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The evolutionary advantage of limited network knowledge

Jennifer M. Larson

New York University, 19 W. 4th St., New York, NY 10012, United States

HIGHLIGHTS

- I model the enforcement of cooperation when networks spread gossip relevant to punishment.
- Network structure matters for enforcing cooperation.
- Limited knowledge of network structure among the actors makes enforcing cooperation easier.
- Social sciences show real people have cognitive limits to network knowledge.
- Groups with imprecise network knowledge have an evolutionary fitness advantage.

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ABSTRACT

Groups of individuals have social networks that structure interactions within the groups; evolutionary theory increasingly uses this fact to explain the emergence of cooperation (Eshel and Cavalli-Sforza, 1982; Boyd and Richerson, 1988, 1989; Ohtsuki et al., 2006; Nowak et al., 2010; Van Veelen et al., 2012). This approach has resulted in a number of important insights for the evolution of cooperation in the biological and social sciences, but omits a key function of social networks that has persisted throughout recent evolutionary history (Apicella et al., 2012): their role in transmitting gossip about behavior within a group. Accounting for this well-established role of social networks among rational agents in a setting of indirect reciprocity not only shows a new mechanism by which the structure of networks is fitness-relevant, but also reveals that *knowledge* of social networks can be fitness-relevant as well. When groups enforce cooperation by sanctioning peers whom gossip reveals to have deviated, individuals in certain peripheral network positions are tempting targets of uncooperative behavior because gossip they share about misbehavior spreads slowly through the network. The ability to identify these individuals creates incentives to behave uncooperatively. Consequently, groups comprised of individuals who knew precise information about their social networks would be at a fitness disadvantage relative to groups of individuals with a coarser knowledge of their networks. Empirical work has consistently shown that modern humans know little about the structure of their own social networks and perform poorly when tasked with learning new ones. This robust empirical regularity may be the product of natural selection in an environment of strong selective pressure at the group level. Imprecise views of networks make enforcing cooperation easier.

1. Introduction

Groups of individuals have social networks that structure interactions within the groups. Evolutionary theory increasingly turns to the fact that social networks can constrain who encounters whom to explain the emergence of cooperation (Eshel and Cavalli-Sforza, 1982; Boyd and Richerson, 1988, 1989; Ohtsuki et al., 2006; Nowak et al., 2010; Van Veelen et al., 2012). However, social networks perform another evolutionarily important function in groups of individuals: they transmit gossip about behavior, an activity that occupies approximately two-thirds of individuals' conversation time (Dunbar, 2004). When considering the role of networks in the spread of information, the relevant constraint becomes who *communicates* with whom.

I model a group of strategic agents who use gossip that spreads through their social network to identify and sanction uncooperative behavior via indirect reciprocity (Nowak and Sigmund, 1998, 2005; Wedekind and Milinski, 2000; Fishman, 2003; Mohtashemi and Mui, 2003; Brandt and Sigmund, 2004). Accounting for this function of social networks not only shows one mechanism by which networks are fitness-relevant, but also reveals that *knowledge* of social networks can be fitness-relevant as well. In fact,

E-mail address: jenn.larson@nyu.edu

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groups comprised of individuals who possess precise information about their social networks would be at a fitness disadvantage relative to groups with individuals who hold a coarser picture of their networks.

Empirical work has consistently shown that modern humans know very little about the structure of their own social networks and perform poorly when tasked with learning new social networks (Bernard et al., 1980, 1982; Bondonio, 1998; Simpson et al., 2011; De Soto et al., 1968; Picek et al., 1975; Freeman, 1992; Kumbasar et al., 1994). This robust empirical regularity may be the product of natural selection in an environment of strong selective pressure at the group level. Imprecise views of networks make enforcing cooperation easier.

2. Networks and the evolution of cooperation

Social networks research is premised on the recognition that individuals have ties to some – often not all – others within a group of interest, and these ties connote affinity, or frequent interaction, or preferential treatment, or kinship, or a channel of information, or a source of peer pressure, or possibly all of these. Social networks structure relationships among individuals within groups.

Social networks appear to have been a part of group structure over long timescales (Apicella et al., 2012). Evolutionary theory increasingly turns to this structure as part of the explanation for the emergence of cooperation (Nowak et al., 2010): repeated interactions with social contacts allow for direct reciprocity (Boyd and Richerson, 1988), closed communities allow for indirect reciprocity (Boyd and Richerson, 1989), and the ability to form lasting associative connections fosters cooperation that persists over time (Eshel and Cavalli-Sforza, 1982).

Key to these explanations is a set of interactions that are structured – who encounters whom is limited and fixed (Ohtsuki et al., 2006). However, as groups become more sophisticated, complex and mobile over time, the structure may manifest itself not in constraints on who *encounters* whom but on who *communicates* with whom. The more collaborative activities a group undertakes, the more chances there are to encounter all others in the group while communication about behavior in these encounters may be confined to social contacts. In a modern market setting, for instance, members of a group may all have a chance of transacting with any other, but the social network determines whom they tell about their interactions.

The role of networks in information spread has been widely recognized. In modern societies, social networks have been found to structure communication relevant to finding jobs (Granovetter, 1973), learning about new agriculture technologies (Conley and Udry, 2010), making financial decisions (Duflo and Saez, 2002), making preventive health decisions (Rao et al., 2007), establishing social collateral (Karlan et al., 2009), becoming aware of opportunities for gain (Larson and Lewis, 2016), and, frequently, gossiping about the behavior of others (Dunbar, 2004; Gluckman, 1963).

Some argue that language may have evolved to facilitate group bonding (Dunbar, 1998), perhaps specifically to allow gossip as a means of social control as group size became large (Enquist and Leimar, 1993; Wilson et al., 2000). A host of non-evolutionary models show that social sanctioning by peers can enforce cooperative behavior (Kandori, 1992; Greif, 1993; Fearon and Laitin, 1996; Dixit, 2004; Wolitzky, 2013; Larson, 2016), and experimental subjects gossip in ways that ultimately support higher levels of cooperation (Sommerfeld et al., 2007).

Standard models of the evolution of cooperation leave little room for communication and gossip in the form observed among modern humans.[1] In these models, agents need know nothing about the environment they are in, the game they are playing, what individuals far away are doing, and they do not form a forward-looking strategy. Such approaches generate elegant explanations for the evolution of cooperation and its stability. However, given the empirical role that social networks play in spreading information, the utility of this information for sanctioning strategies that are able to promote cooperation, and the observation that evolution may also shape social networks (Apicella et al., 2012), a full understanding of the fitness implications of social networks requires accounting for realistic gossip.

3. Network knowledge

The model below isolates a mechanism by which social networks bear on group fitness: groups of strategic actors use gossip transmitted through their network to identify and punish non-cooperators. Accounting for gossip in a strategic setting reveals a surprising relationship between cooperation and network knowledge: knowing less about one's network can make enforcing full cooperation easier.

Limited network knowledge facilitates cooperation because individuals occupying certain positions within a network can be particularly tempting targets of misbehavior. Some are unable to spread gossip about others' misbehavior widely and quickly, and so misbehavior targeted at them is more difficult to sanction. When everyone perfectly knows the full network structure, these individuals can be perfectly identified and targeted. When instead individuals possess a coarser, limited view of their network, identifying the most vulnerable can be impossible, removing the temptation to act uncooperatively.

The advantage of limited network knowledge helps make sense of the robust empirical finding that modern humans know very little about their own social networks despite making constant use of them. Individuals perform consistently poorly when recalling the structure of their own social networks and when retaining information about new social networks (Bernard et al., 1980, 1982; Bondonio, 1998; Simpson et al., 2011). People rely on a series of imprecise compression heuristics to store the complicated object in memory (Brashears, 2013; Krackhardt and Kilduff, 1999; De Soto, 1960), recall networks with a high degree of error (De Soto et al., 1968; Picek et al., 1975; Freeman, 1992; Kumbasar et al., 1994), and assign low salience to the precise recall of links (Killworth and Bernard, 1976; Brewer and Webster, 2000). Early human groups would not have been much easier to keep track of since even the smaller social groups of the Pleistocene had around 50 members (Dunbar, 1992), yielding 2450 possible relationships.

The model below shows that precise knowledge of the network structure can confer a fitness *disadvantage* on the group – limited knowledge of the network makes enforcing cooperation easier, often substantially so. This suggests that under multilevel selection (Pacheco et al., 2006; Chalub et al., 2006), in the presence of high selective pressure at the group level (Bowles, 2006, 2009), groups of individuals with a limited capacity to know and recall the full network face an evolutionary advantage.

[1] While some argue that gossip may be a source of rapid agreement on a player's reputation (Ohtsuki et al., 2009; Nakamura and Masuda, 2011; Ghang and Nowak, 2015), with an attendant danger of manipulation through false gossip (Nakamaru and Kawata, 2004; Nowak and Sigmund, 2005; Sommerfeld et al., 2007), gossip has yet to be incorporated as the flow of information through links in a social network or among strategic, forward-looking players.