cooperation if the image score of the recipient is larger than a certain value *or* the image score of the donor is less than a certain value. Here the idea is that if an individual has a low image score it may be advantageous to increase the score by helping others regardless of how low their image score is.

Model implementation
The model is implemented in Netlogo 4.1.1

References
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