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COEXISTENCE OF SOCIAL NORMS BASED ON IN- AND OUT-GROUP INTERACTIONS

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The question how social norms can emerge from microscopic interactions between individuals is a key problem in social sciences to explain collective behavior. In this paper, we propose an agent-based model to show that randomly distributed social behavior by way of local interaction converges to a state with a multimodal distribution of behavior. This can be interpreted as a coexistence of different social norms, a result that goes beyond previous investigations. The model is discrete in time and space, behavior is characterized in a continuous state space. The adaptation of social behavior by each agent is based on attractive and repulsive forces caused by friendly and adversary relations among agents. The model is analyzed both analytically and by means of spatio-temporal computer simulations. It provides conditions under which we find convergence towards a single norm, coexistence of two opposing norms, and coexistence of a multitude of norms. For the latter case, we also show the evolution of the spatio-temporal distribution of behavior.

Keywords: Social norms; coexistence; in-group; out-group.

1. Introduction

How individual behavior is determined or at least influenced by social norms is one of the classic questions of social theory. Here, we consider a norm as a rule guiding individual decisions concerning rituals, beliefs, traditions, and routines. Populations of individuals or sometimes even companies or nations often exhibit a remarkable degree of coordinated behavior helping to prevent or govern conflicts. When this coordination is enforced without the help of a central authority, the coordinated behavior and the arising regulation of conflict may be due to the existence of norms. What distinguishes a norm from other cultural products like values or habits is the fact that adherence to a social norm is enforced by sanctions. As Ref. 2 states it: "A norm exists in a given social setting to the extent that individuals usually act

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in a certain way and are often punished when seen not to be acting in this way." Therefore, the existence of a norm is not a matter of yes or no but a matter of degree. In turn, how often a certain action is taken or how often an actor is punished for not taking that action determines the growth or decay of a norm.

A social norm can persist although the initial rational origin changes or even vanishes over time. Actions that were originally performed because they were necessary for surviving under certain environmental conditions may continue to persist as a social norm although the current circumstances no longer require them. Thus, a norm may or may not have a rational foundation. Norms are sometimes unwritten and unspoken rules that become apparent only when they are violated. Nevertheless, in some societies norms are clearly defined rules.

Adherence to norms is enforced by sanctions which may be formal or informal. For instance, in politics, civil rights and civil liberties are not only supported by the power of the formal legal system but as well by informal norms determining what is acceptable [2]. Then again, violation of a norm may be punished on a purely informal level such as by stigmatizing or ignoring the violator. Typical sanction mechanisms used in real life are ostracism, physical retaliation, refusal of social approval, gossip, etc. [11]. In the course of development of a society, it may happen that norms become internalized such that violation of norms is psychologically painful for the deviator even when the sanction mechanism is no longer active [25]. If a norm is internalized by every member of a society, the norm remains stable even without performing any sanction. Another possibility of enforcing a social norm is given by considering one special type of behavior to be the "normal" situation, e.g. in a certain society a leading position can only be assigned to a man, people above a certain age are assumed to be married, and the like. Consequently, the existence of a social network is a prerequisite for successful implementation of social norms.

Although norms determine individual behavior they must be negotiated on the macro level [18]. Different subgroups of a society possess different abilities to transfer their local guidelines to other groups. Basically, the more resourceful groups may allocate resources to less resourceful groups who will support the institutionalization of a certain norm. In the sequel both groups internalize the norm. The resourceful also have the power to sanction deviation which stabilizes the norm and further increases the power of the resourceful. However, not all groups within a society will adopt a certain norm. Individuals may consider themselves associated with an inclusive group (in-group) but also have the desire to dissociate from certain other groups of individuals, the out-groups. This interplay of association and dissociation on the one hand strengthens solidarity within in-groups, but on the other hand allows for coexistence of contradicting norms within a society. Consequently, in one and the same situation, the expectations regarding a certain desired behavior differs among members of different groups [24].

Reference 2 investigates the emergence and stability of behavioral norms within an n-person game. The players can choose to defect and receive a payoff for defection. In the next step, those players who catch the defector out have the

opportunity to impose a punishment but have to bear the enforcement costs. However, if this punishment is costly, a norm to cooperate will not necessarily be established. Each strategy has two dimensions determining the players propensity to defect and the probability to punish deviant behavior. The actors are endowed with limited rationality and apply an evolutionary approach to choose their strategy. They observe each other and the more successful strategies are more likely to be imitated. Numerical simulations reveal that this setup basically does not support the emergence and stability of a norm suggesting cooperative behavior. Since no one has any incentive to punish a defection, the question arises how a norm can ever get established. Therefore, Axelrod employs a metanorm ensuring that agents must punish those whom they detected not punishing observed deviant behavior. With this extension, a norm against defection is established and stable once it is established.

Reference 11 shows that rational actors in a one-shot situation are able to enforce social norms with sanctions even when the punishment is costly. Many papers address the presence of such social norms. For instance, Ref. 22 observes the effects of a presence of family-size norms which indicate that an agent's fertility behavior depends on prices and income as well as on the fertility rate of the cohorts. Reference 21 investigates the interplay between social norms and economic incentives. They consider a continuum of individuals facing the decision to work or to live off public transfers. Those individuals who refuse to work receive a transfer but also suffer from embarrassment due to social stigma. This disutility increases as the share of people refusing to work decreases. Thus, the strength of the social norm, that the source of an individual's means of subsistence should be the individual's own work, is determined endogenously within the modeling framework. The model investigated by Lindbeck allows for two possible outcomes: a low-tax society determined by a majority of taxpayers or a high-tax society carried by a majority of transfer recipients.

Reference 6 analyzes a multi-generation model in which parents can improve their children's matching prospects by increasing savings. If all families do that, the offspring's advantage vanishes since their parents activities offset each other. Nevertheless, the system is not in an equilibrium if all families abandon this effort since in such a situation it would be advantageous for any single family to deviate. Reference 6 showed that there exist equilibria where over-saving takes place as well as equilibria where it is suppressed. In an extended version of this model, Ref. 7 includes a *wealth-is-status social norm*, which means that a woman receiving multiple proposals accepts the one from the wealthiest candidate, and an *aristocratic social norm* where a man's status is inherited. While the former social norm leads to over-saving and deadweight losses, the latter allows one to suppress over-saving within families belonging to the upper class.

Another promising field of application of social norms is the investigation of life course events. Certainly, the timing and sequencing of major events of an individual's life course, such as the first sexual relationship, union formation, leaving

parental home, marriage, and first birth is determined by decisions which are in principle taken by the individual. Nevertheless, the individual's environment has an influence on these decisions. This influence may take place through normative guidelines providing some rules of thumb generated by the society as a whole but also through imitation of the behavior of the individuals who are closely connected — the relevant others. Neglecting these influence mechanisms, that is, not to behave according to the rules may incur some costs for the individual such as the exclusion from a group or the loss of reputation. Therefore, the normative rules guiding the timing of major life course events are enforced by formal and informal sanctions. This qualifies the guidelines to serve as perceived social norms shaping individuals' lives. Reference 4 does an empirical in-depth analysis of perceived norms regarding lower and upper limits on sexual debut and marriage.

Reference 5 introduces an agent-based, one-sex non-overlapping-generations model to understand the dynamics of the intergenerational transmission of age-at-marriage norms. The social norms at first influence the agents mate search decisions. In the case of a successful search resulting in a marriage, the norms of the partners are transmitted to their offspring by means of a certain combiner creating a new norm for the child based on the parents' norms. Reference 1 investigates whether these results also hold in a more complex setup where heterogeneity with respect to age and sex is explicitly taken into account. Moreover, they also include the timing of union formation and fertility into the model. To create a more realistic model of the evolution of age norms, the characteristics of the agents are extended and the social norms are split into two sex-specific norms.

The age-at-marriage norms serve as guidelines for individuals to make decisions about the right point in time to get married. Normative guidelines generally are a decision guidance whenever an individual has to decide about something important. Thus, certain actions are influenced by social norms or social rules that state how individuals ought to behave in certain circumstances.

The individual being in the situation of taking a decision at the micro level is guided by social norms imposed at the macro level. Moreover, the set of all micro level decisions within a certain society generates the macro level behavior of the system which may either strengthen the existing social norms or weaken them if there is a collective trend to deviate. Thus, the long-run development of social norms is the result of collective dynamics within a social network. The society is a system containing a large number of individuals interacting through their social networks to serve their own needs. References 15–17 provide a theory of embeddedness suggesting that all economic action accomplished either by individuals or by organizations is enabled, constrained, and shaped by social ties among individuals. The number of connections may vary among individuals but we may assume that there is no completely unconnected individual (except the man on the moon) and no one is connected to all others. The impact of different types of connectivity, i.e. the influence of the network structure under consideration has been extensively studied (see, for instance, Refs. 3, 8, 23, and 26).

Reference 12 emphasizes that human beings are not only the result of biological evolution but also of a process of cultural evolution. In contrast to genes, which can only pass unidirectionally from one generation to the next, norms, ideas, conventions, and customs can pass between individuals distant from each other and even from the children to their parents. Ehrlich and Levin postulate that a clear understanding of the interactions between cultural changes and individual actions is crucial to the success of efforts to influence cultural evolution. Cooperation in human societies relies essentially on social norms even in modern societies, where cooperation substantially hinges on the legal enforcement of rules. A theory of social norms should help to explain how norms emerge, how they are maintained, and how one norm replaces another. Moreover, we do not only want to discuss individual behavior in the presence of norms but also how norms change over time.

The remainder of this paper is organized as follows. Section 2 explains the simulation model we developed to investigate the evolution of norms within a population of artificial agents, followed by a detailed discussion of several model aspects in Sec. 3. In Sec. 4, we present and discuss the results obtained in various runs of numerical simulations, and in Sec. 5, we summarize and interpret these results.

2. The Model

We consider an artificial population featuring N agents. Each agent $i \in \{1, \ldots, N\}$ is linked to other agents from his in-group $I(i)$ and his out-group $O(i)$. That means within the social network of agent i we distiguish between two different subgroups: members of an agent's in-group can be seen as his friends, whereas the members of the out-group are regarded as persons with whom he has adversary relations (enemies). The number of agents in $I(i)$ is given by $k_i := |I(i)|$ and the size of $O(i)$ is $l_i := |O(i)|$. The behavior of agent i at time t is denoted by $x_i^t \in [0,1]$ and the current behavior of all agents within an in-group determines the group's social norm.

We further assume that $I(i)$ and $O(i)$ are always disjoint and that the in-/out-group relation is symmetric, e.g. $j \in I(i) \Leftrightarrow i \in I(j)$ and $j \in O(i) \Leftrightarrow i \in O(j)$. So, for example, an agent can neither belong to another agent's in- *and* out-group nor not be included in another agent's in-group (or out-group respectively) if he conversely belongs to the latter agent's in-group (out-group).

If agents i and j belong to the same in-group but deviate from each other, they receive (and impose) a punishment which increases with the difference $x_i^t - x_j^t$ between their social behavior. In order to ensure a symmetric punishment and to ease the model's analytical tractability, we simply choose the square of that difference, $(x_i^t - x_j^t)^2$. Consequently, agent i receives a disutility for deviating from his in-group members' behavior which is proportional to $\sum_{j \in I(i)}(x_i^t - x_j^t)^2$. Moreover, the agents are reluctant to change their own behavior, which is characterized by a disutility proportional to $(x_i^{t+1} - x_i^t)^2$. Finally, each group of the population has the desire to express its own identity. Therefore, agents obtain a positive utility by

differing from the out-group proportional to $\sum_{j \in O(i)} (x_i^t - x_j^t)^2$. We assume that agent i can only observe the current behavior within the population but does not have the ability to anticipate future movements of other agents. So, to determine the utility maximizing behavior x_i^{t+1} at time $t + 1$, he uses the previous behavior x_j^t of his in-/out-group members (including his own behavior x_i^t).

Introducing the parameter $\alpha \in [0, 1]$ to adjust the weight of his utilities and disutilities caused by his own opinion on the one hand and his in- and out-group members on the other, the utility function which agent i wants to maximize becomes

$$U(x_i^{t+1}) = -\alpha(x_i^{t+1} - x_i^t)^2 + (1 - \alpha)$$

$$\times \left[- \sum_{j \in I(i)} (x_i^{t+1} - x_j^t)^2 + \sum_{j \in O(i)} (x_i^{t+1} - x_j^t)^2 \right]. \tag{1}$$

Note that therefore the higher α is, the more an agent will be punished for deviating from his behavior at the previous timestep. On the other hand, the outer influence from in- and out-group will increase with growing group-sizes k_i and l_i.

Assuming that an agent cannot foresee the impact of his own decision on the other agents' behavior, the partial derivatives of (1) become

$$\frac{\partial U(x_i^{t+1})}{\partial x_i^{t+1}} = -2\alpha(x_i^{t+1} - x_i^t) + 2(1 - \alpha)$$

$$\times \left[- \sum_{j \in I(i)} (x_i^{t+1} - x_j^t) + \sum_{j \in O(i)} (x_i^{t+1} - x_j^t) \right], \tag{2}$$

$$\frac{\partial^2 U(x_i^{t+1})}{(\partial x_i^{t+1})^2} = -2 \left[\alpha + (1 - \alpha)(k_i - l_i) \right]. \tag{3}$$

If the utility function is strictly convex (i.e. its second derivative is positive), the optimal x_i^{t+1} must be either zero or one. But this means every agent's choice will always be one of these extreme values, which seems inappropriate for further consideration as the spectrum of behavior would be reduced to only two possible values. For this reason, we assume

$$\alpha + (1 - \alpha)(k_i - l_i) > 0. \tag{4}$$

It is sufficient (but of course not necessary) for this condition that every agent's in-group consists of at least as many members as his out-group does. Otherwise, we must choose α close enough to one.

With assumption (4), the utility maximizing $x_{\max}$ becomes

$$x_{\max} = \frac{\alpha x_i^t + (1 - \alpha)(\sum_{j \in I(i)} x_j^t - \sum_{j \in O(i)} x_j^t)}{\alpha + (1 - \alpha)(k_i - l_i)}. \tag{5}$$

As $x_i^{t+1} \in [0, 1]$ is required, we set

$$x_i^{t+1} = \begin{cases} x_{\max} & \text{for } x_{\max} \in [0, 1], \\ 0 & \text{for } x_{\max} < 0, \\ 1 & \text{for } x_{\max} > 1, \end{cases} \qquad (6)$$

to choose the optimal value within this interval and by this define the dynamics in a way that always $x_i^{t+1} \in [0, 1]$. If $x_{\max} < 0$, we choose the left border of that interval, and if $x_{\max} > 1$, the right one.

3. The Isolated In-Group Mechanism

3.1. *Costs of sanctions*

Now, we will have a look at the costs of being punished and at the costs of imposing a punishment. Recall that in the simple version of the simulation model of Ref. 2, the agents are reluctant to impose a punishment since there is no economic incentive to punish and it even incurs costs. However, as Ref. 13 points out, sanctions are the decisive factor for norm enforcement. Anyhow, in the real world individuals are willing to impose a punishment even if this is disadvantageous in economic terms as long as the costs of imposing a sanction are not very high. In an experimental setup deployed in Ref. 14, a third party observes test persons in a prisoners' dilemma and has the option to punish players for defecting. Although disadvantageous from a purely profit-maximizing point of view, third parties are willing to punish defection particularly when the opponent cooperated. Thus, the enforcement of norms is largely driven by nonselfish motives. These findings may empirically justify Axelrod's approach to include a metanorm. In our model, we exercise a similar approach by just taking it for granted that people are punished and impose a punishment, respectively, if agents deviate from the behavior of their in-group [recall Eq. (1)]. Nevertheless, a social norm will only be enforced by sanctions if the costs of punishing are much lower than the costs of being punished. In principle, the sanction mechanism in our model is totally symmetric as in case of deviation of two agents they will receive an identical decrease of utility. But having a high majority for a certain opinion in a group offers a slightly different interpretation: let us assume a fully connected group of individuals without any further links to outer agents. Moreover, since we are only looking at the sanction but not at the desire to deviate from the out-group, we assume them to be empty so that all links with the group represent in-group connections. We further assume having an agent deviating from the homogeneous rest of the group, i.e. we have the two types of behavior x_1 and $x_j = x$ for $j \in \{2, \ldots, n\}$. Because of its dominance within the group, the latter opinion could be considered as this group's norm.

If agent 1 refuses to converge toward the other agents (i.e. $x_1^t = x_1 \forall t$) and the other agents refuse to converge as well, he receives a disutility

$$U(x_1) = -(1 - \alpha)(n - 1)(x_1 - x)^2 \qquad (7)$$

from being punished while the other agents have to bear the costs

$$U(x_j) = -(1 - \alpha)(x_1 - x)^2 \tag{8}$$

for imposing the punishment. Therefore, the disadvantage of being punished is $(n - 1)$ times higher than the enforcement costs.

Considering the isolated out-group mechanism (empty in-groups) in an analogous situation, every agent would receive a positive utility $\tilde{U}(x_i) = -U(x_i), 1 \leq i \leq n$ for deviating from his out-group. So the change in utility caused by deviation can be interpreted as a reward instead of a punishment here.

If the agents maximize their utility in a scenario with empty out-groups, we can conclude from Eq. (5) that their behavior in the next time step becomes

$$x_1^{t+1} = \frac{\alpha x_1^t + (1 - \alpha)(n - 1)x^t}{\alpha + (1 - \alpha)(n - 1)}, \tag{9}$$

$$x_j^{t+1} = \frac{(1 - \alpha)x_1^t + [\alpha + (1 - \alpha)(n - 2)]x^t}{\alpha + (1 - \alpha)(n - 1)}, \quad 2 \leq j \leq n. \tag{10}$$

From that, it follows that the deviator (agent 1) makes a $(n - 1)$ times bigger movement than the other group members. For $\alpha = 1/2$, the agents converge to a common behavior already after one iteration.

3.2. *Status within a group*

In real populations, the status of an individual determines his power and influence and also his propensity to adhere to social norms. Individuals with a higher status gain more from community membership which also increases the threat of ostracism. If an individual gains little or nothing from community membership, the threat of ostracism is of little importance [7]. In this simulation, the number of links an agent possesses represents his status within the population. As we can see from the utility function or directly from the dynamics in (5), the possible punishment and therefore an agent's change in behavior increases with the size of his in-group. Hence, the number of connections determines the influence of the individual on the behavior of the population but also the number of people who can punish an agent for deviating from their own behavior. Consequently, agents with a higher status are more interested in corresponding to their relevant others than those with a low status.

3.3. *Connections to other models*

Note that in the case every agent's out-group is empty (e.g. $k_i = 0$), we have $x_{\max} \in [0, 1]$ and the dynamics can be written as

$$x^{t+1} = Ax^t \tag{11}$$

and therefore

$$x^{t+1} = A^{t+1}x^0 \tag{12}$$

with $x^t = (x_1^t, \ldots, x_N^t)^T$, x^0 representing the initial behavior and a $n \times n$-matrix $A = (a_{ij})$ defined by

$$
a_{ij} = \begin{cases} \dfrac{\alpha}{\alpha + (1-\alpha)k_i} & \text{for } i = j, \\[3mm] \dfrac{1-\alpha}{\alpha + (1-\alpha)k_i} & \text{for } i \neq j, \ i \in I(j), \\[3mm] 0 & \text{for } i \neq j, \ i \notin I(j). \end{cases} \tag{13}
$$

One can easily verify that A is row-stochasticm, i.e. in any row, its components sum up to one. Thus, omitting the out-group mechanism, we get a special case of the model introduced in Ref. 10.

So, if we only consider the punishment of deviation from the in-group, an agent's behavior is a weighted mean of his own and his in-group members' behavior one timestep before. The dynamics thereby only depend on A and its powers. If the powers of A converge to a matrix with identical rows, all agents will finally adopt the same global social norm. Sufficient and necessary conditions for this can be taken from Ref. 19. Hence, the asymptotic behavior of the agents qualitatively only depends on the in-group structure and its representing graph or adjacency matrix. A change of the initial vector x^0 or the parameter α within the interval $(0, 1)$ would only affect the value of the limit but not the qualitative asymptotic behavior.

In the absence of out-group interactions, our model is also connected in both its formulation and some limiting results to the model of Ref. 9 whereas the agents interact pairwise in the latter case. Furthermore, Ref. 20 also provides attracting and repulsive forces in continuous opinion dynamics as an extension of Ref. 9. There, the agents attract each other if their current distance in behavior is below a threshold while repulsion occurs if this distance is above a second threshold. In our model, not the agents' current state but the in-/out-group structure determines whether attraction or repulsion takes effect on them.

4. Simulation Results

Evidently, our model's dynamics heavily depend on the in-/out-group structure of the agents, which can be arbitrary complex. In our simulation, we generate random in- and out-groups considering the spatial relation between the agents, which is defined by an additional network: in our setting a two-dimensional lattice with periodic boundary conditions. The spatial effect is brought into play by assuming that, for an agent, it is more likely to have (positive or negative) relations to other agents in a certain neighborhood compared to far distant agents. Thus, with $N(i)$

denoting the neighborhood for agent i, we define

$$p_1^+ = P(j \in I(i)|j \in N(i)),$$

$$p_1^- = P(j \in O(i)|j \in N(i)),$$

$$p_2^+ = P(j \in I(i)|j \notin N(i)), \tag{14}$$

$$p_2^- = P(j \in O(i)|j \notin N(i))$$

as the probabilities for an agent $j \neq i$ to be in the in- or out-group of agent i. We further assume $p_1^+, p_1^- > p_2^+, p_2^-$, which means that it is more likely for an agent to be in another one's in- or out-group if he is in that agent's neighborhood (see Fig. 1). Based on these probabilities, we construct a random in-/out-group structure for every agent.

In our simulations, we always consider $N = 900$ agents, each with a Moore-neighborhood of size 13×13, with the agent placed in the center. For $\alpha = 0.9$, Fig. 2 shows the agents' trajectories and the distribution of their behavior after the last timestep of simulation for in-/out-group realizations for different values of the probabilities from Eq. (14). The first two examples show simpler cases: in Figs. 2(a) and 2(b) we observe that the agents very quickly converge to a consensus very close to 0.5, so here the spectrum's center is the norm all agents finally conform to. This case always appears if the size of the agents' in-group is large compared to their outgroup-size.

Figures 2(c) and 2(d) show a setting where we find a wider spectrum of behavior. Here, every agent has about five times more friends than enemies in his neighborhood while outside of this the ratio is *vice versa* (with lower absolute numbers). So, it is more likely for an agent to accord with his neighbors, which also makes
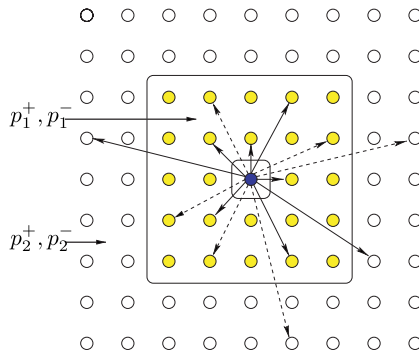

Fig. 1.   Two agents are in each other's in-group (out-group) with a probability p_1^+ (p_1^-) if they are neighbors with respect to the Moore-neighborhood of size 2. Otherwise, the probability is p_2^+ (p_2^-). Solid lines illustrate the central agent's in-group relations while his out-group relations are represented by dashed lines. Note that $p_1^+, p_1^- > p_2^+, p_2^-$, i.e. there are more relations to neighbors than to agents outside the neighborhood.
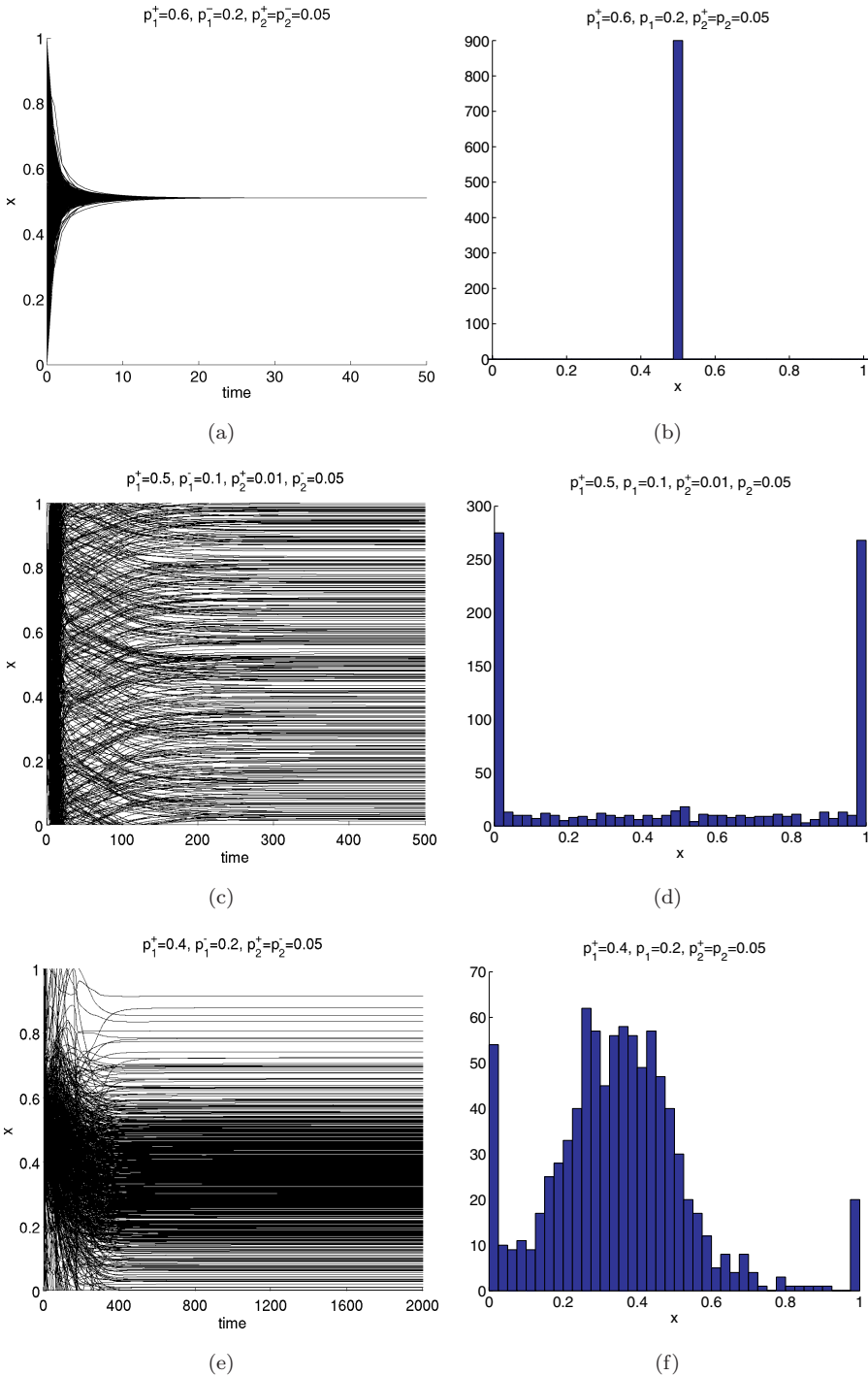
Fig. 2. Trajectories and distribution of the agent's behavior x_i after the last step of simulation: (a) and (b): 50, (c) and (d): 500, (e) and (f): 2,000 time steps.

a more likely emergence of local clusters plausible. The simulations show that in this situation, we find about one third of the agents stabilizing at each end of the spectrum while the last third is almost equally distributed over $[0, 1]$.

The most interesting situation is shown in Figs. 2(e) and 2(f): the setting is similar to Figs. 2(a) and 2(b), only p_1^+ has been reduced from 0.6 to 0.4. This reduction of each agent's in-group in his neighborhood reduces the attracting force between the agents sufficiently to avoid a global consensus in behavior. Instead of this, we find about three peaks in the distribution: one at the empirical mean of approximately 0.37 and two at the end of the interval whereas the peak at zero is higher than at one.

For this situation, Fig. 3 depicts the spatial evolution of the agents' behavior over time. Already after two iterations, the initial random distribution has been evened out to a level close to 0.5 for almost all agents — this also applies to most other observed settings. So, we have a short time scale where attraction between the agents is dominant. On a second, larger timescale we observe a differentiation of the agents' behavior: after 50 steps, we find that agents in the upper region prefer values greater than 0.5 whereas at the opposite side values lower than 0.5 are preferred. Furthermore, the empirical mean of the agents' behavior decreased clearly under the initial value of 0.5. In the next picture, we find the the upper-left corner dominated by agents with values higher than 0.5 while the remaining area the majoritarian behavior is clearly lower than 0.5 and the overall empirical mean is already lower than 0.4. As we see in Figs. 3(e) and 3(f), this situation remains stable for the rest of the simulation, so neither the contracting nor the dispersing forces prevail by driving the agents to total consensus or polarization respectively. An animated computer simulation (in color) of the whole spatio-temporal evolution shown can be found at www.sg.ethz.ch/research.

Varying the parameter α [without violating Eq. (4)] to change the weight for an agent's own behavior and that of his in- and out-group, respectively, did not change the results qualitatively and only affected the system's time to reach its stationary state — a larger α increases an agent's weight on his own behavior and extends this time.

5. Conclusions

In this paper, we have studied the emergence of social norms to allow for a better understanding of the self-organized dynamics of social behavior in human societies. Our model considers several influences explicitly: persistence, i.e. the individuals' reluctance to alter their behavior, solidarity, the desire to be associated with a certain group (the in-group), and the desire to differ from some individuals belonging to the out-group. These three components have been incorporated in an agents' utility function to be maximized. While some literature on social norms suggest that norm enforcement is driven by nonselfish motives (Ref. 14, for example), we consider profit maximizing agents but explicitly define a disutility obtained from deviations within the in-group. Thus, instead of inserting a metanorm as in Ref. 2,
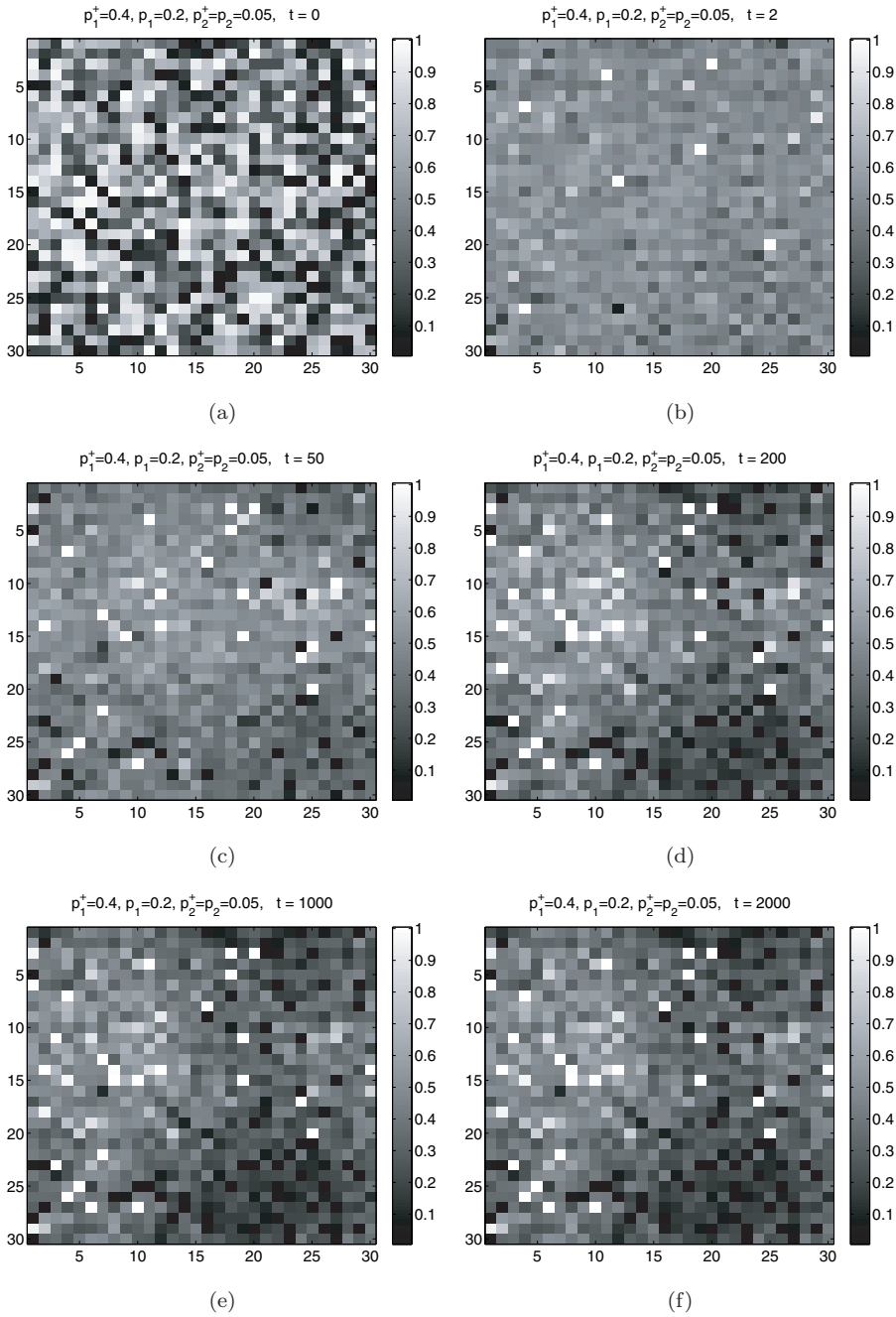
Fig. 3.   Spatio-temporal evolution of the agent's behavior x_i, which is coded in grey scale. The probabilities for the in- and outgroup relations within and outside the neighborhood are chosen as $p_1^+ = 0.4$, $p_1^- = 0.2$, $p_2^+ = p_2^- = 0.05$, which allows for the spatial coexistence of a multitude of different norms. The corresponding distribution is shown in Fig. 2(f). From this histogram, it is clear that there are at least three dominating peaks, which can be interpreted as different social norms.

the agents in our model are just assumed to experience a disutility from deviation or bear the costs of imposing a sanction, respectively.

The agents' in- and out-group-structure — one of the key features of our model — is chosen randomly with the restriction that an agent is more likely linked to neighboring agents than to those outside his neighborhood. Hence, an agent's interaction is not restricted to this neighborhood, but its influence on him is higher compared to the rest of the population. Depending on these probabilities, we could observe different effects. The greater the in-group size is compared to the out-group size, the more the attracting forces between the agents dominate and lead to global consensus at the center of the spectrum of behavior. If we increase the out-group size to a certain level, the attraction between agents is still dominant at the beginning whereas on a larger time scale we find a differentiation of the agents' behavior leading to stable clusters with different social norms. Further increasing of the out-group size results in a polarization of the agent's behavior with a majority equally distributed over the two extreme values zero and one.

We analyzed the model analytically and by means of computer simulations where the simulation is not systematic but restricted to interesting examples. As a major finding, our model is appropriate to explain the emergence and the stable spatio-temporal coexistence of different social norms prevalent in certain subgroups of the society. Further, the final distribution of behavior is smoother compared to the opinion dynamics model of Ref. 20, which also provides coexistence in a spatio-temporal setting caused by attractive and repulsive forces between the agents. We want to emphasize that the topology of the social network, in particular the in- and out-group structure, is crucial for the development of the agents' social behavior. For the model under consideration, we can imagine situations which may not converge into a (quasi)stationary distribution, i.e. agents change their social behavior constantly over time and the social norm adjusts instantaneously. While this kind of scenario may also have some relevance, we argue that a social norm should change only on time scales larger than the dynamics of the agents' individual behavior (which is shown as a quasistationary phenomenon in this framework).

A future extension of the model shall include the fact that in reality an individual's social network is not static, but changes over time. In our model, this can be covered by an explicit dynamics of the probabilities $p_1^+, p_1^-, p_2^+, p_2^-$. More generally, one could also consider feedbacks between the agents' behavior and the in- and out-group relations or a network topology which changes endogenously.

Acknowledgments

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