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Model: Vigilant sharing *v1.0.1*

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ODD Model Description

The ABM was developed using the NetLogo modeling environment (Wilensky 1999). The model description follows the ODD (Overview, Design concepts, Details) protocol for describing individual- and agent-based models (Grimm et al. 2006), as updated by Grimm et al. (2010).

1. Purpose

The purpose of the model is to test the hypothesis that food distribution patterns in a small-scale non-agricultural group are driven by intentional consumption leveling on the part of sharing individuals. To test this hypothesis, interactions among individual agents are simulated within a realistic setting. It is assumed by design that agents will attempt to level consumption inequalities with a given probability. The hypothesis is deemed supported if observable food distribution patterns can be reproduced by the model when agents have a high probability of conforming to intentional consumption leveling behavior in their sharing interactions.

2. Entities, state variables and scales

Agents of the model are hunters who forage for and share food that will be consumed within their households. Hunters are further subdivided into *top*, *regular*, and *poor* as per their efficiency (following Wood and Marlowe's (2013) data on best, median and poorest married Hadza hunters observed in seven different camps). The state variables of agents are *own-income*, the amount of kilocalories in possession of a hunter that were procured by himself, and *share-income*, the amount of kilocalories in possession of a hunter that were procured by other hunters and subsequently tranferred to him. The time step of the model represents one day and simulations were run for 2,000 days.

3. Process overview and scheduling

The time-step starts with the assignment of caloric incomes to the three hunter types according to their success and acquisition rates for two resource types: large-game meat and other foods. Total calories acquired by a hunter added to his *own-income*.

The initial assignment of caloric incomes is followed by food distributions. First, a given proportion of directed hunter dyads corresponding to the conformity parameter value set at the beginning of the model run is selected as *active*. Only active dyads engage in the sharing of large game meat or other types of foods. Food distributions begin with large game-meat sharing. Each hunter who acquired large game is selected randomly and without repetition to share his bounty. Potential receivers who meet the necessary conditions for becoming actual receivers are added to a receiver list, and the bounty is equally shared among the giver and all receivers included in the list. The total calories shared by a giver are deducted from his *own-income*, whereas the amount obtained by each receiver is added to his *share-income*.

After initial distributions, hunters move on to further distributions of all foods – both the other food types they acquired and the meat they received in initial distributions. Directed hunter dyads whose targets meet the necessary conditions for becoming actual receivers are randomly selected. Again, the joint income of giver and receiver is shared equally between them. If the giver has positive *share-income*, the total amount he gives is deducted from his *share-income* primarily; only when his *share-income* reaches zero are the remainder donated calories deducted from his *own-income*. The total calories transferred in the sharing interaciton are then added to the receiver's *share-income*. If there are no more directed hunter dyads whose targets meet the necessary conditions for receiving shares, the model proceeds to the next time-step.

4. Design concepts

4.1. Basic principles

Erdal and Whiten's (1996) model of the evolution of counterdominant tendencies to subvert dominance hierarquies in the human species provides a sound evolutionary rationale for the kind of intentional leveling behavior observed in small-scale human groups and vastly discussed and documented by social anthropologists over the years. Their model predicts the emergence of a complex evolved human psychology which, as regards the sharing of food and other strategic resources, manifests itself as a *sense of fairness*, "an interest in ensuring that 'others do not get more than I do' and then, through anticipation of others' reactions, that 'I do not take more than others'" (Erdal and Whiten 1994, 177). Motivationally founded on this sense of fairness, the form of behavior the authors describe as *vigilant sharing* is such that prosocial concerns are constrained by self-interest (others should not get more than one does), while self-interested concerns are constrained by prosociality (one should not get more than others). Because vigilant sharing is based on irreducibly prosocial *and* self-interested motivations, it diverges from behavioral assumptions typically adopted in mainstream branches of economics and evolutionary theory, and which attempt to reduce prosocial behavior to self-interested (selfish and perhaps also nepotistic) proximate motivations.

4.2. Emergence

The model allows us to track various emergent patterns of food-sharing behavior by tracking and comparing information stored in the agents' state variables.

4.3. Adaptation

The only adaptive decision is whether to share or not with a potential recipient.

4.4. Objectives

The fact that food sharing is driven by a sense of fairness on the part of hunters implies that their explicit goal in sharing interactions is to promote consumption leveling. See *Prediction* below for a description of how this is accomplished.

4.5. Learning

Agents do not change their adaptive traits over time.

4.6. Prediction

Reductionist models of prosocial behavior typically assume that humans (through rational choice) or other organisms (through evolved behavioral rules controlled by genetic expression) make decisions *as if* they were attempting to solve a constrained optimization problem. Here, on the other hand, individuals are guided by a different internal model. Consistent with vigilant sharing, it is assumed that hunters base their sharing decisions on recipient need relative to the social group as a whole. A sharing individual attempts to determine whether a potential recipient reinforces group-level inequality by comparing the Gini index of all group incomes with the Gini index of all group incomes *except for* the potential recipient's current income; if the former value exceeds the latter, he decides to share unilaterally. The script used for computing the Gini-index for a set of values was adapted from Wilensky (1998).

4.7. Sensing

Hunters are assumed to know the caloric income of every other hunter and be able to infer whether it contributes to reinforce group-level inequality. Although the model is unspecific about mechanisms that generate the relevant information and underlie their cognitive capacities, the most plausible initial assumption would be that sharing – even when it happens as a one-to-one resource transfer – is a group task (Carletti et al. 2020) whose solution depends on the building and constant update of a collective mental map shared among hunters through linguistic communication.

4.9. Stochasticity

The total amount of kilocalories acquired by an individual hunter each day varies stochastically according to the acquisition and sucess rates of top, regular and poor hunters (following Wood and Marlowe's data on best, median and poorest married Hadza hunters observed in seven different camps). In large-game meat distributions, potential givers are selected in random order without repetition. Further distributions of all foods happen between potential giver-receiver dyads that are selected randomly until no remaining dyad satisfies the conditions for a sharing interaction to take place.

4.10. Collectives

No collectives of agents are represented in the model.

4.11. Observation

Seven outcome variables are collected which describe the following dimensions of Hadza food distributions: *sharing depth by hunter type* – mean percentage of total kilocalories acquired by individual hunters that are donated to other households, disaggregated by hunter type (top, regular, and poor hunters); *sharing depth by food type* – mean percentage of total kilocalories acquired by individual hunters that are donated to other households, disaggregated by food type (large game meat and other types of foods); *sharing breadth by food type* – mean percentage of potential receiving households that actually receive shares from individual hunters, disaggregated by food type (large game meat and other types of foods). All outcome variables are collected at the end of a simulation and represent means from values obtained at each time-step.

5. Initialization

Model runs start with a population of one top, three regular, and three poor hunters who differ in daily success rates and average daily acquisition rates of two different resource types (large game and other foods). The number and distribution of hunter types, as well as the other default parameter values defining succcess and acquisition rates for each hunter type, follow Wood and Marlowe's data on married Hadza hunters observed in seven different camp sites. Besides, at the beginning of a model run, the probability that any potential giver-receiver dyad will conform to the sharing rule at each time-step is defined. See Table SI for descriptions, default values and simulated ranges of model parameters.

6. Input data

The model does not use input data to represent time-varying processes.

7. Submodels

7.1. Forage

Hunters initially have zero calories in both their *own-income* and *share-income*. The *own-income* of an individual hunter of a given type is then updated by the following procedures:

- Add a_m/p_m kilocalories to the hunter's *own-income* with probability p_m
- Add a_o/p_o kilocalories to the hunter's *own-income* with probability p_o

where

$p_m \equiv$ daily probability of acquiring large-game meat;
$p_o \equiv$ daily probability of acquiring other food types;
$a_m \equiv$ mean daily caloric acquisition of large-game meat;
$a_o \equiv$ mean daily caloric acquisition of other food types.

The caloric threshold k that distinguishes large-game meat from other food types is accordingly defined as the ratio a_m/p_m for regular hunters, who are the least efficient acquirers of large-game meat.

7.2. Sharing

The sharing of food begins with widespread distributions of large-game meat and only then proceeds to further one-on-one distributions of all food types. The probability that a hunter i will conform with the sharing rule when interacting with a hunter j is defined at the beginning of a model run. The set of potential giver-receiver dyads that conform to the sharing rule is updated each time-step as follows:

- For each dyad (i, j) in the population, add (i, j) to set A with probability p_c

where

$(i, j) \equiv$ directed hunter dyad representing a potential giver i and a potential receiver j;
A ≡ the set of directed hunter dyads that are active in a given time-step;
$p_c \equiv$ probability of conformity to the sharing rule.

Define the total income c_i of hunter i before a sharing interaction as the sum of his own-income o_i and his share-income s_i. Given the equitable nature of distributions, the total donations d_i of the hunter in a sharing interaction are given by the equation:

$$d_i = c_i - \left(\frac{c_i + \sum_{j \in S} c_j}{n}\right)$$

where

S ≡ set of hunters who qualify as receivers in a sharing interaction;
n ≡ number of hunters included in the set S.

Finally, let $G(\cdot)$ be a function that computes the Gini-index for a set of values, I the set of total caloric incomes of all hunters in the group, and I_{-i} the set of total caloric incomes of every hunter in the group *except for* hunter i. The rules for both primary distributions of large-game meat and further distributions of all foods may now be represented.

Rule for primary distributions. Randomly select a hunter i such that $c_i \geq k$ as the giver of large-game meat. Now for each other j in the group, if the following conditions obtain:

- $(i, j) \in A$
- $c_i > c_j$
- $G(I) > G(I_{-j})$

then include j in the receiver set S and update incomes as described below. Repeat the rule without repetition for every hunter who qualifies as a giver of large-game meat. If no remaining hunter qualifies as such, move on to the rule for further distributions of all food types.

Rule for further distributions. Randomly select a hunter dyad (i, j) meeting the following conditions:

- $(i, j) \in A$
- $c_i > c_j$
- $G(I) > G(I_{-j})$

then update incomes as described below. Repeat the rule for every hunter dyad that meets the conditions. If no remaining dyad meets the conditions, collect outputs and move on to the next time-step.

Rule for income updating. In both primary and further food distributions, incomes are updated as follows. Let primed variables represent the updated value after a sharing interaction. For the hunter i who gives food in a sharing interaction,

- if $s_i \geq d_i$ then set $s'_i = s_i - d_i$ and $c'_i = o_i + s'_i$
- if $s_i < d_i$ then set $s'_i = 0$ and $o'_i = o_i - (d_i - s_i)$ and $c'_i = o'_i$

For each of n hunters j who receive food from hunter i in a sharing interaction,

- set $s'_j = s_j + d_i/n$ and $c'_j = o_j + s'_j$

References

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