COMPLEX NETWORK APPROACHES TO SMALL TEAM ANALYSIS. CONFLICT AND GENDER

Núria Rovira Asenjo

Dipòsit Legal: T 342-2014

Doctoral Thesis

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Department of Chemical Engineering

University Rovira i Virgili

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Supervised by:
Dr. Marta Sales-Pardo
Dr. Roger Guimerà
Dr. Tània Gumí

Department of Chemical Engineering
SEES Lab & METEOR research groups

Tarragona
2014

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UNIVERSITAT ROVIRA I VIRGILI
University Rovira i Virgili
Department of Chemical Engineering
Av. Països Catalans, 26
47007, Tarragona
Phone +34 977 55 86 43

Dr. Marta Sales-Pardo, Dr. Roger Guimerà, and Dr. Tània Gumí

CERTIFY:

That the present study entitled "Complex network approaches to small team analysis: conflict and gender", presented by Núria Rovira Asenjo for the award of the degree of Doctor, has been carried out under our supervision at the Chemical Engineering Department of the University Rovira i Virgili.

Tarragona, 20th Dec, 2013

Dr. Marta Sales-Pardo Dr. Roger Guimerà Dr. Tània Gumí

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Summary

Despite the well-documented benefits of working in teams, teamwork also results in communication, coordination and management costs, and may lead to personal conflict between team members. In a context where teams play an increasingly important role, it is of major importance to understand conflict and to develop diagnostic tools to avert it. Here, we investigate empirically whether it is possible to quantitatively predict future conflict in small teams using parameter-free models of social network structure. We analyze data of conflict appearance and resolution between 86 team members in 16 small teams, all working in a real project for nine consecutive months. We find that group-based models of complex networks successfully anticipate conflict in small teams whereas micro-based models of structural balance, which have been traditionally used to model conflict, do not.

We developed the Team Analytics web tool, which is an implementation of our group-based model of complex networks in an user friendly on-line tool. We use this tool to make an intervention to three real teams and we find that it accurately diagnoses team dynamics and predict future conflict among team members. We also analyze the relation between conflict and performance of the team. The development of such tools can benefit companies.

On the other hand, we present a study about gender differences on

leadership. Gender stereotypes still play an important role in society. On account of this, leadership positions are still more related to men stereotypes, and therefore women are discriminated to access such roles. This study aims to understand the mechanisms behind the stereotype influences on the leadership evaluation process. Toward this end, we analyze data of the evaluations of 45 leaders (33% women) from 258 team members (39% women), all of them work in small teams to develop specific engineering projects. We apply mediation analysis and team network analysis and we find that female leaders are better evaluated than male leaders at the beginning of the project. However, at the end of the project these differences disappear. We also find that the network clustering of female leaders grows significantly more than the clustering of male leaders. With these results on hand, we observe that, at the beginning, female leaders are outmatched with an "increment of competence" due to the influence of gender stereotypes. Later, this advantage vanishes together with the surprising effect of having a female leader.

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Abbreviations

URV	**U**niversity **R**ovira i **V**irgili
ETSEQ	**E**scola **T**ècnica **S**uperior **D**'Enginyeria **Q**uímica
IP	**I**ntegrated **P**roject
Q1	**Q**uadrimester **1**st
Q2	**Q**uadrimester **2**nd
TA	**T**eam **A**nalytics
GE	**G**lobal **E**valuation

Dedicated to
my father, who would have been proud of me,
to my mother,
to Salvatore and our future baby.

Chapter 1

Introduction

In the last decades, teamwork has become an integral part of work practices both in business and in science [1, 2]. Teamwork is supposed to increase performance [2], especially when team are diverse [3, 4, 5]. Additionally recent work shows that the collective intelligence factor of a team is higher than those of individual team members [6]. The downside of teamwork comes through communication, coordination and management costs [7, 8]. Because of the impact of teamwork in society, studies on this topic are gaining relevance.

Teamwork is essential in many disciplines. For instance, in medicine, it has become a really important practice due to the need of collaboration to save patients, when a surgery needs the intervention of different medical specialists [9] or in cases of integrative medicine, related with device development, where collaboration between doctors and engineers is necessary [10]. Another example is in sport and competition, where teamwork plays an important role because performance and the results are closely related with the effective collaboration among team members [11]. Recent studies on scientific collaborations have shown the increasing role of collaborations in science [2], the effect of team composition in success [12] and the increase

of an author's impact due to collaboration [13].

Because of the importance of teams, in recent years, the Science of Team Science has emerged as a new field to study teams. It includes a combination of conceptual and methodological strategies to understand and enhance the outcomes of large-scale collaborative research [14]. The Science of Team Science is an interdisciplinary field that includes social and communication sciences, network science, information science and cognitive and behavioral sciences [15, 16] and tries to develop new tools and structures to improve the efficiency and success of team science initiatives [14]. However, despite the amount of research in teamwork field, most of methods as recently it has been shown [17], are more focused in large-scale initiatives and they leave aside the smaller teams [15]. To provide solutions for all team science initiatives, it is mandatory to develop new tools for all different team scales.

Until now, social science research on teamwork has used traditional micro-level methodologies to study small systems [18, 19, 20, 21, 22]. And the challenging application could be the implementation of macro-level large-scale theories developed in the context of complex network science to study small systems [23, 24, 25, 26]. In contrast to micro-level theories, macro-level theories study the system as a whole in order to understand the effect of specific processes occurring within the system.

Recently, Katz and coauthors suggested [27], the implementation of complex network methodologies to study small teams, specifically, the application of small network quantitative analysis. Indeed, teams can be understood as complex systems, because macroscopic behavior of a team is more than the sum of the individual components [28]. The dynamics within the team, the adaptive behavior, the coordination and the interac-

tion among team members convert the small system in a complex system [29].

In the fifties and sixties, within the context of social psychology, Bavelas introduced a mathematical model of the communication patterns for small groups, giving rise to the concept of group structures. Bavela's model already defined some concepts related with networks [30]. During those decades, some authors applied these kind of methods to resolve socio-psychological problems of small group research [31, 32, 33]. Unfortunately, there was no significant progress on those models for a long time, in part because of the mathematical limitations. It was not until a decade ago that Katz and coworkers put forward again the relevance to bring back the network perspective into team science [27].

Following these steps, the main objective of this thesis is to put forward the complex network approach to the study of small teams and social sciences. First, we started with the study of conflict within teams because of the link between conflict and repercussion on team performance. To properly showcase the advantages of our approach, we applied complex network analysis to teams and compared it with the results obtained from traditional socio-psychological methodologies. As a result of our research, for the first time we were able to show quantitatively that complex network methodologies are better suited to analyze and predict conflict in small teams that commonly used methodologies in social science. Second, we analyzed the role of gender on teamwork, specifically the impact of gender on leadership. Our results show that complex network metrics are correlated with results from socio-psychological methodologies thus opening new insights into the mechanisms affecting communication between team members and leaders.

1.1 Complex networks

A graph is a collection of nodes connected by edges. Networks are useful representations of many real-world systems such as, computer networks, social networks, organizational networks, neural networks, metabolic networks, networks of citations between papers, etc [24]. These real-world networks are often complex, that is, they display non-trivial topological characteristics, comparing to simple mathematical models for graphs.

In this thesis we will only consider networks of nodes of a single type. In this case, networks can be of two types: undirected and directed. In undirected networks edges are bidirectional, that is they imply a relationship between two nodes, whereas in directed networks edges have a specific direction, that is edges run from one node to another.

Basic metrics to analyze the topological structure of a network are the following:

- *Degree:* is the number of edges (or connections) that the node has to other nodes. In case of directed networks, there are two different kind of degrees, the in-degree, which is the number of incoming connections, and the out-degree, which is the number of outgoing connections [24, 34].

- *Betweenness:* it can be measured for nodes and edges. Node/edge betweenness is the total number of shortest paths between every pair of nodes in the network that pass through a specific node/edge [35]. The betweenness centrality can be measured in both directed and undirected graphs.

- *Clustering coefficient:* It is a measure of the density of connected triangles in the network.The global clustering coefficient measures the fraction of connected triangles out of all the possible triads. The local clustering coefficient of a specific nodes measure the fraction of pairs of neighboring nodes that are connected out of the possible pairs of neighbors. The local clustering coefficient of a networks is then the average of the clustering coefficients of each node [36].

- *Degree distribution:* is the probability distribution of the degrees of the whole network [23]. Also it could be applied in directed networks, using the in-degree and the out-degree.

In 1998, Watts and Strogatz [36] put forward the idea that the complex network of interactions between components in a complex system is, to a large extent, responsible for its behavior. This concept contributed to the development of network theory [35, 37] and creation of new tools and its analysis.

In fact, most real world networks display universal features: a scale-free degree distribution and high clustering. A scale-free degree distribution decays as a power-law ($p(k)\ k^{-\alpha}$), which is a particular mathematical function. The power law implies that the degree distribution of the network has no characteristic scale [38]. Networks are said to be highly clustered when the clustering coefficient is higher that of an equivalent network with the same number of edges and degree distribution in which edges have been positioned at random. Highly clustered networks show the so -called small -world effect in which the distance between any two pairs of nodes in the networks grows as *log N* (N is the number of nodes in the network). In

the social sciences, the small-world effect is also known as the 'six degrees of separation' effect shown by Milgram in 1967. Milgram asked people in a town in the center of the US (Omaha) to send a letter to a person he new in Boston. If they did not know the person, they could send the letter to a person they thought could know this person. On average, the letters went through six people before reaching the final destination, thus putting forward the idea that two arbitrary people in the world are connected by only six degrees of separation, this means, that the diameter of the corresponding network of social connections is not much larger than six. A wide variety of real-world networks display this property [36].

Despite these universal properties, the study of local (node or edge centered properties) had modest success in explaining emergent behavior in complex systems [39]. Global approaches to network analysis offer a new perspective to study networks. In particular, the networks community took a leap forward when researchers identified that real-world networks display an organization structure (in communities) that goes beyond local clustering [40]. Communities are groups of nodes that are more densely connected than to nodes in other communities. Interestingly, this division into groups is related to network function and dynamics [41, 42]. However, there are other divisions of nodes into groups that share specific properties in the pattern of connections that could be more suitable for specific real-world cases, such as the network of sexual contacts in which typically nodes in the same group do not interact with nodes in that group [43, 44]. Recently, the study of the structure the network has been also examined using network inference [44, 45, 46], which focuses on obtaining logical conclusions about the structure the network with static and dynamic data.

Until now, global approaches have been applied exclusively to large-scale networks. However, it still remains a challenge to demonstrate the suitability of this approach for the analysis of small scale social networks in which there are of the order of 10 nodes, and the fear is that there is not enough 'statistics' for global analysis to provide meaningful information. Nonetheless, in this thesis we face this challenge.

1.2 Team conflict

Conflict is defined as the appearance of tension among team members. Is well known that conflict interferes with team functioning and in most of the cases may offset the benefits of teamwork [3, 47, 48, 49, 50]. According to the social science discipline within the context of group processes, team conflict is divided in three categories as described bellow: relationship conflict, task conflict and process conflict [48].

- *Relationship conflict* arises when there are interpersonal incompatibilities among team members that involve personal issues. Some examples of this kind of conflict could be: dislike among team members, feelings such as irritation, frustration, animosity, annoyance, etc.

- *Task conflict* arises when there are different viewpoints and opinions related to the team's task. This kind of conflict usually generates discussions within the team and personal excitement, but without the implication of interpersonal negative emotions.

- *Process conflict* arises when there are controversies within the team about how to accomplish a task. In other words, process conflict is re-

lated to the execution of team duties, such as who should do what, or how what is the work load of each member. A typical example would be the disagreement among team members about who is responsible to complete a specific task.

The three types of conflict are related with the outcomes of the team. It has been demonstrated in different previous studies that relationship conflict is the kind of conflict more direct and negatively related with team performance [51]. Moreover, in recent studies it has been shown that also process conflict affects negatively team performance, the satisfaction of team members and the coordination of the group [52].

However, conflict related with the task of the team could be beneficial in team effectiveness or in team performance, because of the team enrichment by the differences in point of views and opinions of the team members. Although this only happens in cases that task conflict is not related with relationship conflict, otherwise task conflict could be even detrimental for team performance [51].

Recently, Tekleab and Quigley [53] proposed a new perspective to avoid relationship conflict based on team composition. The similarity among team members helps to deal relationship conflict. According some experiments, if team members are more similar in agreeableness, conscientiousness and emotional stability then, they could be more capables to face relationship conflict. In addition, these similarities could avoid negative affective reactions, that commonly appear in relationship conflict.

Another example where teams diminish and even can avoid relationship conflict is in the case of virtual teams, that become more popular in some specific contexts of work [54]. Virtual teams have difficulties to express

the emotions because of the physical limitation and for this reason, they experience less or no relationship conflicts.

Despite the amount of research about team conflict, the study of conflict is still very important due to the implication of it in many different work contexts and for the awaken interest in society. Because of this, is very important to follow studying team conflict, in order to understand it, develop diagnostic tools to avert it, and, ultimately, develop strategies to mitigate it. Therefore, in the present thesis we propose the development of a new method to predict the appearance and resolution of conflict related to relationship conflict in small teams.

1.3 Leadership and gender

In 2013, the number of women in European Parliament tripled and rose to 35.1% comparing to 1979. However, women are still in the minority and hold lower status positions (e.g., there are only three out of fourteen Vice-Presidents and only two-out of five-Quaestors). It must be emphasized, that the European Parliament illustrates quite optimistic statistics. In the private sector, women hold 24% senior management positions globally, and only 19% of board roles around the world. The gender inequality is not only limited to business. For example, according to the US National Science Foundation, women hold only 21% of full science professors position and only 5% full engineering professors. Importantly, they earn approximately 18% less than men occupying the same positions [55]. Although times have changed, there are still many barriers that prevent women from developing a full career.

For instance, in STEM (science, technology, engineering, and mathematics) disciplines the ratio of publications of women faculty members is much lower than in men. In fact, it is only higher in disciplines where is more risky to achieve an academic position [56]. Closely related of this is the statistic of patents in universities, where women faculty members only patent at about 40% of the rate of men [57]. But not only in research there are gender differences, also in economics there are studies that show, for example, that women make smaller economical investments in comparison to men. This means that women take less financial risks [58].

Furthermore, this unequal situation worsens if one considers the challenge of achieving a leadership position. Many studies show that leadership evaluation differs depending on the gender of the leader (e.g., [59]). In general, female leaders are evaluated less favorably than male leaders, specifically in evaluations of future potential leaders [60]. This tendency is due in part to the vivid leadership stereotypes that generally reflect more male than female characteristics (e.g., [61]). These stereotypes may also affect women, because they have a tendency to undervalue their contributions in collaborative context, in particular if they collaborate with men. This tendency affect women sense of confidence and self-esteem and also influence them to be promoted to leadership positions [62].

To confront all these disadvantageous situations that nowadays still affect women professional careers, there are some specific learning programs, concretely in the management contexts, that are focused on the educational changing [63]. These programs aim at creating awareness among women leaders, this may change the dynamics of gender in the organizations.

In this thesis, we studied the leadership differences between female and

male leaders by the team evaluations obtained. We also analyze the differences of the team network structure depending on whether the leaders are females or males. All in all, we offer new results that help a better understanding of gender differences on leadership context. Research like this should bring awareness in society about gender inequality and thus encourage fair play in women professional career promotion, specially when they are running for responsibility positions.

In the following chapters of this thesis, we present a new approach to study social problems following a complex networks approach. The results derived from these thesis are remarkable not only because of the methodological approach to study small teams but also because of the opportunity it offers to carry out experiments with real teams.

Chapter 2

Sample and data description

This chapter is decoded to describe the data used in the development of this thesis. In what follows I describe the collection process of the data and I characterize the population sample that participated in this process.

2.1 Description of the school projects

The flagship of the Escola Tècnica Superior d'Enginyeria Químima (ETSEQ) at the Universitat Rovira i Virgili (Tarragona, Catalonia) is the educational programme based on Project-Based Learning methods [64] that has been implemented during the last two decades. The central part of this programme is the Integrated Project (IP). The IP consists on an open-ended project that teams of students enrolled in the same curricular year need to perform during an academic year. The goal of the IP is for students to integrate the knowledge and skills acquired in the different subjects into the solution to an engineering problem.

To perform the IP, first year students are grouped in teams with a fourth-year student as a team leader. First-year students are all of them involved in the IP which is a course of the academic curriculum. The

composition of the teams is based in the following process. All first-year students are randomly assigned to one of four or five large groups. From each of these groups, four teams (between 5-6 members each) are defined by the balance of the personality traits of their members. The personality traits are obtained by the administration of Belbin Self Perception Inventory [65, 66], which defines the team roles preferred by individuals. The optimal balance of a team depends on the diversity of roles that the team has, the more the diversity of roles the more balanced a team.

Fourth-year students (leaders) are enrolled in the Project Management in Practice course that combines the experience of leading a project team with the training provided on the principles of leadership and personal development activities such as writing a personal learning journal and receiving personal coaching. To become leaders of first-year students they have go through a selection process. The process of selecting team leaders is central to guarantee team success due to the empowered role that leaders have in the IP. For this reason, it is necessary that fourth-year students are volunteers to be leaders of a team. Then, the selection process is divided in two-steps, steps based on the most common selection process in companies, to identify potential team leaders. In the first step, two prerequisites are established: candidates must have no courses pending from the first year and be sufficiently motivated to lead IP teams. In the second step, students are given a personality profile test with the following three instruments: (a) the Belbin Self Perception Inventory [65, 66], which defines the team roles preferred by individuals; (b) the Myers-Briggs Type Indicator [67], which defines the 16 personality types; and (c) the Managerial Style Questionnaire [68], which identifies the styles used by leaders [69].

2.2 Collection data

During three academic years (2010-2011, 2011-2012, 2012-2013), we collected data from online surveys of the chemical engineering students enrolled in the IP at the URV. The total sample analyzed is of 303 students, of which 45 are team leaders (33% women) and 258 are team members (39% women) with a mean age of 21 years. The data was collected through an online survey that includes questions to evaluate different aspects of teamwork and leadership. We administered the same survey twice a year, in December, three months into the project and in May, at the end.

2.2.1 Survey description

To create surveys we used OPINA, a survey service of the university [1], and we created a platform to generate personalized surveys, send them to all of the students and collect the data from the answered surveys. Until now, ETSEQ had a independent system to administrate surveys and collect data from them, depending of the academic year, the professor responsible, etc. Therefore, with the creation of this platform, we unified a global system in the ETSEQ to collect data about IP projects with a common survey for all academic years and a common process to analyze obtained data. Figures 2.1, 2.2, 2.3, 2.4 and 2.5 show series of screenshots illustrating survey appearance in this platform.

The survey is divided in 4 parts: leader evaluation (in case that the respondent is the leader, this part is a self-evaluation), that contains questions about the performance of the leader, members evaluation (in case that

[1] `https://tramits.urv.cat/ebabel/`

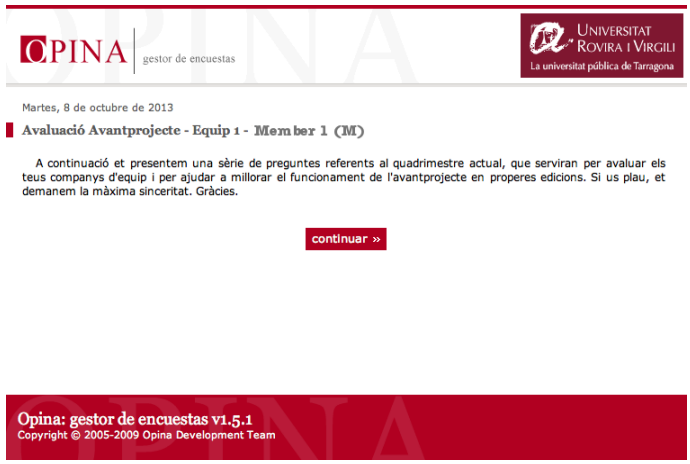

Figure 2.1: Survey introduction.

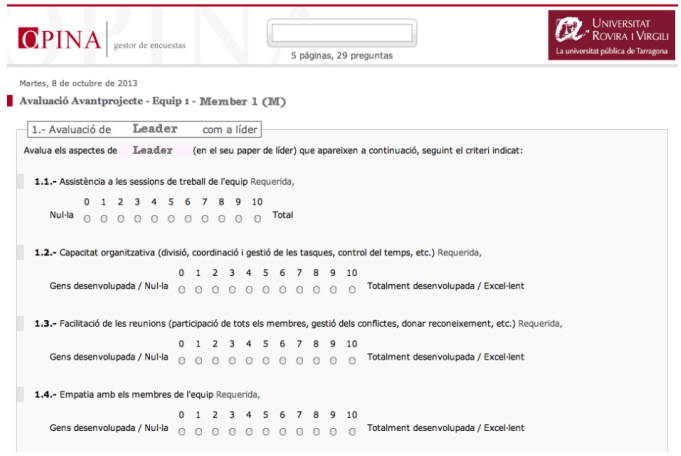

Figure 2.2: Survey: leader evaluation.

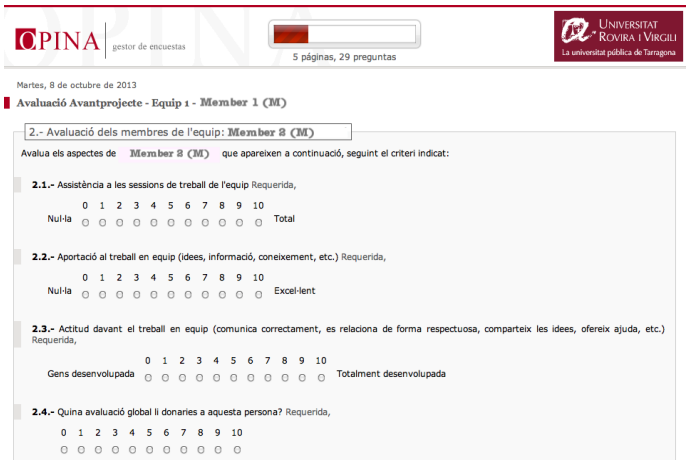

Figure 2.3: Survey: member evaluation.

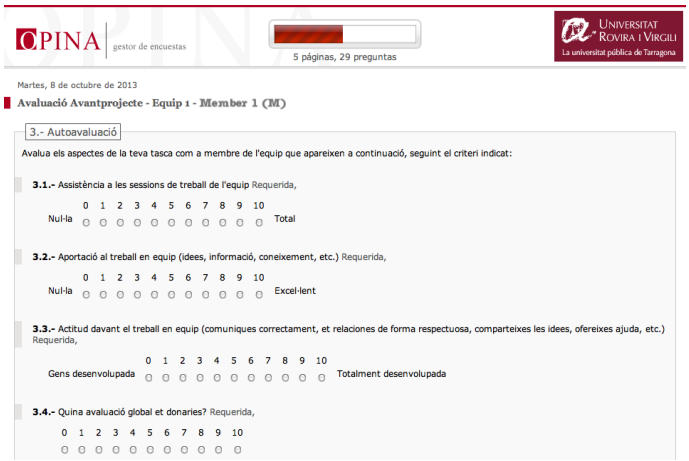

Figure 2.4: Survey: self-evaluation.

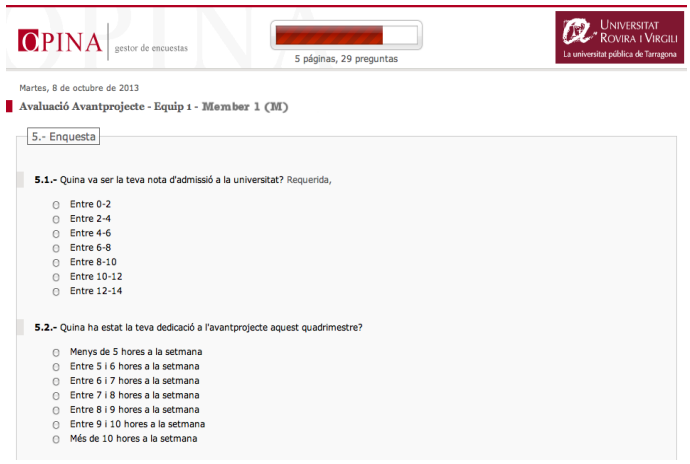

Figure 2.5: Survey: general questions about the project.

the respondent is a member, has to evaluate the other members and also evaluate him/herself), that contains questions about the behavior of the members in the team. Then a general survey, that contains some general questions regarding to the project functioning and have some open questions that that members can answer freely. Finally, the tutor evaluation, that contains some questions about the function and support of the project tutor that students have. All questions are presented in the sections before described as follows:

Leader evaluation: 1) Attendance at teamwork meetings; 2) Management skills (coordination, task management, time control, etc.); 3) Meeting facilitation skills (achieving participation of all members, conflict management, public recognition of good work, etc.); 4) Empathy with team members; 5) Motivation capacity (motivate team members, produce changes in

team members' behavior to achieve objectives); and 6) Global evaluation of the leader. Thus, the answers are measured in 11 points scale, where 0 means: Not developed / Non existent/ Poor; and 10: Completely developed/ Excellent. Finally, the question 7) Would you choose her/him as a leader in a new team? With a Yes/No answer. Last questions is only required to answer for the team members.

Member evaluation: 1) Attendance at teamwork meetings; 2) Teamwork contribution (ideas, information, knowledge, etc.); 3) Teamwork attitude (properly communicating, being respectful, sharing ideas, offering help, etc.); 4) Global evaluation of the member. Answers are also measured in 11 points scale, where 0 means: Not developed / Non existent/ Poor; and 10: Completely developed/ Excellent. The following questions can not be self-evaluated. Question 5) Did you share specific work tasks with this member?; 6) Would you like to work with this member in a new team?; 7) Would you choose her/him as a leader in a new team?. The answers for last questions are Yes or No.

General survey: 1) What was your dedication to the IP during this quadrimester?: less than 5 hours per week, between 5 and 6 hours, between 6 and 7 hours, between 7 and 8 hours, between 8 and 9 hours, between 9 and 10 hours, or more than 10 hours per week. 2) How do you consider your knowledge, after completing the IP, compared to that you would have if you do not had participated?: much higher, higher, the same, lower, much lower. 3) The presence of a leader in a team is: essential, important, useful, dispensable, harmful; 4) What kind of conflict arises more often in your team? (multiple options question). The possible answers are: different involvement of members in the project, lack of communication within the

team, delay in delivery of tasks by some members, generic problems with the leader, personal problems between team members, lack of integration of a tam member, lack of motivation of one or more members and poor team performance; 5) What have you learned from working in a team?; 6) Discuss any aspects related to teamwork that you think that are relevant (topics that would highlight features that improve performance, outstanding situations, etc.).

Tutor evaluation: 1) Attendance at tutorial meetings; 2) The tutor relationship with the students is respectful. 3) It has been useful the function of the tutor? Answers are also measured in 11 points scale, where 0 means: Non existent/ Totally disagree; and 10: Completely/ Totally agree. Finally, question 4) Would you choose again this tutor in a new project? With a Yes/No answer.

The original version of the survey (Catalan) and the English version are included in the Appendix A and B.

Chapter 3

Predicting future conflict between teammembers with parameter-free models of social networks

3.1 Introduction

Teamwork is increasingly important. In science, where teamwork has been best studied quantitatively thanks to the large amount of data available, studies have forecast the shift from individual work to teams for over a century [70]. Indeed, the classic studies of de Solla Price predicted that by 1980 no articles in chemistry would be authored by single authors [71]. Although these predictions have not come true, recent studies indicate that teamwork has become more frequent in virtually all fields and subfields of science [2, 5]. Parallel to this, there has been an increase in the impact of works produced by teams to the point that, today, the most highly cited works in all fields are overwhelmingly produced by teams [2, 72]. This tendency is due in part to external factors such as the increased complexity of cutting edge research [5], the widespread use of new technologies [72], the growth of the number of researchers, and the trend towards greater spe-

cialization [2]. There is also mounting evidence that diversity provides an intrinsic advantage to teams, and that teams composed by diverse individuals have higher performance than teams composed by similar individuals [3, 4, 5]. All in all, the "collective intelligence factor" of a team is a better predictor of team performance than the abilities of each team member [6].

Despite the benefits of teams, teamwork also results in communication, coordination and management costs [7, 8]. More importantly, conflict arises in teams from tension among members. Conflict (in particular, conflict that is related to personal relationships) is known to interfere with team functioning and may offset the benefits of teamwork [3, 47, 48, 49, 50]. In a context where teams play an increasingly important role, it is important to understand conflict and to develop diagnostic tools to avert it.

Here, we investigate empirically whether it is possible to quantitatively predict future conflict in small teams. Rather than using regression analysis for "conflict forensics" (that is, to explain a posteriori what factors correlate with higher levels of conflict in a given team) [49, 51, 73, 74], we focus on first-principles parameter-free models of social network structure, and on prediction rather than postdiction. As recently suggested [26, 27], analyzing teams as networks poses the methodological dilemma of choosing between "micro-level" socio-psychological theories such as structural balance [18, 19, 20, 21, 22] and "macro-level" theories developed in the context of network science [23, 24, 25, 26]. We show that, paradoxically, statistical network methods can successfully anticipate conflict in small teams whereas some of the most widely-used micro-level sociological theories cannot.

3.2 Methods

3.2.1 Data collection

During the academic year 2010-2011, we collected data on teamwork evaluation and preferences of 86 chemical engineering students that are grouped into teams facing an open ended project that lasts 9 months. We collected our data through an online survey that includes questions to evaluate different aspects of teamwork. We administered the same survey twice (December, survey I, and May, survey II).

Our sample consists of sixteen teams with the same structure: a fourth year student that plays the role of team leader and first year team members; the number of team members for which we have complete data (that is, that reported in both surveys I and II) ranges from 3 to 7, with most teams having 5-6 members (Table. 3.1). Team membership was determined as follows. First, individuals were randomly assigned to one of four large groups. From each of these groups, four teams were defined so as to balance personality traits of their members (based on a personality test) but otherwise randomly.

In our analysis, we focus in the answers of two yes/no questions from the survey: 1)" Would you choose this person to work with you in a new team?"; 2) "Would you choose this leader to lead a new team?". We use the answer to these questions as a proxy for the quality of interactions among team members. Thus, a yes answer would be a positive interaction whereas a no answer would be indicative of conflict among the pair of team members.

With this information we construct a directed network for each one of the surveys I and II, in which the link from member A to member B can be of two types $l^I_{AB} = Y$ or $l^{II}_{AB} = N$. We only consider interactions between pairs of team members for which we have complete information, that is, when both members have answered both surveys.

Table 3.1: Teams and reported interactions between team members.

		Number of interactions			
Team	Team size	YY	YN	NY	NN
A	5	10	4	3	3
B	6	20	3	2	5
C	6	26	0	3	1
D	5	12	3	1	4
F	5	10	5	0	5
G	3	5	0	1	0
H	4	7	4	0	1
I	3	3	0	1	2
J	7	29	7	1	5
K	6	24	2	0	4
L	7	18	3	10	11
M	6	21	0	4	5
N	5	16	1	2	1
O	7	34	3	1	4
P	4	12	0	0	0
Q	4	10	1	1	0
Total	83	257	36	30	51

3.2.2 Data collection

Link reliability score

We have extended the formalism developed in [44] to obtain the link reliability score S^{LR}, that is, the probability that a link from member A to member B is of type Y in survey II, $l^{II}_{AB} = Y$, given the observation N^O of all interactions reported in survey I.

The fundamental assumption of this approach is that the structure of the network of interaction within a team can be satisfactorily accounted for by a model M, which is unknown but belongs to a family $\mathcal{M}$ of models. Then, the probability that a link from member A to member B is of type Y, $l_{AB} = Y$, given the observed network N^O is [44]

$$S^{LR} = p(l^{II}_{AB} = Y|N^O) = \int_{\mathcal{M}} dM\, p(l^{II}_{AB} = Y|M)\, p(M|N^O)\,, \qquad (3.1)$$

To estimate this integral we rewrite it, using Bayes theorem, as [44, 75]

$$S^{LR} = p(l^{II}_{AB} = Y|N^O) = \frac{\int_{\mathcal{M}} dM\, p(l^{II}_{AB} = Y|M)\, p(N^O|M)\, p(M)}{\int_{\mathcal{M}} dM\, p(N^O|M)\, p(M)}\,. \qquad (3.2)$$

Here, $p(N^O|M)$ is the probability of the observed interactions given a model and $p(M)$ is the *a priori* probability of a model, which we assume to be model-independent $p(M) = \text{const}$.

For the family of stochastic block models, we have that for a given partition of team members into groups, there is a probability $Q(\alpha, \beta)$ of there being a link of type Y from a member in group α to a member in group β, and a probability $(1 - Q(\alpha, \beta))$ of there being a link of type N.

Note that because we are dealing with a directed network, $Q(\alpha, \beta)$ is not a symmetric matrix since for each block model team member A will be classified into two groups: a group for the outgoing links profile ($\sigma_{A\,\mathrm{out}}$), and a group for the incoming links profile ($\sigma_{A\,\mathrm{in}}$). Thus, if A belongs group α for outgoing links and B to group β for incoming links, we have that [75]

$$p(l_{AB}^{II} = Y|M) = Q(\alpha, \beta)\ ; \tag{3.3}$$

and

$$p(N^O|M) = \prod_{\alpha \in G_{\mathrm{out}}, \beta \in G_{\mathrm{in}}} Q(\alpha, \beta)^{n^Y(\alpha,\beta)} (1 - Q(\alpha, \beta)^{n^N(\alpha,\beta)})\ , \tag{3.4}$$

where $n^{Y/N}(\alpha, \beta)$ is the number of links of type Y/N between member groups α and β, and $G_{\mathrm{out/in}}$ is the set of groups for outgoing/incoming link profiles in block model M. Additionally, the integral over all models in $\mathcal{M}$ can be separated into a sum over all possible partitions of the members into outgoing and incoming link groups, and an integral over all possible values of $Q(\alpha, \beta)$. These integrals can be carried out exactly to get [44, 75]

$$S^{LR} = p((l_{AB}^{II} = Y|N^O) = \frac{1}{Z} \sum_P \left(\frac{n^Y(\sigma_{A\,\mathrm{out}}, \sigma_{B\,\mathrm{in}}) + 1}{n(\sigma_{A\,\mathrm{out}}, \sigma_{B\,\mathrm{in}}) + 2} \right) \exp(-H(P))\ , \tag{3.5}$$

where the sum is over all partitions of the team members into outgoing and incoming link groups, $n(\sigma_{A\,\mathrm{out}}, \sigma_{B\,\mathrm{in}}) = \sum_{\mathrm{T:\{Y,N\}}} n^{\mathrm{T}}(\sigma_{A\,\mathrm{out}}, \sigma_{B\,\mathrm{in}})$ is the total number of known interactions from groups $\sigma_{A\,\mathrm{out}}$ and $\sigma_{B\,\mathrm{in}}$, and

$H(P)$ is a function that depends on the partition only

$$H(P) = \sum_{\alpha,\beta} \left[\ln(n(\alpha,\beta)+1)! - \sum_{T:\{Y,N\}} \ln\Big(n^T(\alpha,\beta)\Big)! \right] . \tag{3.6}$$

The sum in Eq. (3.5) can be estimated using the Metropolis algorithm to sample partitions [44].

Structural balance score

To obtain S_{AB}^{SB} we look at all the possible triads of members in a team that include members A and B. Then, we count the number of balanced triads $t_{\rm bal}(Y)$ when $l_{AB} = Y$, and the number of balanced triads $t_{\rm bal}(N)$ when $l_{AB} = N$. We the obtain

$$S_{AB}^{SB} = t_{\rm bal}(Y) - t_{\rm bal}(N) . \tag{3.7}$$

According to structural balance theory, a balanced triad is one in which there is an odd number of positive reciprocal interactions. A positive reciprocal interaction is one such that $l_{AB} = l_{BA} = Y$.

For all the graphs and discussions in the main text we use the definition above for the structural balance-based score. One may argue, however, that this definition is somewhat restrictive because if an interaction is not reciprocal to start with, each of the nodes can only improve overall balance by switching, but never by staying in the same state. Therefore, we also consider here a second structural balance score S_{AB}^{SB2}

$$S_{AB}^{SB2} = S_{BA}^{SB2} = t_{\rm bal}(l_{AB} = l_{BA} = Y) - t_{\rm bal}(l_{AB} = l_{BA} = N) . \tag{3.8}$$

that is, the difference between the number of balanced triangles when both links AB and BA are positive and the number of balanced triangles when both links AB and BA are negative. As we show in Figure S1 (Supplementary Information), this definition does not yield higher predictive power than the one discussed in the main text.

Hybrid scores

For each link AB, we obtain a hybrid score S^H_{AB} by combining LR and SB sores. However, because S^{LR} is normalized, $S^{LR} \in [0, 1]$, and S^{SB} is not, we first need to normalize S^{SB}. For each link AB within team T, we obtain the normalized SB score $\widetilde{S}^{SB}_{AB}$ as follows

$$\widetilde{S}^{SB}_{AB} = \frac{S^{SB}_{AB} - S^{SB}_{T\,\min}}{S^{SB}_{T\,\max} - S^{SB}_{T\,\min}} \,, \tag{3.9}$$

where $S^{SB}_{T\,\min}$ and $S^{SB}_{T\,\max}$ are the minimum and maximum scores in team T, respectively.

We then obtain a hybrid score for each link S^H_{AB} by linearly combining S^{LR}_{AB} and $\widetilde{S}^{SB}_{AB}$,

$$S^H_{AB} = \alpha S^{LR}_{AB} + (1 - \alpha)\widetilde{S}^{SB}_{AB} \,, \tag{3.10}$$

where $\alpha \in [0, 1]$ is the parameter that allows us to interpolate between SB ($\alpha = 0$) and LR ($\alpha = 1$) score rankings.

3.3 Results

3.3.1 Measuring conflict and conflict evolution in small teams

Our study draws upon a long history of network experiments with teams and small groups, dating back to the experiments carried out in the 50's by the Group Networks Laboratory at MIT [26, 31]. We analyze data from 16 small teams with 3 to 7 members each, for a total of 86 team members and 374 reported within-team interactions between them (Table. 3.1). All teams worked in the same open-ended project for nine consecutive months. Importantly, the teams we analyze were facing a real task as opposed to a simplified experimental task, and their members had real incentives and experienced real conflicts that developed throughout the extended duration of the project.

To track the development of conflict in the teams, we administered the same survey to all team members twice, at the middle and end of the project (surveys I and II, four and nine months into the project, respectively). In the survey we asked all individuals about their disposition to work with each of the other team members in the future. We use the answers to this question to construct two directed networks for each team in which a link from member A to member B can be of two types, namely, $l_{AB} = Y$ if the answer was positive (A is willing to work with B in the future) and $l_{AB} = N$ if the answer was negative (Fig. 3.1). We use changes in link type between the two surveys as a proxy for conflict appearance/resolution: conflict appears when a link of type Y in survey I becomes N in survey II; conflict resolves when a link of type N in survey I becomes Y in survey

II. In what follows, we will denote interactions between team members as $l^I l^{II}$, l^I being the link type from survey I and l^{II} the link type from survey II (for example YN denotes a link where conflict arose during the project). Of the 374 reported interactions between individuals, 257 were YY, 36 were YN, 30 were NY and 51 were NN (Table. 3.1).

3.3.2 Structural balance versus block model-based link reliability

In social network analysis, conflict evolution has traditionally been studied using the concept of "balance," which focuses on the state of network triads (or, more generally, network cycles) [18, 19, 20, 21, 22]. In a directed graph, a triad is in a balanced state when there is an odd number of positive reciprocal connections between individuals [20]; otherwise, a triad is in an unbalanced state. According to this theory, unbalanced states produce tension and generate changes towards balance [18]. For example, if A and B have a positive relationship and so do A and C, then if B and C have a negative relationship (so that the number of positive reciprocal interactions in the triad is two) there is a tension pushing towards either the $B-C$ relationship becoming positive or one of the others becoming negative. Since the idea of balance revolves around the relationships between small groups of individuals (in this sense we say that it is a "micro-level" theory), it seems a priori well-suited to study the evolution of conflicts in teams.

At the other end of the spectrum of social network models, block models postulate that social actors can be classified into groups such that all actors within a group have similar patterns of interactions with actors in other groups [44, 76, 77, 78]. These are "macro-level" models in which the

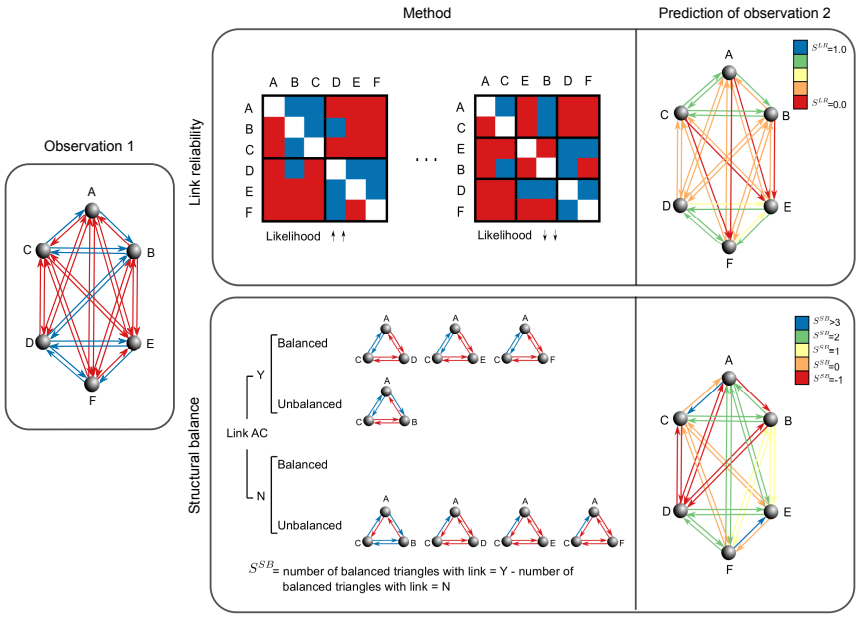

Figure 3.1: **Parameter-free network methods for conflict prediction. (a)** For each team, we build a network using the information from survey I (Methods). A blue link from A to B means that A would like to work with B in the future so that $l^I_{AB} = Y$. A red link from B to A means that B would not like to work with A in the future, thus $l^I_{BA} = N$. To predict which links are more likely to be Y (or N) in survey II (Methods), we apply two different methods: link reliability **(b)** and structural balance **(c)**. **(b)** The link reliability method samples all possible partitions of nodes into groups. For each partition, it calculates the probability that $l^{II}_{AB} = Y$ according to that partition. The total probability that $l^{II}_{AB} = Y$ (reliability) is then a weighted sum of these probabilities over all possible partitions (Methods). The weight (likelihood) of a partition depends on how well it describes network connectivity. (*continues to next page*)

Figure 3.1 (*follows from previous page*): As an illustration, we show the matrix representation of two partitions. Each row/column corresponds to a node. Matrix elements show link types Y or N color coded in blue and red, respectively. The matrix on the left has a high likelihood because nodes in the same group have similar connection patterns; the matrix on the right has a low likelihood because nodes in the same group have different connection patterns. Finally, we use the reliability scores for each connection to obtain a prediction for observation 2. Link reliability values are color coded following the color bar. **(c)** The structural balance theory assumes that a balanced triad exists when the number of reciprocal relations is an odd number. To obtain a score S^{SB} for every link, we count the number of balanced triangles in the network t_{bal} when $l^I = Y$ minus the number of balanced triangles in the network when $l^I = N$. For instance, when $l^I_{AC} = Y$, there are three balanced triangles, while when $l^I_{AC} = N$, there are no balanced triangles, thus $S^{SB}_{AC} = 3$. We use these scores to build a prediction for observation 2. Link scores are color coded following the color bar.

fundamental unit of the models is the group, not the individual, and therefore seem a priori less well-suited to study small teams. However, methods based on block model inference are known to accurately identify reliable and unreliable interactions in large complex networks [44].

Given these considerations, we compare the ability of structural balance theory to predict conflicts within teams to that of a statistical method that uses block models to describe team interactions (Fig. 3.1).

In particular, we are interested in predicting the state of each link l^{II}_{AB} in the second survey, based on the structure of the team network in the first survey using two methods: the structural balance method (SB) and the link reliability method (LR). SB focuses on the balance of relations induced by

the presence of a positive (Y) interaction from member A to member B. In particular, we define the S^{SB} score of each link as the difference between the number of balanced triangles t_{bal} within the team when $l^I_{AB} = Y$ and the number of balanced triangles within the team when $l^I_{AB} = N$, that is $S^{\mathrm{SB}}_{AB} = t_{\mathrm{bal}}(Y) - t_{\mathrm{bal}}(N)$ (Fig. 3.1c).

In contrast, LR uses a Bayesian approach to sample over all possible stochastic block models of a network to estimate the "reliability" S^{LR} of each link, that is, the probability that the link is of type Y based on the observation of the whole team network obtained from survey I (Fig. 3.1b and Methods) [44, 75].

3.3.3 Conflict prediction performance

Note that whereas the LR method assigns a probability for each link to become Y or N, the SB method does not, thus we cannot directly compare outputs from the two methods for each of the links. To compare both methods we analyze instead their ability to rank links within teams. From a ranking perspective, we expect that the higher the score the larger the probability that the link is of type Y in survey II; conversely, the lower the score, the larger the probability that a link is of type N in survey II.

To measure the ranking accuracy in the case of conflict appearance, we take, for each team, all possible (YY, YN) link pairs and calculate the number of times the YY link in the pair has a higher score than the YN link in the pair, according to each method. Conversely, for conflict resolution, we record the number of times that the NY link has a score higher than the NN for all possible (NY, NN) link pairs within each team.

For the LR method we find that YY links have higher scores than YN

links 61% of the time (conflict appearance), and that NY links have scores higher than NN links 67% of the time (conflict resolution). This means that, using the LR method, links with a lower score are consistently more likely to produce conflict in the future (survey II), both when conflict exists and when it does not exist at the time of survey I. In contrast, for the SB method, YY links have higher scores than YN links only in 47% of the cases, and NY links have scores higher than NN links in 55% of the cases.

To assess the significance of these results we proceed as follows. For conflict appearance, we consider the ratio n_{YY}/n_{YN} between the number of times that the score of a YY link is higher than the score of a YN link (n_{YY}) and the number of times the reverse is true (n_{YN}). Analogously, for conflict resolution we consider the ratio n_{NY}/n_{NN} between the number of times that the score of a NY link is higher than the score of a NN link (n_{NY}) and the number of times the the reverse is true (n_{NN}). We denote these ratios as the normalized prediction performance for the appearance of conflict (n_{YY}/n_{YN}) and for the resolution of conflict (n_{NY}/n_{NN}) (Fig. 3.2a), respectively. We compare the values obtained for the SB and LR methods to those obtained by resampling the scores of all links, which corresponds to a null model in which links are not separated at all. We find that, at a 5% significance level, the LR method is significantly more accurate than the null model at predicting both the appearance (with p-value $p = 0.030$) and resolution ($p = 0.032$) of conflicts. In contrast, the SB method is not ($p = 0.704$ and $p = 0.232$, respectively).

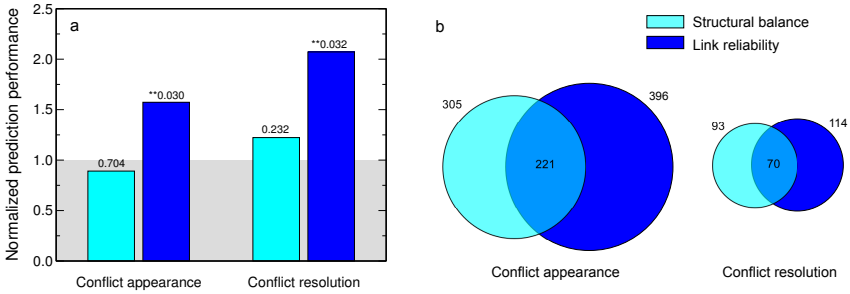

Figure 3.2: **Performance of parameter-free network methods for conflict prediction. (a)** We show the performance of the LR (blue) and the SB (cyan) methods, for conflict appearance and resolution. For conflict appearance we consider the ratio between the number n_{YY} of times that the score of a YY link (positive in surveys I and II) is higher than the score of a YN link (positive in survey I and negative in survey II) in the same team, and the number n_{YN} of times the reverse is true. Analogously, for conflict resolution we consider the ratio between the number n_{NY} of times that the score of a NY link is higher than the score of a NN link, and the number n_{NN} of times the the reverse is true. We denote these ratios as the normalized prediction performance for the appearance of conflict (n_{YY}/n_{YN}) and for the resolution of conflict (n_{NY}/n_{NN}). To establish the significance of these results, we compare the values of the normalized prediction performance obtained for the SB and LR methods to those of the null model obtained by resampling the scores of all links within each team. We find that the LR method is significantly more accurate than the null model ($p = 0.030$ for conflict appearance and $p = 0.032$ for conflict resolution), whereas the SB method is not ($p = 0.704$ for conflict appearance and $p = 0.232$ for conflict resolution). (*continues to next page*)

Figure 3.2 (*follows from previous page*): **(b)** We show the overlap of LR and SB methods, for conflict appearance and resolution. The numbers in the figure indicate the number of correctly ranked link pairs n_{YY} and n_{NY} (for conflict appearance and resolution, respectively) for each of the methods LR (blue) and SB (cyan), and for their overlap.

3.3.4 Overlap between methods and hybrid scores

Although the SB method does not seem to consistently predict neither future conflict resolution nor appearance, it may still be possible that it captures different information from that captured by the LR method, so that the predictions of both methods are complementary (Fig. 3.2b). For conflict appearance, we find that the LR method accurately ranks $n_{YY} = 396$ (YY, YN) link pairs, whereas the SB method accurately ranks $n_{YY} = 305$ pairs, of which 221 pairs match up in both methods. For conflict resolution, we find that the LR method accurately ranks $n_{NY} = 114$ (NY, NN) link pairs, whereas the SB method accurately ranks $n_{NY} = 93$, of which 70 pairs match up in both methods.

Since the predictions of the SB method are not a perfect subset of the predictions of the LR method, it is interesting to see if a simple combination of both methods can provide a better prediction of conflict evolution than each of the two methods separately. To investigate this, we define a hybrid score S^H that linearly combines the scores of both methods, $S^H = \alpha S^{LR} + (1-\alpha)\widetilde{S}^{SB}$, where $\widetilde{S}^{SB}$ is a properly normalized version of S^{SB} and α is a parameter that enables us to interpolate between each one of the original methods (Methods). As we show in Fig. 3.3 this hybrid score does not improve, in general, the predictions of the LR method. For

conflict appearance, even a small contribution of the SB score is enough to offset the predictive power of the LR method. That is not the case for conflict resolution, but in any case predictions do not significantly improve those of the pure LR method.

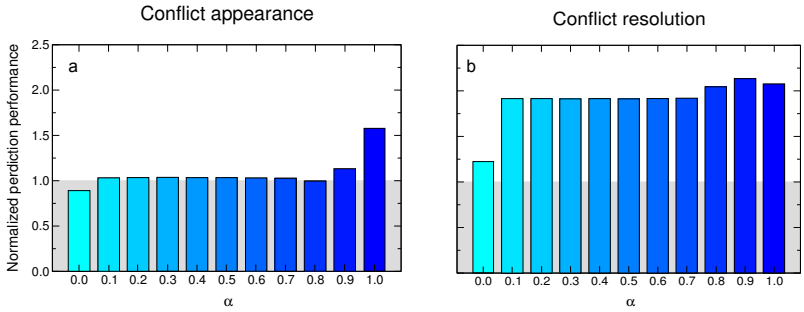

Figure 3.3: **Hybrid scores for conflict prediction.** We introduce a hybrid score (S^H) obtained from the linear combination of the scores of both methods, S^{LR} and S^{SB} (Text and Methods). We plot the normalized prediction performance of the hybrid score for conflict appearance, **(a)**, and conflict resolution, **(b)**, as a function of a parameter $\alpha \in [0, 1]$ that enables us to interpolate between $S^H(\alpha = 0) = S^{SB}$, and $S^H(\alpha = 1) = S^{LR}$.

3.3.5 Alternative structural balance score

To obtain S^{SB}_{AB} we look at all the possible triads of members in a team that include members A and B. Then, we count the number of balanced triads $t_{\text{bal}}(Y)$ when $l_{AB} = Y$, and the number of balanced triads $t_{\text{bal}}(N)$ when $l_{AB} = N$. We the obtain

$$S^{SB}_{AB} = t_{\text{bal}}(Y) - t_{\text{bal}}(N) \, . \tag{3.11}$$

According to structural balance theory, a balanced triad is one in which there is an odd number of positive reciprocal interactions. A positive reciprocal interaction is one such that $l_{AB} = l_{BA} = Y$.

For all the graphs and discussions in the main text we use the definition above for the structural balance-based score. One may argue, however, that this definition is somewhat restrictive because if an interaction is not reciprocal to start with, each of the nodes can only improve overall balance by switching, but never by staying in the same state. Therefore, we also consider here a second structural balance score S_{AB}^{SB2}

$$S_{AB}^{SB2} = S_{BA}^{SB2} = t_{\text{bal}}(l_{AB} = l_{BA} = Y) - t_{\text{bal}}(l_{AB} = l_{BA} = N) \; . \qquad (3.12)$$

that is, the difference between the number of balanced triangles when both links AB and BA are positive and the number of balanced triangles when both links AB and BA are negative. As we show in Supplementary Figure 1, this definition does not yield higher predictive power than the one discussed in the main text.

3.4 Discussion and conclusion

Our contributions are of methodological and practical importance for team science. While conflict has long been recognized as one of the main issues in team performance, it is very hard to predict in small teams, precisely because the small size of the teams leaves us with little information about what factors are truly driving conflict dynamics. This poses a methodological challenge that we have addressed by investigating whether micro-based

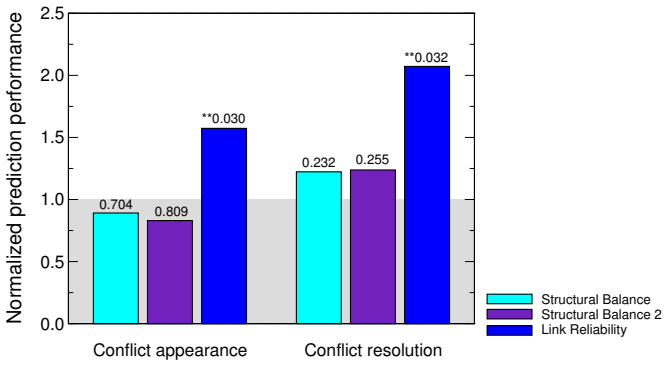

Figure 3.4: **Alternative balance score.** Same as Fig. 3.2, but including the alternative definition of the structural balance-based score $SB2$.

models of structural balance or macro group-based models are more appropriate to tackle the problem. Our results demonstrate that it is possible (albeit difficult) to predict conflict in small teams. Specifically, we find that group-based models have more predictive power, which suggests that the lack of data is better addressed by the complete probabilistic treatment that these models make possible, than by the more detailed models of team dynamics. The immediate practical implication of this finding is that, to avert conflict, groups can in principle be monitored in non-invasive ways (since only the network structure is needed, as opposed to, for example, detailed psychological accounts of team members). Our results thus highlight the relevance of the agenda put forward by Katz and coworkers, when they called for bringing the network perspective back into team science [27].

Chapter 4

Development of Team Analytics tool and application of the method with an experimental intervention to real teams

The aim of this chapter is to describe the development of a web application using the method prediction and resolution of conflicts (see Chapter 3). This tool can be applied to small teams involved in real projects (e.g., industry, human resource department, etc). In the following sections, we describe the commercial tool and the use of this tool as part of an intervention to mitigate conflict.

4.1 Development of Team Analytics tool

We designed a commercial tool named Team Analytics (TA) to predict and resolve conflicts based in the method described in Chapter 3. This tool aims to facilitate the application of a model to predict conflict in small teams.

TA is a web application that can predict potential future conflicts within a team. By social network analysis, this instrument identifies that there

may be conflicting connections within a network and the degree of the same conflict. The results obtained from the application allow an assessment of the level of conflict within a team through the identification of high risk interaction and of suitable candidates for an intervention.

TA tool is user friendly and is mainly divided in 3 blocks of users: the administrator of the tool, team components and the TA owner. The administrator is the person that wants to use and implement this strategic diagnostic to analyse a small team (e.g., professional coach, human resource department, etc.). Team members and also team leader are those that will be analysed by the tool. Finally, the TA owner, is who is behind of the computational tool, the responsible to provide the results of the analysis and to adjust the necessary details for the proper functioning of the TA tool.

TA tool has been developed by our research group, not only the graphic design but also the technical and computational development[1].

The general flow diagram of the tool usage is showed in Figure 4.1.

The tool works in the following way: first, the administrator of the tool have to introduce the data of the users (members and leader) in the application. Second, TA sends automatically to all users the same crossed evaluation survey and collects the data from the answers. Finally, TA reports to the administrator the results for each team. These results provide a report easy to understand that contains the following sections: a network of each team with potential conflicts indicated, the scores for each link of the network, the list of the most prone candidates to generate conflict and the candidates more suitable to mediate the conflict.

[1] `http://team-analytics.seeslab.net/`

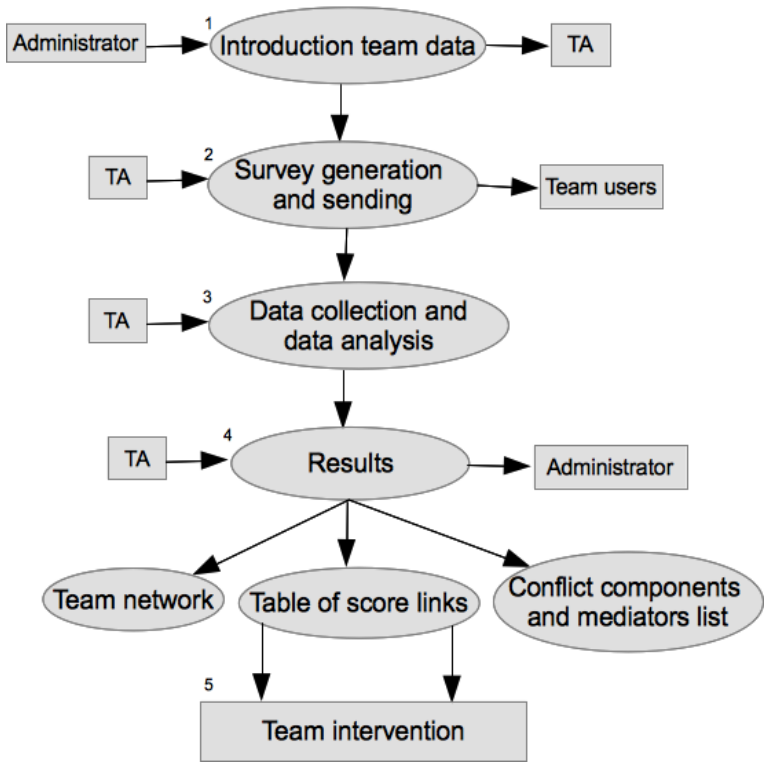

Figure 4.1: General diagram of TA functioning.

The following figures are series of screenshots that show the appearance of the TA tool in the section of team users survey:

- Figure 4.2 shows the first step of the survey that contains some demographical questions.
- Figure 4.3 shows the tab of the leader evaluation with some of the survey questions.

- Figure 4.4 shows the section of the survey to evaluate team members.
- Figure 4.5 shows last part of the survey that contains an open section to write general comments about the team.

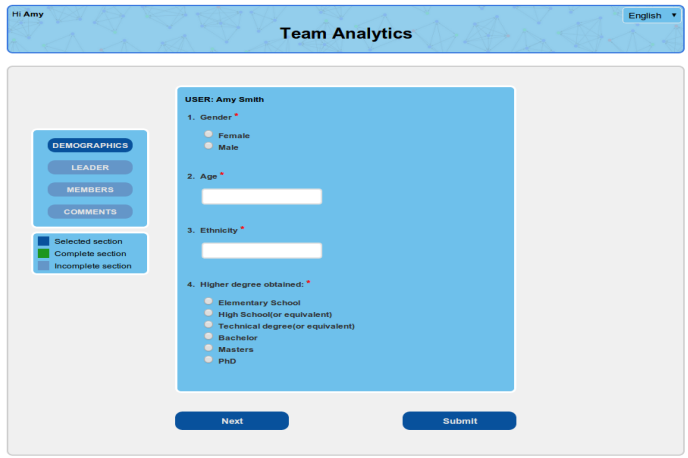

Figure 4.2: TA, demographic questions about the user (team member or leader).

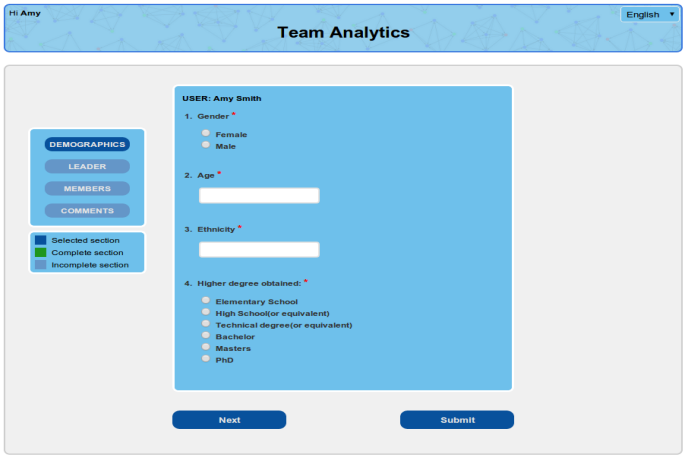

Figure 4.3: TA, questions about the leader evaluation.

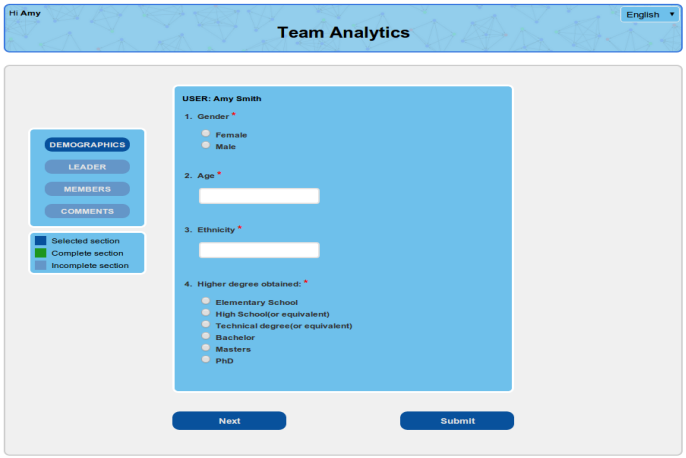

Figure 4.4: TA, questions about team members evaluation.

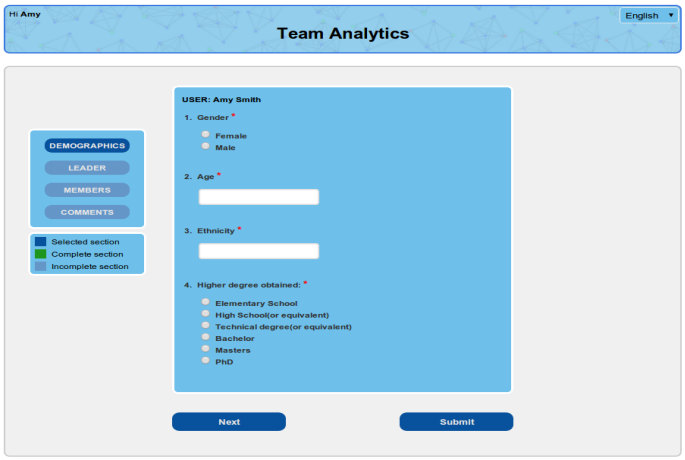

Figure 4.5: TA, open section to introduce general comments.

The figures below are a couple of screenshots that show the computing environment of TA application for the administrator user. The first figure is the tab to log in the application and the second figure shows the menu with all options of the application that the administrator can modify or introduce.

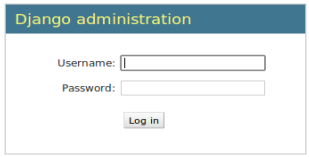

Figure 4.6: TA, log in section for the administrator user.

TA application has been developed with the web-framework Django,

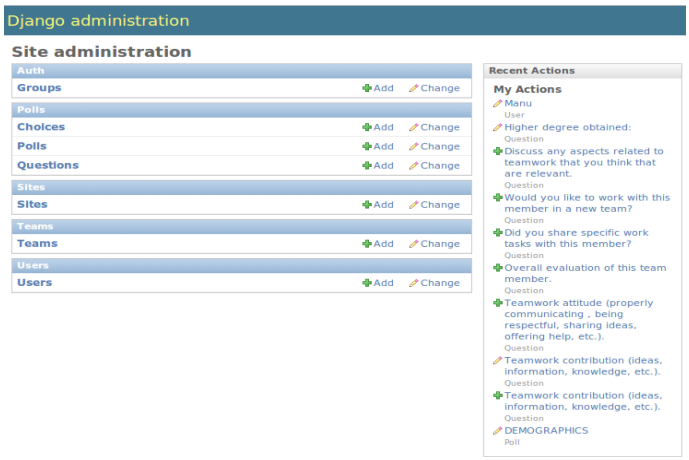

Figure 4.7: TA, menu options of the web site for the administrator user.

that provides the environment of the web site for users, both team members and administrator users. Behind the graphical environment, the application has all the codes that analyse data and provide results. These codes have been written in the following programming languages: Python, C and html.

Due to the model of conflict prediction is very accurate and predicts close to reality the team dynamics, the TA tool is a great instrument to not only diagnose conflict, but also to provide a platform for solutions. We believe that this model has great value and should be made commercially available with TA tool, once we finish the minor improvements and implement more details in the packaging.

4.2 Intervention: team conflict resolution model

The educational model of ETSEQ with the integrated project has provided the opportunity to test and validate the Team Analytics tool. To test this model was designed an applied experiment to real teams. Specifically, three teams were selected for a direct intervention related with their team conflicts.

4.2.1 Introducing the protocol

Our research team have developed a protocol to predict the degree of conflict among members of a given team or group. This protocol is included in the computational tool TA, which uses specific information of the survey results that teams answered, to predict team conflict dynamics.

This protocol has two steps: first, participants of a given team have to fill out a survey. Then, we use the computational model to analyze one of the survey questions to predict the conflict dynamics of the team.

The model uses the structure of the team interaction network to obtain the reliability of each connection between two team members. If the reliability is high, the expectation is that it is unlikely that conflict will emerge in this relationship in the near future, while a low reliability indicates that it is likely that conflict will emerge (see Methods in Chapter 3).

Additionally, the computational tool uses survey and model data to produce figures which portray team composition and how individual team members collaborate or have conflict or could have/resolve conflict in the future. These graphs allow an assessment of up to what extent conflict is present, which members have the biggest conflict with whom, and which

team member is best suited to mediate this conflict.

Based on the survey and the model's prediction, a tailored dialogue with the team and its members can take place, allowing the exploration of the conflict and above all, designing solutions.

4.2.2 Selection of intervened teams

The experiment was developed during the academic year 2012-2013. During this year the total sample that used the Team Analytics tool were fifteen teams. After the survey administration and taking into account the results of surveys, we selected three of the fifteen total teams to validate the model. The results of the three teams networks are showed in figures 4.8, 4.9 and 4.10.

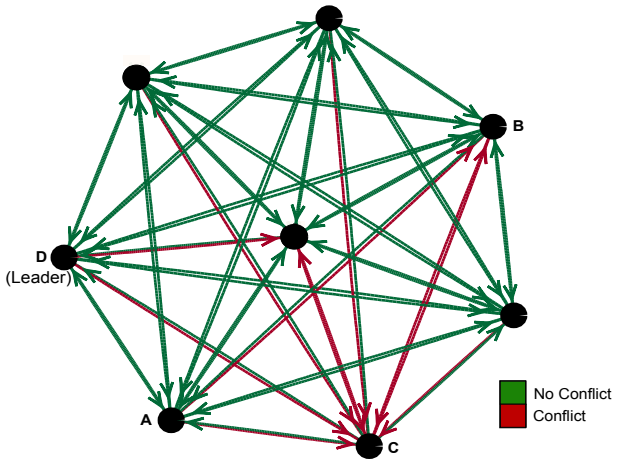

Figure 4.8: Team network of the first team intervened.

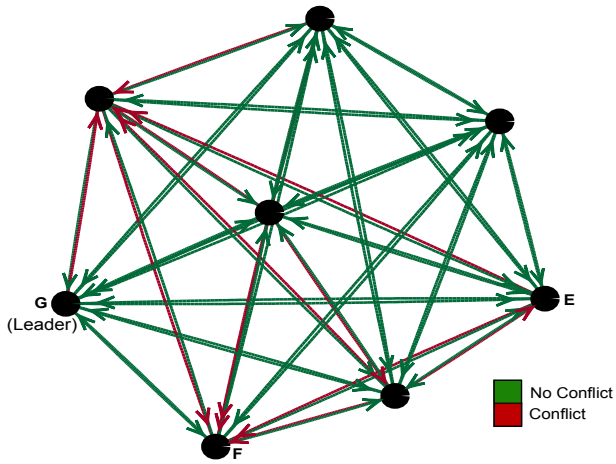

Figure 4.9: Team network of the second team intervened.

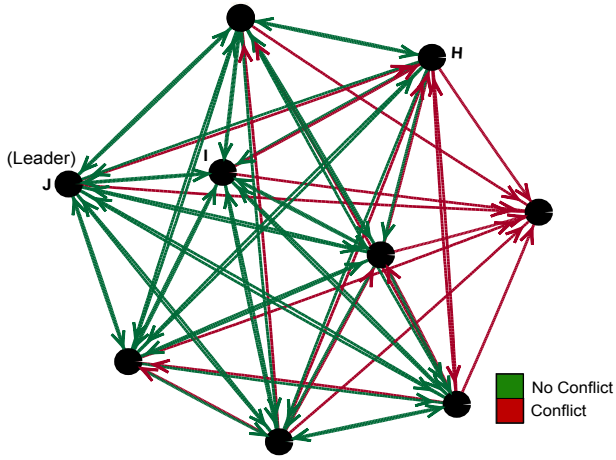

Figure 4.10: Team network of the third team intervened.

The selection of these teams was based in the following rules. Firstly, we divided all teams in three main groups that we named: green, yellow and red, depending of the number of conflicts detected in the survey results. The green group is this with less conflicts while red group is the most conflictive. Thus, we decided to intervene three teams from the red group to check if conflicts detected previously by the survey could be resolved through the intervention.

4.2.3 Intervention

The intervention of the three teams selected was carried out with the collaboration with Dr. Hans-Jörg Witt, who is a professional consultant. The planning of the complete long-term intervention was defined before the intervention according to the steps showed in the diagram of Figure 4.11. Firstly, we had to apply TA method and obtain the team diagnostic. To do it we administered the survey to the team and we obtained conflict prediction results. Therefore, we made an intervention to all team members, with special interviews with the most conflictive members and with the leader. After the intervention, we proposed to follow up the leader for a while, giving to the leader some advises regarding how to conduct team conflicts. Finally, we recommended a second administration of the survey to check if team conflicts decrease and / or if the team dynamics changes.

The experimental interventions that we carried out with the three selected teams were divided in three parts. First, we had an intervention to all team members to talk about the team and to provide a comfortable environment with team cohesion. Second, we had especial interviews with one or two members recognized as the most conflictives of the team. These

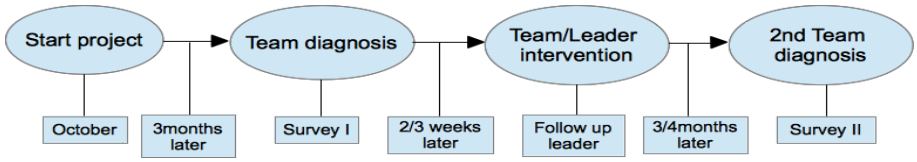

Figure 4.11: Diagram of the team conflict intervention.

members are those that had more negative connections (red color) in the network. In the first team are the members B and C, in the second team is the member F and in the third team is the member H. And we also had an interview with the member that had the best relationship, according the results of our method, with the most conflictive member of the team, this means, the person that had the highest score within the negatives scores. We understand that this member could help the most conflictive member to be accepted again in the team and to be reintegrated in it. These members are the A,E and I for each team, respectively. Finally, we had an interview with the leader (indicated in the network) to have a general view of the team. The interventions were made by semi-structured interviews based on the following questions:

1. Since when do you belong to this group?
2. How do you perceive the teamwork so far? Please use a scale from 1 to 5.
3. What were the conflicts you had so far with team or a specific team member? In case of a specific team member: would you be willing to indicate a name? Why that specific individual?

4. Why did the conflict/s happen? Needs/ perceptions/ power/ values/ feelings and emotions/ culture.

5. What would it take to change your perspective to collaborate better, and to resolve the conflict constructively? What are the changes needed in your behavior? What are the changes needed in the other individuals/s behavior?

6. What support would you need?

7. What would success look like?, but in most of the cases: Do you want to say something else about your team?

4.3 Measurements of team performance

After the intervention of the three teams selected, we wanted to check if the number of negative connections has been changed in the second administration of the survey. Moreover, to understand if the changes in the network affected the performance of the team, we used the grades obtained in the integrated project, as a measure of performance. In both variables, connections and grades, we obtained data from the first quadrimester and from the second (Q1 and Q2 respectively). We normalized their values between 0 and 1.

To do it, we checked the relation between the fraction of 'nos' (number of 'nos' in the network/number of links) and the team grades, in both, Q1 and Q2. We found an increasing relationship in Q1 and Q2 , in other words, a tendency of the increasing of grades related with the increasing of the fraction of 'nos' (Fig.4.12).

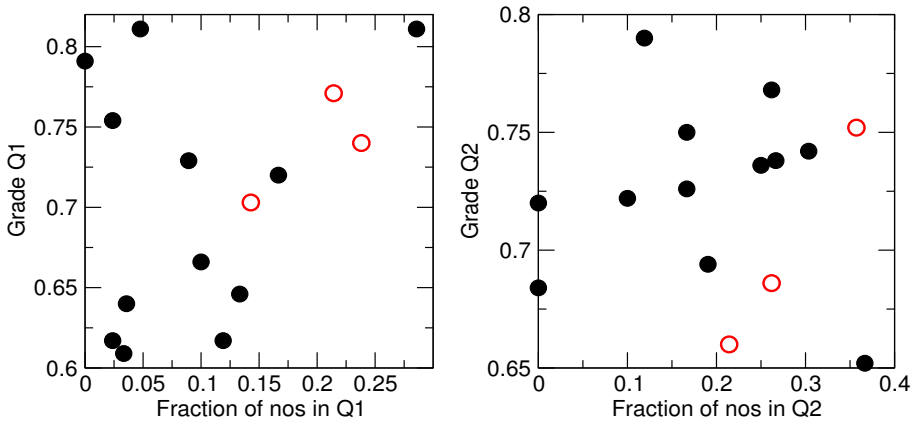

Figure 4.12: **Relation between grades and fraction of nos.** The plot on the left shows the grades of the first quadrimester (Q1 - y axis) versus the fraction of nos in the first quadrimester (Q1 - x axis). Each dot corresponds to a team. Empty circles (red) correspond to those teams upon which were intervened, whereas black circles are the rest of teams. The plot on the right shows the same but for the second quadrimester (Q2).

Therefore, to interpret the relation of 'nos' and grades between quadrimester, we plot the relation of the fraction of 'nos' for each quadrimester and the same for the grades. On one hand, we found that in general the fraction of 'nos' increased in the Q2. And on the other hand, we saw that the relation of grades depend of the results in the Q1. In the case that the grades in Q1 were lower in the Q2 increased, whereas, the teams with higher grades in Q1 tended to decrease the grade in Q2. Even in Q2, the total range of grades is a bit smaller (0.65,0.8) than Q1 (0.6,0.85) (Fig.4.13). Curiously, in the three intervened teams, the fraction of 'nos' increased (although more moderately) while the grade was lower in Q2 than in Q1.

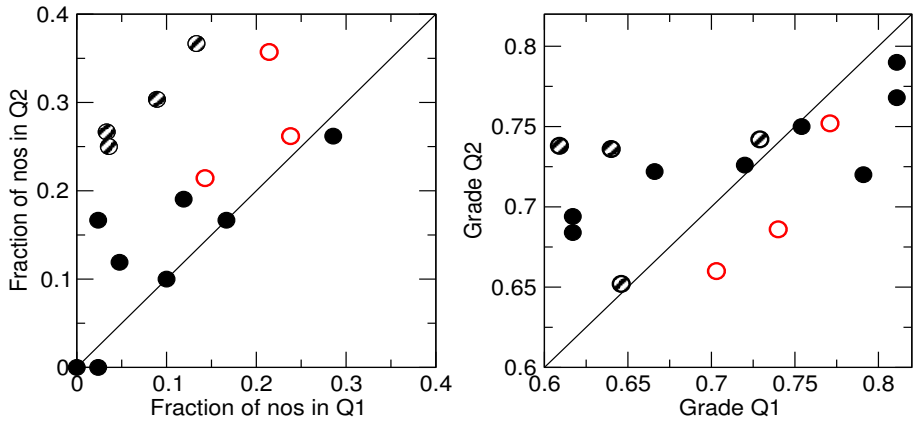

Figure 4.13: **Comparison fraction of nos and grades for Q1 and Q2.** The plot on the left shows the fraction of nos in the Q2 (y axis) versus the fraction of nos in the Q1 (x axis). The line corresponds to the diagonal (i.e., equal fraction of nos in Q1 and Q2). Each dot corresponds to a team. Empty circles (red) correspond to those teams upon which were intervened. Black circles with stripes correspond to those teams with the largest deviation from the diagonal. Dots to the left of the diagonal show an increase, whereas dots below the diagonal show a decrease. Note how for most of the teams the fraction of nos increases in Q2. The plot on the right shows the grade of the integrated project in Q2 versus the grade in Q1. The line again shows the diagonal (equal grade in Q1 and Q2). Dots to the left of the diagonal show an increase, whereas dots below the diagonal show a decrease. Symbols are equal to those in the left plot. Note that teams with lowest grades in Q1 tend to improve their grade in Q2, however, teams with highest grades in Q1 had a lower grade in Q2. Overall the range of grades in Q2 is smaller (Q2 is in the range [0.65,0.8] while Q1 is in the range [0.6,0.85].

Finally, we calculated the relative increase from Q1 to Q2 of grades and of the fraction on 'nos' (Fig.4.14). We found that there is a general positive

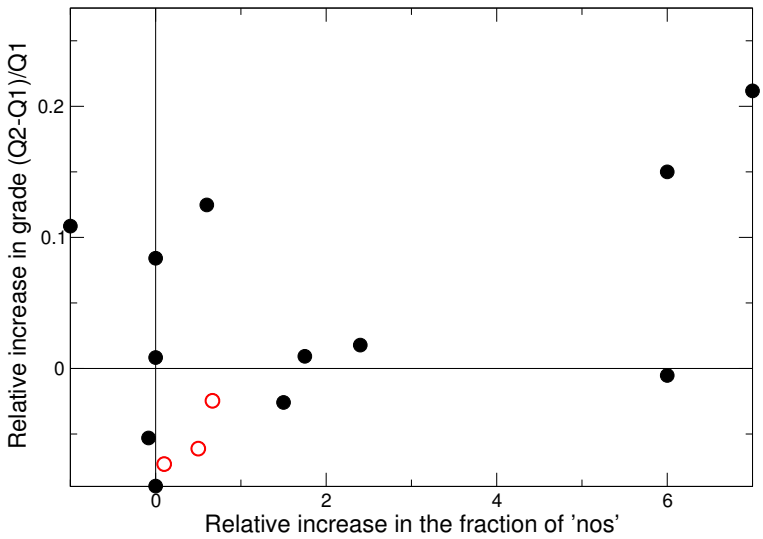

Figure 4.14: **Relative increase of grades and fraction of nos.** The plot shows the relative increase in grade (Q2-Q1)/Q2 (Q1,Q2 are the grades in Q1 and Q2, respectively) versus the relative increase in the fraction of nos (fnoQ2-fnoQ1)/fnoQ1 (where fnoQ1, fnoQ2 is the fraction of nos out of the total answers within a team in Q1 and Q2, respectively). The lines correspond to the x and y zero axis. Note that both quantities are positively correlated.

correlation between the increase of the fraction of 'nos' and the increase of grades. However, the three teams intervened increased the fraction of 'nos' but also decreased the grade in Q2. We understand that this does not mean a cause-effect relationship between both, grades and 'nos'. One of the possible explanation could be that as team members gain experience, they become more critical with their team mates work and their grades also improve. But, this is only one interpretation and of course here are many

other factors that could be playing a role and explain these results.

In any case, we have further work to do regarding the interventions of the teams and with their performance and conflict.

Chapter 5

Analysis of the gender role in leadership positions, by the application of different methodological approaches

5.1 Introduction

Gender stereotypes still play an important role in society. According to previous research, women are perceived as more communal (affectionate, helpful and friendly) compared to men that are perceived as more agentic (aggressive, ambitious, dominant) [79, 80]. On the other hand, leader stereotypes are more related to men stereotypes i.e., more to agentic (masculine) than women (feminine) characteristics (e.g., [79]). This mismatch causes discriminative behaviors that disable women to access leadership positions (which are perceived as masculine) in general and/or evoke discrimination reactions to women who hold such roles [79].

Initial impression formation can be strongly influenced by gender stereotypes. For example, women are less likely to be selected as leaders than men. When women and men are already assigned to a leadership role, the influence of gender stereotypes on their evaluation turns out to be less

strong [60, 81], but meta-analysis of leader evaluation showed that women can suffer some disadvantages when they are evaluated as potential leaders [82]. This effect could be explained in terms of congruity theory [60]; the incongruity between female roles and leader role leads to less favorable judgments of women in leader positions.

However, in some situations, women are advantaged [59]. In general, women are perceived as interpersonally oriented and more democratic than men, while men are more task-oriented and autocratic compared to women [83].

There are at least three arguments for better evaluation of women:

1. Different leadership competencies among women and men, for example, women are more interpersonally oriented while men- more task-orientated [82]. Despite the leadership stereotypes, it was shown in the last decade that transformational leadership becomes the most popular leadership style in nowadays companies (e.g., [84]). The transformational leadership style is more focused on the others in contrast to transactional leadership that is more focused on goals [61, 85]. This means that the transformational leadership style is more connected with communal attributes thus may be more commonly connected to women leaders. This may then be reflected in leadership evaluations with women manifesting more transformational leadership skills while men manifest more transactional skills [86]. For this reason, women could be advantaged as leaders, once they achieve the position.

2. The 'shifting standards model' [87, 88] suggests that as we all hold

vivid stereotypes, we judge members of the stereotyped groups using category-specific standards. For example, a female leader (male-dominated field) will be judged as more agentic and less communal than most women [89] because she is evaluated according to a female standards (low agency and high community). As we mentioned before women are evaluated as more communal than men, while men are evaluated as more agentic than women. However, these differences disappear when the information about the target role and/or target sex is introduced. In other words, female and male leaders are perceived similarly on communal and agentic dimensions [89] only if the evaluators are aware of the type of the domain and the sex of the leader. It was documented in the literature that leadership positions can be divided into female and male-dominated occupations [90]. The most female-dominated occupations are for instance nurse and social workers, while the most male-dominated are firefighters and police officers. Engineering is definitely more male than female-dominated although shifting standards may apply. Hence, female leaders could be evaluated accordingly with lower (female) standards while men could be evaluated accordingly with higher (male) standards because it is a male - dominated field.

3. In line with previous literature, agency and communion are two main dimensions of social perception [91] and communion is generally more important than agency [92]. Interestingly, the distribution of communion and agency judgments can differ under specific circumstances, for example, in a situation of low- and high-dependency. Wojciszke

and Abele [92] demonstrated that in bureaucratic organizations that are characterized by low outcome dependency, the evaluation of the leaders are more communal (less agentic) while in business organizations (characterized by high dependency) they are more agentic (less communal). In our sample, teams do not have a deep hierarchical structure because they work more in a horizontal way and the outcomes of the particular team members are not directly dependent on the particular leader's outcome. On the other hand, team leaders are focused on the collective success of the team. Therefore, they are at the service of team members' interests, and according to the findings of Wojciszke and Cislak [93] this should lead to communal evaluation.

Based on the above mentioned arguments, our research aims at investigating differences in the evaluation of female and male leaders and whether these evaluations may change over time. In particular, we wonder what happens when women enter a male-dominated field as team leaders. Will they receive a negative evaluation because of role incongruity [60] or will they be better evaluated than men due to within-sex standards [87, 88], or to their transformational leadership style?

We formulate the following hypothesis:

H1. We expect that female leaders at the beginning will have an advantage in the evaluation comparing to male leaders. It will be caused by the fact that males are commonly associated with leadership positions and female leaders in this case will be evaluated much more positive than male leaders.

Moreover, what happens over time when women and men serve as team leaders? After the initial impression individualization should take place

[94, 95], that is, the impact of gender stereotypes should decrease over time and leaders' gender should not play a role in the evaluation any longer.

We hypothesize that:

H2. The global evaluation of female and male leaders will become similar over time, that is, female and male leaders will be evaluated similarly at the end of the project.

We analyze the role of a leader's gender in their evaluation when particular leadership characteristics are taken into account. There are different approaches in the literature about efficient leadership [96]. In our study we used four general dimensions of good leadership: management, meeting facilitation skills, empathy and motivation.

We hypothesize:

H3. Management, meeting facilitation skills, empathy and motivation will be mediators between the leaders' gender and leaders' global evaluation.

Furthermore, we also analyze the role of the leader in the team network structure. To do this, we analyze some physical properties of the team networks based on the definition of centrality.

H4. Team networks of female leaders will be come more clustered than team network of male leaders.

Taken together, the present study is unique. First, we investigated the evaluation of leader in real projects simulating companies' environment, very close to the real life (e.g., they have to design a chemical plant in one defined country following some guidelines). Second, we analyze real leaders, both females and males who have been awarded a position (not potential leaders as evaluated in many previous studies). Third, our study is longitudinal and illustrates data of a nine month project. Thus, our

data is very genuine compared to simplified experimental task and other longitudinal studies. Fourth, the study includes the novelty of combining methodologies from different disciplines such as: i) mediation analysis, from social-psychological methodologies and ii) network analysis, from complex network methodologies.

5.2 Method

The participants of our study are engineering students who were involved in real projects at their university. In these projects students are facing real tasks during 9 consecutive months. In order to evaluate their social competences and leadership competences an online survey was created fulfilling official educational guidelines of this program. Some of the data had been used for predicting conflict in teams [97], but the set of data presented in this study has not been used before.

5.2.1 Sample and design

We analyze data from 45 small teams between 3 to 7 members each, with most teams having 5-6 members. The total sample is 303, of which 45 are team leaders (15 women and 30 men) and 258 are team members (100 women and 158 men).

Teams composition is as follows. Team members are first year students and all of them are involved in the project which is a course of the academic curriculum. Leaders are fourth year students involved in a Project Management in Practice course and their selection process is based on a leadership test, a team roles test and their personal motivation.

5.2.2 Materials

The questionnaire captured a description of four different leadership competencies and the global evaluation of the team leaders.

Every participant was asked to evaluate four characteristics of his/her particular leader. The question is as follows: "Please evaluate the following aspects of [*Name of the Leader*]".:

1. Organizational capacity (coordination, task management, time control, etc.).
2. Meeting moderation skills (achieving participation of all members, conflict management, public recognition of good work, etc.).
3. Empathy with team members.
4. Motivation capacity (motivate team members, produce changes in team members' behavior to achieve objectives).
5. Global evaluation of the leader.

Thus, the answers are measured in 11 points scale, where 0 means: Not developed / Non existent/ Poor; and 10: Completely developed/ Excellent.

5.2.3 Procedure

During three academic years, we collected data from online surveys. Specifically, we administered the same survey to all teams twice (Time I: in the fourth month of collaboration; Time II: in the ninth month). In the survey we asked all participants about the leadership competencies of their leaders.

5.3 Results

5.3.1 Changes in leaders' evaluation

We made an analysis of variance of the global evaluation (using the mean of the global evaluation that each leader obtained from all team members) comparing females and males leaders, with repeated measurements (time I and time II of the administration survey). The statistical test used for the analysis was the one-sided Mann-Whitney U. As posed in Hypothesis 1, we found at a 5% significance level, that at time I participants evaluated female leaders significantly more favorable than male leaders ($U = 53, p = 0.039$). Whereas, at time II the participants evaluated female and male leaders similarly ($U = 89, p = 0.490$) (see left panel of Fig. 5.1 and Table 5.1). As we show in the right panel of Fig. 5.1 female leaders worsen (improve negatively) in its global evaluation between time I and time II, contrary to male leaders, that improve along time. The change of the global evaluation between female and male leaders is significantly different at a 5% of significance level ($U = 48, p = 0.021$).

We also analyzed the differences between the global evaluation of the first and second quadrimester for females and males leaders with the same statistical test. We found that female leaders don't have significant differences between Q1 and Q2 ($U = 46.5, p = 0.409$) while the global evaluation of male leaders increase significantly between Q1 and Q2 ($U = 110, p = 0.051$) (see Table 5.1).

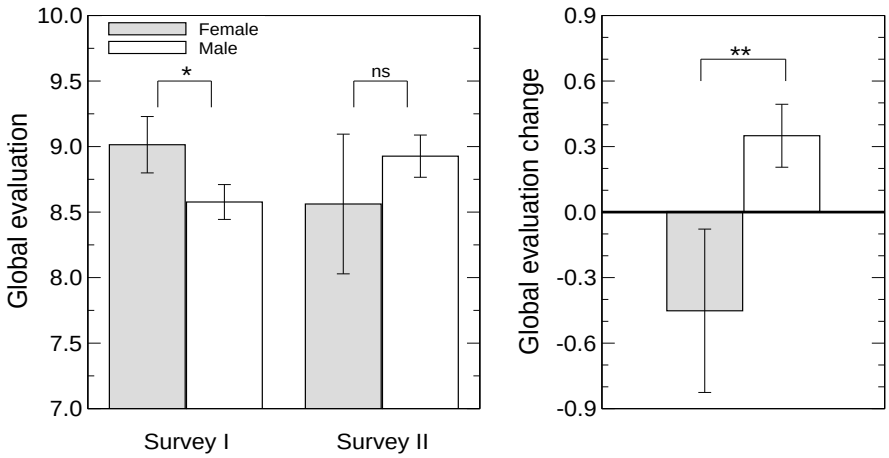

Figure 5.1: Time measurements for the global evaluation.

Table 5.1: Gender differences on global evaluation (GE).

Gender	GE Q1	*SD*	GE Q2	*SD*
Female	9.01	0.22	8.56	0.53
Male	8.58	0.13	8.93	0.16
p-value	0.039*		0.490	

5.3.2 Mediation analyses

We used bootstrapping to test a multiple mediator model [98]. We examined whether management skills, meeting facilitation skills, empathy and motivation explained the relation between gender of the leader (female and male, coded 1=female and 2= male), and global evaluation. We used 5000 bootstrapped samples in this analysis. In Time I, it demonstrated that all these competences are mediators of the relationship mentioned before. Then we examined each of the mediators separately when controlling for the effects of the other mediators. The analysis showed that management skills ($b = -0.11$, $SEb = 0.05$, $CI = [-0.214, -0.024]$), meeting facilitation skills ($b = -0.07$, $SEb = 0.04$, $CI = [-0.188, -0.014]$), empathy ($b = -0.07$, $SEb = 0.04$, $CI = [-0.164, -0.009]$) and motivation ($b = -0.13$, $SEb = 0.06$, $CI = [-0.277, -0.017]$) are mediators between leaders' gender and global evaluation. The total effect of gender of the leader disappeared when the mediators were introduced ($b = -0.037$, $SEb = 0.08$, $CI = [-0.199, -0.125]$). It women are perceived as leaders with higher competences in management ($b = -0.497$, $SEb = 0.04$, $CI = [-0.900, -0.095]$, meeting moderating skills ($b = -0.544$, $SEb = 0.053$, $CI = [-0.937, -0.095]$, empathy ($b = -0.45$, $SEb = 0.05$, $CI = [-0.879, -0.022]$ and motivation ($b = -0.59$, $SEb = 0.22$, $CI = [-1.105, -0.069]$.

The highest influence on global evaluation has motivation ($B = 0.23$, $SEb = 0.04$) and management ($B = 0.22$, $SEb = 0.04$) The influence of empathy and meeting was little bit lower ($B = 0.16$, $SEb = 0.05$, $B = 0.14$, $SEb = 0.05$).

The analysis clearly documented that all four leadership characteristics analyzed fully mediate the relation between gender of the leader and global evaluation (see Fig. 5.2).

In Time II, the relation between independent and dependent variable was insignificant. Therefore, further mediation analysis can not be conducted.

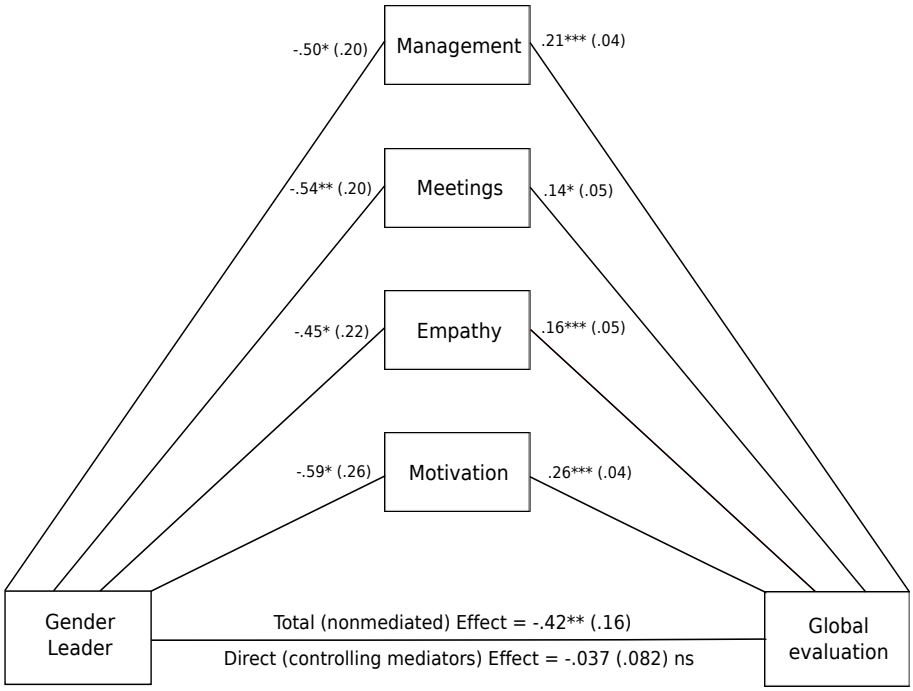

Figure 5.2: Mediation analysis of the gender leader and global evaluation.

5.3.3 Network analysis

We hypothesize that changes in the global evaluation should happen in parallel with changes in the internal structure of team. Therefore, we analyzed some properties of the team networks in terms of several definitions of centrality. To do this we used the data of one yes/no question of the survey: "Would you choose this person to work with you in a new team?". Thus, we construct directed networks from the answer to question, so that connections between nodes (members and leader) have a direction associated with them. We consider answer yes as a connection in the network and answer no as a non-connection in the network. We did the same analysis for the data obtained in the first and second quadrimester and we found significant differences between the networks of female and male leaders. (view Table 5.2).

Table 5.2: Data of relative clustering (RC) property for females and males in the Q1 and Q2.

Gender	RC Q1	*SD*	RC Q2	*SD*
Female	0.92	0.06	1.03	0.13
Male	1.08	0.08	0.90	0.11

Specifically, we calculated the means of males and females for the following network properties: in-degree, clustering and betweenness.

- *Degree:* is the number of edges (or connections) that the node has to other nodes [24, 34]. In our case, the network is directed, this means that edeges have a direction associated with them. We only take into

account the in-degree of the leaders, which is the number of incoming connections.

- *Clustering:* It is a measure of the density of connected triangles in the network [36]. We compare the clustering coefficient of male and female leaders.

- *Betweenness:* is the total number of shortest paths that go through a given node [35].

To obtain the significance of network properties, we compared the means of females (for each network property and team) with the means of males. All results were normalized for each team. To measure the significance of this comparison we applied the one-sided Mann-Whitney U statistical test. The results of this analysis show that, only in the case of the clustering property, the differences between females and males leaders networks are significant ($p = 0.033$). In particular, the clustering of female leaders grows significantly more than the clustering of male leaders (see Fig. 5.3 and Table 5.2).

The rest of the network properties, in-degree and betweenness were similar for both networks of females and males leaders. This means, that the differences were not significant.

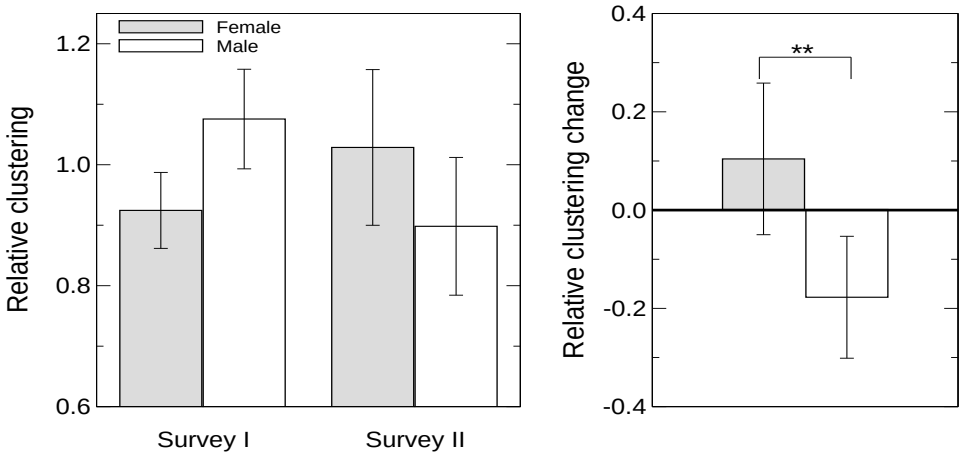

Figure 5.3: Measurements for the network clustering property.

5.4 Discussion

The aim of our research was to analyze the dynamics of female and male leadership evaluations. Especially, we were interested in how the perceived gender differences affect these dynamics.

Our findings demonstrate a certain female advantage at the beginning, because they were evaluated more positively, in comparison to male leaders in the first evaluation, i.e., male leaders were perceived less positively than female leaders. These results support previous findings of female advantage in leadership evaluation [82]. Interestingly, we also show that this female

advantage disappears in time, which has not been documented in the literature before. The evaluations of female and male leaders are leveled at the end of the project and there are no differences between them. We assume that the reason of this dynamic is a 'surprise effect'. This effect regards only women who gained a leader position because it is still not a women's typical role [81]. Hence, we claim that the evaluators are influenced by gender stereotypes and as a consequence they somehow reward female leaders by overestimating their leadership competencies. This mechanism would be strengthened by the fact that our leaders were leaders in an engineering field that is still dominated by men.

Similarly, this surprise effect might apply also to male leaders in feminine domains (e.g., caretaking roles). It seems that the stereotypes of our participants influence not only women evaluations but also men. Male leaders were evaluated more negatively in the first evaluation and more positively in the second one.

Surprisingly, using different methodologies such as network properties analysis, we also found that there are differences between female and male leaders' networks. Female leaders have more connected networks, this means that they provide a warm environment to establish more relationships between team members. This fits with gender stereotypes, because of women are perceived as communal (e.g., affectionate, helpful and friendly) [79], interpersonally oriented [83] and focused on the others [61]. Whereas men are perceived as agentic (e.g., aggressive, ambitious, dominant) [79], task oriented [83] and focused on goals [61].

It is shown in all our analyses that gender of the leader has an important impact on leadership evaluation. However, over the time this influence

fades. Our results revealed that at the beginning global evaluation of the leaders is influenced by the gender of the leader. In contrast, in the second measurement, we found that the influence of gender disappears. This means that the participants evaluate the leadership competences without the influence of gender stereotypes.

Chapter 6

Conclusions and future work

This thesis resolves around the study of small teams through the perspective of complex networks. Using empirical data, we have investigated issues related to gender and conflict. Specifically, we conclude the following:

- One of the most important results of this thesis is the development of a tool based on complex networks methodologies to predict appearance/resolution of conflict within small teams. This method not only provides a higher accuracy than traditional methods, but also offers a new approach to study social problems in a practical and very simple way. The conclusion from our work is that complex networks methodologies are appropriate tools for small social network analysis. However, we will need further work to show the usefulness of other large-scale approaches to small social networks, especially because it is the first time that network perspective is applied to small team science.

- Conflict has become the focus of attention of a number of research studies due to the important role that teams play in most of the work contexts. The development of tools to avert conflict such as

the Team Analytics, is not only beneficial for companies, but also it is an important way to bring back science in to society. Our plan is to improve the tool and perform more experiments in different teamwork contexts (i.e., business and management, research, sports, politics, education, etc.), before launching it.

- Regarding the results obtained by the Team Analytics web tool and the intervention experiment to three real teams, we understand that the amount of conflict detected in the network is not directly related with the change in performance of these three teams we intervened. Most likely, this is because team members become more demanding as they gain experience and evaluate team conflict in a more strict way. However, because of the small sample size, our data is not enough to draw significant conclusions. Therefore, we should carry out more experiments with many more teams to obtain more accurate results. Additionally, we should design a better strategy to do the team interventions in order to understand the evaluation system of conflict among team members in relation to team performance.

- Finally, we find that complex network metrics are complementary to other socio-psychological traditional methodologies such as mediation analysis. While simple network metrics has a long standing tradition in social network analysis, this has remained quite an isolated practice. By combining both approaches, we find that female leaders are better evaluated than male leaders at the beginning of the Integrated Project and that the relative clustering of female leaders grows with time more than that of male leaders. These findings are consistent

with the fact that in a context of male dominance women are accepted as a leaders only after they show that they have leadership competences. Even though studies on gender differences are at the vanguard of research, it is necessary to study more and understand better the gender dynamics in society and thus provide new perspectives to reach gender equality.

In short this thesis leaves an important methodological contribution to team science and social networks research. The results in this thesis open the perspective of using large-scale complex networks tools for the analysis of small-scale social systems and how to combine complex networks methodologies with traditional approaches in social science.

Appendix A

Catalan version of the conflict prediction survey

The next survey corresponds to the original version (in Catalan) of the IP online survey described in Chapter 2.

ENQUESTA PROJECTE INTEGRAT

Nom.....
Cognoms.....
Género .....
Edat .....

A continuació et presentem una sèrie de preguntes referents al quadrimestre actual, que serviran per avaluar els teus companys i el teu/va líder i per ajudar a millorar el funcionament del projecte integrat en les properes edicions. Si us plau, et demanem la màxima sinceritat. Gràcies.

1. AVALUACIÓ DEL LÍDER / AUTOAVALUACIÓ

Nom i Cognoms del líder .....

Avalua els aspectes del teu/va líder que apareixen a continuació, seguint el criteri indicat (si has desenvolupat el rol de líder, autoavalua't si us plau):

	Nul·la										Total
1- Assistència a les sessions de treball de l'equip.	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐

	Gens desenvolupada/ Nul·la									Totalment desenvolupada/ Excel·lent	
2- Capacitat organitzativa (divisió, coordinació i gestió de les tasques, control del temps, etc.).	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐
3- Facilitació de les reunions (participació de tots els membres, gestionar els conflictes, donar reconeixement, etc.).	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐
4- Empatia amb els membres de l'equip.	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐
5- Capacitat de motivació (motivar als membres de l'equip, aconseguir canvis en les conductes dels altres per tal d'assolir els objectius marcats).	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐
6- Quina avaluació global li donaries a aquest/a líder?	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐

	Si	No
7- El triaries com a líder en un nou equip?	☐	☐

2. AVALUACIÓ / AUTOAVALUACIÓ DELS MEMBRES DE L'EQUIP

Avalua els aspectes de tots els membres del teu equip (tu inclòs) que apareixen a continuació, seguint el criteri indicat (si has desenvolupat el rol de líder, no t'has d'autoavaluar):

Nom i Cognoms.....

	Nul·la 0	1	2	3	4	5	6	7	8	9	Total 10
1- Assistència a les sessions de treball de l'equip.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
2- Aportació al treball en equip (idees, informació, coneixement, etc.).	Nul·la 0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Excel·lent 10 ☐
3- Actitud davant el treball en equip (comunica correctament, es relaciona de forma respectuosa, comparteix les idees, ofereix ajuda).	Gens desenvolupada 0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Totalment desenvolupada 10 ☐
4- Quina avaluació global li donaries a aquest/a líder?	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	10 ☐

Si t'estàs autoavaluant no contestis les preguntes 4, 5 i 6.

	Sí	No
5- Has treballat directament amb aquesta persona durant aquest quadrimestre?	☐	☐
6- El triaries per treballar en un nou equip?	☐	☐
7- El triaries com a líder en un nou equip?	☐	☐

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COMPLEX NETWORK APPROACHES TO SMALL TEAM ANALYSIS. CONFLICT AND GENDER
Nuria Rovira Asenjo
DL: T 342-2014

3. ENQUESTA

1- Quina ha estat la teva dedicació a l'avantprojecte en aquest quadrimestre?

- ☐ Menys de 5 hores a la setmana
- ☐ Entre 5 i 6 a la setmana
- ☐ Entre 6 i 7 hores a la setmana
- ☐ Entre 7 i 8 hores a la setmana
- ☐ Entre 8 i 9 hores a la setmana
- ☐ Entre 9 i 10 hores a la setmana
- ☐ Més de 10 hores a la setmana

2- Com creus que són els teus coneixements, després d'haver acabat l'PI, en comparació als que creus que tindries en cas de no haver-hi participat?

☐ Molt superiors ☐ Superiors ☐ Iguals ☐ Inferiors ☐ Molt inferiors

3- Creus que l'existència del rol de líder dins d'un equip és:

☐ Imprescindible ☐ Important ☐ Útil ☐ Prescindible ☐ Perjudicial

4- Quins són els conflictes que més s'han donat dins del teu equip?

- ☐ Diferent implicació per part dels membres al projecte
- ☐ Falta de comunicació dins l'equip
- ☐ Retard en l'entrega de tasques per part d'alguns membres
- ☐ Problemes generals amb el líder
- ☐ Problemes generals amb professors
- ☐ Problemes personals entre membres de l'equip
- ☐ Falta d'integració d'algun membre en l'equip
- ☐ Falta de motivació per part d'un o més membres
- ☐ Baix rendiment de l'equip

5- Què has après amb l'experiència de treballar en equip?

6- Comenta qualsevol aspecte que creguis rellevant, relacionat amb l'avantprojecte integrat (aspectes que no s'han preguntat i que vols remarcar, aspectes que millorarien el funcionament, situacions destacades d'aquest període, etc.).

4. AVALUACIÓ DEL TUTOR

Avalua els aspectes del teu/va tutor que apareixen a continuació, seguint el criteri indicat:

Nom i Cognoms del tutor.....

1- Assistència a les sessions de tutoria.	Nul·la 0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Total 10 ☐
2- El tutor es relaciona de forma respectuosa amb els estudiants?	Totalment en desacord 0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Totalment d'acord 10 ☐
3- Ha estat útil la funció del tutor?	Nul·la 0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Total 10 ☐

4- T'agradaria tornar-lo a tenir com a tutor? Sí ☐ No ☐

NOTA: Les dades d'avaluació de l'avantprojecte integrat seran utilitzades per dur a terme estudis de recerca i millora continua d'aquest. Per aquesta finalitat, les dades es mantindran sota l'anonimat en tot moment. En cas de disconformitat, preguem que ho manifestis al teu coordinador. Gràcies.

Appendix B

English version of the conflict prediction survey

The next survey corresponds to the English version of the IP online survey described in Chapter 2.

INTEGRATED PROJECT SURVEY

Name.....
Surname.....
Gender .....
Age .....

In what follows, we will ask some questions regarding your team. The overall objective of the survey is to evaluate the team work of each of your colleagues and to help us improve the performance of the team of the future. Please, answer the questions honestly.

1. EVALUATION OF THE LEADER / SELF-EVALUATION

Name and surname of the leader.....

Evaluate the following items concerning your leader following the specified criteria (if you are the leader, please evaluate yourself):

1- Attendance at meetings of teamwork. (Non existent / Total) 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐

2- Management skills (coordination, task management, time control, etc.). (Not developed / Non existent / Completely developed/ Excellent) 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐

3- Meeting facilitation skills (achieving participation of all members, conflict management, public recognition of good work, etc.). 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐

4- Empathy with team members 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐

5- Motivation capacity (motivate team members, produce changes in team members' behavior to achieve objectives). 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐

6- Overall evaluation of the leader. 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐

7- Would you choose her/him as a leader in a new team? Yes ☐ No ☐

2. EVALUATION/ SELF- EVALUATION OF TEAM MEMBERS

Evaluate the following items of team members following the specified criteria (if you are a team member, please evaluate yourself as well):

Name and surname of the member.....

	Non existent / Null / Not developed										Total / Excellent / Completely developed
	0	1	2	3	4	5	6	7	8	9	10
1- Attendance at meetings of teamwork.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
2- Teamwork contribution (ideas, information, knowledge, etc.).	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
3- Teamwork attitude (properly communicating , being respectful, sharing ideas, offering help, etc.).	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
4- Overall evaluation of this team member.	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

If this is your self-evaluation, please don't answer the questions 4, 5 and6.

	Yes	No
5- Did you share specific work tasks with this member?	☐	☐
6- Would you like to work with this member in a new team?	☐	☐
7- Would you choose her/him as a leader in a new team?	☐	☐

3. GENERAL SURVEY

1- What was your dedication in IP during this quadrimester?

- ☐ Less than 5 hours per week
- ☐ Between 5 and 6 hours per week
- ☐ Between 6 and 7 hours per week
- ☐ Between 7 and 8 hours per week
- ☐ Between 8 and 9 hours per week
- ☐ Between 9 and 10 hours per week
- ☐ More than 10 hours per week

2- How do you consider your knowledge after completing the IP, compared to that you would have if you do not had participated?

☐ Much higher ☐ Higher ☐ The same ☐ Lower ☐ Much lower

3- The presence of a leader in a team is:

☐ Essential ☐ Important ☐ Useful ☐ Dispensable ☐ Harmful

4- What kind of conflict arises more often in your team? (You can select multiple options).

- ☐ Different involvement of members in the project
- ☐ Lack of communication within the team
- ☐ Delay in delivery of tasks by some members
- ☐ Generic problems with the leader
- ☐ Personal problems between team members
- ☐ Lack of integration of a team member
- ☐ Lack of motivation of one or more members
- ☐ Poor team performance

5- What have you learned from working in a team?

6- Discuss any aspects related to teamwork that you think that are relevant (topics that would highlight features that improve performance, outstanding situations, etc.).

4. TUTOR EVALUATION

Evaluate the following items concerning your tutor following the specified criteria:

Name and surname of the tutor…….....

1- Attendance at tutorial meetings. Non existent / Total: 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐

2- The tutor relationship with the students is respectful? Completely agree / Completely disagree: 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐

3- It has been useful the function of the tutor? Null / Excellent: 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐

4- Would you choose again this tutor in a new project? Yes ☐ No ☐

DISCLAIMER: The data collected from this survey will be used to conduct research. For this purpose, the data will remain anonymous. In case of disagreement, please contact with the organization. Thank you for your collaboration.

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