A Gendered Analysis of Leadership
in Enterprise Social Networks

Giorgia Di Tommaso, Giovanni Stilo, Paola Velardi

Department of Computer Science
Sapienza University of Rome, Italy
{ditommaso,stilo,velardi}@di.uniroma1.it

Abstract

The present study is concerned with the analysis of women's leadership in a less formal work environment, such as an enterprise social network. Our aim is to answer the following research questions: *RQ1: Are Enterprise Social Networks a conductive environment to support the emergence of women informal leadership? RQ2: If answer to RQ1 is positive, do women actually exploit this opportunity?*

Problem statement and methods

According to (Grimsley 2015) informal leadership is *"the ability of a person to influence the behavior of others by means other than formal authority conferred by the organization through its rules and procedures"*. In the context of our research, "other than formal authority" is the environment provided by an on-line enterprise social network (ESN): we refer to this specific kind of informal leadership as *network leadership*. Network leadership is especially important since more and more companies are adopting ESNs as a tool to increase their productivity through better communications, collaboration and knowledge sharing (Fidelman 2013).

To study network leadership in ESNs, we defined a methodology which draws on organization theory and on a computational model based on multiplex networks. This model, along with a social network analysis toolkit developed in the context of the present study[1], enables the systematic empirical analysis of social behaviors in a three-years dataset of message threads exchanged within a large multinational enterprise, Reply, as a function of gender, roles, and discussed topics. We also analyzed a smaller, yet very popular, enterprise dataset known as the Enron dataset (Klimt and Yang 2004). Both use cases confirm the main findings of this study: i) women are very active and exhibit leadership, technical competence and ability to connect communities to a greater extent than what would be expected given their lower representativeness, both in terms of absolute numbers and roles; ii) males, especially managers, have a tendency to create closed circles and they exhibit role homophily more than

[1]http://www.progetto-fiordaliso.it/

gender homophily, while women are gender homophilous but are less sensible to roles; iii) women are equally active in technical and organization topics, thus contradicting the stereotype that women are less competent than men in technical subjects.

Network leadership has been commonly analyzed in terms of *bonding* and *bridging* (Daly 2011), where bonding ties are the edges in a social network connecting an individual with other actors in the network, while bridging ties are those connecting otherwise isolated groups or communities within the network. Network leadership indicators have been related to the notions of *centrality* and *brokerage* (Brass 1992) (Burkhardt and Brass 1990) (Daly 2011), respectively measured with reference to an actor's bonding and bridging capabilities. Scholars hypothesize that highly central leaders have "increased influence over the network due to access to multiple resources and the potential to create new linkages that may enhance social capital" (Balkundi and Kilduff 2006), and that leaders with a high brokerage capacity are able to go beyond their "power circle" and play an important coordination role. We may conclude that, in sociological literature on network leadership, effective leaders are identified as those who are both prominent actors within their entourage and able to perceive the existence not only of their surrounding ties but also of ties connecting other groups (*network leadership = centrality + brokerage*).

In agreement with these studies, we model network leaders as those individuals showing a high degree of both *centrality and brokerage*. The Network Leadership Rank is defined as follows: $NLR(u) = \alpha_1 LCR(u) + \alpha_2 LBR(u)$ where $LCR(u)$ and $LBR(u)$ are the *leadership centrality and brokerage ranks* of an employee u. The coefficients α_1 and α_2 balance these two qualities. We here set $\alpha_1 = \alpha_2 = 0.5$ however these coefficients, as well as any other parameter in our model, should be set in agreement with managerial strategies of a company, as a complementary support for decisions on career advancements. To model leadership centrality LCR, we defined a measure which draws on organization theory and on a multiplex formulation of PageRank. In the multiplex network, three interaction layers are considered, modeling respectively *empowerment, collaboration* and $trust$, where empowerment takes into account the tendency to start discussion threads and involve co-workers in the decision process, collaboration is the will-

	2012	2013	2014
# active users	932	1367	2085
% active females users	23%	20%	21%
# and % of active executives (males and females)	264 (28,3%)	346 (25,3%)	435 (20%)
% active female executives	25,3%	25%	**41,3%**
#threads (of which, with at least one comment)	13625 (4113)	18727 (4043)	19356 (4001)
%threads (with comments) started by females	15%	24.5%	**25 %**
#comments	20272	17187	16560
% female comments	17.9%	27.3%	20%
% females in top LCR	23%	23%	**7%** (22%)
% females in top LBR	**26%**	**27%**	**32%**
% females in top NLR	**33%**	**36%**	19%(**41%**)

Table 1: Summary data for the TamTamy network

ingness to answer messages and contribute to a discussion, and trust considers explicit expressions of agreement with a colleague, such as $likes$. Details on this model are provided in (Di Tommaso, Stilo, and Velardi 2017). The brokerage rank LBR is based on the KPP-NEG algorithm (Borgatti 2006). To analyze discussion topics, we automatically classified the content of exchanged messages or threads in three macro-categories: technical (T), leisure (L) and organizational/administrative (O/A), using state of the art text mining and machine learning techniques. Since threads may belong to multiple categories, we only considered those with a "crisp" classification. Finally, to study the formation of "power circles", we compared the prior probability that an employee sends a message to a co-worker in absence of role/gender conditioning with the observed interactions.

Experiments and data analytics

The dataset used for our study is a three-year dump (2012-2014) of the TamTamy[2] enterprise social network, designed by Reply, a large international network of specialized companies in the field of digital services. TamTamy is mostly used as a business tool, to support knowledge sharing and teamwork, and is based on a thread model, much in the same style as Facebook. For every message, author, role, gender and timestamp are provided. Messages are mostly in English and Italian, with a few German threads. Overall, the TamTamy dataset includes over 50.000 threads from around 2000 different users. To the best of our knowledge, this is the largest and lengthiest enterprise dataset considered in literature: for example, the dataset used in (Cao et al. 2013) spans over only 6 months while the popular Enron dataset, used in many studies, includes mails from only 158 users. The Enron dataset, which we used only to confirm our strongest findings, spans over two years (2000 and 2001) and includes about 2000 messages in which both sender and receiver are company members.

Table1 presents summary data (for the sake of space hereafter we only show data from the TamTamy dataset). The network leadership measures computed for individual users

are the previously mentioned LCR and LBR (Di Tommaso, Stilo, and Velardi 2017). The last three lines in Table 1 show the % of females among top LBR, top LCR and those who are both top LBR and top LCR, i.e. the *Network Leaders* (NL), according to what we stated in Section . Top leaders have been selected as those with an LBR or LCR value $v \geq avg(v) + 2 \times SD(v)$ during the analyzed period. These individuals represent more or less 6-7% of the population, which seems a reasonably selective threshold.

Hereafter, we analyze more in detail our data, with the objective of answering our two research questions.

RQ1: Are Enterprise Social Networks a conductive environment to support the emergence of women informal leadership?

To answer RQ1, we first analyze Table 1, where "interesting" values, with reference to our focus on women leadership, are highlighted in bold. The evidence that women informal leadership is higher than what would be expected given their percentage in the network (which is shown in line 2 of Table 1) is summarized in what follows:

1. Females are more authors than commenters: While the number of active females stays more or less the same during the three years (20-23%), women progressively became more proactive (female thread authors increase from 15% to 25%), and furthermore, executive (managers or partners) women became *significantly*[3] more active than their male counterpart, since active female executives have been 41% of active executives in 2014, even though female executives were 27%. These data show that, as the use of TamTamy as a collaboration tool was progressively encouraged by the company, women (especially executives) increased their empowerment ability. Instead, the percentage of female commenters shows some variability, with a peak on year 2013.

2. Females excel as network brokers: Table 1 shows that women are systematically among the top brokers (this is also confirmed in Enron). The percentage of women in top brokers is significantly higher than the percentage of active female users. Women excel in the ability to share information and their intermediary role is highlighted in the ESN.

3. Females are no different from males as central leaders: The Table also shows that women are among top central leaders proportionally to their presence (though we noted that the majority of these top leaders are placed in the highest positions of the ranking) but this percentage drops to 7% in 2014. However, as also shown in the last column of Table 1, during the first part of year 2014 the percentage of women in top leaders was more or less the same as in previous years (22%). The second semester 2014 is then to be considered an anomaly caused, as we could diagnose inspecting users' activity time series, by the sudden and total disappearance from the network of four women with top LCR, which caused a significant reduction of network connectivity. Unfortunately, the motivations for this drop-off could not be

disclosed by Reply.

4. Females top brokers are often also top central leaders: The most remarkable result is that the % of female Network Leaders(NLR) is significantly higher than the prior probability of female co-workers, except the second "anomalous" semester 2014, in which we already noted a drop in LCR. When considering the aggregated result along the three years, however, there were 47% women in the intersection between top LBR and top LCR co-workers.This is motivated by the fact that there is a high overlapping between top female central leaders and brokers, while the same is not true for males, who are either central leaders (slightly more than females) or brokers (significantly less than females), but rarely both. Note that this result is also confirmed in Enron.

Taken together, our evidence suggests that women are well aware that knowledge sharing and networking have become increasingly important activities in today's organizations (Dubrin 2011), and despite their being a minority, they play a primary role especially in engaging and connecting their colleagues. Considering the collaborative and knowledge-sharing purpose of the TamTamy network, the higher intermediary (brokerage) ability of women in such ESN reveals their distinctive inclination to participative behaviors. By and large, these findings positively answer our question RQ1, to the extent that the more "feminine" setting created by an ESN leads to the emergence of women as leader, compared to more "masculine"-oriented environments. According to our arguments, this is mainly due to the greater consistency between female leadership characteristics and the context where leadership is exhibited (Iannotta, Gatti, and Stilo 2016).

We now consider a second research question: **RQ2: If answer to RQ1 is positive, do women actually exploit this opportunity?**

We already remarked that the increased proactivity of women employees (and more notably, of executives) along the period of observation seems to demonstrate an awareness of the increased career opportunity implied by their participation in the social network. Hereafter we compare more systematically the behavior of male and female employees in the search of gender-specific behaviors.

Homophily An important aspect of co-workers interaction is homophily, defined as the tendency of individuals to associate and link with similar others. Several studies on the effect of homophily in interpersonal relations (e.g., (Sidiropoulou 2009) (McPherson, Smith-Lovin, and Cook 2001)) confirmed that homophily can also become a barrier to effective knowledge sharing, when strongly homophily-oriented individuals are not exposed to external stimuli and new experiences. In fact, while facilitating co-ordinated action by managers, homophily may adversely restrict decision-making options (Balkundi and Kilduff 2006). Therefore our first objective, with reference to RQ2, is to analyze gender homophily.

Denoting with g ($= male, female$) the gender of co-workers, we model the $g - homophily$ as the conditioned probability that a g-sender sends a message to (or comments a thread by) a g-receiver: $\frac{P(g-sender \cup g-receiver)}{P(g-receiver)}$. The null hypothesis is as follows: H0 (neutrality): *there is no statistically significant difference between the probability that a g-sender communicates with a g-receiver and the prior probability of g-sender*. H1 (homophily) and H2 (anti-homophily) are straightforward. To test our hypotheses we divide the dataset into 3-months slots and, in each slot, we estimate $P(g - sender \cup g - receiver)$ as the number of messages posted by a g-sender to a g-receiver (purging additional comments posted by the author itself), while $P(g - receiver)$ and $P(g - sender)$ are estimated by the number of such messages addressed to a g-receiver or originated by a g-sender, respectively. Next, we apply the Wilcoxon signed-rank test[4], which is a paired difference test. Since Wilcoxon test implies counting the number of times the difference between pairs is positive or negative, without considering the amount of the difference, we also compute a z-test over the full period to rank significant results (according to Wilcoxon) as highly or moderately significant. Our TamTamy data show that both males and females are homophilous (according to Wilcoxon test), however, females are considerably more homophilous than males according to the z-test: in fact, for females H1 is accepted with $p = 7.12e - 08$ while for males we obtain $p = 0.02111$ (hence $p \geq 0.01$ and H1 is rejected). Gender homophily in Enron is even stronger: the z-test shows that females are definitely more homophilous since we obtain $p = 1.392e - 05$ while for males we obtain $p = 0.001574$. These results are in contrast with (McPherson, Smith-Lovin, and Cook 2001) and with (Thelwall 2009) who did not detected substantial women homophily, however their experiments were conducted on friendship networks, representing a less formal environment than an enterprise social network. A homophily result similar to ours was instead obtained in (Szell and Thurner 2013) with reference to an on-line combat game: this type of social network is more similar to an enterprise social network than to a friendship network, since relationships are established according to confidence and competence, rather than socialization needs.

Influence of roles To assess the influence of roles, commenters and authors are partitioned in 8 categories depending upon their gender g and role r ($= executive, employees$). In this experiment, we tested all possible combinations of commenter and author. Each individual may belong to any of 8 categories: *female, male, executive, employee, female-executive, female-employee, male-executive, male-employee*, for a total of 8×8 significance tests. For example, we test if female executives have a strong tendency to comment threads authored by a female, or by an executive, or by a female executive. As before, the case for neutrality (H0) is one in which the estimated conditional probability is not statistically different from the prior probability of a *C-sender*, where C is one of the 8 categories. We here summarize only the relevant outcomes. In agreement with (Cao et al. 2013) we noted that roles do influence social relations, but this is definitively more true for males. The main result emerging from this experiment is

---

[4]https://en.wikipedia.org/wiki/Wilcoxon_signed-rank_test

	Technical	Leisure	Org/Adm
n. of classified threads	2340 (54,9%)	157 (3,7%)	1767 (41,4%)
n. of classified topics	218 (55,5%)	35 (8,9%)	140 (20%)
% females in top topic LCR	40,0 %	40,0%	40,0%
% females in top thread LCR	20,0 %	50,0%	40,0%
% females in top topic LBR	50,0 %	60,0%	50,0%
% females in top thread LBR	50,0 %	50,0%	40,0%

Table 2: LCR and LBR as a function of topic categories

that males are influenced both by gender and role: in Tam-Tamy, males executives mostly answer to male executives (H1 is accepted with $p = 1.555e − 09$) and male employees mostly answer to male employees ($p = 0.0004347$), while they are anti-homophilous towards males with a different role and anti-heterophilous towards females in general. Women instead are influenced primarily by gender since they show neutrality (H0) towards females in different roles. Furthermore, female executives are more "democratic" than male executives, since they show neutrality towards employees ($p = 0.381$) while male executives are strongly anti-heterophilous towards employees ($p = 4.006e − 08$). In Enron we obtained basically the same results (marked role homophily especially for male executives, less sensitivity to roles for females). However, the Enron data show a higher variability, and for some points in the temporal series the statistical significance is low.

Competence analysis Finally, we analyzed gendered network behavior as a function of discussed topics. Our results show that women are active also in networks dealing with very technical topics, as summarized in Table 2, referring to TamTamy. We remind that we considered only threads showing a strong membership to a single category. The first two rows of the table show, as expected, that the enterprise social networks is used mainly to discuss about technical and organization/administrative issues , while leisure topics are a minority. The subsequent rows show the percentage of women among the first top leaders and brokers in the two networks originated by the subset of classified topics and threads. The percentage of women participation in these two networks was 20,7% and 20,1%, respectively. These values represent the prior probability against which values in rows 3-6 of Table 2 should be compared. When restricting to focused topics, women leadership and intermediary skills are significantly greater than what would be expected given their minority presence in the network. These results are stronger than for in Table 1, showing that, as pointed out in several recent articles[5], women are more competent than confident. Table 2 also clearly shows that women are equally active in technical and organization topics. This is very interesting since it contradicts the stereotype that women are less competent than men in technical subjects.

With reference to RQ2, we may conclude that, though female appear to be as competent as males on the various discussion topics, either technical or organizational, they are somehow isolated by their male colleagues, who are less ho-

mophilous with reference to gender only, but are extremely homophilous towards gender and role: to say it once more with (Dubrin 2011), the "old boy's networks" have the effect of pushing women, despite their intrinsically more democratic behavior, in closed circles. Though we cannot prove that gender homophily in female co-workers is influenced by the strong role-gender homophily of males, this seems to be at least one of the causal factors, corroborated by the fact that female leaders (either executives or network leaders) are more "gender neutral", while this is not the case for male leaders.

References

Balkundi, P., and Kilduff, M. 2006. The ties that lead: A social network approach to leadership. *The Leadership Quarterly* 17:419–439.

Borgatti, S. 2006. Identifying sets of key players in a social network. *CMOT* 12(1):21–34.

Brass, D. J. 1992. Power in organizations: A social network perspective. *Research in politics and society* 4(1):295–323.

Burkhardt, M. E., and Brass, D. J. 1990. Changing patterns or patterns of change: The effects of a change in technology on social network structure and power. *Administrative science quarterly* 104–127.

Cao, J.; Gao, H.; Li, L. E.; and Friedman, B. 2013. Enterprise social network analysis and modeling: A tale of two graphs. In *INFOCOM, 2013 Proceedings*, 2382–2390.

Daly, A. J. 2011. Leadership and social networks. In *Encyclop. of Social Networks*. Sage, LA. 479–483.

Di Tommaso, G.; Stilo, G.; and Velardi, P. 2017. Detecting network leaders in enterprises. In *21st. IEEE CSCWD*.

Dubrin, S. 2011. Creating knowledge through networks: a gender perspective. *GWO* 18(1):90–122.

Fidelman, M. 2013. The rise of enterprise social networks. https://goo.gl/36VmJP. Accessed: Jan., 2016.

Grimsley, S. 2015. Leadership: Definition and Explanation. https://goo.gl/FXyQUU. June, 2015.

Iannotta, M.; Gatti, M.; and Stilo, G. 2016. Leveraging the enterprise social network for the emergence of women?s leadership. In *32nd EGOS colloquium*. SAGE.

Klimt, B., and Yang, Y. 2004. Introducing the enron corpus. In *CEAS*.

McPherson, M.; Smith-Lovin, L.; and Cook, J. M. 2001. Birds of a feather: Homophily in social networks. *Annual review of sociology* 415–444.

Sidiropoulou, A. 2009. Homophyly and interpersonal ties as facilitators of knowledge sharing. *Master thesis* 91.

Szell, M., and Thurner, S. 2013. How women organize social networks different from men. *Scientific reports* 3.

Thelwall, M. 2009. Homophily in myspace. *JASIST* 60(2):219–231.

---

[5]among which https://goo.gl/Kasybl