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Competition between Social Groups, In-group Favoritism and Population-level Cooperation

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Abstract

Humans are social beings; people are predisposed to join groups, categorize the social world into groups, and prefer fellow in-group members over out-group members. Social groups in turn compete for individuals and especially for the resources of individuals to maintain the cultural practices and symbolic markers of the group. We modeled the effect of this competition on population level cooperation. Using game theoretic and network science methods, we found that groups would develop and maintain norms that restrict their members to join other groups. If every group can maintain such norms against every other group (the topology of the group-network is complete), the society is composed of closed communities which do not cooperate with each other. Changing the topology of the group-network can yield larger cooperating components within the population, because, in this case, members of antagonistic groups can join a third group, thereby allowing cooperation between them. The results suggest that the individuals' ability to join more than one social group is crucial for maintaining cooperation in large populations.

Introduction

Groups play an essential role in the structure of human societies: humans are inherently social beings; people are predisposed to join groups and to derive part of their identity and self-esteem from group–membership (Baumeister and Leary 1995; Fiske 1992; Hogg et al. 2008; Leary and Baumeister 2000; Leary 2010; Tajfel and Turner 2004). Social exclusion, lack of group membership can lead to psychological and physical symptoms (Cikara and Van Bavel 2014; DeWall and Richman 2011; Eisenberger et al. 2003; Gardner et. al 2000; Kerr and Levine 2008; Pickett, Gardner 2005), suggesting that human psychological mechanisms reflect an important aspect of the evolutionary history of the species, namely, living in groups for millions of years (Boehm 2012; Bowles and Gintis 2011;

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Dunbar and Shultz 2007; Neuberg et al. 2010; Richerson and Boyd 2005; Sober and Wilson 1998). As the community gets bigger and more complex, in order to be able to cope with the computational demands of the social world, people perceive more categories, more groups (Macrea and Bodenhausen 2000), and individuals can become members of more than one group at the same time, e.g. family, ethnic and religious community, nation, workplace groups, imagined and virtual communities (Anderson 2016; Brewer 2010).

A social group has important, distinctive features—norms. Norms are informal rules that emerge through interactions of the members, guide and restrict the behavior of members, and distinguish one group from another (Cialdini and Trost 1998; Hogg 2010; Kameda et al. 2005; Richerson and Heinrich 2012; Sanfey et al. 2014). Humans have an innate predisposition to internalize the norms of the groups they belong to (Chudek and Heinrich 2011; Spitzer et al. 2007) and they devote resources (most importantly time and cognitive capacity, but also material resources) to maintain the cultural practices of the given community. A social group without members to practice its norms is non-existent—the norms that governed the behavior of members of historical social groups can still be preserved and known, but no one is actually a member of that group, so it does not play any role in the social structure of the current societies (for example, we possess knowledge of the norms held by the priesthood of Cybele, the originally Anatolian goddess, later adopted in ancient Greece and Rome, but that religious cult has become merely historical since it has no followers anymore to internalize those norms, see e.g. Ferguson 1985).

Moreover, individuals develop so-called in-group favoritism, that is, they prefer fellow group members over out-group members, and are more likely to cooperate with them than others (Darley 2008; Efferson et al. 2008; Voci 2006; Everett et al. 2015; Fu et al. 2012 Greenwald and Pettigrew 2014).

Social groups in turn are competing for the resources of members, especially for their time, to maintain the cultural practices, norms, and symbolic markers that distinguish them from other groups. In this study, we investigate how the group competition for members and for their resources along with the interplay between in-group favoritism and multi-group membership affect population-level cooperation. To end this, we developed a model which applies game theoretic and network science methods.

The Model

In the model, it is assumed that people cooperate only with their in-group partners. If there is only one group in the society and everyone is a member, then cooperation is complete in the sense that in-group favoritism is applied to everyone, so no-one is excluded from that due to group membership (see Figure 1. a).

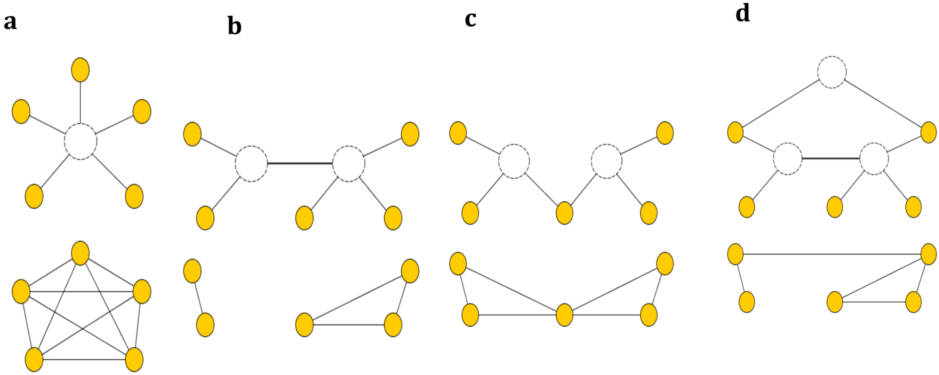

Figure 1. Social structure and cooperation. The graphs in the first row show group membership. The colored and white nodes represent individuals and groups, respectively. An edge between a group and an individual represents group membership. Edge between groups means possible strategic interaction; dual membership is not allowed between connected groups. The lower graphs are the individual projection graphs of the upper graphs, where an edge indicates cooperation between two individuals. (a) One group, every individual is member of the same group, the projection graph is complete, i.e. everyone cooperates with everyone else. (b) Two groups, dual membership is not allowed, the projection graph is disconnected. (c) Two groups, dual-membership is allowed, the projection graph is connected. (d) Three groups, dual-membership is partly allowed, the projection graph is connected.

However, with two (or more) groups, individuals might be members of one group, but not the other(s). In this case, they do not cooperate with people from the other social group, and the community becomes fragmented (see Figure 1.b). This problem can be solved by allowing individuals to join both groups; thereby they can cooperate with individuals from both groups (see Figure 1.c). This social structure can be grasped by using a bipartite graph in which there are two types of nodes: one represents the individuals (colored ones in Figure 1), the other the social groups (white ones in Figure 1), an edge between an individual and a group represents membership. The projection of individuals in the graph shows the cooperation network between individuals (see Methods section). That is, the projection graph is derived from the bipartite graph such that individuals constitute the nodes of the projection, and an edge between two individuals indicates they are members of the same group (see the graphs in the second row in Figure 1), hence they can cooperate with each other directly. In this case, a fragmented society is understood as a projection graph which is not connected (see Figure 1.b); there are sub groups which do not have connections to other parts of the graph.

In our model, there are *n* individuals and *m* groups. The individuals start with an initial resource endowment, *r*. A fraction of this resource (*r/k*, *k>0*) is randomly allocated to one of the groups, thereby the individual becomes a member of that group. The process is repeated until all the endowment is distributed to groups. During this process, the situation when an individual, already member of one group and joins a new one, can be seen as in a strategic situation between the two corresponding groups: cooperation in the case of a group means allowing its members to join the other group, while defection means forbidding it. To be precise, defection means that there are certain norms in the group which implicitly or explicitly restrict the members from joining the other group. For example, the fans of the Boston Red Sox and New York Yankees baseball teams hardly root for the rival team, or for another example, consider the institution of dual-citizenship; the process of acquiring a first citizenship is usually straightforward, but gaining a second one is conditional: one usually must apply and meet certain criteria.

Why would such norms and conditions exist? When an individual joins two (or more) groups, she has to divide her resources between the groups. However, if a group restricts its members from joining the other group, there is a chance that the individual will spend the rest of her resources on the given group as well. Specifically, in the model, whenever an individual becomes a member of 2 groups and both are cooperators *vis-à-vis* each other, the individual remains a member of both groups. If one of the groups defects, then the individual withdraws the resource (*r/k*) devoted to the cooperating group and it is reallocated randomly to a group, so given the number of groups is *m*, then with *1/m* probability the resource is reallocated to the defector group. In case of 2 defector groups, the individual randomly withdraws the resource from one of them, and it is reallocated to a group randomly. The exact payoff matrix of the situation can be seen in Table 1.

Table 1. Payoff matrix between two groups (row player perspective)*

	C	D
C	0	-r/k
D	1/m x r/k	-½ x r/k + ½ x 1/m x r/k

*The characters *r*, *m* and *k* denote the total resources of an individual, the number of groups in the model, and a constant (*k*>0), respectively. If both groups cooperate, the individual remains member of both groups. Whenever a defector meets a cooperator, the individual leaves the latter group and their resource is randomly allocated to a new group. Upon mutual defection, the individual leaves one of the groups randomly, and their resource is reallocated to a new group randomly.

To ensure dynamics in the model, a fraction of every individual's resource is reallocated in every 10 periods (on average). The evolutionary stable strategy is DD, that is, both groups forbid dual group membership. In the bipartite graph of the model, edges between groups are allowed, which represent the possible strategic interaction between two groups, thus they can develop norms regarding dual membership with the other group. Lack of edge between groups practically means they do not "see" each other, they do not engage in a strategic situation. In other words, if an individual becomes a member of two such groups during the resource allocation process, she retains both memberships. The reasons for the lack of such strategic interaction in real life can be that the groups in question are new or not populous enough and have not had the time and/or the resource to form and spread such norms. A complete graph topology of groups, therefore, means that every group can develop and maintain norms *vis-á-vis* every other group (i.e. there is an edge between every group node). In this case, the evolutionary stable strategy spreads so that every group restrains its members from joining other ones. Consequently, the social structure ends up being fragmented; the projected graph of individuals is disconnected, every individual is a member of only one group, and there is no cooperation between the members of different groups (see Figure 1.b). The complete graph structure of groups can be thought of as a mature, static social structure, much like a very rigid caste system.

Besides the complete graph topology, for comparison, we explored the effect of using scale-free group topology and star topology. The scale-free property can be found in numerous real world networks ranging from friendship networks to citation and protein networks (see e.g. Barabási 2016), and essentially designates a graph that has many nodes (in fact, the large majority) with only a few connections, while there are very few nodes with many connections (for a strict definition see the Methods section). The star topology is a graph that has a central node, every other node is connected to this one, but there are no connections between the non-central nodes. It would represent a group structure where all the groups can engage in strategic situation with the same social group (the central node), but other than that, the members of the social groups are free to join other groups. Star topology describes a social structure where every social community is defined against the same social group.

Results

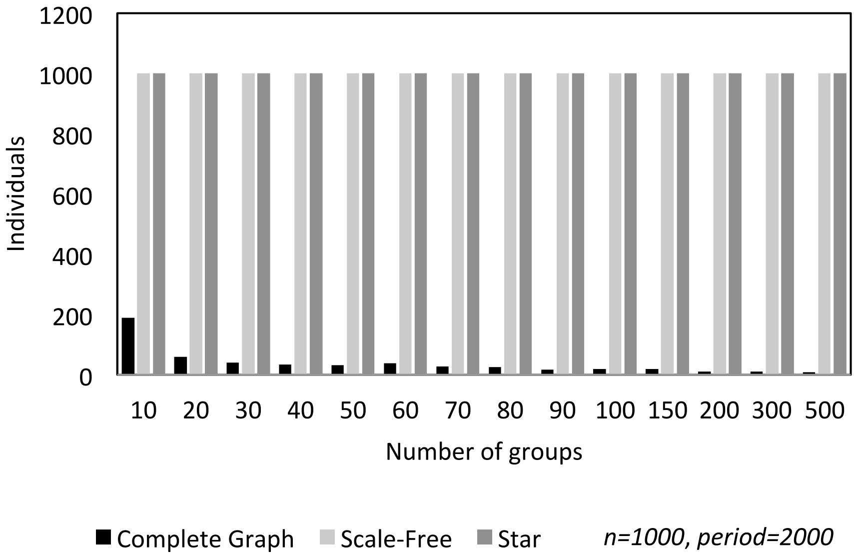

Figure 2. The size of the largest connected component in the individual projection graph. The graph shows the simulation results using different inter-group topology (complete graph, scale-free and star topology, respectively) at different values of *m* (group number). The variables *n* and *period* denote the number of individuals and the length of the simulation, respectively.

We implemented a computer simulation to get numerical insights into the models' behavior; the results can be seen in Figure 2. For our purposes, the most interesting attribute is the size of the largest component of the individual projected graph. The largest component is the largest connected subgraph of individuals, i.e., the most populous subset of individuals who can cooperate with each other, either directly or indirectly. The values of the largest component were investigated at different group numbers (*m*). The largest component in the complete graph setting gets smaller and smaller as the number of groups increases, suggesting that the society is composed of small, closed communities which do not cooperate with each other and have approximately the same number of members. On the other hand, in the other two settings, the largest component covers the whole society. It is important to emphasize that the evolutionary stable strategy spreads in the other two settings as well, although in those cases, the groups are not able to restrict their members thoroughly since they cannot develop norms against every other group in the society. Therefore, there might be situations when two individuals are members of two different groups which restrain their members from joining the other group, but at the same time they are members of a third group against which no such norms exist, thereby they are able to cooperate with each other. This is illustrated in Figure 1.d.

Conclusions

In-group favoritism can both promote and undermine cooperation. It has been suggested by social psychologists and scholars of conflict that antagonistic groups might be able to resolve issues by creating a new, common identity (Dovidio and Gaertner 2010; Fry 2006, 2012) which can serve as an umbrella, and in-group favoritism can be extended to former out-group members. Historians have documented many examples when different groups, such as tribes allied under a common name in order to achieve some common goal, e.g. capturing lands, came together to defend against a common enemy (Gat and Yakobson 2013; Turchin 2007) and, in turn, their original group identity faded away. For an example, consider the largest German tribe, the Franks. The name *Franci* first appeared around AD 250 and described a loose warrior confederacy consisting of small tribes. Initially, the Franks were carrying out defensive and offensive operations in the provinces of Gaul and later built one of the most influential empires in Europe. The identities of the constituting tribes were preserved for centuries, however, with time, eclipsed by the Frankish one and eventually disappeared almost entirely (Geary 1988; Todd 2004). These people basically created a new social group (Frank) which allowed them to retain tribe membership and still cooperate at a larger scale. Our results support and provide an explanation for these observations and suggest that the individuals' ability to join and internalize the norms of more than one social group is crucial for maintaining cooperation in large populations.

Methods.

Formally, the model is a quadruple, that is, $M = (I, G, J, T)$, where:

I is the set of individuals,

G is the set of groups,

J is a set of unordered pair (*i,j*) where $i \in I$ and $j \in G$,

T is a set of unordered pair (*x, y*), where $x, y \in G$.

G and *T* express group-membership relations, and the topology of inter-group relations, respectively. If $(a, b) \in T$ then *a* and *b* engage in a strategic interaction, that is, they play the game whose payoff matrix can be seen in Table 1. The strategy played by the *i*th group is based on a probability variable, p_i, where initially $p_i \sim U(0,1)$. The selection mechanism is truncation selection, i.e. the least performing ten percent of groups (in terms of total resources) copy the *p* value of the best performing 10 percent of groups (De Jong 2006).

The individual projection graph is $P = (I, E)$, where:

I is the set of individuals,

E is a set of unordered pair (*m, n*) where $m, n \in I$. $(m, n) \in E \Leftrightarrow$ there exist a $g \in G$ such that (m, g) and $(n, g) \in J$. In other words, this is a graph of individuals, where an edge exists between two individuals if they are members of the same group(s).

Star topology: there is an $x_0 \in G$, such that for every $y \in G$ $(x_0, y) \in T$ and for all (x, y) where $x \neq x_0$ and $y \neq x_0$ $(x, y) \notin T$.

Scale-free topology: the degree distribution of the graph is the following:

$P(k) \sim k^{-3}$

where *k* is the number of connections. The equation expresses that the probability that a randomly chosen node has *k* connections is asymptotically k^{-3}.

The scale-free group-topology was constructed using the Barabási-Albert algorithm (Barabási and Albert 1999), the giant component is computed using depth-first search algorithm, and the actual agent-based model was implemented in Java language.

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