JASSS

Felix Flentge, Daniel Polani and Thomas Uthmann (2001)

Modelling the Emergence of Possession Norms using Memes

Journal of Artificial Societies and Social Simulation vol. 4, no. 4
<http://www.soc.surrey.ac.uk/JASSS/4/4/3.html>

To cite articles published in the *Journal of Artificial Societies and Social Simulation*, please reference the above information and include paragraph numbers if necessary

Received: 30-Mar-01 Accepted: 30-Sep-01 Published: 31-Oct-01

Abstract

In this paper we study the emergence and the effects of a possession norm in an artificial society. We link the study of norms and the concept of memes as put forward by Richard Dawkins. Normative behaviour is modelled using memes as carriers for certain behaviours. For our simulations we extend the sugarscape model from Epstein and Axtell (1996) and give the agents the possibility to claim possession of a "plot" of land. Memes regulate the behaviour of the agents regarding the land claims of others. It turns out that the probability for the survival of the population is much higher when possession claims of others are respected. However, there exist short term disadvantages for agents respecting the possessions of others. Thus, the need for a possession norm arises. The introduction of sanctions provides a good possibility to enforce the norm as long as no costs arise for sanctioning agents. We also investigate different kinds of meme propagation and their effects on the establishment of the norm.

Keywords:

Agent-based Simulation; Artificial Societies; Memetics; Social Norms; Social Simulation; Socionics

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Introduction

1.1

From the social science point of view, the simulation of fundamental properties of social systems may be helpful to construct and improve theories. The simulation of some qualitative properties of social systems makes it possible to ascribe the high complexity of such systems to the co- operation of a few relevant factors. An inherent advantage of individual- (i.e. agent-) based simulation as compared to standard techniques of simulation is the opportunity to model the individual *and* the local interaction of the individuals instead of having to develop a more-or-less plausible 'mean-field' model of societies.

1.2

On the opposite shore, namely in the field of computer science, the aim to construct multi-agent systems poses difficulties typically found in human societies, e.g. the problem to achieve co-ordinated behaviour without a centralised regulation or the problem to choose a proper action from a large number of possibilities. This leads in a natural way to approaches motivated by examples from human society and making use of models and theories from social science. By this, one hopes to find solutions for key problems of co-ordination or communication for which natural societies often display efficient and robust solutions.

1.3

Social norms are important parts on the macro level of social systems and influence the behaviour of individuals. Their various functions are the enabling of co-ordinated behaviour, the control of aggression or the reduction of complexity in social situations. This makes them an interesting issue for multi-agent systems research. We try to investigate the question when and how these macro properties can emerge from individual behaviour and how they influence the evolution of the system as a whole. A full model for 'real' societies is far off our scope. Instead, we try to build a simple model and to simulate certain specific mechanisms that might appear in human societies. As we will show, typical problems concerning the emergence and the enforcement of norms will indeed occur in our simulations.

1.4

Our agents are purely reactive and have no internal reasoning capacity. We wish to show that even with these types of agents it is possible to simulate an emergent macro property like a social norm. As a basis for our model we use the sugarscape model of Epstein and Axtell (Epstein/Axtell 1996) because this relatively simple model can be readily extended for our purpose. We decided to simulate possession norms because this fundamental type of norms fits smoothly into the sugarscape scenario. After outlining former work on the simulation of norms we will present our view on norms and link this view to the concept of memes. The sugarscape model and our extensions are described in the subsequent section. Following that, we present our results and finish with some conclusions.

Previous Work

2.1

Previous work in simulating norms concentrates either on the possibility whether a norm emerges or not (Axelrod 1986, Coleman 1986/87) or on the effects of an explicitly given norm (Conte/Castelfranchi 1995, Castelfranchi/Conte/Paolucci 1998, Saam/Harrer 1999). Coleman uses the prisoner's dilemma to study the influence of the social structure on the effectiveness of sanctions. In his simulations he divides a population of 100 individuals into subgroups and matches the individuals in these subgroups to play the prisoner's dilemma. The individuals can remember a given number of partners and their last action (defect or co-operate) and follow a strategy that uses this information. Coleman concludes that co-operation emerges easier in small groups.

2.2

Axelrod chooses an evolutionary approach to study the emergence of norms. According to him, norms "... exist in a given situation if individuals act in a certain way and are often punished when seen not to be acting in this way." (Axelrod 1986, p. 1097). In his game theoretic approach he constructs a 'norms game' based on the prisoner's dilemma. He uses a kind of genetic algorithm to evolve strategies that consists of the components *boldness* to violate norms and *vengefulness* to punish norm violations. In some cases, the populations show low rates of boldness and high rates of vengefulness which indicates that a norm has emerged. This emergence of norms can be improved through the introduction of metanorms, i.e. norms that prescribe punishment for those who do not punish norm violations.

2.3

Conte and Castelfranchi (Conte/Castelfranchi 1995) investigate how norms control and reduce aggression and how they influence individual differences. They simulate agents moving in a two-dimensional common world and eating food to gain strength. Agents can attack each other while eating food, which takes some time. Conte and Castelfranchi compare three different conditions: 'blind aggression' (always attack whenever the costs of alternatives are higher), 'strategic' (only attack when your opponent's strength is not higher than your own) and 'normative' (agents own food appearing in their neighbourhood and can not be attacked while eating their own food). They state that aggression (the number of attacks) and inequality (the standard deviation of the agent's strength levels) is lowest and the agents' average strength is highest under the 'normative' condition.

2.4

Castelfranchi, Conte and Paolucci (Castelfranchi/Conte/Paolucci 1998) continue this work to study the role of normative reputation. They split the agent population into two halves, each following different norms (blind or strategic, blind or normative, strategic or normative). It exposes that now the normative agents have the lowest average strength because there are cost-free advantages for transgressors. Castelfranchi, Conte and Paolucci give the agents the possibility to distinguish between norm abiding ('respectful') and norm circumventing ('cheating') behaviour. The agents learn through direct interaction which agents are 'cheaters' and which are 'respectful'. The normative strategy is changed in such a way that it is only applied to 'respectful' agents and is tested against the strategic agents. It turns out that this is not enough to improve the situation of the normative agents. Only when neighbouring agents are allowed to share their knowledge about 'cheaters', the normative agents do almost as well as the strategic ones.

2.5

Saam and Harrer (Saam/Harrer 1999) extend the Conte/Castelfranchi-model and try to show that the results of Conte and Castelfranchi are only valid for egalitarian predator-collector societies. They introduce unequal heritage and unequal renewal of resources favouring the agents with more strength. In this case, the norms cause higher inequality. They also develop a model which is based on Haferkamp's theory of action approach to deviant behaviour. In this model the agent population is divided into an in-group and an out-group with different power and strength. The members of the in-group comply with the norm and each member have to pay one unit of its resources each step for the institutionalisation of the norm. These resources are redistributed among all agents. The members of the out-group deviate from the norms and are sanctioned by the members of the in-group. Sanctioning decreases the resources of both agents, but increases the power of the sanctioning agent. The power of an agent influences the nutritional value of the food appearing in the cell he is in. The normative strategy now does better than the blind one (higher average strength, lower aggression and inequality), but the strategic agents are stronger and have less aggression than the normative, i.e. the function of the norm to control aggression has vanished. Saam and Harrer's simulations make clear that the functions of norms strongly depend on the conditions in the society.

2.6

In our simulations we study both the emergence and the effects of norms. A norm may or may not emerge and we compare the effects of the existence resp. the non-existence of it. Different possibilities to enforce the emergence of the norm are investigated (sanctions with and without sanctioning costs).The emergence of norms is modelled using the meme concept as described in the next section.

Social Norms and Memes

3.1

Social norms are more or less compulsory, generally accepted prescriptions for human actions. They regulate what should and what should not be done in specific situations and are based on general values. The individuals internalise social norms during socialisation. Non-observance of norms is punished with sanctions (Schäfers 1986). A very important aspect of norms is that they make the individual's behaviour more predictable and allow others to act regarding to the expected behaviour. Other functions of norms depend on their specific contents, e.g. norms that regulate co-ordination or control aggression.

3.2

Coleman (1990) states two conditions for the emergence of norms. First, there must be the need for a norm. Such a need exists if the action of an individual affects a group of other individuals, the effects of this action are similar for the members of that group and the impact of this action on the group can not be resolved by simple transactions. Second, to satisfy this demand for a norm it is necessary that the beneficiaries of the norm sanction the norm violation. Because sanctioning is often combined with costs, they have to solve the problem of sharing these costs and the benefit for each must be higher then its individual costs. This problem is called second order free-rider problem, because every individual would prefer to benefit from the norm without paying the sanctioning costs. As we will see, this problem will also arise in our simulations. Norms may be set by institutions, result from voluntary agreements or emerge without planning. The latter case could be called '*evolutionary*' norm emergence. In this case, norms result from regularities in behaviour. These regularities in behaviour may arise through direct reward or through imitation of a model (Opp 1983). We will try to model some kind of 'evolutionary' norm emergence without planning. Due to the lack of social structures and communicating possibilities in our model, the other types of norm emergence are far off our scope.

3.3

This evolutionary emergence of norms from regularities in behaviour can be combined with the concept of memes as put forward by Dawkins (Dawkins 1976). Memes are parts of cultural tradition, e.g. thoughts, cultural techniques, behaviours, etc. They are similar to genes because they are able to replicate themselves. The difference is that they may change during lifetime while genes cannot. Passing on memes is a cultural process, they are passed from an individual to another by imitation. Some memes are more successful than others and are more likely to be imitated, so we may speak of a memetic evolution process.

3.4

We model social norms using certain behaviours connected with some memes. If an individual knows and respects a norm, it acts in a certain way. In our agent model, certain behaviour classes are implemented, the presence or absence of which is encoded by the presence or absence of certain memes. Note that, in our model, for reasons of simplicity we make use of a clear-cut association of specific memes and certain behaviours. However, similarly to genes in biology, in general there is no a priori reason to assume that behaviour classes could be cleanly separated and that the individual behaviours could be matched to specific unique memes. This is a specific assumption in our model.

3.5

To behave according to a certain norm can be viewed as displaying a certain class of behaviours. In our case such a behaviour is e.g. respecting the possession of others. We will call the meme that encodes the corresponding behaviour in our model the 'possession meme'. Not to behave in this way may be sanctioned by others. This sanctioning behaviour is encoded by another meme in our model. This meme will be called 'sanctioning meme'.

3.6

We say that a social norm is present if in an agent society both behaviours are displayed by a sufficient portion of the population. Note that we do not require the individuals to display both behaviours. In other words, possession respecting behaviour and sanctioning behaviour may well be separated, which is the case if the individuals who should follow the norm are not the same who enforce it. In our model only agents will attempt to enforce the norm that obey it themselves.

The Model

4.1

To model the emergence of possession norms we extend the sugarscape Model by Axtell and Epstein. We believe that the extension of a well-known model offers many advantages. Results can be seen in an broader context, can be compared to already available results and may be easier understood. The reliability of the extension and the extended model can be tested through replication of old experiments (Axelrod 1997). We choose the sugarscape model because, although being relatively simple, it offers various possibilities for extensions in different directions. We stay as close as possible to the original model and make changes to parameters or rules only where necessary for our purpose. Thus, wherever we do not have an explicit motivation to deviate from their model, we will use the Epstein and Axtell settings without further discussion. In the following we first describe the sugarscape model of Epstein and Axtell and then our extensions in detail.

The Sugarscape Model

4.2

The goal of Epstein and Axtell is to construct artificial societies that model certain characteristics of real societies. The aim is not to create a realistic image of a real society but to find simple local rules leading to certain global effects. Their sugarscape Model consists of agents that inhabit a landscape. The landscape is realised as a kind of cellular automaton and provides a special resource, namely sugar. The cells can contain different amounts of sugar. Agents move in this landscape, collect the sugar and feed upon it. Epstein and Axtell use variations of this basic model to create and study a variety of different phenomena, like population growth, wealth distribution or migration in a polluted environment.

4.3

Cells and agents have certain properties and execute certain rules. A simulation run consists of a sequence of simulation steps. During one step each agent and each cell is invoked once in random order to execute the relevant rules. Fig. 1 shows such a simulation step (the rules mentioned are described in the next paragraphs).

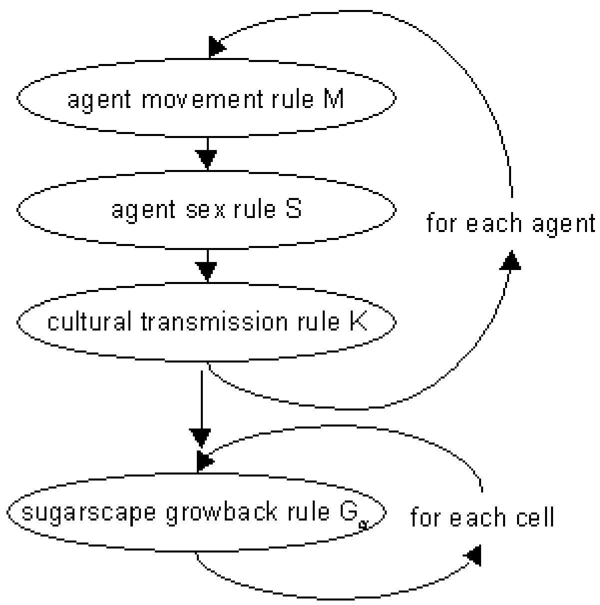

Figure 1: Structure of a simulation step

4.4

The landscape is a 50x50 grid of single cells. The cells have a *current sugar level* and *maximum sugar capacity* which ranges from zero to four. Fig. 2 shows the landscape used by Epstein and Axtell. The landscape contains two sugar peaks and forms a torus, i.e. agents can move across the border and reach the landscape on the opposite side. Agents do not enjoy 'equal opportunity' due to the varying maximum sugar capacity. If agents are lucky they are born in the 'sugar highlands', if not, in the 'sugar lowlands'. The renewal of the sugar in the cells is regulated by the Sugarscape Growback Rule G_α:

Sugarscape Growback Rule G_α In each simulation step, the sugar content of a cell grows by α units until it reaches the maximum sugar capacity of the cell. α is an integer.

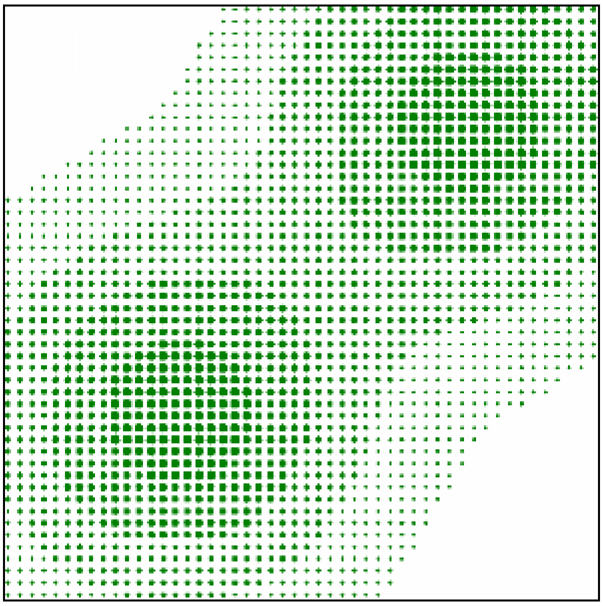

Figure 2: The sugarscape landscape. The size of the dots is proportional to the sugar capacity of the cells.

4.5

The agents move in the landscape given by Fig. 2 and collect sugar from the cells. They collect all sugar from a cell at once and their sugar carrying capacity is unlimited. Agents use up a certain amount of sugar each simulation step. This amount only depends on the *metabolism rate* of the agent, which denotes the amount of sugar an agent uses up each step. If an agent has no more sugar or if he reaches a certain *maximum age,* he dies and is removed from the simulation. Agents are only able to see objects in the four main directions (not diagonally) and have only a limited *vision range,* which denotes the maximum distance (measured in cell units) at which agents are able to detect objects. Agents thus only have limited knowledge of the world.

4.6

Properties like vision range, metabolism rate or maximum age are fixed integer values and do not change during the agent's lifetime. These properties vary from agent to agent in a certain range, i.e. agents are heterogeneous with respect to these properties. On the other hand, all agents follow the same behavioural rules. Since the agents are heterogeneous regarding their properties, however, these rules have different effects.

4.7

Agents are only able to move to cells in their vision range which are not occupied by other agents. In particular, agent movement is determined by the *Agent Movement Rule M*:

Agent Movement Rule M

- search those unoccupied cells in vision range with a maximum amount of sugar
- if several such cells are present, choose the closest one
- go to this cell
- collect all the sugar in the cell

4.8

Interactions between agents can only take place if the agents are in neighbouring cells (only in the main directions; not diagonally). Agents can reproduce. There exist both male and female agents. Agents are fertile if their age is in a certain range and if they have at least as much sugar as at their own birth. Fertile agents always perform the *Agent Sex Rule S*:

Agent Sex Rule S

- select a neighbouring agent randomly
- if this neighbour is fertile, if the neighbour belongs to the opposite sex, and if at least one of both agents has an unoccupied neighbouring cell, a new agent is created and placed on this cell
- if the sugar level of the current agent is high enough to reproduce again, and if there are other neighbours that were not selected this update, repeat rule S for another neighbour

4.9

The new-born agents inherit the properties of their parents. Metabolism rate, vision range and maximum age are inherited with a probability of 1/2, i.e. for each of these three categories the new-born agent has either the same integer value like the one or the other parent. No mutation is applied. From each parent the agent gets half of the sugar the parent had at its birth.

Cultural Tags and Memes

4.10

To simulate cultural traits that may change during an agent's life time, Epstein and Axtell introduce so-called *'cultural tags'*. Each agent has some of these tags which can assume two different values each (true/false). Neighbouring agents adjust their cultural tags following the Cultural Transmission Rule K[1].After each agent's movement, this rule is performed with each neighbour.

Cultural Transmission Rule K

- choose randomly one of each neighbour's tags
- if the tag of the neighbour has the same value as the tag of the current agent, do nothing, otherwise set the neighbour's tag to the same value as the current agent's tag.

4.11

Epstein and Axtell study the formation of cultural different groups and introduce rules for combat between these groups. When they introduce a second resource (spice), the tags determine which resource is preferred by an agent and thus influence his behaviour.

4.12

Due to the similarity to the concept of memes by Dawkins and the role these tags play in our model, we will call them *memes*. We say that an agent does or does not carry a certain meme depending on the value of the corresponding tag. In our context, these memes have much more influence on agent behaviour than in the original work of Epstein and Axtell. The Cultural Transmission Rule K is also used for the memes.

They are passed from parents to children, thereby modeling the influence of the parents' education. While this may resemble a Lamarckian process, we construe this as a cultural process. In contrast to genetic inheritance, the memes may be changed by other agents during lifetime.

Extension of the Sugarscape Model towards Norm Simulation

4.13

We extend and modify the sugarscape model to study the emergence of possession norms. An agent in a specific cell can mark this cell if it has not already been marked before by a different agent. Other agents can see these marks if the cell is in their vision range. If an agent dies, all marks he set during his lifetime are deleted. By marking, a cell does not automatically become an agents' possession. Only if the other agents respect the mark, i.e. if they do not collect sugar from the cell, the cell can be considered to be in possession of the agent by which it has been marked.

4.14

The memes regulate the agent's behaviour with respect to marked cells. There is a possession and a sanction meme. If an agent carries the possession meme, he never will collect sugar from marked cells. Also, under *Movement Rule M* he will not move to such a cell as long as he sees cells where he can collect sugar. Only agents that have the possession meme mark cells. Thus, the possession meme actually encodes two behaviours: marking cells and not collecting sugar from cells marked by others. It would be possible to encode these behaviours in different memes, but we chose to encode both behaviours into a single meme.

4.15

The sanction meme regulates the behaviour regarding 'norm violation'. If an agent carries both the sanction and the possession meme, he will sanction all agents that collect sugar on cells marked by other agents if these agents are in his vision range (i.e. he is capable of observing the violation). Sanctioning a norm violation means that the sugar level of the violating agent is decreased by a certain value. The sanctioning agent also loses some sugar because he has to pay the costs of the sanction.

4.16

The introduction of memes makes it necessary to change *Movement Rule M.* When the possession norm is activated, agents are less motivated to move near other agents, because the cells near another agent are often in the possession of other agents, preventing the moving agent to collect sugar from the cell. For that reason we need the *Movement Rule MS*, which favours reproduction to collecting sugar:

Movement Rule MS

- if current agent is not fertile, perform *movement rule M*
- otherwise search all unoccupied cells in vision range neighbouring a fertile agent of the opposite sex
- if no such cell is found, perform rule M, otherwise go to a cell with a maximum amount of sugar
- if several such cells are present, choose the closest one
- collect all the sugar from the cell

4.17

To test which of the rules M and MS is preferable in an evolutionary sense, we give our agents a 'movement gene'. If the 'movement gene' is active the agents perform rule MS, otherwise rule M. Fig. 3 shows the evolutionary advantage of rule MS. The figure shows the portion of agents with the movement gene. The other parameters are chosen like the standards from Epstein and Axtell: rule S and G_1 are active, vision range and metabolism are randomly chosen integers from one to four, maximum age is a random integer between 60 and 100.

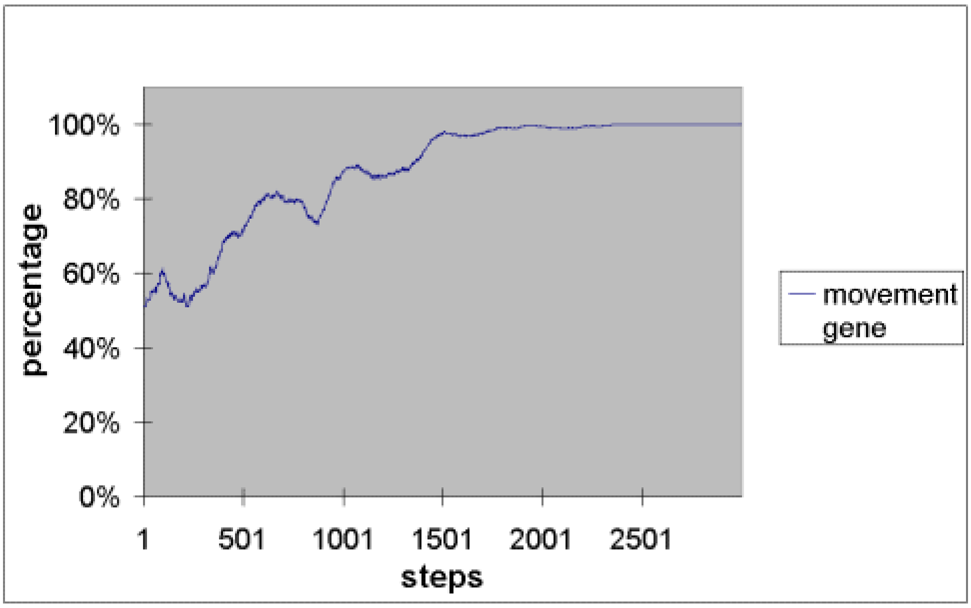

Figure 3: The portion of agents with the movement gene. Agents with the gene perform rule MS, others rule M. Rules S and G_1 are active, vision range and metabolism range from one to four.

4.18

In addition to the cultural transmission rule K we also use an alternative *cultural transmission rule K+*. The rule K+ works similar to K, but here, the cultural adoption of the memes depends on the sugar level of both agents. The 'poorer' agent adapts his meme to the memes of the 'richer' agent. Thereby, the behaviour that seems to be more successful is imitated. Like rule K, K is performed after an agent's movement.

Cultural Transmission Rule K+

- for each neighbouring agent select randomly one of his memes
- if the meme has the same value as the corresponding meme of the current agent, do nothing. Otherwise set the meme of the agent with less sugar to the same meme value as that of the agent with more sugar. If both agents have the same sugar level, the meme of the newly arrived agent is adopted.

4.19

We choose K and K+ for its simplicity. Many other rules are possible. For example, one could use Latané's Theory of Social Impact as Nowak and Latané did in their simulations (Nowak/Latané 1994, Latané 1996). This theory states that the "...social impact is a multiplicative function of the strength, immediacy, and number of people influencing an individual" (Latané 1996, p. 289). In our model one could use one agent's sugar wealth to determine the strength and use the distance between two agents as a measure for immediacy.

4.20

Some changes with respect to the model developed by Epstein and Axtell (the "original" sugarscape model), in particular concerning the metabolism rate and the vision range, were made. In the original model, these values evolve during the run. In our model, we keep values for metabolism rate and vision range fixed during each simulation, but vary these values for different simulation scenarios. This allows us to better control the conditions of the simulations and to interpret the results more easily. We use the same sugarscape landscape as in the original model (Fig.2) with the difference that we multiply the original cell's sugar capacity (ranging from zero to four) by ten, to allow more variations of the metabolism rate (from two to ten).

Results

5.1

Since the model offers a lot of options to modify the simulation parameters, it is not possible to test all combinations of the parameters. We will keep some parameters fixed during all our simulations and will vary other systematically. In choosing the values for the fixed parameters, we use the same as Epstein and Axtell did for their simulation. A change concerns the age of the agents in the first simulation step of a run. Epstein and Axtell use an age of zero for all agents, which causes very 'unnatural' age distributions at the beginning of the runs and takes some time to normalise. In our simulation, we use a random current age for each agent of the first generation distributed equally between zero and the maximum age of the individual agent instead.

Table 1: Ranges of the fixed properties

parameter	***range***	***meaning***
initial sugar level	50-100	the amount of sugar the agents of the first generation get at birth; the following generations inherit their initial sugar from their parents
maximum age	60-100	the maximum number of simulation steps an agent lives; he may starve earlier if he does not collect enough sugar; children inherit the maximum age from one of their parents
male fertility start	12-15	the number of the simulation steps when the male/female fertility starts/ends; children inherit the fertility range from the parent with the same sex
male fertility end	50-60	
female fertility start	12-15	
female fertility end	40-50	
number of memes	11	the number of memes influence the probability for each single meme to be changed through cultural transmission; in our model only two memes have a special meaning

5.2

Different from Epstein and Axtell, we perform not only single runs for each parameter setting, but always do 100 simulation runs of 2000 steps for each with different random seeds. We also change metabolism rate and vision range systematically from two to ten in steps of two while we keep the other parameters fixed. This makes it possible to study emergence versus non-emergence and the effects of the norms and sanctions under conditions that offer different degrees of advantage to the agents. In our experiments, we vary both the sugar penalty for agents that are punished by sanctions and the costs for the sanctioning agent.

5.3

As landscape we use the original sugarscape landscape with tenfold sugar capacity for the reasons stated above. We always start with 400 agents and always use the rules MS, S and G_1, which means that in each step each cell gets one piece of sugar up to the cell capacity. For cultural transmission we use the rules K or K+ or none of these rules, which means that memes are only passed on from the parents to their children.

Effects of Possession Memes

5.4

Before we try to model the emergence of the norm we just wish to know how the possession meme affects the society. First, we set the possession meme to false for all agents and do not use cultural transmission. In the following series of experiments we set the possession meme to true for all agents. Metabolism rate and vision range is varied systematically. It turns out that, without the possession meme, under unfavourable conditions the population often becomes extinct before the 2000 simulation steps are over. Figs. 4and 5 show the portion of the runs in which the population survived for the different metabolism rates and vision ranges. Note that, since we performed 100 runs for each set of parameters, the survival frequency is numerically equivalent to the percentual survival probability.

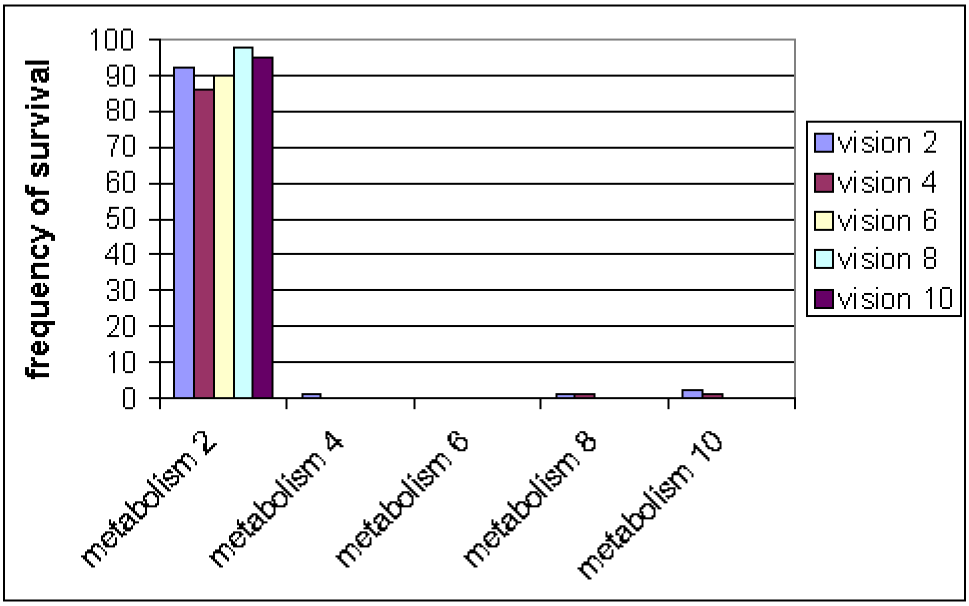

Figure 4: Frequency of survival without possession meme. The figure shows that number of the runs in which the agent population survived 2000 steps versus different metabolism rates and vision ranges

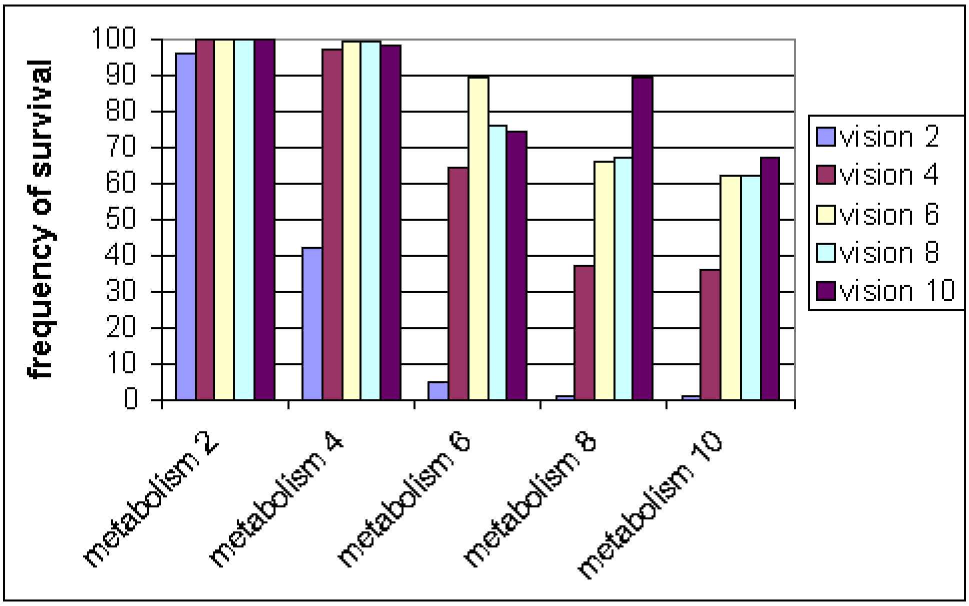

Figure 5: Frequency of survival with possession meme

5.5

As the figures show, survival frequency is much higher if the agents mark cells and respect possession. Without the meme, the agents are only able to survive with a metabolism rate of two. Vision range has no effects on that. With the meme, the agents survive more frequently under unfavourable conditions. In this case, especially for high metabolism rates, vision range affects the survival probability, which is due to the fact that for existing possession memes it is extremely important to have a large vision range to find sugar on unmarked or self-marked cells. With small vision range an agent may possess a large number of cells, but if he does not see them, he will not be able to make use of them.

5.6

A closer analysis of the reasons for the extinction of the population without possession memes shows that, without the meme, the agents are often too poor to reproduce. This is due to the fact that they usually collect less sugar on the average than with activated possession meme. The advantage of possession is that it can guarantee a higher sugar income, because more sugar can 'grow' in the cells until it is collected. So agents can collect more sugar per step. For an agent with a metabolism rate of two it is sufficient to own two cells. He can shuttle forth and back and can collect two pieces of sugar each time, because no other agent will eat the sugar belonging to it.

5.7

An interesting point regards the carrying capacity of the landscape. With activated possession, less agents live in the landscape on average. Fig.6 shows the average number of agents living in the landscape (if the population survived the 2000 steps) for different vision ranges and metabolism rates. Without the meme the result is shown only for metabolism rate two because for other rates the population almost always becomes extinct.

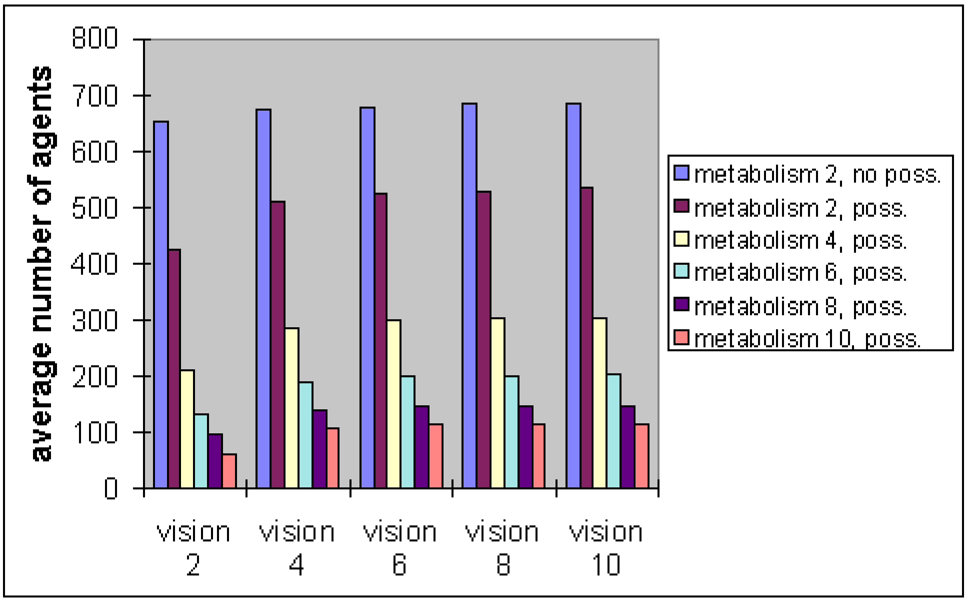

Figure 6: Average number of agents in simulation runs with (poss.) and without (no poss.) meme and different vision ranges

5.8

Vision range hardly influences the carrying capacity of the landscape (except the step from vision range two to vision range four). For metabolism rate two there is a big difference in the average carrying capacity with and without the possession meme. Without possession meme there are about 150 more agents living in the landscape because resources can be used up better in this setting. Sugar is wasted if a cell reaches the maximum capacity and no agent collects this sugar. This happens more often with existing possession because the agents do not collect sugar in foreign cells and do not know about 'their' cells if they are not in their vision range. As it can also be seen in Fig. 6, the vision range has practically no impact on the carrying capacity of the landscape (especially for vision ranges higher then two). For low metabolism rates population density without the meme is higher, but for larger metabolism rates agents can only survive with the meme.

Establishment of Possession Norms

5.9

Next, we want to study whether the possession meme is able to assert itself, so we give half of the population the possession meme and switch on the cultural transmission rule K. The sanction meme is not active. Since we have eleven memes (as in the original Epstein/Axtell model), the probability to pass the possession meme is 1/11. As we see in Fig. 7, the result is that the survival frequency is just as bad as in the case where no possession memes exist.

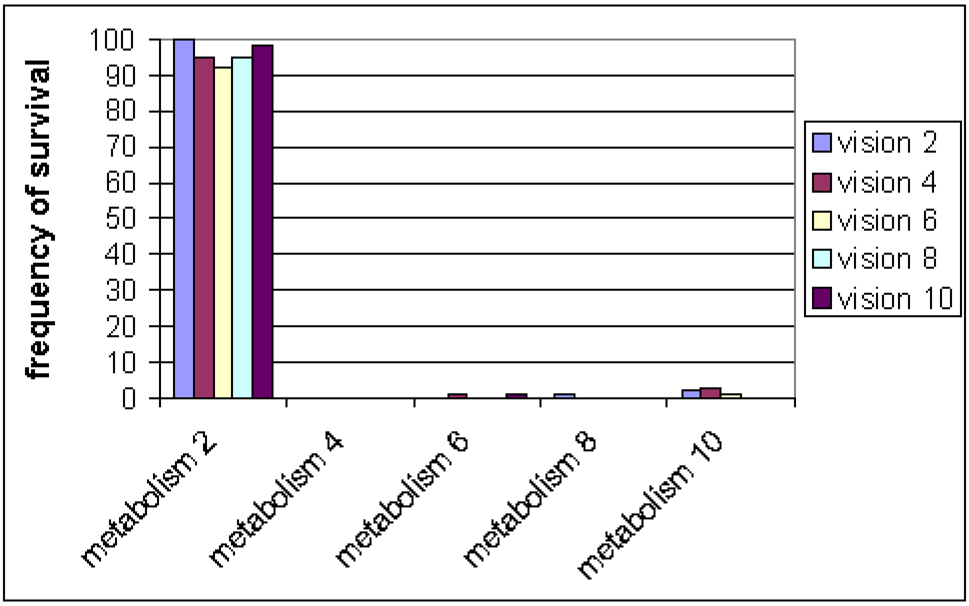

Figure 7: Frequency of survival with active possession meme in 50% of the initial agent population

5.10

A closer look at the proportion of the agents with the possession meme after the 2000 steps shows, that the meme could only assert itself two times. In all other runs, the meme disappears. A look at runs where the population becomes extinct shows that, after the meme disappears, the population becomes extinct. So the reason for the extinction is the inability of the possession meme to establish itself. Fig 8. shows the extinction of the population in a run without possession memes with a metabolism rate of four and a vision range of six. Fig. 9 shows a run with exactly the same parameters except that there half of the agents know the possession meme at the beginning. The population survives slightly longer but after the meme disappears, it also becomes extinct.

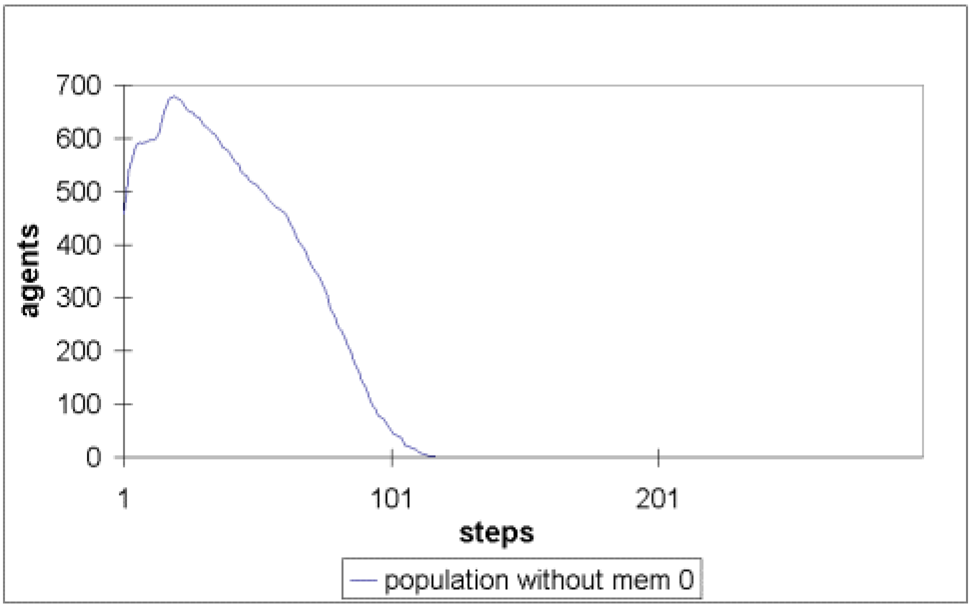

Figure 8: Population growth without possession meme, a metabolism of four and a vision range of six

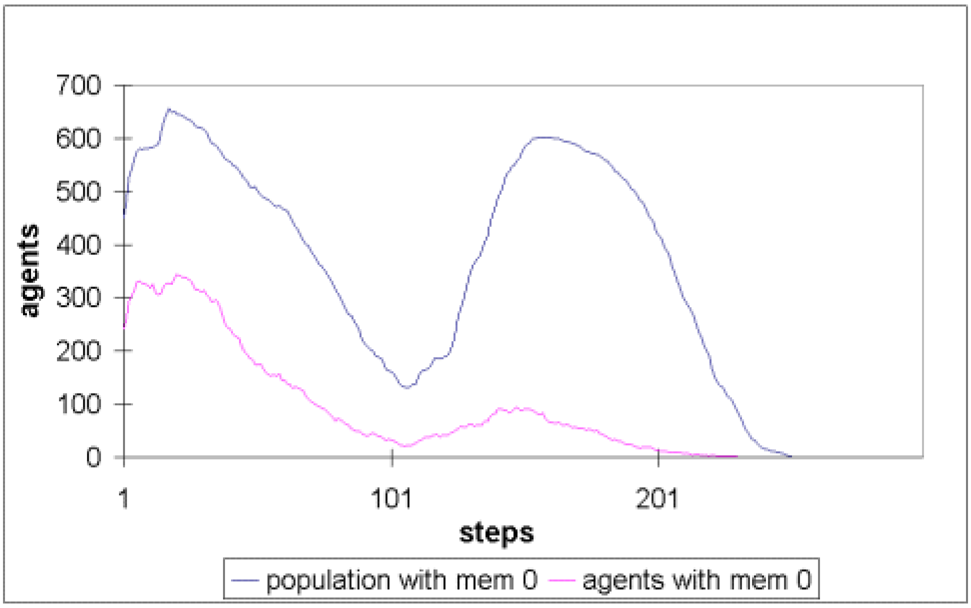

Figure 9: Total population size (higher curve) and number of agents with possession meme (lower curve), metabolism four and vision range six

5.11

At first, the portion of the agents with active possession meme is approximately 50% which remains stable even during the initial decrease of the population size the first 100 steps (note that we plot the absolute size of the population and not the relative portion of agents with active possession meme). This portion only begins to vary as the population size begins to increase. The agents without possession meme can reproduce significantly better. When the population size reaches the second maximum of approximately 600 agents, only between 10% and 20% of the agents have a possession meme. During the next drop of the population size, the meme finally becomes extinct. The non-observance of the possession meme results in short-term advantages for the agents, so that they can reproduce considerably more often. As a result, the portion of the agents respecting possession decreases, so that the meme finally disappears completely and as a consequence the agents become extinct. Agents not respecting possessions of others gain short-time advantages even if their behaviour endangers the survival of the whole population in the long run.

5.12

To enforce the establishment of a possession norm, sanctions have to be introduced. Thus, we activate the sanction meme and apply a punishment of four on those who do not follow the norm. First, we do not apply sanction costs. We investigate whether the norm is able to establish itself if we have 50% supporters in the beginning. In other words, the possession meme is active in half of the population at the beginning and the sanction meme in the whole population, i.e. all agents carrying the possession meme sanction its violation.

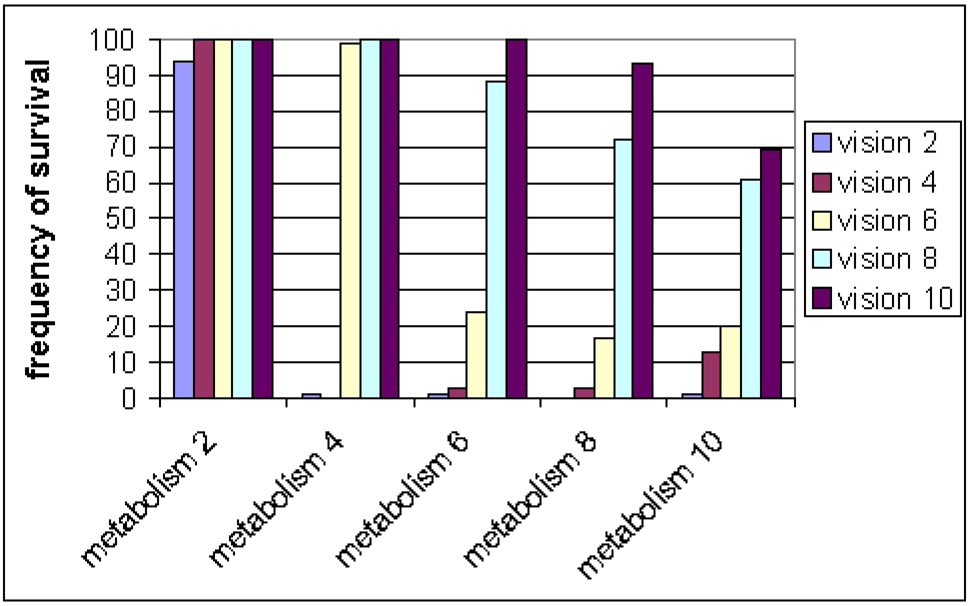

Figure 10: Frequency of survival with 50% possession meme, 100% sanction meme and a punishment of four

5.13

As can be seen in Fig. 10, the survival frequency is better than without sanctions, especially for high vision ranges. This is due to the establishment of a possession norm, as a closer analysis shows. In the cases where the population survived all agents have the possession meme in the end. The vision range has a high impact on the assertion of the norm: the smaller the vision range, the harder it is to establish the norm. Fig. 11 shows this correlation for a metabolism rate of six and punishments of two, four and six. The impact of the vision range on the establishment of the norm can easily be explained: with high vision ranges there are more agents that observe a norm violation. Accordingly, the overall punishment for a violation is considerably higher than for small vision ranges.

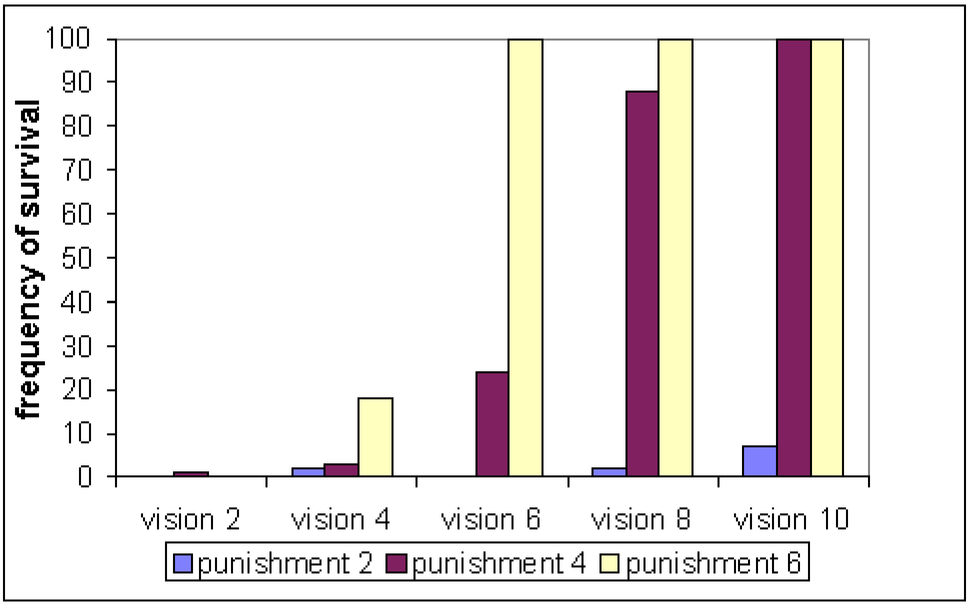

Figure 11: Frequency of survival with metabolism six, vision range reaches from two to ten, 50% possession meme, 100% sanction meme and various punishments

5.14

If at the beginning of a simulation the sanction meme is only present in half of the population, i.e. at the beginning only approximately one quarter of the population punishes norm violations, punishment has to be approximately twice as high in order to achieve the same effect. That means that the overall punishment is the crucial factor for establishing the norm.

5.15

If costs exist, sanctioning agents have disadvantages compared to those who do not sanction. Although they have an interest that norm violating agents are sanctioned, they also have an interest in not being the one who performs the sanctions. So we have a second order free-rider problem in this case. The collective long-term interest in establishing the norm is opposed by the short-time advantage in saving the costs for the sanctions. If costs exist, the survival frequency drops due to the difficulties in establishing the norm. This is demonstrated by Fig. 12 with a punishment of twelve and costs of four. At the beginning of a simulation, both the possession and the sanction meme are active in 50% of the agent population.

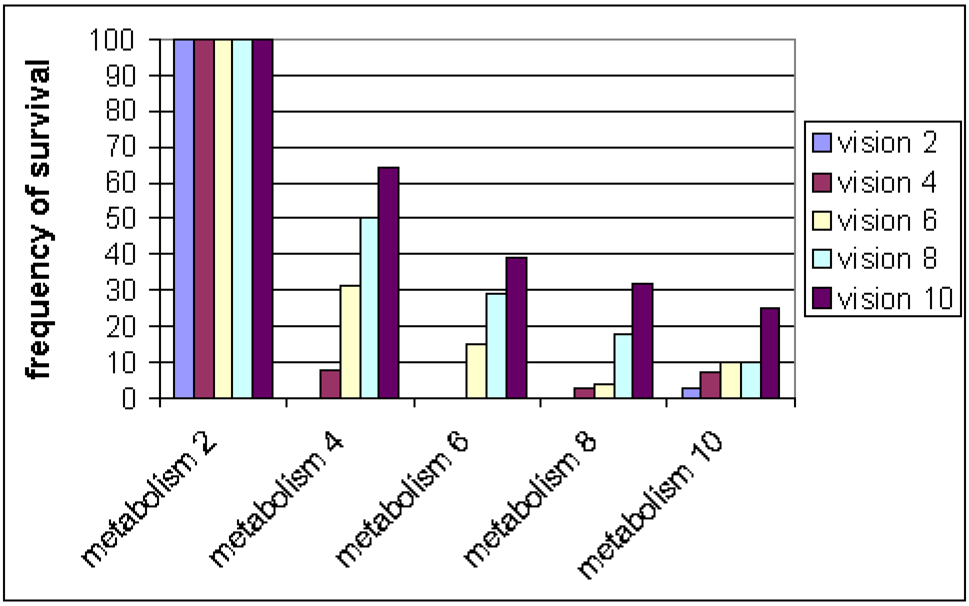

Figure 12: Frequency of survival with 50% possession meme, 50% sanction meme, punishment twelve and costs of four

5.16

In case of a run with a metabolism rate of four and a vision range of six, Fig. 13 illustrates two points: at the beginning the possession meme can propagate very well, the portion of the sanction meme, however, decreases right from the beginning. If this drop is strong enough, the possession meme loses its advantage and its portion drops as well. From an individual's point of view, the problem of the costs mainly does not consist in paying for sanctions, but in the fact that there are others which do not pay anything. This way, these agents have a 'parasitic' advantage compared to the sanctioning agents, which causes the portion of the sanction meme to decrease.

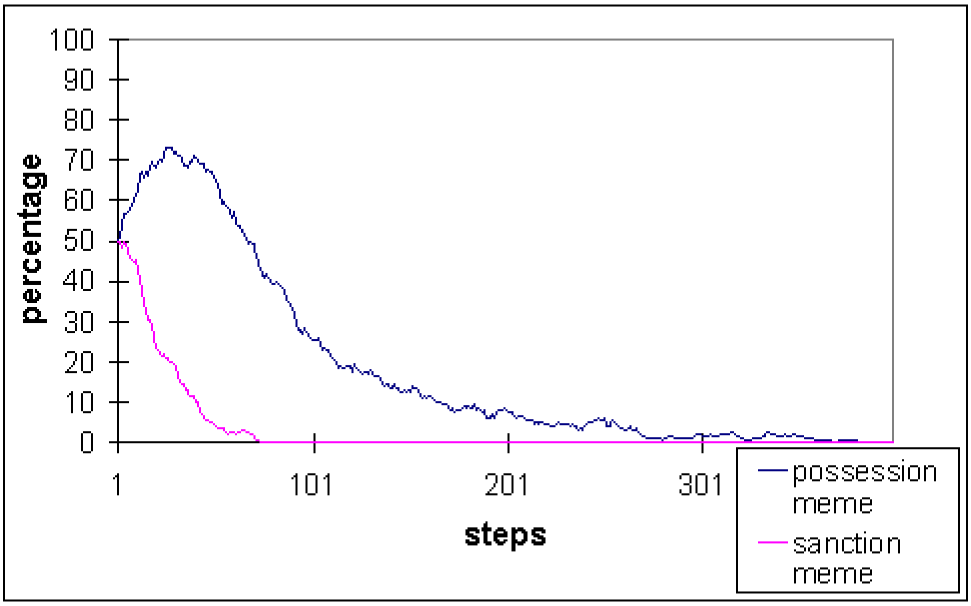

Figure 13: Percentage of the possession meme and the sanction meme with costs four, metabolism four, and a vision range of six

Role of the Memes

5.17

In order to analyse the role of the memes more precisely, one can compare the performed runs with further runs in which either no culture transfer rule is active, i.e. inheritance of memes only works from parents to their children, or the modified rule K+ is valid. It turns out that similar effects occur in both cases. As long as no sanctions exist, the enforcement strength of the possession meme is even slightly worse than before. That is because both K+ and a disabled cultural transmission speed up the disappearance of the meme. The average time until the possession meme disappears, is given in Fig. 14, with a metabolism rate of two and a 50% portion of agents with active possession meme at the beginning of a run. In this case, the sanction meme is not active. The plots show that with rule K, the possession meme displays the longest survival time. Agents without the meme reproduce more often, but the evolutionary pressure is a little bit weakened since K ignores the success of the meme's owner.

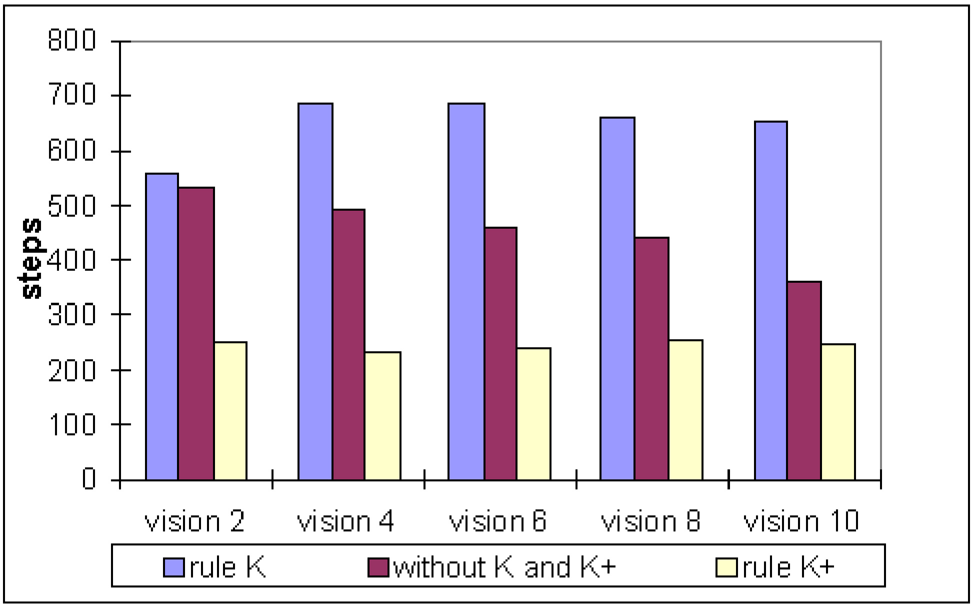

Figure 14: Average time until the possession meme disappears with metabolism two and 50% possession meme at the beginning of the run

5.18

However, if sanctions are introduced, agents can survive more easily, both without any cultural transmission rule at all or with rule K+, than with rule K. This becomes clear by comparing Fig. 10 with Fig. 15. In both cases 50% of the agents know the norm at the beginning and all agents knowing the norm sanction its violation. In Fig. 10 rule K is valid, in Fig.15 no cultural transmission takes place (the results are very similar to the case where K+ is valid). Especially for vision ranges of four and six the survival frequency with disabled cultural transmission and with K+ is significantly better. The better survival frequency is due to the fact that the establishment of the norm is speeded up.

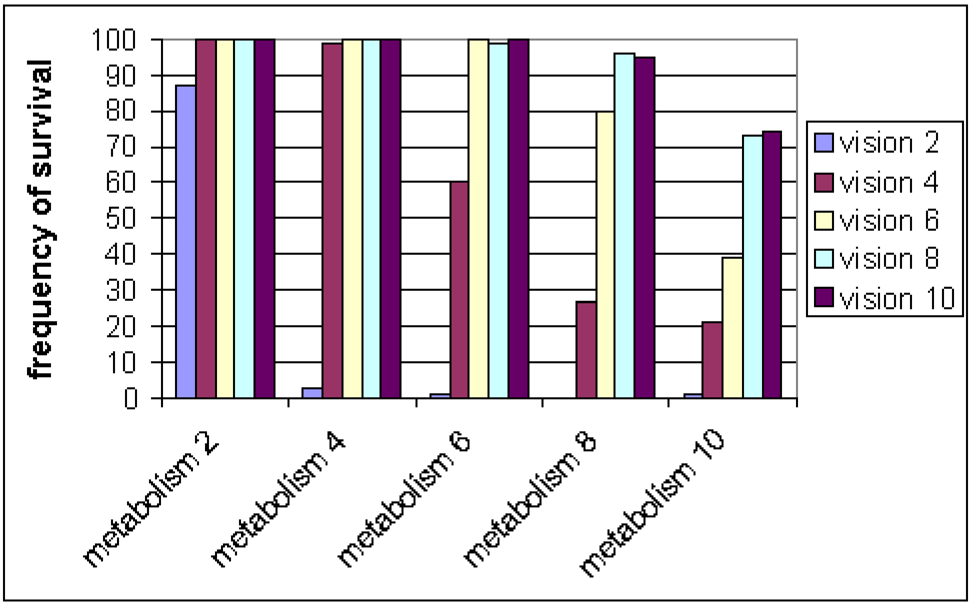

Figure 15: Frequency of survival without cultural transmission with 50% possession meme, 100% sanction meme and a punishment of four

5.19

In case of existing sanction costs, the agents society survives a little bit better with rule K than without, as a comparison between Fig. 12 and Fig. 16 shows. However, the situation is not so easy to analyse because two memes are involved, but it seems that rule K slows down the disappearance of the sanction meme and thus promotes the establishment of the norm.

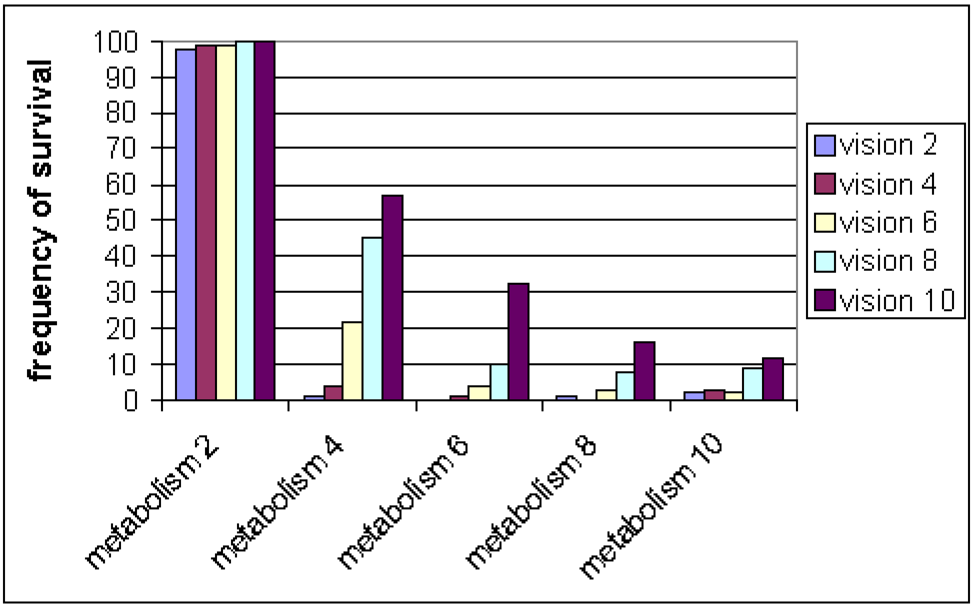

Figure 16: Frequency of survival without cultural transmission with 50% possession meme, 50% sanction meme, punishment twelve and costs of four

Conclusion

6.1

In our simulations the existence respectively the non existence of possession has a strong impact on the probability of survival of the agent population. A notion of possession enables the agent society to survive better also under unfavourable conditions. Thus, from the society point of view, there is a need for a possession norm. As we have seen, norms can emerge under certain conditions. We will try to explain our results in the light of Coleman's theory of norm emergence. We have to clarify whether there is a need for a norm from an individual point of view or not. In other words: are there external effects which cause an individual demand for a norm? An agent collecting sugar may influence agents close to him because he reduces the amount of sugar they can collect at once. However, especially for high metabolism rates this causes a problem because in this case the agents vitally depend on collecting a large amounts of sugar at once. Thus, we find that there is indeed a demand for a norm.

6.2

In any case, it is not obvious how to enforce the norm in this scenario because the agents have some short-term advantages if they do not respect the norm. There exists a gap between the individual and the collective rationality. This is a typical dilemma found in human societies. Examples are the protection of the environment or the duty to pay taxes. Sanctions have to be introduced to impose costs on agents deviating from what is desirable for agents who obey the norm and for the society as whole. Sanctions provide a good possibility to enforce the norm as long as they are not combined with costs for the sanctioning individual. If such costs exist, we have a second order free-rider problem. To achieve the emergence of norms, this problem has to be solved. Without costs, no problem exists and the norm emerges if the sanctions are sufficiently high. With costs, the probability of the emergence depends on both the level of costs and the level of punishment. The problem could be solved with metanorms as Axelrod showed in his simulations (Axelrod 1986) or through proper mechanisms which allow to share the sanctioning costs among all members of the society. Institutions are such mechanisms to share the costs of enforcing norms. Furthermore, sometimes institutions are also responsible for setting norms. On the other hand, institutions are, in turn, based on norms. It would be an interesting task for the future to simulate this two-way dependence of norms and institutions.

6.3

A closer investigation of the meme propagation shows that rule K slows down both the disappearance of a meme and its enforcement. The influence of short-term success on the distribution of memes is decreased slightly by K. In such a way, the possession meme can survive a bit longer than without sanctions. On the other hand, if sanctions are introduced, the meme does not establish itself that fast. In case of existing sanction costs, the positive effect of rule K particularly seems to be that the drop of the sanction meme in the population is slowed down and therefore the possession norm can assert itself more easily.

6.4

As we have shown, norms could be modelled using Dawkin's concept of memes. Due to the flexibility of this concept it should be easy to model some other kinds of norms, norm emergence and norm propagation. We believe that the combination of norms with the concept of memes offers various opportunities for constructing multi-agent systems as well as for sociological theory building and social simulation.

6.5

A problem of our current model is that the agents are not able to change their behaviour due to learning processes during life-time. Integrating some learning mechanisms in the agents would make it possible that agents learn when to respect and when not to respect the norm. It would also be interesting to combine our model with approaches that give agents the possibility to recognise other agents, so that they could regulate their behaviour according to the experiences they have already made with a certain agent. The long-range goal is to enable the agents to organise themselves and to build up institutions, leading to the emergence of more complex society structures.

Notes

<DT

[1]Epstein and Axtell use K as symbol for a combination of two rules:The agent cultural transmission andthe group membership rule. Since we do not need the group membership rule, in our work K only denotes the cultural transmission rule. Note that, apart from that, we use the original cultural transmission rule without modification.

Online Resources

Executables (Win 95/98/NT), source code (Borland Delphi 4) and tables of all our experiments are accessible via <http://www.Informatik.Uni-Mainz.DE/~flentge/norm-sim_eng.html>

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