How social network features and organizational structure impact team performance in uncertain environments

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Abstract

Teams are framed as individuals embedded in hierarchical and knowledge networks, who interact among each other with the aim of accomplishing a common task. Social interactions are the means through which team members exert their mutual social influence, change opinions, and converge to a common understanding. In this paper, we investigate how the density and connectivity of the team knowledge network and the team organizational structure relate to team performance. The latter is measured in terms of level of agreement among the team members (consensus outcome). We first develop a theoretical model grounded on social influence theory and then a computational model based on the Ising approach. Successively, we carry out a broad simulation analysis in environments characterized by different levels of uncertainty. Results show that high-density values of the team knowledge network are beneficial in the majority of cases, but may become detrimental, when the uncertainty of the environment is low, the team knowledge network exhibits a random connectivity, and the team organizational structure is characterized by high centralization of the authority and a strong leadership behavior. We also find that scale-free connectivity of the team knowledge network hinders the achievement of consensus, compared to the random connectivity case. Based on the simulation results, we finally identify the best organizational structure that should be adopted to improve the consensus outcome.

Introduction

In today’s highly complex and uncertain environment, teams are effective coordination mechanisms contributing to firm competitive advantage[1,2,3,4]. Indeed, teams are more and more adopted by the organizations to address a very large variety of projects, ranging from new product development, R&D activities, production and marketing issues, and so on. For this reason, a wide body of literature has analyzed the determinants of team performance with the aim of providing important lessons on how to design highly effective teams[2,5,6].

A recent stream of research has focused the attention on how social network features relate to team performance. Teams are viewed as social communities involving team members and members external to the team, such as those belonging to the original organization. Nodes (members) are linked to each other by social relationships (ties). Structural features of the team social networks such as density, centrality, and status have been shown to be associated with team performance[7,8,9,10]. However, the debate among scholars is still open, and a final consensus has not been reached yet[9]. As an example, some studies found a positive effect of density on team performance[11], whilst others did not[8]. Therefore, more research is required on these issues.

This paper contributes to this stream of studies and argues that, to reach a better understanding of how social network features relate to team performance, it is needed to introduce the role played by the team organizational structure, which governs the relationships among team members. The relationship between the team organizational features and team performance has been investigated in a parallel stream of research[12,13,14,15], which has put in evidence that the team organizational structure is one of the most important antecedents of team performance.[16] However, so far these two lines of inquiry have remained independent. No study has captured the existence of an interaction between the team social network features and team organizational structure in affecting team performance. In light of this interplay, the effect of the social network features on team performance should vary within diverse team organizational structures, so contributing to explain the controversial outcomes found in the previous literature and observed in practice.

We ground our theoretical argumentations on the theory of social influence. We develop a theoretical model that identifies the main features of the team social networks affecting team performance and that includes the influence of the team organizational structure and environmental uncertainty. Team decision making is conceived as an opinion formation process of the team members driven by the social influences. The latter stimulate convergence towards a common understanding[17,18,19,20], and facilitate the reaching of consensus among team members on how to accomplish the task[21]. Consensus – recognized by previous studies as an important team goal – is used here as indicator of successful teams[22,23]. Two types of social influences are identified, due to the existence of hierarchical links and to the search of knowledge support. Team members are thus considered embedded in two types of team social networks, i.e. the hierarchical and the knowledge networks. The density and connectivity of these team social networks are considered prominent social features affecting the efficacy of social influence in consensus reaching. Environmental uncertainty, making the individual less prone to rely on the opinion of the interacting individuals, is assumed to decrease the efficacy of social influence in reaching consensus.

We develop a computational model to explore the interactions among the main variables of our conceptual model. We rely on the Ising model of interacting spins to simulate the opinion formation dynamics inside the team social networks. The Ising model describes how a group of individual agents tends to point in a common direction (behavior). It was originally developed in physics, but counts a number of applications in social science and is particularly suited for studying the dynamics of social opinion formation [24,25,81,82]. We carry out a simulation analysis to explore the effect of increasing density and diverse connectivity of the knowledge network on the consensus outcome in different team organizational structures and in environments characterized by diverse levels of uncertainty.

We chose agent-based simulation as a research methodology because it is particularly valuable to conduct explorative investigations when multiple variables interact one with each other, resulting in non-linear and unpredictable system behavior. For example, in[26] opportunities for research in NPD team context using agent-based simulations have been highlighted. In particular, the Ising approach fits very well with the conceptual framework of our study: each agent's state (individual opinion) is influenced by the state (opinion) of the neighbors (the interacting individuals in the social network). Each agent is allowed to change the opinion, governed by a transition probability, which depends on the energy level of the system (level of conflict) and by the external temperature (the environmental uncertainty).

The paper is organized as follows. We first present the theoretical background of this paper. Then, we describe the Ising model of team by identifying the main variables and dynamics. Successively, we discuss the simulation analysis and present the results of the simulation. The paper ends with discussion, conclusions, and limitations.

Literature Background and Theoretical Model

Team social networks

A relatively recent approach to study teams employs social network theory[27]. Teams are framed as clusters of nodes (individuals), joined by a variety of links (relationships). As to the node, internal and external team networks are commonly distinguished. Internal networks are those involving only individuals belonging to the team, whilst external networks involve links between team members and external individuals, such as the members of others teams or the members of the organizations[10]. Depending on the type of link, literature distinguishes between instrumental and expressive networks, which differ in the content (nature of the resources) flowing through the link[28,]. When this content is identified as information resources and knowledge (which are needed to solve tasks), the network is defined as instrumental, whereas it is expressive when the content of ties is related to affective relations such as friendship or trust[9].

Herein, two types of instrumental networks are considered, because important in supporting team members to make decisions: the hierarchical and the knowledge networks. The hierarchical network consists of individuals (nodes) and ties originate from a formal hierarchical relationship between the chief and his/her subordinate[29,30]. The team hierarchical network maps the power relationships inside the team and between team members and the organizations one. For example, self-managed team guided by a project manager, is characterized by an internal hierarchical network, with hub-spoke connectivity, and an external network, in which only the project manager reports to the organizational CEO.

The knowledge network includes links emerging from informal relationships when members seek support in terms of knowledge from the others[31]. A similar network can be found in Chung and Jackson[10], which maps a team network of work relationships, where the interactions derive from the shared job activities and are made to seeking job-related advice and sharing work knowledge. In such a network team members exchange tacit and confidential knowledge to improve their job performance. Sparrowe et al.[8] map a similar network made up of the relations through which individuals share knowledge resources in terms of information and assistance useful to the completion of the task.

Social influence theory and team decision making

Social influence occurs when an individual adapts his or her behavior, attitudes, or beliefs to the behaviors, attitudes or beliefs of others in the social system[32]. Social influence theory argue that social interactions are conduits of opinion formation, which stimulate convergence towards a common understanding of a situation and shared mental models among individuals[20]. In fact, individuals tend to observe what others do in decision-making situations and try to adapt their actions to the dominant behavior[33]. Social influence theory applies to teams framed as social networks. During the decision making process the team members receive two types of social influence, because of their involvement in the hierarchical and knowledge networks. The hierarchical ties exert pressure on team member, because individuals usually prefer to avoid contrasts with the members in higher hierarchical positions. The knowledge ties influence the team member, because individuals tend to conform to the opinions of the members with higher knowledge on the task[34,35]. Team members have an initial opinion on the decision to make, but then change it, because of their search for reaching consensus with interacting individuals[21].

We conceive here the team decision-making process as an opinion change process accomplished by each team member and guided by the social interactions occurring in the hierarchical and knowledge networks. Team members have an initial opinion on the decision to make, but then change it, to reach a shared solution associated with a high level of agreement among the team members. During the decision making process, new distributions of opinions among the team members continuously emerge as the social interactions take place, until a high level of consensus is reached inside the team.

Conflict and consensus

Research addressing consensus in teams is related to the studies on team conflict. Three types of conflicts have been identified: task, process, and affective conflicts. The task conflict emerges when team members have different opinions about the work. The process conflict is when team members disagree on the approach to carry out tasks and group processes. Affective conflict, instead, involves anger or hostility among team members[36].

Our conceptualization concerns task conflict because team members can be in disagreement about the decisions to make. For example, members assigned to make choices on the same decision could have diverse opinions: a member could prefer a young target segment and another a mature one; an individual a long distribution channel, another a web-based one, and so on. In the case of decentralized teams, members making diverse decisions (e.g., one the target market, the other the product style) can be in conflict, if the decisions they make are incoherent. For example, incoherence occurs when the member deciding the target market prefers a young segment, and the other one prefers an old style product more coherent with a mature segment.

Reaching a high level of agreement among team members on how to accomplish the task is recognized by previous studies as an important team goal and an indicator of a successful team[37, 38] . Horwits and Horwits[21] consider social integration as a team-level performance to be improved, because the resolution of disagreements is a time-consuming task, absorbing effort and creating confusions and anxiety on team members[39,40] . Consistently, we define the reach of consensus inside the team a dimension of the team performance, measured by the degree of agreement among the members on how to accomplish the task.

The relationship between the social network features and consensus outcome

The basics of our model is that the team behaves as a set of individuals changing their opinions on the decisions to make, based on the social influences received by the interconnected individuals with whom they seek to be in agreement.

Structural theory on social influence[41] argues that the structural features of the social networks play a critical role influencing the efficacy of the social interactions in fostering consensus and resolving conflict. Thus, the social network features of the knowledge and hierarchical networks should play an important role on team decision-making process, viewed as opinion formation process guided by the social interactions. In this respect, density is particularly effective. Increasing density strengthens the social influences received by the team member, who is forced to change the opinion. Consistently, previous studies have found that teams with densely interpersonal ties achieve their goals better, because their members are more committed to stay together[9,41,42,43] and because exchange information broader and timelier[44,45]. Highly interconnected ties facilitate the development of social integration and organizational commitment, resulting in high consensus[7].

A further social feature influencing the efficacy of social interactions is the connectivity structure. A rich stream of studies in sociophysics has investigated this aspect[24,25]. The connectivity describes the global properties of the network such as the average path length between nodes, the clustering coefficient, and the degree distribution. One of the original specification of social network is the random structure, where interactions occur on a random basis and most nodes have approximately the same number of links[46]. The random network is characterized by a short path length, a low clustering coefficient, and, for large networks, by a Poisson degree distribution[46]. However, it is known that social networks often exhibit a scale-free structure, which is characterized by a node distribution connectivity that follows a power law[47]. The scale-free network also possesses a short path length and a low clustering coefficient. Researches in management and organization science investigating the relation between the connectivity of team social networks and team performance are lacking. To the best of our knowledge, only Oh and Jeon[48] analyzed the effect of the connectivity (scale-free vs. random) of the open software social community on the herding behavior. Literature lacks of studies investigating the joint effect of density and connectivity on consensus outcome. We consider both density and connectivity of the team social networks (hierarchical and knowledge) as prominent variables affecting the consensus outcome.

The influence of the team organizational structure

The team organizational structure is the coordination mechanism ruling the relationships among team members during the decision making process. The team organizational structure is mainly defined by the following variables: the centralization of the authority, the level of team independence, and the leadership behavior. The centralization of the authority is high when teams are guided by a project manager[49]. Leadership behavior changes according to the project manager managerial style. Two styles are prominent: direct vs. empowering leadership[50]. Direct leadership is associated with a project manager (DPM), who tends to drive the team by exerting a very strong influence on the members. In such a case, it is very likely that team members do not express and motivate their actual opinions but prefer to change them to be in agreement with the leader. The empowering project manager (EPM) tends to take into account team member's opinions, to promote the interactions and discussions, so as to converge to a common understanding of the task, and formulates its opinion on the basis of the information collected during the management of the team[50,51].

Team independence has been seen as an antecedent of team effectiveness[12,15]. Great autonomy is associated with a weaker influence of the individuals external to the teams (interactions occurring in the external social networks) compared to individuals belonging to the team (interactions in the team internal social networks).

Table 1 summarizes the considered alternative feasible combinations of the aforementioned organizational variables. Four organizational structures are so distinguished: two types of autonomous teams characterized by the two diverse leadership behaviors of the project manager, and two types of not-autonomous team differing on the existence or not of the project manager[12,15].

Table 1

The alternative IO team organizational structures

	Autonomous — EPM	**Autonomous — DPM**	**Heavyweight**	**Functional**
Centralization of authority	Yes	Yes	Yes	No
Strong leadership	No	Yes	Yes	No
Degree of team independence	High	High	Low	Low

In light of our conceptualization of the team as social networks and decision making as opinion formation process, the organizational structure affects the consensus outcome by means of the effect it has on the features of the hierarchical social network. In particular, the team organizational structure affects the connectivity of the team hierarchical networks. In the presence of high centralization of authority, the internal hierarchical network is characterized by a hub-spoke connectivity, because all team members centrally report to the project manager. The external hierarchical network is characterized by the link between the project manager and the CEO and by the links between the functional managers of the organization and the functional team members. In the case of low centralization of authority, the team internal hierarchical network simply does not exist, because all members belong to the same hierarchical level and do not have a chief. The external network shows a structure where the team members are linked to the functional managers of the organization. The degree of team independence determines the weights of the hierarchical tie, so that when independence is high (low) the external links exert a low (high) influence.

The contingent role of the environmental uncertainty

There is a general accord about the conceptualization of the environmental uncertainty in task projects. For example, in NPD projects it mostly concerns unfamiliarity with or inability to understand technological and market changes[52,53], but it is also associated with the degree of novelty of the technology required[49,54,55,56]. Even though some studies have highlighted the direct impact played on the team performance, a recent stream of research has focused on the moderating effect of the environmental uncertainty on the relation between the team/project characteristics and team performance[52,53,57]. For example, Song and Montoya-Weiss[58] analyzed the moderating effect of perceived technological uncertainty on the relationship between some project features (cross-functional integration, marketing and technical project synergy, and proficiency in marketing and technical development activities) and NPD performance. Swink[59] studied the effect of collaboration and NPD performance in diverse conditions of technological uncertainty. Calantone and Rubera[60] investigated the moderating role of environmental uncertainty, which has been traditionally considered as a moderator of the relationship between inter-functional collaboration and new product program performance.

Very few studies have analyzed the relationship between environmental uncertainty and the efficacy of the social influence for conflict resolution. Song and Montoya-Weiss[58] argued that high-perceived technological uncertainty tends to increase the difficulty of reaching consensus and may increase the propensity for conflict. Individuals when perceive a great uncertainty about the technology and market are less likely to rely on the opinions of the others, because the chance that they are erroneous is high. Based on the above and in light of our conceptualization, we argue that environmental uncertainty reduces the efficacy of the social influence as a mechanism useful to the formation of common opinions. In such a case, the team members are less prone to change their opinion based on what interacting individuals do. Consequently, the establishment of the agreement among team members is harder. Figure 1 shows our conceptual model.

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Fig. 1: The conceptual model

The Simulation Model

The Ising model

The Ising model was originally developed in physics but counts numerous applications in social science[61], in particular it has been employed to model the social behaviors of economic agents in financial markets[62], to analyze social opinion formation process[24,25], to model the decision-making process of teams[81], to study herding dynamics in open source software communities[48] and to investigate learning processes in the organizations[82]. In all cases, the way in which those systems evolve is described using tools and concepts from statistical physics.

We mainly refer to the use of Ising model to predict the opinion formation dynamics, which fits very well the conceptual framework of our study. In these applications, in fact each agent's state (individual opinion) is influenced by the state (opinion) of its neighbors. Each agent *i* is allowed to change its opinion, governed by a transition probability *pi*. Among the different types of dynamics, governing the probability of opinion change, we choose Glauber's dynamics[63], in which both the social impact exerted by the neighbors ($?E_i$) and the social temperature (T), according to the formula, influence the probability that the agent *i* changes its opinion:

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The social impact is related to the energy level of the system, which increases if the individuals have conflicting opinions and decreases in case of agreement. The interacting agents tend to minimize the energy level of the system (level of conflict), thus leading it to a state with a higher level of agreement. The social temperature, likewise thermal noise in physical systems, tends to destroy the ordering effect of the social interactions, as increasing temperature tends to equalize the probabilities of flip and stay of opinions. Low temperatures imply rigid behavior in which the opinions are largely determined by the states of the neighbors (interacting individuals), whereas high temperatures imply random behavior in which the opinion formation process becomes independent from the neighbors.

The model of the team task

We consider a team of *S* members. The task assigned to the team consists in making decisions on a set of variables. For example, if the team task concerns a new product development, the team should make diverse decisions concerning the target market, the product features, the production process, and so on. Each team member is in charge of a decision, referring to its specific functional competence (for example, the target market for the marketing member) and expresses an opinion on this during decision-making process. The individual opinion is modeled as a binary variable, where +1/—1 are the two possible values of the product attribute. Even though the number of available options is more than two in real cases, we prefer this option because it does not affect the qualitative dynamics of the system and makes the treatment simpler.

The model of the hierarchical and knowledge networks

Figure 2 shows a hierarchical network where the organization (red color) has size N = 21, and is characterized by a three-level hierarchical structure, where the first level corresponds to the firm's CEO, the second to the managers of the functional departments, and the latter to the operating units. In Figure 2a the team (yellow color) has size S = 10 and is characterized by the presence of a project manager (PM). The hierarchy of the team is split in two-levels in which all the team members belonging to the second hierarchical level directly report to the PM As to the external hierarchical network, the project manager reports to organization’s CEO, team members report to the functional managers. In absence of a project manager, the team internal hierarchical network is flat: all team members belong to same hierarchical level. In the external hierarchical network each of the team members directly report to a functional manager of the organization (Figure 2b).

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Examples of hierarchical networks: team members are in yellow color, organization members are in red. Blue links identify those members interacting through the external networks

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The team and the organization fixed, we generate the internal and external knowledge network by define the connectivity (random or scale-free) and the average number of links per node (*K*) both for internal and external networks, respectively. In Figure 3, an example of knowledge network is shown for $K = 3$ assuming a random connectivity. To study the effect of the density we generate knowledge networks with increasing *K*. To study the effect of connectivity we consider two patterns, i.e, the random vs. scale-free.

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An example of knowledge network with random connectivity and average number of links per node K=3: team members are in yellow color, organization members are in red color. Blue links identify those members interacting through the external networks.

The social interactions and their impact on the level of conflict

Hierarchical networks

The level of conflict E_i^H associated with the member *i* due to the relationship in the hierarchical networks is:

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where (s_i and (s_j are the opinions of the members *i* and *j* at time *t*, A_{ij} models the independence of the team members from the organizations and I_{sj} is the impact of the hierarchical status of the individual *j*. The symbol < > indicates that the sum is limited to the nearest neighbors of the *i*-th member, i.e. to those individuals that are directed connected to the *i*-th individual.
The hierarchical status of the individual *j* is associated with his hierarchical level l_j. A disagreement with an individual belonging to a higher hierarchical level is weighted more than the disagreement with one member belonging to a lower level. This means that the probability to change opinion is higher if the individual has a different opinion with his/her chief rather than with an individual sharing the same hierarchical status. The quantity I_{sj} is then defined as follows:

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where the hierarchical level l_j = 1 is an integer, which increases as one moves from the top (CEO and PM) to the bottom of the hierarchy. The quantity $\mu=10$ instead tunes the decay rate of I_{Sj}.
The parameter A_{ij} models the level of independence of the team members. For autonomous teams, the opinions of the individuals not belonging to the team are less influential than the team member opinions, thus exerting a lower impact on the level of conflict. In this case of high autonomy, A_{ij} = 0.2 when one of the interacting members belongs to the team and the other do not, whilst A_{ij} = 1 in all other cases. Low autonomous teams are characterized by A_{ij} = 1 for all types of interactions.

Knowledge networks

The level of conflict associated with the i-th member due to the interactions in the knowledge networks is:

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where (s_i and (s_j are the opinions of the members i and j, F_{ij} models the impact of diverse functional competencies of the team members, D_j is degree centrality of the node j, i.e. a measure of the status of the member in the knowledge network.
As for the quantity F_{ij}, we assume that a disagreement between team members with different functional competences leads to a higher level of conflict ($F_{ij} = 1$) than when the two members have the same functional competence ($F_{ij} = 0.8$). On the other hand, a disagreement between two members with different functional competences but belonging to the external networks influences less on conflict ($F_{ij} = 0.8$), than in the case of same functional competence ($F_{ij} = 1$).

A central agent in the knowledge network is an individual who provides support in terms of knowledge to the other members. In particular, we assume that when the individual i is in disagreement with a high central member, the level of conflict increases at a greater extent. D_j is computed through the eigenvector degree centrality[64].

Summarizing, the total impact on the level of conflict of the individual i is given by summing up Eqs. (2), (4).

Simulation of the opinion formation process

We assume that at the beginning each member expresses an opinion concerning the decision. The opinions of members within the organizations and the team are generated by drawing at random from a uniform distribution. The interactions among individuals in the social networks exert an influence on each member that may cause he/she to modify his/her opinion as described above. For each member i the probability of changing the opinion is given by (1), where ?E_i is the difference between the level of conflict which would be obtained if the individual changed his/her opinion and the actual level of conflict. The social temperature T introduces a degree of randomness in the behavior of the members of the team, which models the environmental uncertainty: the higher the uncertainty the higher the temperature T. All team members and the members of the organizations change their opinion following Glauber’s dynamics. In the case of a project manager with a direct leadership behavior, we set the probability that the PM changes his/her opinion to zero.

The simulation proceeds as follows. At each time step an individual i is chosen at random. The probability that the individual i changes his/her current opinion is computed using (1). Then, a random number z is drawn from a [0,1] uniform distribution. If $z < p_i$, the individual changes the opinion, otherwise the current value is kept. At each time step the standard deviation of the opinions of all team members and the dispersion of the opinion of the members of the original organizations are calculated. The simulation proceeds step-by-step until, after a certain number of steps, the opinion dispersions become stationary.

Table 2 summarizes how the diverse team organizational variables are coded in the simulation model.

Table 2

The code of the team organization variables	
Organizational variable	**Coding variable**
Centralization of authority	Existence of project manager
Leadership behavior	Project manager’s probability to change opinion
Level of independence	A_{ij} where i is a team member and j a member of the organization

Simulation analysis and results

A simulation analysis is conducted to explore how the density and connectivity of the knowledge network related to the team consensus outcome in different team organizational structures and different uncertainties of the environment. Four different team organizational structures are modelled (Table 3). Two social temperatures T = 4, 16 are considered.

Table 3

The model of the team organizational structures				
	Autonomous – EPM	**Autonomous – DPM**	**Heavyweight**	**Functional**
Centralization of authority	Two-level hierarchical team network	Two-level hierarchical team network	Two-level hierarchical team network	One-level hierarchical team network
Leadership behavior	p(change)	p(change)=0	p(change)=0	p(change)
Degree of independence	A_{ij} = 0.2	A_{ij} = 0.2	A_{ij} = 1	A_{ij} = 1

The organization size is set $N = 40$ members, arranged in four hierarchical levels and three units per level. The team is characterized by a size $S = 8$. The team hierarchical network is defined according to the team organization structure. Four density values of the team network have been chosen, ranging from *0.6* to *1*, by changing the average number of links K. The external knowledge networks have a fixed value of $K = 2$.

The total number of simulated scenarios is *16*. For any given scenario the simulations are replicated *1000* times for different randomly chosen initial states, and the final performance is computed by averaging the value of the dispersion of team member opinions across the replications.

Results: the effect of density and connectivity on consensus outcome

Low environmental uncertainty

Figure 4 shows the opinion dispersion as a function of the network density, for each team organizational structure and for random and scale-free connectivity.

In the case of random connectivity, increasing the density of knowledge network may lead to a reduction or to an increase of the team member opinion dispersion, depending on the team organizational structure. For autonomous teams with empowering leader (A-EPM) and for functional teams (Functional), increasing the density causes a reduction of the opinion dispersion, because of the stronger influence exerted on each team member (Figures 4a and 4c). In the case of autonomous teams led by a PM with a direct leadership behavior (A-DPM) and for heavyweight teams (Heavyweight), the opposite effect is observed (Figures 4b and 4d]. In fact, two driving forces coexist: on one hand the presence of the strong leader tends to drive the team member opinions towards her/his opinion, on the other hand the stronger influence among the individuals may lead a significant part of the members to converge to an opinion different from the one of the leader. This results in a final increase of opinion dispersion. Interestingly, in the case of scale-free networks, increasing density always leads to a reduction of the team opinion dispersion (independent of the team organizational structure). In free-scale networks, indeed, only a few nodes have a high number of links, whereas the majority of the team members has a significantly small number of links. Therefore, the leader has, on the average, a small number of connections, which strongly limits his/her influence on the final degree of consensus: the majority of team members will tend to reach a higher level of agreement leaving out, eventually, only the leader with his/her opinion.

As to the effect of the connectivity, in all cases scale-free networks show the worst performance, since, in this type of network, a large fraction of nodes is weakly linked (few connections) to the other nodes, and, therefore, receives a scant influence from them. Therefore, a large number of nodes do not converge to a common opinion but randomly change their opinion driven by the social temperature *T*. It is worth noticing that A-EPM teams are less vulnerable than other team structures to the negative effects of the scale-free pattern. In this case, the performance difference between random and scale-free networks is smaller.

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Fig. 2: Team opinion dispersion for S=8 and low uncertainty T=4

High environmental uncertainty

Figure 5 shows results in the case of high social temperature *T=16*. The high temperature makes almost negligible the differences between the performance of diverse organizational team structures and network patterns. This is expected because high uncertainty tends to destroy order, thus leading to an almost completely random behavior of team members.

However, we still observe that increasing the density causes a small reduction of the team opinion dispersion in all cases.

As to the effect of the connectivity, also in this case scale-free networks show the worst performance, since a large fraction of nodes is weakly linked (few connections) to the other nodes, and receives a scant influence from them.

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Fig. 3: Team opinion dispersion for S=8 and low uncertainty T=16

Comparison across the team organizational structures

Random network

Our results show that in contexts characterized by low uncertainty (Figure 6a), the best organizational structure is the autonomous team with an empowering leadership behavior of the PM (A-EPM). The functional team performs similarly, whereas the heavyweight and the autonomous teams (which are both characterized by the presence of a direct leadership behavior of the PM) show the worst performance. In fact, in order to achieve a high level of agreement, it is important that all members are allowed to change opinion while converging to a common idea. In the case of a PM with a direct leadership behavior this condition is not fulfilled and the final agreement is low. For functional and A-EPM teams all members may change idea, communicate with each other and share opinions. However, the empowering PM further improves the performance as he/she stimulates the convergence towards a common opinion.

For high uncertainty (Figure 6b), the teams characterized by the presence of a PM (A-EPM, A-DPM, and Heavyweight) show the best performance. At high temperature, team members follow a chaotic behavior, and the existence of a team leader is beneficial, as it introduces order into the system. The functional team is the worst performer because it is characterized by the absence of the project manager.

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Fig. 4: Comparison among the diverse team organizational structures in the case of random networks

Scale-free network

In the case of low uncertainty (Figure 7a), the best organizational structure is the autonomous team with empowering PM (A-EPM), while the worst one is the autonomous team with a PM adopting a leadership behavior (A-DPM).

For high uncertainty (Figure 7b), although differences between different structures are very small, the heavyweight appears to perform better. As observed above, a strong leader is beneficial when uncertainty induces chaotic behavior of team members because he/she is able to drive the team towards his/her personal opinion. Functional teams show the worst performance independent of the density values: the absence of a leader determine the conditions for which the chaotic behavior induced by uncertainty propagates inside the team, worsening the performance.

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Fig. 5: Comparison among the diverse team organizational structures in the case of scale-free networks

Discussions, Conclusions, and Limitations

Social interactions are important mechanisms explaining how teams behave when making collective decisions on how to accomplish a task in scenarios characterized limited information. In such a case, team members tend to rely on the opinions of the interacting individuals and to change their own one, to reach a shared solution and a high agreement among the team members.

Our study makes an important contribution to team research, as it investigates how the organizational structure and the density and connectivity of the knowledge network relate to team performance, the latter measured in terms of consensus among the team member opinions. We confirm that the density of the knowledge network relates to team performance and that the organizational structure moderates this relationship. We found that increasing density mostly plays a beneficial effect on team consensus, but we also identified circumstances under which the opposite effect holds true. This result confirms most of research literature, which reports a positive effect of the density on team performance[7,10,11,41,42,43,44,71,72,73,74],but also explains why in some cases the positive effect of the density of the team social networks was not found[8]. In particular, we showed that, in environments characterized by low uncertainty (such as for teams involved in NPD projects concerning mature technology or incremental innovation) increasing density is detrimental for team performance, when the team knowledge network is characterized by a random connectivity, the team is characterized by a centralized authority and led by a strong leader with a direct leadership behavior. For a scale-free connectivity, increasing density is beneficial whatever the team organizational structure is, but the extent of the positive effect is lower in the case of heavyweights teams.

Our study also shed light on how the connectivity of the knowledge network relates to team performance. We extend results of previous research, which has mainly focused on the centrality of social networks[8,9]. Similarly to the results reported in Oh and Jeon[48], which investigated the effect of connectivity of the social network community on the herding behavior, we found that the scale-free connectivity is detrimental for team performance both in low and high uncertain environments, compared to the random one. While the highly connected members converge to a common opinion, all the others, being poorly connected, receive a scant influence and change their opinion at random, driven by the level of uncertainty, thereby maintaining a high level of disagreement inside the team.

A further contribution of our study concerns the organizational team design. We extend previous works on the topic by taking a social network perspective and identifying the best team organizational structure, which offers the highest performance under several circumstances characterized by two social network features of the knowledge network (density and connectivity) and diverse environmental uncertainty. We found that for teams involved in projects characterized by low environmental uncertainty (for example in the case of NPD projects involving mature technologies and incremental innovations), the choice of the organizational structure is not influenced neither by the density nor by the connectivity of the team knowledge networks. In such low uncertain contexts, the best organizational structure is the autonomous team led by an empowering project manager, able to rely and exploit the competencies and opinions of all the members. This result is consistent with previous studies concerning the effect of a leadership behavior on team effectiveness. For example, Tost et al.[51] recognized that formal leaders having strong power can hurt team performance, because they dominate team interactions and are not open to others' input, thus reducing the openness of team communication and the sharing of the opinions among team members. Similarly, Sivasubramaniam et al.[70] find confirmation of the negative effects of team leadership on group cohesiveness.

For teams involved in projects characterized by high environmental uncertainty (innovative technologies and radical innovations), we found that the best team organizational structure strongly depends on the type of connectivity of the team knowledge networks. Random connectivity calls for autonomous teams with a project manager adopting a direct leadership behavior, regardless of the density, because he/she is particularly valuable to drive the team towards a common opinion, when the team members chaotically behave. This result contributes to explain why, in disagreement with Tost et al[51], some studies found that one of the strongest determinants of NPD team performance is the use of team led by a strong project leader[49,75,76,77]. Scale-free connectivity calls for the presence of the project manager independent of density and connectivity.

Based on the arguments mentioned above, we recommend empowering project managers for guiding projects in case of low uncertainty, but in the case of new technologies or radical innovation projects, associated with high degree of uncertainty and conflict, a strong leadership behavior of the project manager should be preferred. In such contexts, adopting socialization mechanisms is beneficial for increasing team performance. For example, in the NPD projects concerning mature technologies or incremental innovations we recommend caution in increasing density in presence of a project leader with strong leadership behavior. Managers should also consider the possibility to modify the type of connectivity of the team knowledge networks and push towards the creation of more symmetric and democratic links among team members. Rivkin and Siggelkow[78] suggest a similar strategy as an effective way to improve complex systems performance.

This study presents some limitations. It is based on the assumption that a high consensus among team members could worsen team performance, in agreement with studies highlighting the existence of a negative relationship between the level of conflict in team and team performance. The degree of team consensus however may be not related to the quality of the decision[79,80] and could be high consensus on very poor decisions. We intend to introduce this aspect in the future research. Moreover, even though the decision-making problem is framed as a set of decisions, we do not explicitly model each of them and assume that each decision can take only two values. This strong approximation, needed to implement the Ising approach in a relatively easy way, will be relaxed in the future steps of this research. In particular, we would like to model more explicitly the decision variables and give to each of them more options.

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