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# Distributing Information in Small-World Networks: Four Social Cases of the Process of Contagion in Spain.

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# Abstract

This case study is part of a research project based in Spain between 2011 and 2014 on the social institutions and affective processes involved in what is normally referred to as social movement. Our purpose is to study how information circulates in small-world networks in which the dynamics are modeled with a stochastic version of the Greenberg-Hasting's excitable model. This is a three state model, in which a node can be in an excited, passive, or susceptible state. Only in the susceptible state does a node interact with its neighbors in the small-world network and its interaction depends on a probability of contagion. We introduce an infection probability, which is the only parameter in our implementation of the Greenberg-Hasting's model. The small-world network is characterized by a mean connectivity parameter and by a disorder parameter.

The resulting dynamics are characterized by the average activity in the network. We have found transitions from inactive to active collective regimes, and we can induce this transition by varying. We search for different dynamics within small-world networks of citizens' organizations by going through the following steps: identifying alliance patterns; looking for robust small-world attributes and how they are constructed; and interpreting the three modes of our model.


# 1 Introduction

As Amaral and Ottino (2004) argue, the difference between the complicated and the complex is not just quantitative; it is also qualitative. Complex systems require both an augmentation of the conceptual framework and new tools. This work follows Amaral and Ottino's suggestion. We present four narratives from members of different collectives in Spain related to new forms of governance in the context of democracy. These narratives explain the networks which have adjusted to the modes induced by the citizens; a new space opened up by a series of negotiations and interactions between actors from the indignados movement. This work is relevant to the evolving field of dynamics of complex networks, which continues to develop with a recent trend exploiting an unprecedented level of collaboration across physical and social sciences (Millgram, 1967; Travers & Millgram, 1969; Aldrich, Carter & Ruef, 2004; Birley & Stockley, 2004). We analyze how information is shared in the small world through a contagious process. In particular, we search for different dynamics within small-world networks of citizens' organizations in Spain by going through the following steps: identifying alliance patterns, i.e., the actors in excited nodes; looking for robust small-world attributes and how they are constructed; and interpreting the three modes of our model. Our interest here focuses on the identification of different small-world networks and processes of contagion within specific local settings.

In order to achieve its objectives this paper include 5 sections namely Background, Model Application, Methodology, Analysis, and Conclusion

# 2 Background

Travers and Millgram (1969) explain that social networks are in some sense tightly woven, full of unexpected strands linking individuals seemingly far removed from one another in physical and/or social space. A small-world network offers a high level of flexibility for organizing and connecting a diversity of actors. Ithiel Pool and Manfred Kochen (1979) have demonstrated this interconnectedness experimentally. Among the most studied models, the small-world network model of Watts and Strogatz (1998) can be tuned to interpolate between a regular and a random network, a very attractive property that allows us to explore the consequences of network disorder on dynamics. In this model, we start from an ordered ring in which each node is connected to its nearest neighbors, K, and then we randomly rewire each connection with probability p. This construction allows us to tune the graph between regularity ($p = 0$) and disorder ($p = 1$), where small-worlds are in the intermediate region $0 < p < 1$. For these intermediate values of p, the network has a small average distance between nodes and, at the same time, a high clustering coefficient, which in a social network can be translated as saying that, on average, someone's friends are also friends of each other, a feature that a random network does not exhibit. This model, conceptually, has been useful in modelling the collective action of neurons in the brain. It has been reported that the brain has a small-world architecture, with the synchronization of widely separated neurons in the visual cortex (Gray et al., 1989). Network analysis of the human connectome revealed robust small-world attributes.

Networks can operate near to a critical level. This criticality has been observed in magnets, water, and cortical networks. Think of a piece of iron, for example, where all the electrons spin in the same direction. At low temperatures there are no fluctuations, and at high temperatures large fluctuations destroy coordination between the spin of the electrons. At the critical temperature, fluctuations are allowed, but not so much to destroy coordination (Beggs & Timme, 2012). In a neural network, at the critical point, neurons can communicate most strongly and over the largest number of synapses.

Apart from choosing a network model, we needed to choose a model for the dynamics of the network; we chose the widely used cellular automata model of Greenberg-Hastings. In the Greenberg-Hastings model each node is assigned to one of the three following states: susceptible, excited, or passive. The state of a cell evolves with the following rules:

1. If a cell is in the excited state at time t then it is in the passive state at time t+1.
2. If a cell is in the passive state at time t then it is in the susceptible state at time t+1.
3. If a given cell is in the susceptible state at time t, and at least one of its neighbors is in the excited state at time t, then the given cell is in the excited state at time t+1 with probability r; otherwise the given cell remains in the susceptible state.

In this context r would be a measure of the average state of the small-world system. A greater r can imply, for example, a greater (collective) confidence in a specific action. This is a simple and widely used reaction-diffusion model.

# 3 Model Application

Our purpose is to study how information circulates in small-world networks in which the dynamics are modeled with a stochastic version of the Greenberg-Hasting's excitable model. It is important to stress that it is only in the susceptible state that a node interacts with its neighbors in the small-world network. We search for critical dynamics in our modeled social system. Criticality has been proposed to be a characteristic feature in brain dynamics and this suggests a condition for optimized information processing (Haimovici et al., 2013).

Information is shared in our small-world through a process of contagion. We introduce an infection (or transmission) probability r, which is the only parameter of our implementation of the Greenberg-Hasting's model. The small-world network is characterized by a mean connectivity parameter K and by a disorder parameter p. The resulting dynamics are characterized by the average activity in the network, which we denote F. We have found transitions from inactive to active collective regimes, and we can induce this transition by varying r, K, or p. An excited node is an active member of the network, an activist that wants to share information to the rest of the small-world.

Information is shared in our small world network through a contagious process in this way:

- An excited node (a member of a social movement) sends a message (for example, a call for a demonstration). For the next time step, this node will become passive.
- Only susceptible nodes receive this information, with probability r. This means that even if I get close to an activist, I can ignore the message. However, a high r implies a better probability my attention will be drawn to that activist.
- Any node in the passive state at time t becomes susceptible in the next time period, t+1.
- If there is no excited node close to a node in the susceptible state, the susceptible node continues in its current state.
- The contagion continues to follow this sequence.

Just as in the organization of the brain, where a large correlation between neurons exists when the system is in a critical state, criticality in society is present when a big crisis provokes change in the everyday life of the citizen; there is a transition to a qualitatively different collective state. Criticality in institutions results in an innovation of the traditional model as happened in the Arab Spring, the Occupy movement in the US and Europe, and the Umbrella movement in Japan. Moving from a neural system to a social system, criticality in society could be observed with the presence of conflicting orientations between institutions and citizens. We consider these institutions as linkage systems that bridge across micro systems of social interaction to macro levels of organization as defined by Mohr and White (2008). Social systems are complex systems, because they have a large number of nodes acting in accordance with rules that may change over time and that may not be well understood, as explained by Amaral and Ottino (2004). Complex systems are able to self-organize and as a result of the interaction of the units which comprise the system, something new is created (Amaral & Ottino, 2004).

# 4 Methodology

This case study is based on social institutions and affective processes involved in what normally is referred to as social movement in Spain between 2011 and 2014. We will apply the model presented in the previous section to four narratives from members of different social institutions. The following are the participants and the institutions that they represent:

- Actor 1 from Plataforma de Afectados por la Hipoteca (PAH - Movement of Mortgage Victims);
- Actor 2 from 15Mpedia, InformaSol, Padland and Peoplewitness;
- Actor 3 from Candidatura d'Unitat Popular (CUP - Popular Unity Candidates);
- Actor 4 from Asamblea Vivienda Centro (AVC - Housing Center Assembly).

The four cases represent different types of social institutions with a strong component of militancy and responsibility for citizens. We present these institutions because they embody a type of innovation and creation in the Spanish scenario in the last few years. They offer different examples of how information is distributed in small-world networks through narratives and actions.

# 5 Analysis

We show different dynamics within small-world networks of citizens' organizations by going through the following steps: identifying alliance patterns; looking for robust small-world attributes and how they are constructed; and interpreting the three modes of our model. Our interest here focuses on distributed information of different small-world networks and processes of contagion within specific local settings as we observe in the next sections.

### 5.1 Identifying Alliance Patterns

Mario Diani explains (1992, p. 8): "A social movement is a network of informal interactions between a plurality of individuals, groups and/or organizations". A network is not an immutable architecture or infrastructure but is a concept: it is a useful tool to describe something, not what is being described (Latour, 2005, p. 131). In this first part of our analysis, we will identify the actors and the excited nodes at time t.

In the indignados movement in 2011 in Madrid, the network was constructed by multiple excited nodes. According to Actor 2:

"And finally, a map was constructed to present these networks and the community began to use this technology. The first version of the map started on the Democracia Real Ya [DYR - Democracy Real Now] platform (see www.unalineasobreelmar.net/mapa-conceptual-de-la-acampada/), where pro-mobilization citizenship, including 300 associations and collectives, began to share information for a call to protest, visiting centers, associations, social centers, occupied places, to feed the protest, to convert this event in a massive event. Thanks to this call, we arrived at a macro-manifestation where everybody knew this,

except newspapers, and old and traditional technology where this kind of news doesn't appear. So the protest was organized in different Facebook groups, a popular and massive technology. Everybody has a Facebook account, or at least knows what it is. Thanks to these messages and posts, they had a complete mess. It's funny but it worked!”

At the beginning of May of 2011, the crisis in Madrid affected the society at large. At time t, 300 excited nodes shared and moved information to other nodes. These 300 excited nodes promoted the ‘macro-manifestation’ using social networks. They started the distribution of information.

At time t+1, some susceptible nodes remained in the same state, and didn’t share information to the others nodes. These susceptible nodes were old and traditional media such as newspapers. Other new media were affected by this information and shared the information. This dynamic happened and began the contagious process of converting a susceptible node into an excitable node. Excited nodes in the small-world are the actors of these networks that started the distribution of information and tried to turn on the movement.

Diani and Donati (1999) explain that when mobilization takes place on a large scale it usually relies upon connecting structures provided either by local branches of the organizations or other types of organizational infrastructures. For example, relational contexts in which activists of different movements may come in contact with each other and informal networks operating as trans-movement free spaces. Thanks to Facebook and Twitter, associations and collectives where the nodes may not have had a close relationship, at criticality can begin to share information with others nodes that they usually don’t have any connection with.

The main point in this section is that criticality rcrit in society can be achieved in some contexts and not achieved in others. In the West End case that Granovetter (1976) mentions, when a critical situation arose, residents of this area of Boston didn’t form a neighborhood network to combat the threat of renewal, because the area was much too fragmented and lacked solid representation in institutions and associations. The West Enders’ inability to organize to fight the renewal project was the opposite of the experience in Madrid. In 1958 in Boston, effective local protest against City Hall was still a rarity and there was no precedent for successful organizing (Gans, 1974) and not much excited nodes to promote the protest. Nodes were poorly connected across the different segments of population heterogeneity. We agree with Jacobs (1961), when he stresses the importance of a few people who “hop-skip”, because of their unusual sets of connections which may bring together disparate parts of a community. This process is the key to provoking or not provoking a collective contagion in small-world networks. These people who “hop-skip” are the excited nodes who can communicate with many other nodes in a critical state of the system. The number of these “hop-skip” actors marks the difference between the success and failure of a social movement.

In another part of the country, Catalonia, Actor 3 explains who the excited nodes in that network are.

“It’s not a new political subject, but it is a process started 30 years ago. There are 101 assemblies in Catalonia composed of activists. We are independents, feminists and socialists. It is a political activism institution; we create new ways to do activism. Only where there is an assembly is there a social movement (independent, feminist, socialist). It always needs this support.”

The number of excited nodes in this network is 101, corresponding with 101 assemblies. At time t, 30 years ago, these excited nodes were the starting point from which began the contagious process of the network. At subsequent times, information circulated and activated others nodes and activism was distributed in a favorable environment, connecting different parts of the society. In a region of the country (e.g., Catalonia) or in a big city (e.g., Madrid) the excited nodes connected with the rest of the nodes in the network at time t+1 to construct or maintain robust ties as we will analyze in the next section.

### 5.2 Looking for robust small-world attributes and how they are constructed.

Robust ties between nodes of networks means strong links of trust between actors (Belli, Broncano, 2017a, 2017b). Networks are the expression of pure coalitional processes, where actors share resources in order to achieve specific goals. In this scenario, Actor 2 explains how the indignados movement was distributed from the center to the periphery of the city of Madrid thanks to these robust small-world ties:

“Assemblies and meetings continued months later that 15-M, in the squares of different neighborhoods. Many people understood this distribution to be like a fade of the focus of the movement, but that is probably not a correct analysis. In the neighborhoods, the assemblies encountered the perfect context to act from the basis of the society. For this, CUP (Actor 3), Podemos [We Can], Partido X [X Party], Carta por la Democracia [Letter for Democracy] and many other social institutions, found the perfect playground to construct the technology of the horizontal democracy. It is a step in which the 15-M began its participation decline, and it didn’t have the same start force, but it arrived at the limit of what people and tools can do to an assembly movement. And when this limit is arrived at, the people find other forms to continue the fight, the empowerment. It is a long process that continues today, and we have played, tried, and been given possibilities in other places. In this way we have become social institutions, yet still existed in each technology that we used, because we loved it, because it was a form of empowerment.”

Nodes formed strong connections between them at the time. The small-world network continued to share information to self-organize itself. Different nodes connected with other nodes of different networks, like the CUP (Actor 3). Empowerment was achieved by increasing the connectivity parameter K, the basic key to construct these robust connections. Empowerment and strong positive emotions, which enforce confidence and can be viewed as increasing the parameter r, help to construct these robust ties between nodes. Information in this context circulates from the core to the periphery of the movement without losing the force and the intensity. Robust ties are constructed thanks to trust shared between actors of this small-world. According to Actor 2:

“After the protest, some police violence, and more things which happened, the emotions of the participants could not stop there. Forty people campaigned in the square the first night, the 15th of May

2011, and it began to gain force on another technology, Twitter. Using tweets, hashtags, connections between different places in the country, the trajectory was drawn and people communicated between themselves, zigzagging technologies."

The probability of contagion is bigger when robust ties are present in a small-world network. Empowerment helps the continuation of communication between nodes, and technology helps to shape the communication between nodes. Distributing information represents a strong, valuable connection between nodes to establish patterns of trust and to construct robust ties between nodes. Actor 2 said:

"It was an authentic explosion. In the first tweets the message was 'we don't move from here' and that everybody had to come there to the square. Every single person that we had spoken to before, that were in some way activists or had an activist discourse, needed to come to the square. It's not so easy to understand what's happening there, but everybody must come. An explosion means that everybody looked in that direction, in Sol. At that time, 2011, the common technology to communicate in a fast and ubiquitous way was the SMS message. Everyone sent SMSs to each person in their contact list who had participated in others movements and protests. And of course, they also used emails. Then these people in the square begin to mailing to everybody. For example, one mail described a letter sent to the Government Prefecture asking not to dissolve the protest. In the end the protest didn't dissolve in this way, but the central point was, wow, this mail was sent from that person that I had never spoken with about these things, and now this person is interested and cares about us and wants to stop the dissolving of a protest that I've never discussed with that person."

"Homophily is the principle that a contact between similar people occurs at a higher rate than among dissimilar people" (McPherson, Smith-Lovin & Cook, 2001, p. 416). Because individuals who share similar interests are more likely to know each other, these individuals tend to form dense clusters in which everyone knows everyone else (Aldrich & Kim, 2007). In a critical state, some nodes that normally do not share information, suddenly communicate between themselves. The SMS message from an excited node to a susceptible node caused surprise in Actor 2. A susceptible node at time t+1 became an excited node because it shared the same statement in the network. Maybe this susceptible node can be described as a contagious, healthy node which is sensitive to the situation and agrees with the change of status. The circulation of information in a critical state put nodes in contact that under normal conditions would not have any type of relationship.

Social network research pointed out that a core belief underlying modern social network analysis is the importance of understanding the interactions between actors. Under conditions of low interdependence between actors and little or no social interaction, network processes and their effects will tend to be minimized. But in a critical state the networks work thanks to the multiples and long ranged interconnections between nodes. For Millgram (1967), society is not built on random connections among persons but tends to be fragmented into social classes and cliques. Nodes in the last context are connected for this perspective; someone that has interchanged the same thoughts and interests in the past and that now, at the critical state, appears a valid reason to exchange information, to respond

against the state of the system. The network changes its activity but always existed. Perhaps it is only at criticality that the network is visible for the rest of society.

As Actor 4 explains:

“Obra social is composed of three 15M assemblies [networks] to solve the emergence of neighbors’ problems [housing].”

This is another example that can help us understand how robust small-world ties have strong impact in a critical situation. Nodes are connected between themselves to share the same problem in society, in this case the problem of housing. Context affects these nodes and they create robust ties to share information and to organize their collective action. A common purpose allows us to create this network and to propagate information. A new network is composed (Obra Social – Actor 4) from an old network (15M – Actor 2).

According to Actor 1:

“The institutional path is a key part of this movement to block a law, for example, the collection of signatures. My first thought was ‘It’s a stupid thing to collect signatures’. But later I discovered that it was a strategy, because collecting signatures is an excuse to evangelize people. You go to the street to collect signatures and you tell the people what has happened. With 1.5 million signatures collected, we exposed the lie that collecting signatures in Spain is not useful because you cannot change the things. It is a tool of self-deception.”

The new network could be constructed in this way, as Actor 1 explains. A collective action, to collect signatures, is useful to create robust ties to share information and to establish connections between nodes. Some actors that sign are susceptible nodes at time t, and at time t+1 become excited nodes thanks to this strategy of collecting signatures and creating new ties.

According to Actor 4:

“The composition of this group is heterogeneous. They are not only immigrants or vulnerable youth. Our work is empowering people and to lower the barrier that you are the cause and I am the activist. It is progressive work to elevate the person so that they are empowered. We study the cases, delegating different people to listen to the rest of the people. We are doing pedagogy, a familiar model to prevent eviction like PAH [Actor 1]. The language is power, I observe this in assembly. I am an academic, and I need adequate discourse. We need to do politics with people desde abajo [from the bottom]. We don’t use specific terms, but a natural language that everybody understands.”

Robust small-world ties are constructed with the purpose of responding to a specific event in this case. Our probability of contagion r is the probability of empowerment that excited nodes transmit to susceptible nodes. It works as a contagion between nodes of the small-world, teaching people how to lower barriers between activism and non-activism status. If two people know each other by name, this

need not move their relationship out of this category if their interaction is negligible. Homans (1950) says that the more frequently persons interact with one another, the stronger their sentiments of trust for one another are likely to be.

According to Actor 4:

“How do we work? We work in commissions. We meet each Monday evening in Lavapies. We work with sponsors. A sponsor is someone that helps you to find a solution for your problems. If you have a sponsor when you explain your case, two people may decide to follow you and to help you in this case. We construct a schedule, to construct a case in a collectivist way in a commission. Our everyday work is to achieve objectives. When someone enters an assembly, they need to understand that the cases are shared. My problem is your problem and vice versa. There is not only your problem. Everything is collectivized. Nobody is an expert. But we learn to be an expert in the process. Empowering is a conjunction of networks. An assembly cannot exist without these networks; this is the mixed model of Obra Social.”

At time t, the sponsor figure is an excited node that knows a susceptible node to pass information on Obra Social to, and will bring her to the meeting on Monday evening. At time t+1, the susceptible node will be an excited node and she will then act as a sponsor to another susceptible node. Networks like these criticize individualism and look for a subjective transformation in order to achieve empowerment; this is the key to understanding how robust small-world attributes are constructed. The most important factor in the construction of small-world ties is the probability of empowerment contagion r. If this works, at time t+1 we observe the phenomenon that Actor 4 explained in the previous extract.

### 5.3 Interpreting the three modes of our model

In this last section of our analysis, we present how information is circulated in a small-world network following the Greenberg-Hasting’s model. Consider the testimony of Actor 2:

“Because these meetings continuously changed location and it was impossible for the participants to arrive at these places because the change was continuous, it was necessary to generate and to elaborate a new network of communications, new forms of distributing information. And many times, the use of a certain tool was not updated and so information was interrupted and not shared with the participants of the meeting. The use of these online tools to organize meetings was a chaotic process, because people didn’t understand where the meeting was, they were wrong, or changed continuously. Everything in spring and summer 2011 was genuine chaos. Probably nowadays it would be completely different to organize a camp like that. During these past three years we enjoyed some development; we have very ingenious tools today—for example, a handbook about training—and there is much desire to use these things. For instance, these camps that emerge in every part of the country, the assemblies in the neighborhood or townhall have maintained their tools of distributing information in the network. The common problem is that many times the communication management is centered on one person and that she is saturated with all of this information, too many mails, too many tweets. She cannot continue and so the assembly

loses connection, it becomes marginalized and isolated. Many of these assemblies disappear because the message doesn't arrive."

Information is distributed in this network chaotically; from an excited (and saturated) node to the rest of the network. Actor 2 defines himself as a bureaucrat of the indignados movement, someone that is not used to speaking in an assembly, because he just collects information, contrasts it, shares it, tries new and different tools, receives feedback, constructs systems and infrastructure to manage this information, etc. He is an actor with a central role in this network regarding the sharing of knowledge in the social institution.

Transmission of information and ideas takes place through some technical device, regardless of the level of technical sophistication. Examples range from mail or SMSs addressed to members and sympathizers. Heider (1958) and Newcomb (1961) explain that if strong ties A-B and A-C exist, and if B and C are aware of one another, anything short of a positive tie would introduce a psychological strain into the situation since C will want her own feelings to be congruent with those of her good friend A and similarly for B (Granovetter, 1973). A and B are strongly linked, and A and C too, but C and B do not have a strong tie. B-C have a weak tie. The importance of these weak ties is basically to share information (Kerckhoff et al., 1965).

Granovetter (1967) argues that whether a node trusts a given leader depends heavily on whether there exists intermediary personal contacts who can, from their own knowledge, assure her that the leader is trustworthy, and who can intercede with the leader or her lieutenants on her behalf. Trust in the leader is integrally related to the capacity to predict and affect their behavior. Bridging ties would then offer unusual insight into the social dynamics of the community.

For Tilly (1978), the goal is to transform mere aggregates of people sharing the same condition into a social network, and thus more easily mobilize a group. The distribution of information in the square between persons was another type of technology used. They learned that offline communication was faster that online communication. Mouth to mouth was faster than everything posted, tweeted, and distributed in the online network. As Latour (2013) argues, all the networks resemble one another and remain totally invisible, but for a specific aim it is important to know the right tool. And many times, the use of a certain tool was not updated and so information was interrupted and not shared with the participants of the meeting. The use of these online tools to organize meetings was chaotic and discontinuous, because people didn't understand where the meeting was. After those early days of saturated information, many actors of the indignados movement needed to disconnect to avoid burnout. Actor 2 explains how he removed himself from different mailing lists and whatsapp, line, telegram groups, and turned off mobile phone alerts, because this saturation of information exposes the body continuously to mechanical stimulus, like vibrations, ringtones, etc. This shows how a subject can be attached to the technology. The break offered a possibility to reflect on what had happened in those days and to focus and work on a unique technology. For Actor 2 this unique technology was a wiki called 15Mpedia , a free encyclopedia that anyone can edit on the 15-M. Information and data was collected in

the boxes and shared in this platform. In was a trust-distributed environment where information can flow thanks to horizontal processes and networks were constructed in an open and social fashion. When the contagion was interrupted, many actors became passive nodes.

# 6 Conclusion

As Diani and Bison (2004) explain, a social movement process occurs to the extent that long-term bonds and shared identities translate into sustained networks between independent actors in pursuit of shared goals. Network processes are the movement; this distributed information is the movement. Sharing information in these small-world networks has the common characteristic of all complex systems: organization takes place without any external organizing principle being applied and a central characteristic is adaptability (Amaral & Ottino, 2004).

We have observed in this paper how actors are involved in small-world networks. During this time nodes communicated between themselves with randomly chosen connections. In this dynamic, social movement is divided in three different states. The probability r is so important for the success of a movement: the parameter r is a measure of the excitability degree of a population. In our case this is interpreted as a degree of confidence in activism or in the movement, the number of “hop-skip” actors, and the empowerment constructed between actors.

The application of this model to a social context is interesting for two reasons. The first is because it helps to explain how social movements have or have not succeeded in sharing information and empowerment. The second reason is that thanks to this model we can explain how at rcrit many systems respond the same way to a critical situation in different areas.

It would be interesting in the future to apply this contagion model to semantic networks to understand how actors share information, discourses, and meanings in a contagious dynamic.

# Declarations

**Competing interests:** The authors declare no competing interests.

# 7 References


1. Aldrich H., Carter N., Ruef M. (2004). Teams. In *Handbook of Entrepreneurial Dynamics: The Process of Business Creation*, Gartner W., Shaver K., Carter N., Reynolds P. (eds). Sage: Thousand Oaks, CA, 299-310.
2. Aldrich, H. E., Kim, P. H. (2007). Small worlds, infinite possibilities? How social networks affect entrepreneurial team formation and search.*Strategic Entrepreneurship Journal*, *1*(1-2), 147-165.
3. Amaral L., Ottino J. (2004). Complex systems and networks: challenges and opportunities for chemical and biological engineers. *Chemical Engineering Science,* 59, 1653-1666.

4. Belli, Simone; Broncano, Fernando. (2017a) Narratives of trust: sharing knowledge as a second-order emotion. *Human Affairs*, 2017, vol. 27, no 3, p. 241-251.
5. Belli, Simone; Broncano, Fernando. (2017b) Trust as a Meta-Emotion. *Metaphilosophy*, 2017, vol. 48, no 4, p. 430-448.
6. Beggs, J. M., & Timme, N. (2012). Being critical of criticality in the brain. *Frontiers in physiology*,*3*.
7. Birley S., Stockley S. (2004). Entrepreneurial teams and venture growth. In *Handbook of Entrepreneurship*, Sexton D., Landstrom H. (eds.). JAI Press: Greenwich, CT, 129-153.
8. Diani, M. (1992). The concept of social movement.*The sociological review*, *40*(1), 1-25.
9. Diani, M., Donati, P. R. (1999). Organisational change in Western European environmental groups: a framework for analysis.*Environmental politics*, *8*(1), 13-34.
10. Diani, M., & Bison, I. (2004). Organizations, coalitions, and movements. *Theory and Society*,*33*(3-4), 281-309.
11. Gans, H. "Gans on Granovetter's" Strength of Weak Ties"." (1974): 524-527.
12. Granovetter, M. (1976). Network sampling: Some first steps.*American Journal of Sociology*, 1287-1303.
13. Gray, C. M., König, P., Engel, A. K., & Singer, W. (1989). Oscillatory responses in cat visual cortex exhibit inter-columnar synchronization which reflects global stimulus properties.*Nature*, *338*(6213), 334-337.
14. Haimovici, A., Tagliazucchi, E., Balenzuela, P., & Chialvo, D. (2013). Brain organization into resting state networks emerges at criticality on a model of the human connectome. *Phys. Rev. Lett.* 110(178101), 1-4.
15. Heider, F. (1958). The Psychology of Interpersonal Relations. New York,: Wiley.
16. Homans, G. (1950). The Human Group. New York: Harcourt, Brace and World.
17. Jacobs, J. (1961). *The Death and Life of Great American Cities*. New York: Random House.
18. Kerchoff, A., Back, K., Miller, N. (1965). Sociometric Patterns in Hysterical Contagion. *Sociometry,* 28(March), 2-15.
19. Latour, B. (2005). Reassembling the social.*London: Oxford*.
20. Latour, B. (2013).*An inquiry into modes of existence*. Harvard University Press.
21. McPherson, M., Smith-Lovin, L., & Cook, J. M. (2001). Birds of a feather: Homophily in social networks.*Annual review of sociology*, 415-444.
22. Mohr, J. & White, H. (2008). How to model an institution. *Theory & Society*, 37, 385-512.
23. Milgram S. (1967). Small-world problem. *Psychology Today*, 1, 61-67.
24. Newcomb, T. (1961). *The Acquaintance Process*. New York: Holt, Rinehart and Winston.
25. Pool, I., Kochen, M. (1979). Contacts and influence.*Social networks*, *1*(1), 5-51.
26. Tilly, C. (1969). *Community: City: Urbanization*. Mimerographed. Ann Arbor: University of Michigan.
27. Travers J., Milgram S. (1969). Experimental study of small world problem. *Sociometry*, 32, 425-443.

28. Watts, D. J., Strogatz, S. H. (1998). Collective dynamics of ‘small-world’ networks. *Nature*, 393(6684), 440-442.