# A REVIEW OF NETWORK THEORIES ON THE FORMATION OF PUBLIC OPINION

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**Abstract**: Our aim is to review the network concept and its relevance on theories of public opinion formation. For this purpose, after discussing social and policy networks, we are reviewing certain network theories of (i) collective action and (ii) voting choices and preferred modes of political participation. Finally, we are presenting a network simulation of public opinion formation that generalizes Axelrod's adaptive culture model and it is based on both convergent and divergent communicative processes.

## Introduction

The question of how networks (social, political or heterogeneous-hybrid networks) influence political agency and behavior is of tremendous theoretical and practical interest. Although in here we are not going to talk explicitly and assess the role of electronic networks on processes of formation of political and public opinions, it is a generally acknowledged fact how pervasive and ubiquitous computer-mediated communication is today. What instead we aim to do here is to examine certain network theories of (i) collective action and (ii) voting choices and preferred modes of political participation, after having in the beginning briefly sketched the network concept and finally concluding with a concrete network simulation of collective processes of public opinion formation.

## Networks

Networks are met everywhere in the present landscape of society, culture, politics and science and technology. Thus, the word 'network' appears nowadays to have become a fashionable catchword. As Kenis and Schneider have already claimed more than a decade ago: "The term network is on the way to becoming the new paradigm for the 'architecture of complexity' (compared to hierarchy as the old architectural paradigm of complexity: see Simon)" (Kenis & Schneider 1991, 25). In fact, besides many occurrences they have in science and engineering (for instance, neural, 'complex,' self-organized, informational, environmental, transportation and telecommunication networks, etc.), networks are also often met in social science (e.g., social networks, scientometric networks, etc.), in political science ('policy networks') and in economics and organization theories (e.g., networks of innovation, networks in between markets and hierarchies, learning networks, etc.).

Within such an extended spectrum of uses and occurrences of networks, perhaps it is very difficult and even meaningless to try to find a common denominator in a formal definition of this concept. But, at least for our purposes, a generic or 'cognitively shared' (among so many domains) understanding of networks could be described in terms of two entities: *actors* and *relations*. This means that in a network, a set of nodes or actors (individual, aggregate or mixed) are related or linked to each other under specific more or less stable mechanisms, which are defining a non-hierarchical (horizontal) set of relationships among the actors. Now, if one tries to conceptualize 'actors' and 'relationships' in a concrete context, then one realizes that there are so many selections of these terms, which yield different notions of networks. This is why we would like to restrict our discussion in two particular cases: that of a social network (from sociology) and a policy network (from political science).

### *Social Networks*

In social theory, social networks are related to what is usually identified as the 'relational aspect' of social structure. As José López and John Scott remark (2000, 1), although there are many definitions and discussions about social agency and action, very few deal with social structure. By its meaning in everyday life, social structure refers to patterns or arrangements of whatever elements are considered to constitute society. According to the aforementioned authors, social structure points to three independent and complementary aspects of the social: the institutional, the relational and the embodied. Institutional structure is “comprising those cultural or normative patterns that define the expectations that agents hold about each other’s behavior and that organize their enduring relations with each other.” While, relational structure is “comprising the social relations themselves, understood as patterns of … interconnection and interdependence among agents and their actions, as well as the positions they occupy.” Finally, embodied structure is “found in the habits and skills that are inscribed in human bodies and minds and that allow them to produce, reproduce, and transform institutional structures and relational structures” (López & Scott 2000, 3-5).

Relational structure, i.e., social structure as a patterning of social relationships, is usually described as a social network, in which actors are whoever and whatever performs the agencies through which relations among actors develop and hold them together. Thus, actors (or agents) in a social network can be individual people, objects or events but they can be also aggregate units such as organizations, institutions, firms, communities, groups, families etc. The very idea of the social network approach is that relations or interactions between actors are the building blocks or the key factors that sustain and define social structure, despite actors’ ‘nature’ or any other attributes they might be endowed with (Wellman 1988; Wasserman & Faust 1994; Scott 2000).

Typically, interactions between actors result from exchange of resources they hold in the specific social and cultural contexts they are living and communicating with each other, i.e., according to the existing distribution of power or authority relationships, accepted social norms, habits, dependencies, practices, expectations and preferences.

In these interactions, exchanged resources can be either material or informational, such as goods, money, information, services, social or emotional support, trust, influence etc.

Each kind of a resource exchange is considered to constitute a social network relation and actors maintaining the relation are said to maintain a tie. The strength of a tie may range from weak to strong, depending on the quantity, quality and frequency of the exchanges between actors (Marsden & Campbell 1984). Patterns of who is tied to whom reveal the structure of the underlying network: they show how resources flow among actors and how actors are interconnected in the network. In a very well known example of social network analysis, Mark Granovetter (1973, 1974) has investigated the exchange of job information among acquaintances and found that weak ties are quite operationally strong for the diffusion of such information.

### *Policy Networks*

Also in the context of policy studies and political theory, there is a variety of definitions of 'policy networks' according to the attributed sense to the basic terms. For instance, typical actors in a policy network might be either public (like the state, governmental or other public institutions, citizens, etc.) or private (like the market, corporations, interest groups, consumers, etc.) or even mixed-hybridized forms of the former (like modern science the way it is envisaged by Callon [1994]).

The situation becomes even more complicated when one tries to theorize in a general or generic setting the relationships that could possible tie these actors in a policy network. The dominant view in the literature of policy studies is to assume that policy actors carry certain interests and possess certain resources. Therefore, it is argued, the actors are linked together (i.e., they develop their relationships of interdependence or seclusion) when they proceed to mediate their interests and exchange their resources. But this mechanism should not be understood in the sense that the actors' interests and resources (i.e., identities and competences) exist before the actors start to constitute a network: the very idea of the 'relational' perspective is that a network both defines and is defined by its links. After saying this, the question is how in a policy network the actors are managing their relationships. There are two different 'schools' of policy-making answering this question (cf., Börzel 1997, 3), although not in mutually exclusive ways, since there exist hybrid conceptualizations between these two theoretical responses (Mayntz 1993):

- According to the 'interest intermediation school' (Marsh & Rhodes 1992), there is a generic meso-level mechanism of developing relationships in a policy network independently of who the actors are. This goes as follows: depending on whether the involved actors have common or competing interests and what exactly their interests are, they decide with whom, how and for what purpose to exchange their resources. Thus, the actors are taking certain political decisions, formulating, implementing or changing certain policies by their bargains (where they are trying to optimize their profits) or their negotiations (where they are trying to reconfigure their identities).
- According to the 'governance school' (Kenis & Schneider 1991), which is restricted to apply only for public-private interactions of public policy, a policy network between public and private actors is a specific form of governance. As

> David Marsh (1998, 8) argues: "Hierarchy is a mode of governance characterized by a very close structural coupling between the public and private level, with central coordination, and thus control, being exercised by government. In contrast, markets as a form of governance involve no structural coupling and outcomes result from the market-driven interplay between a plurality of autonomous agents drawn from the public and the private spheres; there is no central coordination. In contrast, policy networks involve a loose structural coupling; interaction within networks between autonomous actors produces a negotiated consensus which provides the basis for coordination."

Epistemic communities provide a concrete example of a policy network, in which specific constellations of actors, including both public and private actors, experts and involved citizens are mediating their interests in order to develop a flexible form of governance of complex techno-scientific issues. Epistemic communities have arisen in the field of foreign policy and international relations in the context of international policy coordination of such issues as GATT, the environment, food aid, the world economy, banking regulation, etc. (Haas 1990, 1992; Adler & Haas 1992). Peter Haas (1992, 3) defines epistemic communities as "a network of professionals with recognized expertise and competence in a particular domain and an authoritative claim to policy-relevant knowledge within that domain or issue-area" who "have (1) a shared set of normative and principled beliefs … (2) shared causal beliefs … (3) shared notions of validity … and (4) a common policy enterprise." Therefore, as knowledge is supplied by a network of experts to authoritative policy-makers, it becomes the key variable defining an epistemic community. This knowledge plays a double role. On the one hand, policy actors use it in order to legitimize their actions by resorting to the scientific authority. On the other hand, knowledge is a useful policy resource informing the actors about the means to cope with uncertainty, through which their interests are shaped, but also providing them coherent positions for bargaining (*policy learning*). Note that this knowledge is not just a property of individual actors: it is the content of the shared thinking of the whole epistemic community through which the identity of the community is defined. For instance, although in all international policy arenas the final decisions are made through negotiations between the involved states, there are non-state actors (as scientific experts or other providers of technical advice), who acquire power through their access to and their participation into the production of the relevant knowledge, which is framing the process. Again, as this shared knowledge is an emergent property, it is the structural conditions of epistemic communities the factor which leads to policy convergence and not the behavioral features of the self-interested states-actors, which are responsible for the power bargaining games that the negotiating states might want to play with each other.

## Collective Action

According to an old tradition of social theorizing, public opinions and individual judgments are affected by observations of social aggregates and mass behaviors in relation to the issues of the opinions or the judgments. Thus, in the context of theories of collective action, the formation and change of public opinion can be considered as a mechanism by which a certain action affects other future or remotely occurring actions.

However, according to the traditional treatment of theories of resource mobilization and rational choice, what defines collective action should be the provision of a collective good, which in turn is defined by its nonexcludability (Olson 1965; Hardin 1982). According to Olson (1965), the logic of collective action is based on the assumption that individuals motivated by self-interest will avoid investing resources in a joint endeavor whenever possible, leaving others to contribute their share even though all will benefit, a phenomenon known as "free riding." Therefore, Olson was arguing that "rational, self-interested individuals will not act to achieve their common or group interests" (1965, 2) unless they were given private or selective individual incentives which would reward cooperators or would punish noncooperators.

Although it is undeniable that Olson's arguments opened the discussion on collective action in social theory, nevertheless, subsequently, they were often considered problematic in areas where the existing empirical evidence was opposing them (for instance, in theories of social movements). Thus, Marwell and Oliver and their collaborators in a series of articles and a book published between 1983 and 1993 (Oliver & Marwell 1988; Marwell, Oliver & Prahl 1988; Oliver, Marwell & Texeira 1985; Prahl, Marwell & Oliver 1991; Marwell & Oliver 1993) developed a theory of 'critical mass' which was encompassing Olson's facts about collective action but at the same time attempting to give more realistic solutions to its contested parts. For instance, like most economic theories of markets, Olson had assumed independence of actors making decisions. Oliver (1993) and Marwell & Oliver (1993) have criticized this view and emphasized the importance of the network of relations in which interdependent actors are embedded. Computer simulation experiments by Marwell and Oliver (1993) showed that the extent to which people are interconnected in communication networks increases their willingness to support the collective good. Using a similar research strategy, Marwell, Oliver & Prahl (1988) showed that centralization and resource heterogeneity in the network influenced aggregate contributions to a collective good.

Focusing now on the topic of this paper, there appeared in the 1990s a number of social theorists who were arguing that collective action is formed and sustained less by attention to the collective good than by mechanisms of formation and diffusion of public opinions. An assessment and review of the works citing critical mass theory was recently published by Oliver & Marwell (2001) and, among the cited works there, we will refer to three ones drawing upon network theories in order to explicate mechanisms of public opinion formation.

Thus, Kim & Bearman (1997) have developed an interesting model of opinion changes occurring in a network. Actors increase their interest to participate in public processes if connected with others with higher interest levels who contribute and they decrease their interest if connected to others with lower level who defect. In this sense, collective action occurs if and only if there is a positive correlation between interest and power/centrality and, so, interest heterogeneity is found to have positive effects on 'pulling up' the population's potential for participation.

Bahr & Passerini (1998a, 1998b) have developed a statistical mechanics model of collective behavior in analogy to physical systems. They set up a model in which each actor possesses a 'strength' factor of opinion (or of persuasiveness) and the probability of choosing an opinion is proportional to the number of actors who hold that opinion, i.e., it depends on the group distribution of opinion. They study under what conditions a group changes opinions and how this depends on the size of the group, the volatility of opinions being understood as ‘social temperature.’ They also consider cellular automata in which actors interact only with those at their vicinity according to some well-defined rules and the aim is to study the emergent group patterns. For instance, they observe abrupt phase transitions from consensus to near consensus with well-ordered pockets of opinion at low ‘social temperature’ to less-ordered nonconsensus at higher temperature and in some cases they even observe chaotic transitions.

Ohlemacher (1996) has worked on ‘social relays,’ i.e., mobilization-mediating social networks, based on empirical data on citizens’ campaigns in Germany. Social relays link with weak ties previously unconnected networks acting as brokers of contacts between strangers and, in this way, spreading mobilization to networks outside themselves.

Finally, we are citing Lohmann’s (1994) ‘signaling’ model, which is only indirectly a network model but since its conclusions are very important for theories of critical mass we are presenting it too. This model is based on informational cascades (during the Monday demonstrations in Leipzig, East Germany, 1989-91) in which others’ actions signal the extent of dissent from the regime. Remarkably enough, Lohmann is challenging one of the premises of the theory of critical mass that extremists are important for the formation of the critical mass. Instead she argues that protest accelerates when moderates are involved early in the process.

## Voting Choices and Political Participation

In general, citizen involvement in political institutions and individual decision-making about voting and participation is considered to depend on social psychological perceptions and beliefs, social forces impinging upon the citizen and social and interpersonal interactions among citizens. The dimension of interactions suggests that there should be a relationship between social connectedness and civic participation or voting preferences and a great deal of scholarship in political sociology is devoted to explore this relationship (cf., Knoke 1990a [chapter 2, 29-56]; Huckfeldt & Sprague 1995; Verba *et al*. 1995). In fact, there are three distinct streams approaching the relationship of actors' connectedness with their political behavior in three different ways: (i) the classical approach of surveys measuring actors' attitudes, (ii) the macro-level analysis of collective patterns derived from observations of social aggregates and (iii) the exploration of micro-level interpersonal dynamics developed among interacting individuals.

Since Paul Lazarfeld's and his colleagues' early surveys in the 1940s of individual voting in presidential elections, the decisive factor in individual vote decisions was considered to be the information flow through networks of interpersonal communication (Lazarfeld *et al*. 1948). This approach formed the tradition of the so-called 'Columbia model' of voting studies, the major insight of which was the recognition of the fact that face-to-face contacts were of central importance in processes of opinion formation. Moreover, it was also taken into consideration the mediation of group discussions and the role of self-appointed opinion leaders. In particular, to assess the network effects, the Columbia modelers were measuring an individual's connection to "whole networks of social relations that affect political behavior" (Berelson *et al*. 1954, 94) by collecting data on the voter's three best friends and three closest coworkers. However, the problem with these data was that respondents' self-reports were constructing egocentric networks, which might have been distortions of the actual network structure to the extent that perceptions about other' opinions might have been deliberate or intentional. Consequently, as Knoke (1990a, 36) has argued, "without direct measures from all actors in personal networks, key hypotheses about the political impact of egocentric network structures cannot be rigorously tested."

Another old empirical tradition in political science about the investigation of processes of opinion formation is the 'contextual analysis' of voting choices, as the social and political environments of voters' communities (residential, occupational etc.) are assumed to affect their political orientations through various contextual interventions (Sprague 1982). The main reason is that individuals' embeddedness within a given social, cultural or political context structures their social interactions, both constrains and enables their communicative practices inside particular patterns of behavior. However, as Knoke remarks (1990a, 47), the two types of data that traditionally contextual analysts have employed do not suffice: individual attributes and social unit composition. Knoke argues that a third type of data is needed, the individuals' egocentric network, so that contextual analyses might avoid making erroneous inferences about the impact of contextual influences on voters' choices. In fact, Knoke considers that the egocentric "micro-nets may serve as filters that connect individuals to the larger neighborhood and community social structures" and "through neighboring relations, friendships, and work groups, local residents are exposed to selective portions of their immediate political context" (*ibid*., 47).

Thus, Knoke argues that a network theory of voting should take into account the "effects of both form and content of the egocentric relationships upon an actor's vote decision" (*ibid*., 48). The form of an egocentric network is described by the number of alters to whom an ego is linked and the strength of the ties between the ego and the alters and among the alters. Moreover, "the content of an egocentric network consists of exchanges of political information that may influence ego's perceptions of political choices and their consequences" (*ibid*., 48). For example, Laumann in his study of Detroit white men's voting choices found that the more densely linked the adjacent alters of an ego were, the greater was the political homogeneity of the network (Laumann 1973, 123). On the opposite end, star-like linked egocentric networks tended to be less politically homogeneous and more tolerant to political extremism (*ibid*., p. 127). Similarly, taking into consideration both form and content dimensions, Knoke (1990a, 49) has formulated the following two propositions about the egocentric network effects on voting choices: (i) the influence on ego of strongly tied adjacent alters is higher than the influence of weakly tied alters and (ii) the more political homogeneous are the ego's adjacent alters, the higher is the influence on the ego to adopt her alters choices. In fact, Knoke (1990b) was able to test hypotheses shaped by the above two propositions on data of the 1987 General Social Survey. Of course, there is an extensive literature on social networks and voting choices. For instance, Zuckerman, Valentino & Zuckerman (1994) have developed an interesting structural theory of vote choice arguing that, as individuals vary in their membership in mutually reinforcing social and political networks, they vary in the likelihood of persistently voting for the same political party and never voting for other parties.

However, the fact is that the relationship between personal or individual attitudes and network effects or influences is quite complex. As David Lazer (2001) has been stressing such processes should be canvassed on the basis of a co-evolution between network and individual: individuals simultaneously shape and are shaped by the networks in which they are embedded. Thus, by exploring certain longitudinal, attitudinal and sociometric data (from a USA government agency, the Office of Information and Regulatory Affairs), Lazer has discussed the dual concepts of network elasticity and individuals plasticity. Network elasticity concerns the variable range of interactions and, thus, choices that the network might give to individuals. On the other side, individual plasticity signifies how individuals are affected by their network of contacts.

A different stream of models about the formation of collective public opinion does not focus on aggregates but rather details of individual interaction. Theories of this sort often describe public opinion formation during an election or another kind of political decision. Following some insights of early work by McPhee & Smith (1962) and later explored by Huckfeldt & Sprague (1995), individuals are seen as parts of loosely knit, flexible networks in which information transmission occurs through political discussions. Individuals adjust their opinions on the basis of the perceived quality of the information from individual discussants and other factors. In Huckfeldt's analogy (2001), the formation of public opinion is like collecting the conclusions of thousands of individuals serving on different juries. From the latter perspective, it is important to study a theory of political communication, which investigates the extent to which citizen discussion beyond the boundaries of cohesive groups might influence the dissemination of public opinion. According to Huckfeldt, Beck, Dalton & Levine (1995), cohesive social groups and strong social ties are expected to make the social flow of political information independent from opinion distributions. On the contrary, when social communication extends beyond socially cohesive groups, the flow of information should reflect these opinion distributions. In this sense, Huckfeldt *et al.* (1995) argue that a citizen's social network acts as a filter on the macro environmental flow of political information.

Finally, we should mention that often theories of network influence on political participation are understood from the point of view of social capital (cf., Coleman 1990; Putnam 1993), i.e., through studies of how social capital is converted into civic participation. In this way, considering social capital as a determining dimension of individual behavior (Lake & Huckfeldt 1998; Putnam 2000; Verba *et al*. 1995), it means that social capital should not be treated as an attitude (e.g., norm, social trust or tolerance) but rather it should be conceptualized as a resource of social structure (Newton 1999). As social networks are structuring the flow of information surrounding an individual (Granovetter 1973), the existence of large but loosely coupled networks linking individuals into a wider context increases the probability of exposure of the linked individuals to appeals for political action. In practice, this happens either through participation in informal networks or membership in formal groups (as voluntary associations). Hence, in this sense, social capital is related to both 'social recruitment' and 'political mobilization' (Teorell 2000).

## Formalization

If we want to study how the network concept works in the context of the above theories, getting a handle with empirical work is indispensable. Among many textbooks in the field, one could mention a few characteristic: David Knoke's *Political Networks: the Structural Perspective* (1990a), Robert Huckfeldt and John Sprague's *Citizens, Politics, and Social Communication: Information and Influence in an Election Campaign*.(1995) and Gerald Marwell and Pamela Oliver's *The Critical Mass in Collective Action: A Micro-Social Theory* (1993). However, beyond the empiricist tradition, there is a second – and complementary – intellectual strategy that we are going to employ here in this paper. This is the theoretical strategy of constructing and investigating formal mathematical representations of the processes enacted in network formations of public opinion.

To follow such a mathematical formalization in modeling social phenomena takes for granted that this mathematical modeling is a desirable tool to study social realities. But this is far from being unanimously accepted: many theorists typically reject formal modeling in social research because they are contesting the prominence of positivist mathematical tractability and empiricist falsifiability. For instance, as Ian Shapiro and Alexander Wendt (1992) claim, such a formalization might fall into the trap of rationalist "logicism" when it degenerates into "an exercise in trying to derive an ever widening class of phenomena from the theory rather than an attempt to validate the theory empirically" (202). Thus, Shapiro and Wendt warn: "By confusing what can never be more than devices for hypothesis generation with the conduct of social science itself, they often lose sight of the phenomena that their theories purport to explain, and the disputes about the fine points of analytical models that occupy much of their attention often reside so deeply in a world of counterfactuals that they would never be tested empirically" (*ibid*., 203).

Nevertheless, many theorists often realize the potential of formal explorations as a necessary complement to its alternative – verbal analysis. Thus, the German sociologist Norbert Elias has tried to combine the two possibilities offered by qualitative theorizing and formal modeling by claiming that "the social apparatus for thinking and speaking places at our disposal only either models of a naively egocentric or magico-mythical kind, or else models from natural science" ([1970] 1978, 17).

Similarly, in their criticisms of mathematical modeling, Shapiro and Wendt do not neglect to discuss the potential of formal research as a heuristic to test hypotheses and, thus, to build theories: "Taking an explanation and running with it, driving an as-if causal theory to the hilt, may reveal as faulty the assumptions that hitherto had been taken for granted and may generate research problems and hypotheses for investigation that otherwise would not have been thought of" (*ibid*., 203). In fact, discussing the counterfactual alternative to empirical generalizations, Max Weber (1949) has already suggested that the former "involves first the production of – let us say it calmly – 'imaginary constructs' by the disregarding of one or more of those elements of 'reality' which are actually present, and by the mental construction of a course of events which is altered through modification in one or more 'conditions'" (173). Furthermore, it should not escape our attention that through 'experimentation' of formal models, albeit in the context of a reification inside a formal-artificial world, one can better appreciate the complexity of the unanticipated consequences of human choices and social agencies (Giddens 1979, 258).

Therefore, besides its epistemological limitations, formal modeling may lead to theory development by revealing ambiguities among 'raw' and unprocessed data and by formulating questions which might never be raised by verbal theory alone. Formalization necessarily involves detailed descriptions and specifications of the mechanisms or processes involved in the phenomenon to be modeled. On the one hand, verbal theory can only roughly – sometimes vaguely – sketch interdependencies or causalities among the various relationships appearing in the studies phenomena. On the other hand, formal theory can spell out answers of how these interdependencies, causalities and relationships work out at least in an idealized or counterfactual context, which might serve as a heuristic for the very understanding of the phenomena. In this sense, formal modeling may scrutinize and filter away all the ambiguities of verbal theorizing by providing the experimental ground on which more theoretically complete and empirically consistent reasoning may develop.

## A Simulation

In this section, we are going to discuss an example of a formal modeling – in the form of a simulation – as an attempt to understand how the mechanisms of networked formation of public opinion work in an idealized and counterfactual setting of this simulation. In this context, many theorists have extensively considered simulations as means to address questions about the crisscrossing between social and political networks and their relation to consequences of influence, disagreement, ambivalence, engagement, participation and voting choices (e.g., Johnson 1999; Huckfeldt, Johnson, Sprague & Craw 2000; Ikeda & Huckfeldt 2001).

Here we will narrow down the problem to a family of simulations which are following Axelrod's (1997) suggestion that agent-based models can be useful tools for 'thought experiments' and clarification of theory. Of course, these are not the only simulations used to analyze social emergent phenomena in political processes: Latané's theory of social impact (Latané 1981; Latané *et al*. 1994) is another very well known model providing powerful political (and psychological) simulations.

Axelrod's original simulation is based on an 'adaptive culture model' (as it was named by Kennedy 1998), i.e. a model of dissemination of culture through social interaction proceeding by local convergence and resulting emergence of global polarization at a limited degree. In fact, Axelrod is dealing with the dissemination of culture over a rectangular grid (regular lattice) the nodes (or cells) of which are supposed to be the interacting agents. Each agent possesses a list of numerical attributes, which Axelrod is interpreting as the agents' cultural characteristics. The results of Axelrod's simulation are indicating that over the long run the assumed processes of local convergent interactions are globally homogenizing the culture: almost all individuals are adopting the same culture or in the best case only a very small number of cultures are surviving throughout the model. In other words, the outcome of Axelrod's simulation is either a complete cultural homogenization or a fragmentation into a small number of heterogeneous cultural zones.

Subsequently, many scholars (Kennedy 1998, 1999; Shibanai *et al*. 2001; Greig 2002) have tried to formulate variants of Axelrod's simulation in order to attain a higher degree of global polarization or cultural heterogeneity, which would be a more realistic model of real cultural processes. The necessity of breaking away from a 'homogenization prediction' is attributed by Johnson and Huckfeldt (2001) partly to empirical reasons and partly to normative reasons. On the one side, recent empirical studies have shown that high diversity and considerable disagreement can be sustained by interpersonal networks (Huckfeldt, Johnson & Sprague 2002). On the normative side, as Johnson and Huckfeldt (2001) have argued, "this model has the implication that interaction does erase all differences" and, thus, "one might argue in favor of segregation, or cultural apartheid, as the only way to preserve diversity on the aggregate social level," which of course is a rather discouraging contention.

Here, we would present a similar simulation (analytically developed in Boudourides 2003) in an effort to overcome the restrictions of the produced homogenization in the original Axelrod's model and to manifest that significant diversity and heterogeneity can be sustained over general networks of agents. For this purpose, before showing our simulation in action, let's present where our simulation differs from the previous ones. These differences appear at three spots: (i) the interpretation of agents' attributes, (ii) the positioning of agents and their linkage patterns and (iii) the dynamics of interactions among agents.

### *The interpretation of agents' attributes*

Perhaps this point is of minor importance but we are referring to it in order to make our simulation meaningful at the context of the present paper (which is a review of theories of the formation of public opinions, voting choices, preferences of political participation, etc.). As Axelrod did, agents' attributes are represented by F features (typically, F = 5) and its feature takes values, called traits, in the set of numbers {0, 1, …, T} (typically, T = 9, i.e., 10 traits). Now, agents' features were described by Axelrod as cultural characteristics but we may follow Johnson's and Huckfeldt's (2001) suggestion and think of these features as opinions, issue stances, political allegiances or any other judgments the agents may have on the political sphere which would orient their voting choices or their political participation in one way or another.

### *Agents' positioning*

In the original Axelrod's model as in all of the subsequent simulations that we are aware of, agents are located at the vertices of a regular lattice (a rectangular grid) in such a way that each of them is directly linked with four other agents (with the exception of the side agents – unless boundary periodicity is assumed). Besides the fact that such a social topology is extremely ideal and regular, it happens to be a rather unrealistic one. In fact from modern theories of social networks and complexity studies, we know that social aggregates – at least above a certain size which makes them comparable to large social groups, communities or even society itself – are composing networks of the so-called 'small-worlds' (Milgram 1967; Watts 1999). These networks are rather highly clustered but also they possess many shortcuts among their nodes, which make them somehow in the middle of the hierarchy between regular lattices and random graphs (Watts & Strogatz 1998; Watts 1999).

Therefore, the social topology (for the relative positioning of the agents and the linkage among them) we are using in this simulation is that of an arbitrary graph ('small-world' effects considered elsewhere. As mentioned before, the graph topology is more realistic than the regular lattice (or grid) especially when the number of nodes (agents) is large. However, even with networks of a small number of nodes (agents), the graph topology is certainly more appropriate to the study of network effects because we can test the simulation over different fundamental kinds of network topologies (rings, stars, bridges or relays etc.) in order to explore the role played by various structural parameters on the dynamics of the studied model.

### *Mixed dynamics of interactions*

In order to derive a higher degree of diversity and heterogeneity in the emergent patterns of the simulation, our basic idea is to consider two types of agents and to define different rules of interaction for each of them. Since Axelrod's convergent interactions were only producing a minimal degree of diversity (almost homogenization), we were wondering whether the addition of a small amount of divergent interactions would dramatically increase the level of diversity. In fact, we saw in our simulations that this was the case. To implement this mixed architecture of co-existing convergent and divergent interactions among agents, we thought to divide the population of agents into two groups, homophilic and heterophilic agents:

- Homophilic agents are the ones determined to sustain convergent interactions with other agents (in various ways depending on whether the other agent with whom they are interacting is homophilic or heterophilic). In other words, homophilic agents' disposition is to sustain convergent or amicable interactions with other agents leading to agreement or adoption of the otherness, which tend to produce more similarities among the agents' features (interpreted as opinions, positions etc.).

- Heterophilic agents are the ones determined to sustain divergent interactions with other agents (again in various ways depending on whether the other agent with whom they are interacting is homophilic or heterophilic). In other words, heterophilic agents' disposition is to sustain divergent or contentious interactions with other agents leading to disagreement or rejection of the otherness, which tend to proliferate dissimilarities among the agents' opinions or positions (their features).

At this point, we need to give some theoretical motivations for the above types of interactions. On the one hand, 'homophily' is based on the social psychological 'law of attraction,' i.e. the tendency of human beings to interact with similar ones (Homans 1950, Verbrugge 1977, Kandel 1978). Although quite often homophily is attributed to social influence from social network neighbors, sometimes an alternative explanation is also given. According to this alternative conceptualization, group homogeneity is not so much the product of the interactions of those who are similar but it is could also be the byproduct of repulsion among those who are different (Rosenbaum 1986) – for instance, xenophobia might cluster together homogeneous portions of the population.

On the other hand, if we focus on political processes and we interpret 'heterophily' as the expression of political disagreement (Huckfeldt & Sprague 1995), then the realization of disagreement among citizens is central to political deliberation to the extent that political deliberation among citizens is central to democratic politics. This is due to the following two reasons. First, the importance of disagreement and, thus, heterophily usually is attributed to the fact that, if people do not disagree through their interactions, their own political views are never challenged and consequently there is no social communication or deliberation in this case (McPhee 1963). Second, it is personal experience of political disagreement (heterophily) among citizens what sustains democratic politics. In fact, otherwise, when citizens do not disagree with each other at levels which are kept within manageable bounds, democratic politics is deprived of its vital defining characteristics (Lipset 1981) and it is rather considered to be destabilized.

Coming back to our simulation, the way we denote whether an agent is homophilic or heterophilic is by putting a sign in front of the agent's features: $+[T_1T_2 \ldots T_F]$ would be a feature of a homophilic agent and $-[T_1T_2 \ldots T_F]$ would be a feature of a heterophilic agent.

Now, we are in the position to state explicitly the rules of our simulation, which is based on mixed and opposite interactional dynamics:

<u>Step 0</u>. Initially we have the following:

- a graph of N nodes over which the population of agents is accommodated;

- a randomly chosen distribution of features $\Phi_k$, k = 1, …, N, for each agent k (where $\Phi_k$ is a signed list of F numerical traits of the form $\Phi_k = \leq[T_{1k}T_{2k}\ldots T_{Fk}]$);
- a proportion $n_+$ (0 § $n_+$ § 1) of homophilic agents and a proportion $n_- = 1 - n_+$ of heterophilic agents.

Step 1. At random, pick an agent i and then pick one of its neighbors j (adjacent nodes in the graph).

Step 2. Compare $\Phi_i$ with $\Phi_j$ and then modify $\Phi_i$ as follows:

- If both agents i and j are homophilic, then select randomly a feature on which i and j have different traits and with probability equal to the similarity of the traits of their features change the trait on this feature of i to take the value of the trait of this feature on j (this is exactly Axelrod's rule of convergent interactions).

- If agent i is homophilic but agent j is heterophilic, then select randomly a feature on which i and j have different traits and with probability equal to the half of their similarity of traits change the trait on this feature of i to take the value of the trait of this feature on j.

- If both agents i and j are heterophilic, then select randomly a feature on which i and j have the same trait and with probability equal to the dissimilarity of their traits change the trait on this feature of i to take randomly any value which is different from the common value of i and j.

- If agent i is heterophilic but agent j is homophilic, then select randomly a feature on which i and j have the same trait and with probability equal to the half of the dissimilarity of their traits change the trait on this feature of i to take randomly any value which is different from the common value of i and j.

<u>Step 3</u>. Repeat Step 1 and so on.

Apparently, our algorithm coincides exactly with that of Axelrod's adaptive culture model when $n_+ = 1$, i.e., all agents are homophilic. However, just adding a small proportion of heterophilic agents is dramatically increasing the diversity of the equilibrium state towards which the iterations of the simulation eventually converge. To see this, we are measuring the groups of agents (independently of the sign of their features) composed of agents with identical features (better said: identical traits in all their features). Let's call them 'equifeatured' groups and let G denote the number of equifeatured groups of agents in their population. Initially, because of the random assignment of features, G is almost equal to N, i.e., almost all agents have different features. When the simulation terminates (its iterations converge), we are interested in knowing how much bigger than 1 G is, because G = 1 would signify homogenization while G > 1 diversity. Of course, when $n_-$ Ø 1 (i.e., almost all agents are heterophilic), we know that finally G Ø N. What is more surprising is that dropping a tiny touch of disagreement in a population of agents who are predisposed to interact convergently stabilizes the final level of diversity at a considerably high value, which is by all means much higher than the rather poor level of diversity attained by Axelrod's model, i.e., without any 'spirit of disagreement' inside the population of agents.

Elsewhere we intend to give a detailed analysis and statistics supporting this claim of ours. Here we are only going to give a couple of examples.

The first example is of an one-dimensional lattice of 100 nodes (agents) with degree 4 (which is topologically equivalent to the rectangular grid of 10 x 10 agents with periodic boundaries). Here we are treating the case F = 5 and T = 10, i.e., all the agents have five features and the traits of each one of them takes a numerical value from 0 to 9. We are assuming that $n_-$ = 0.02, i.e., 2 agents are heterophilic and 98 are homophilic. After running our simulation 10 times, we found that finally the average number of attained equifeatured groups is 18.6, which is much bigger than 3.2, Axelrod's estimate of 'stable regions' under the same conditions.

Unfortunately, the graph of the previous example is too large to be appropriately visualized. For this purpose, we will give a second example with a smaller graph: an one-dimensional lattice of 25 nodes (agents) with degree 4 (which is topologically equivalent to the rectangular grid of 5 x 5 agents with periodic boundaries). In this example, to compare with the corresponding Axelrod's measures, we are taking F = 5 and T = 15. Furthermore, we are assuming that $n_-$ = 0.04, i.e., 1 agent is heterophilic and 24 are homophilic. After running our simulation 10 times, we found that finally the average number of attained equifeatured groups is 11.7, which is bigger than (approximately) 7, Axelrod's estimate of 'stable regions' under the same conditions. A visualization of an initial network follows:

Figure 1 about here

Note that the heterophilic agent is almost at the centre of the graph. There is one light gray link, i.e., two agents with two similar traits, and all the remaining links are black, i.e., all the remaining 24 agents either have one common trait or they are completely dissimilar (pairwise).

Leaving the simulation to run for one million iterations, the visualization of the final network is as in the following figure. Notice that now we have eventually ten different equifeatured groups: one clique of seven agents, one clique of six agents, one clique of three agents, two cliques of two agents each and five isolated agents (one of which is the heterophilic agent).

Figure 2 about here

Elsewhere (Boudourides 2003), we are presenting further results of this simulation and to explore how different network topologies (rings, stars, bridges or relays etc.) influence the formation of the final equifeatured groups.

## Conclusions

After discussing the network concept (through social and policy networks) and its relevance on theories of public opinion formation (through mechanisms of collective action and political participation), we have presented in this paper a concrete simulation, which exemplifies a number of aspects of how network interdependences are developed in an idealized context of a mathematical model. This simulation is an extension of Axelrod's adaptive culture model, where it is assumed that culture disseminates through convergent local interactions, eventually producing a global cultural landscape. However, when convergent interactions are formalized as mimetic modifications of actors' attributes, it is not surprising that the diversity levels in such an emerging global landscape tend to be rather low. In fact, the theory of dynamical systems in mathematics suggests that contractive modes of dynamical transformations are always attracted by simple equilibrium states of low complexity. But, in this formal (mathematical) sense, a route to produce chaos and complexity would be through a 'hyperbolic' mixing of both contractive and expansive modes of interaction. This suggestion seems to work out in our simulation too: Using Lazer's (2001) terminology, by increasing the range of possible plastic deformations through the mixing of consensual with oppositional actors, even if the latter are very few, the emergent equilibrium patterns are much more complex than without the presence of the latter. Of course, to explain or interpret what role the effects of contentious behavior play in cultural dynamics, opinion formation, political processes, social communication or collective action is beyond the scope of this paper. The claim we make here in this simulation that an infinitesimal disturbance to local norms suffices to produce higher global diversity of the equilibrium outcomes of an agent-based simulation (of networked actors' attributes) cannot be considered as bearing any normative implications. It is simply a theoretical observation of the immanent structural instability of such a stochastic (and nonergodic) simulation, which was manifested in the computer experiments we have performed.

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## Figures

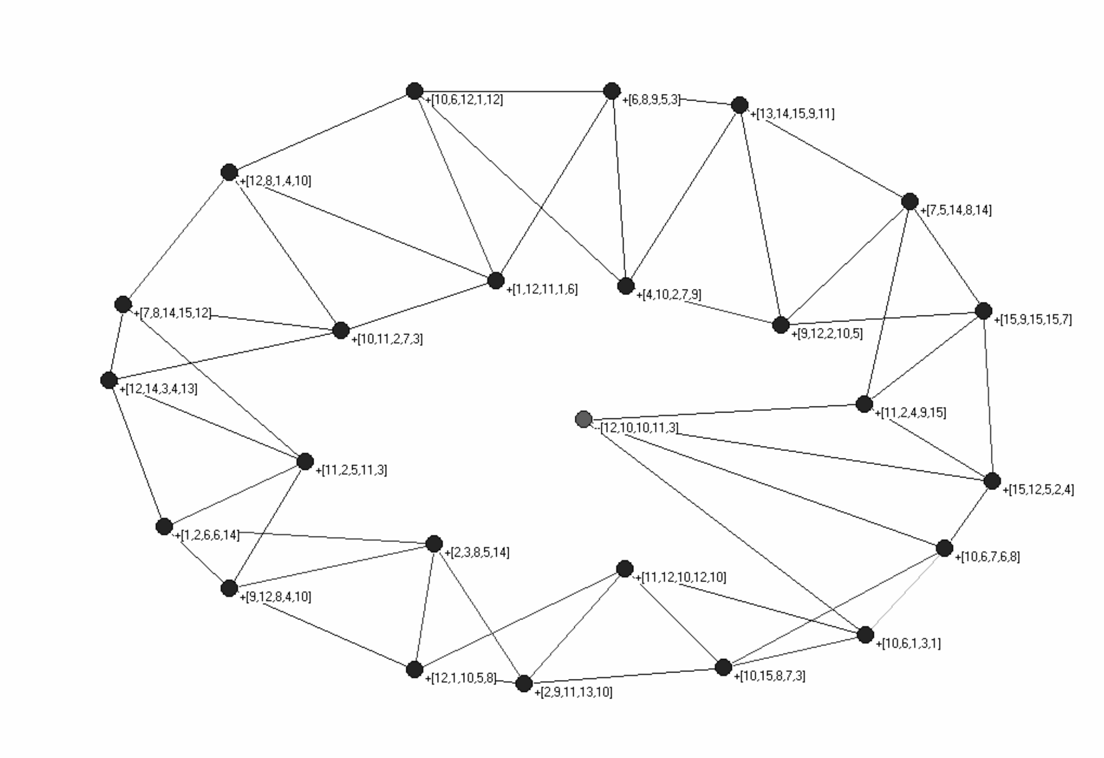


*Figure 1*: The initial (random) distribution of features in the network. Note that agents possess dissimilar features (black links) at most coinciding in two traits (the light gray link).

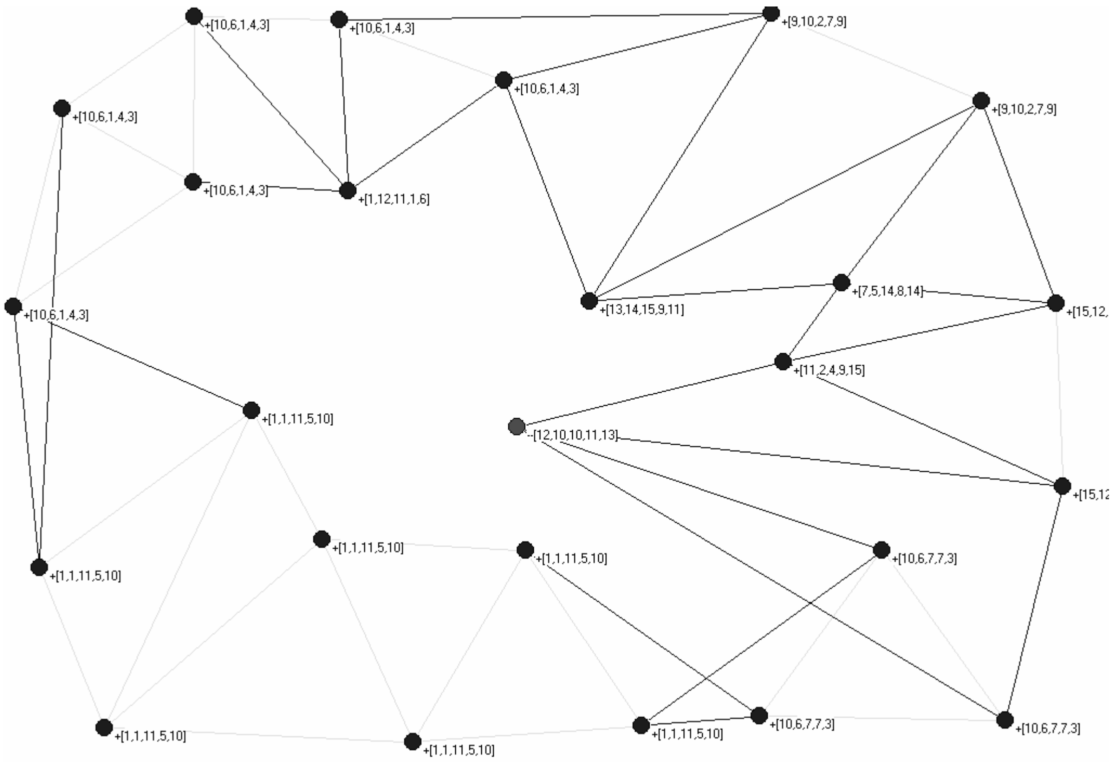


*Figure 2*: The final (equilibrium) distribution of features forming ten equifeatured groups of agents. Light gray links signify complete similarity and black links complete dissimilarity.