

"Mirror, mirror on a chip – tell us who's the most hip..."

The Virtual Mirror: Reflecting on Your Social and Psychological Self to Increase Organizational Creativity

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Abstract

This pioneering study describes preliminary research on how combined analysis of social and psychological self might increase organizational creativity. By measuring inter-human interaction with sensor-equipped tags worn on the body we studied social interaction in a much closer, “microscopic” way than ever before. In a research project with 22 study subjects, who wore the badges during work for one month, we were able to predict social and psychological characteristics such as extroversion, neuroticism, openness, and agreeability based on microscopic social network analysis. We obtained control measures of these values with a standard psychological test (NEO-FFI) and found that a high contribution index was positively correlated with extroversion, and negatively correlated with neuroticism. Fluctuation in betweenness centrality was positively correlated with openness, and negatively correlated with agreeability. We were also able to obtain correlation between social network position and job satisfaction, and extroversion. On the practical side, our project offers preliminary results towards permitting organizations to realign their social structures to increase organizational creativity and effectiveness. On the theoretical side, this paper provides first insights into how social network analysis on the microscopic level might influence organizational research.

1. Introduction

While social network analysis has been applied in different disciplines for more than six decades, there has been renewed interest recently in network research in management science, due to a general shift away from individualist, essentialist and atomistic explanations toward more systematic, contextual and relational understandings (Borgatti & Foster 2003). Past work on idea creation and organizational success has focused on user innovation and the quality of the idea itself (Goldenberg et. al 1999, 2001, Goldenberg & Mazursky 2002). Recently, the relationship between network structure and organizational and individual performance has emerged as an important focus of this research (Katz et al. 2004). Granovetter's (1985) work about the embeddedness of individuals in social networks initiated a revival of social network analysis in management theory and research. Furthermore, the increasing formalization and quantification of social network analysis, as well as the wide availability of computing power, fostered works that examined the relationship between social network structure and group performance (for a review see Borgatti & Foster 2003).

Consequently, much recent work has examined the relationship between quantitative measures on group performance. The two most common measures employed in this kind of analysis are *centrality* (e.g. Baldwin et al., 1997; Balkundi & Harrison, 2006; Brass, 1981; Tsai, 2001), and *density* (e.g. Balkundi & Harrison, 2006; 2005; Reagans & Zuckerman, 2001; Reagans et al., 2004; Sparrowe et al., 2001). Many findings from these studies have conflicted, however. For example, Balkundi and Harrison (2006), Raz and Gloor (2007), Cross and Cummings (2004), and Cummings and Cross (2003) find in their meta-analysis that teams with central leaders in the intra-team network perform better, as well as teams that are more central in the inter-group network. On the other hand, some authors obtained results that showed the opposite. For example, Boyd & Taylor (1998) state that a higher centrality of group leaders results in a lower performance because of the high costs associated with maintaining many relationships. Also Sparrowe et al. (2001) find a negative relationship between advice network centrality and group performance. Sparrowe et al. (2001) find that an actor's individual job performance is positively related to centrality in advice networks and negatively related to centrality in hindrance networks.

In this paper we introduce a modern-day version of the magical mirror of the evil stepmother of

snow white. Using a body-worn sensor network we measure physical interaction of co-located people. The “virtual mirror” permits individuals to map their self-image to the image that their environment has of them, reflecting back to the individual their own personal social and psychological characteristics. This “virtual mirror” helps people to better understand who they are, By repositioning people based on their social and psychological strengths – while respecting individual privacy – permits an organization to make much better use of their talent pool.

Our approach—using social badges that automatically collect data on interactions—addresses these shortcomings by providing a new and richer method to capture the interaction of peers in a social network.

2. Methodology

We analyzed social interaction among a team of 22 employees at a bank in Germany. For the period of one month they were wearing social badges developed at the MIT Media Laboratory (Olguin Olguin et al. 2007), which allowed us to measure the relative location and behavioral characteristics—such as gestures and tone of voice—of their wearers. The social badges combine infrared sensor interaction, bluetooth location measurement, measurement of body movement by accelerometer, and voice and pitch detection. We construct social networks by collecting location and directionality of the wearers’ interactions multiple times per second. To analyze the social networks, we use our Condor software tool, formerly known as TeCFlow, which generates dynamic visualizations of social networks by mining communication archives such as e-mail, phone logs, and blogs (Gloor and Zhao 2006) or—as in this case—social badge logs. Using Condor we conducted a microscopic dynamic social network analysis by collecting social badge interaction – collecting social interaction information on the individual actor level permitted us to zoom in on individuals as with a microscope. Besides the microscopic sensor data we also gathered e-Mail data of the bank employees directly from the bank’s mail server.

This automatically accumulated social network data was complemented by various self-administered surveys of study subjects. They reported their daily assessment of their productivity and satisfaction with their own work. In addition, we assessed their personality characteristics.

To obtain an objective measure of personality traits, we used the Revised NEO Personality

Inventory, or NEO PI-R, a psychological personality inventory. It is based on a five-factor model: Extraversion, Agreeableness, Conscientiousness, Neuroticism, and Openness to Experience. The test was developed by Paul T. Costa, Jr. and Robert R. McCrae for use with adult (18+) men and women. It consists of a self-report form of 240 questions answered on a 5-point scale ranging from “strongly agree” to “strongly disagree” (Costa & McCrae 1983). *Neuroticism* measures the level of anxiety, hostility, depression, self-consciousness, impulsiveness and vulnerability to stress. *Extroversion* measures warmth, gregariousness, assertiveness, activity, excitement seeking, and positive emotion. *Openness* measures an individual’s openness towards fantasy, aesthetics, feelings, actions, ideas and values. *Agreeableness* measures levels of trust, straightforwardness, altruism, compliance, modesty and tendermindedness. The last criteria *conscientiousness* assesses an individual’s competence, order, dutifulness, achievement striving, self-discipline, and deliberation.

It should be pointed out that the concept of extroversion as introduced by Costa and McCrae is different from C.G Jung’s theory (1921). People ranking high in Costa and MaCrae’s extroversion scale also describe themselves as self-confident, energetic, communicative, talkative, cheerful and optimistic. People ranking low on the extrovert scale might be rather reserved than unfriendly, more autonomous than obedient, and more stable than insecure or phlegmatic.

The neuroticism dimension measures individual perception of negative emotional experiences. People ranking high on the neuroticism score are more easily loosing their emotional balance. They worry more, and are more frequently distressed, ashamed, embarrassed or sad. People scoring low on neuroticism, on the other hand, are more composed, at ease, secure, and even-tempered.

As our study subjects were all of German mother language, we used a 60-question German language version of the reduced NEO-PI-R called NEO-FFI (Borkenau & Ostendorf, 1993).

Figure 1 displays a radar chart with the aggregated results of the NEO-FFI completed by our study subject in relation to the representative standard values. The pink line depicts the reference values, the blue line the combined results of our study subjects (N=18). 4 team members did not complete the FFI survey.

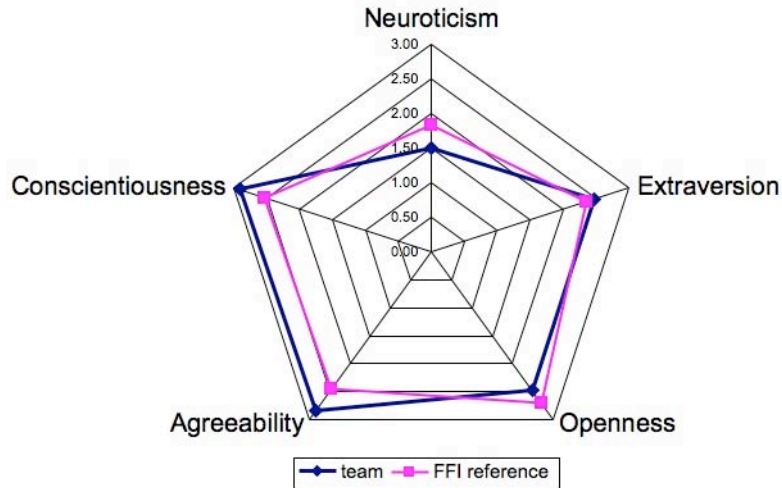


Figure 1. Experimental and reference NEO-FFI values (N=18)

We speculate that the FFI values in figure 1 might be indicative of bank employees.

Conscientiousness and agreeability of our sample off bank employees was higher than the reference values of the general population. Our bank employees were also less neurotic, and less open than the average person, while their extraversion level corresponded to the reference values.

We will now look at how these dimensions can be predicted based on how well-balanced and fluctuating face-to-face interaction and e-mail interaction among the 22 employees is.

3. Measuring Extroversion and Neuroticism

In our first experiment we found a correlation between extroversion and neuroticism of actors and the frequency and directionality of the physical interaction with each other. This interaction was measured by the infrared sensor readings of the actors' social badges. Whenever an actor was facing another actor within a distance of approximately less than 1 meter, his/her infrared sensor would pick up a reading. The most frequent scenario for this was when two actors were speaking to each other. These reading are not necessarily symmetrical, however, because actor A might be facing actor B, while actor B was not looking at actor A. In this case A's social badge will report an interaction, B's infrared sensor, however, will not pick up the signal from A's social badge. Just sitting opposite to a colleague in office generally will not cause an infrared reading since the line of sight in all cases was blocked by computer monitors.

The y-axis of figure 2 shows the accumulated contribution index readings of the infrared sensors of the 22 research subjects. The contribution index has originally been defined for e-mail (Gloor et. al, 2003), for each actor it is $(\text{number of messages sent} - \text{number of messages received}) / (\text{number of messages sent} + \text{received})$. In this case it is defined as numbers of infrared readings picked up by an actor. The higher the value, the more signals an actor picks up. A contribution index of 1 means that an actor looks at other people and is never looked at, while a contribution index of -1 describes an actor who is only looked at while never looking another actor squarely into the face. The x-axis of figure 2 depicts overall activity of an actor by showing his/her accumulated infrared readings over the entire observation period. The more infrared signals an actor picks up or is being picked up in, the farther to the right is her/his location.

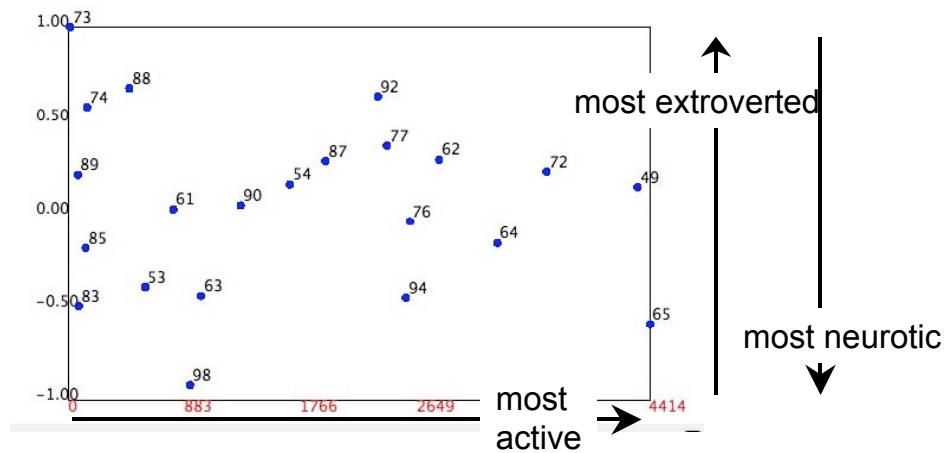


Figure 2. Contribution index predicts extroversion and neuroticism

Based on the definition of extroversion given in the previous section, we speculate that the more one person looks at others, the more she/he is an extrovert. This means that the higher somebody's contribution index, the higher the likelihood that she/he is an extrovert. On the other hand, based on the definition of neuroticism, we can also speculate that neurotic people will not look at others when they talk to them, or in other words, the lower somebody's contribution index, the higher his/her level of neuroticism.

	Neuroticism	Extroversion	Openness	Agreeability	Conscientiousness
CI	-0.73**	0.52*	0.08	-0.13	-0.12
R ² (Adj)	0.5	0.21	-0.06	-0.05	-0.05

Table 1. Correlation of 5 FFI values with contribution index (CI). (+p<0.1 * p<0.05 ** p<0.01)

As table 1 illustrates, there is indeed positive correlation between the contribution index, and extroversion as well as strong negative correlation between neuroticism and contribution index. Note that while in general there is negative correlation (-0.33) between NEO-FFI assessed neuroticism and extroversion, we found even stronger negative correlation (-0.39), although it was not very significant (p=0.13). As expected, we did not get further correlations between the other three FFI dimensions openness, agreeability, and conscientiousness and the contribution index.

4. Correlating Social Network Position and Subjective Perception of Job Satisfaction with Extroversion

Based on the FFI definition of extroverts and introverts in the previous section, we introduce a new extroversion coefficient E_s , using the self-reported daily satisfaction ratings of actors. At the end of each workday, each actor reported on a scale of 1 to 5 her/his self-assessment of (a) personal productivity, (b) level of satisfaction, (c) amount of work done, and (d) level of collaboration on the particular day. E_s is based upon the idea that extroverts, i.e. people who are self-confident, energetic, communicative, talkative, and cheerful should be happier on a day when they have had plentiful communication, i.e. when they have been more central networkers. Introverts, on the other hand, that is people who are reserved, autonomous, and stable should feel more productive and happy on a day with less communication, i.e. where they have had less betweenness centrality. This means that the average of self-productivity and satisfaction ratings (a) to (d) and the social network position of an actor (i.e. her/his betweenness centrality) should be positively correlated for extroverts and negatively correlated for introverts. E_s is therefore defined as follows

$$E_s = \text{Pearson coefficient (daily self productivity ratings/betweenness)}$$

We found that E_s is indeed strongly correlated with the extroversion dimension of NEO-FFI (Corr=0.64, adj R sq= 0.36, $p=0.02$). Not too surprisingly, E_s is also somewhat correlated with the contribution index of an actor, although the correlation is less strong (Corr=0.44, adj R sq=0.12, $p=0.13$).

5. Measuring Openness and Agreeability

In prior work (Kidane & Gloor, 2006) we have found a clear separation between high executing and highly creative knowledge workers: high creativity of an actor correlates with fluctuating betweenness centrality over time, high performance correlates with steady betweenness centrality. In other words, a person with a stable communication structure relative to other team members is better suited for high-executing, more repetitive tasks, while a person with changing communication structures is better suited for creative work. There is also a strong argument to be made for causality being the reverse: people who are more creative might choose to vary the amount of communication in which they engage. For instance, they might intentionally isolate themselves during certain phases of their creative work, leading to fluctuating betweenness centrality. Either way we therefore speculate that people with fluctuating betweenness centrality have higher levels of NEO-FFI openness, i.e. they are more open for new fantasies, actions, and ideas. On the other hand, a person with a more steady betweenness pattern might score higher on agreeability, defined as straightforwardness, altruism, compliance, and modesty in NEO-FFI.

Figure 3 illustrates that department members display widely different communication patterns. The betweenness curves of the actor in the top right window with strong fluctuations both in e-mail and face-to-face (infrared-measured) interaction is an indicator for creativity, the steady pattern of the actor in the lower left window is indicative of a person communicating very little. Comparing the communication patterns of all 22 actors permits us to make a separation between “more agreeable high executors“ and “creatives“ based on the number of local maxima and minima in their betweenness curves. We initially also tried other measures of fluctuation such as variance, unfortunately they did not show correlation with the FFI properties.

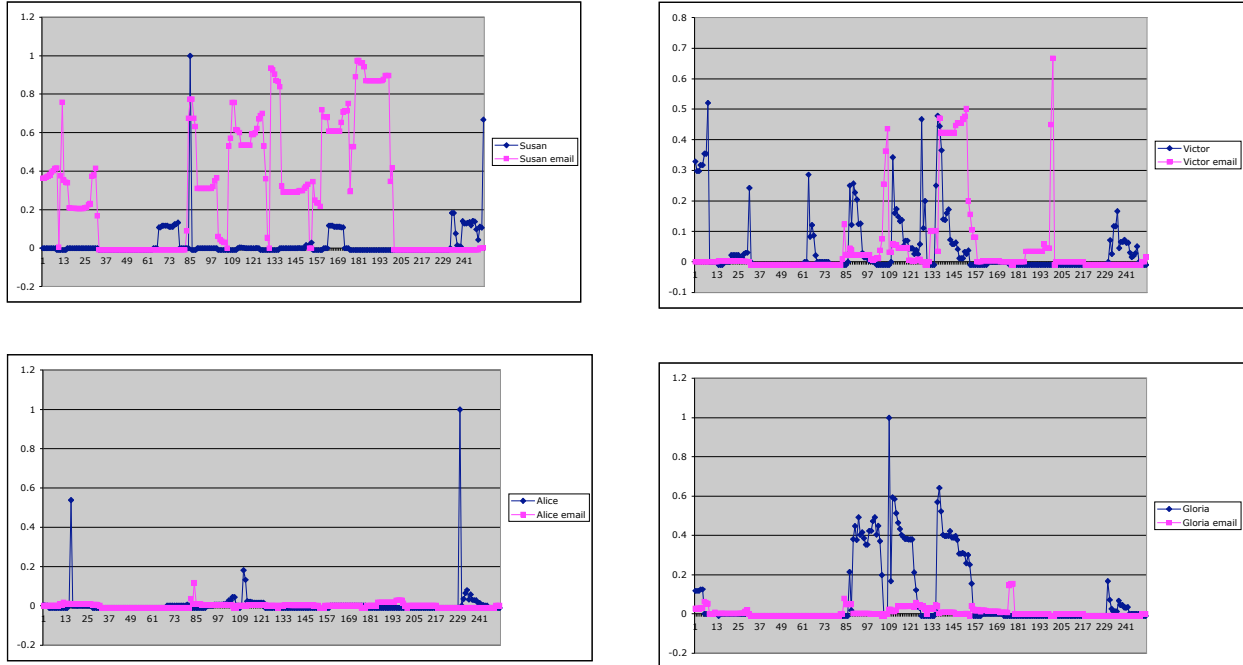


Figure 3. E-mail (purple) and IR/face-to-face (blue) temporal betweenness values of different actors

In our analysis we found correlations between openness and rapidly changing social network position of an actor as measured in fluctuation of actor betweenness centrality ($\text{corr}=0.59$, $\text{adj R sq}=0.3$, $p=0.017$). Note that the social network where we are counting the number of local maxima of actor betweenness centrality is combined of face-to-face and e-mail interaction, as new and creative ideas are exchanged both face-to-face and over e-mail. What this means is that the more an actor changes between being highly central at one time and then being less central the next few hours, the higher is his/her openness for new ideas.

We also found negative correlation in fluctuation of actor betweenness centrality and actor agreeability ($\text{corr}=-0.54$, $\text{adj R sq}=0.24$, $p=0.03$). What this means is that the more the position of actors fluctuates in the group social network, the less agreeable they are. Highly agreeable actors have a more stable communication structure. Again, for our analysis, we combined the e-mail social network with the face-to-face network obtained through infrared sensors, because negative and positive interaction happens both face-to-face and over e-mail.

It should be pointed out that while the correlation of the FFI between agreeability and openness is given as almost non-existent (0.07) (Borkenau&Ostendorf, 1993), we obtained for our sample a stronger negative correlation of -0.26 , which was not significant however ($p=0.33$).

6. Comparing Social Network Position and Extroversion

In this section we rely on a visual analysis of the social networks using the social networking Condor software tool. First we looked at the social networking structures of extroverts. We tried to find correlations between individual network position as measured and actor betweenness centrality. While we obtained a correlation between actor betweenness centrality and some FFI dimensions, it was not significant. Empirically, however, we found that the network position of the “extroverts” is more peripheral than that of the “neutrals” and the “introverts”. As our sample was small ($N=16$) we were not able to obtain mathematically significant results. The visual analysis with Condor produced some interesting insights, though. As figure 4 illustrates, less extroverted people (yellow and black nodes) are more central than strong extroverts, which are very peripheral (red nodes). Purple dots denote actors who did not complete the NEO-FFI test. We can therefore speculate that in face-to-face interactions, as measured by the infrared sensors, people prefer less extroverted people as communication partners.

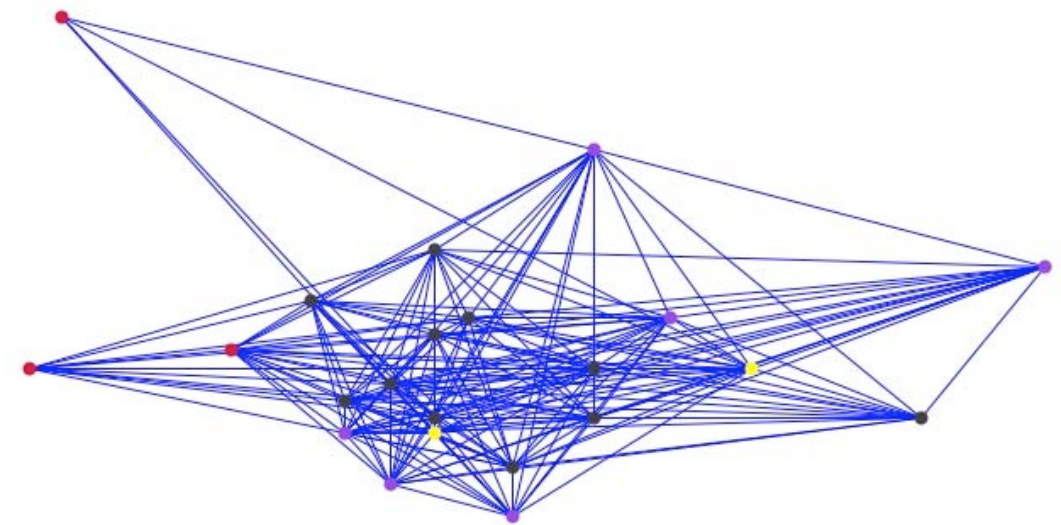


Figure 4. Social infrared network of one month, black nodes are “neutral”, red nodes are “extroverts”, yellow are strong “introverts” by FFI-Extroversion

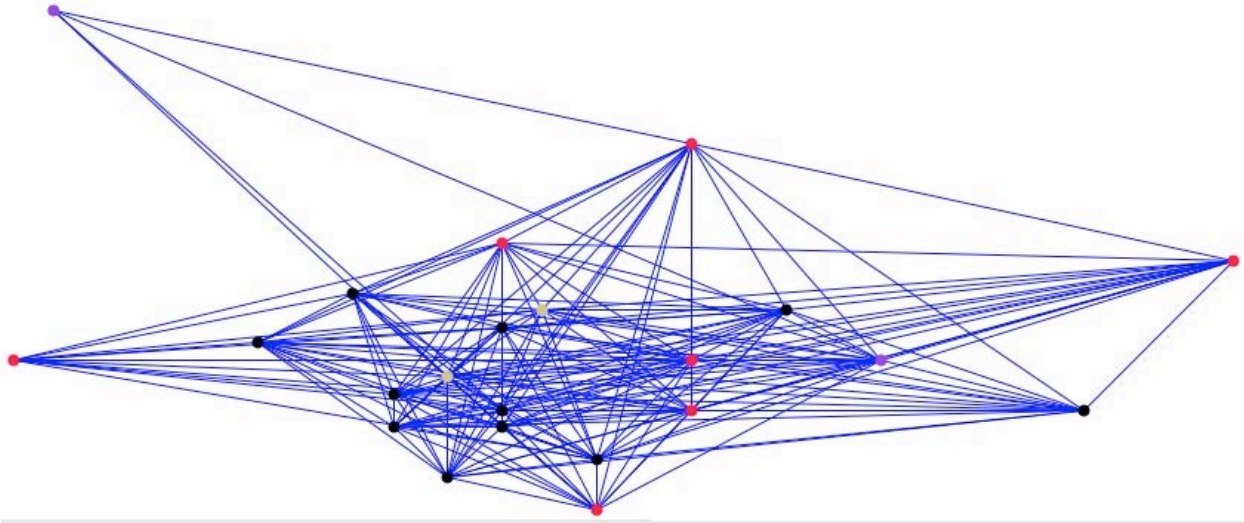


Figure 5. Social IR network of one month, black nodes are “neutral”, red nodes are “extroverts”, yellow are strong “introverts” by E_S

Figure 5 shows the same network of infrared-measured social interaction as in figure 4, this time actors are colored by their E_S . The picture is quite similar to the one of figure 4, in that introverts (yellow nodes) and neutrals (black nodes) occupy more central network positions than extroverts (red nodes).

Figure 6 illustrates individual communication collected by infrared sensors among actors as an adjacency matrix sorted by three levels of extroversion. There is a fourth category (unknown) consisting of the actors who did not take the FFI test. Not surprisingly, the two introverts talk very little with each other, but at least the first one communicates a lot with others (horizontal row), and is also sought out as a communication partner.

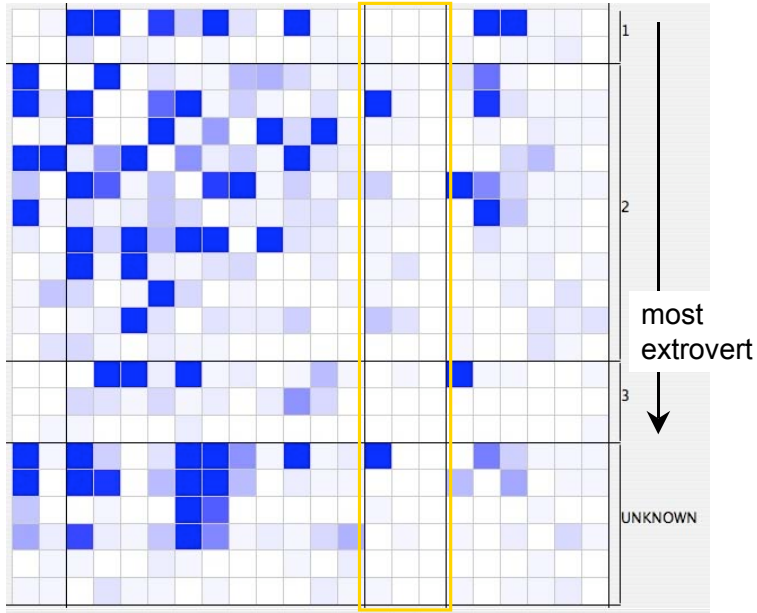


Figure 6. Adjacency matrix of actors, sorted by extroversion

Note how in figure 6 the columns in the matrix denoting communication from other team members to the three most extrovert members are practically empty. But the three most extroverted actors also communicate surprisingly little themselves. Introverts on the other side are surprisingly popular, both in being spoken to, and in communicating with others.

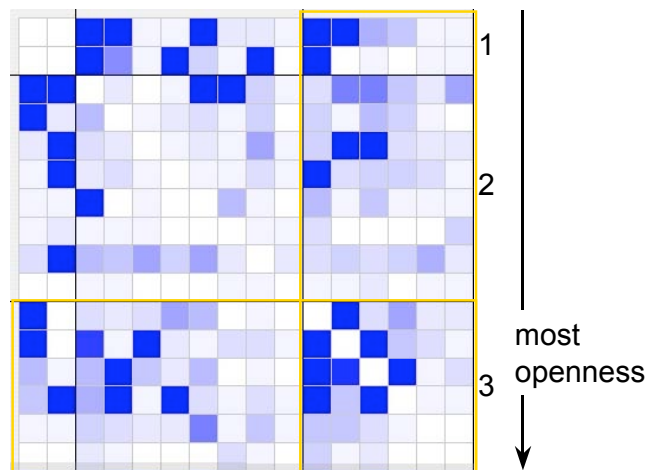


Figure 7. Adjacency matrix (e-mail & infrared) of actors, sorted by openness (N=16)

As the adjacency matrix of the combined e-mail and infrared social network in figure 7 illustrates, the more open-minded an actor is, the more does she/he communicate and is spoken

to. While open-minded people frequently communicate among themselves, they are also sought after by less open-minded people (top 2 rectangles at right in figure 6). Less open minded people, on the other hand, communicate very little, or even not at all, among themselves.

In earlier work we had already found that social network position in e-mail and face-to-face interaction may be (Allen, 1987) but not necessarily is correlated. (Grippa et. al 2006). As figure 8 illustrates, in this study we could not find a correlation between actor betweenness centralities of the e-mail networks and the face-to-face infrared-measured networks.

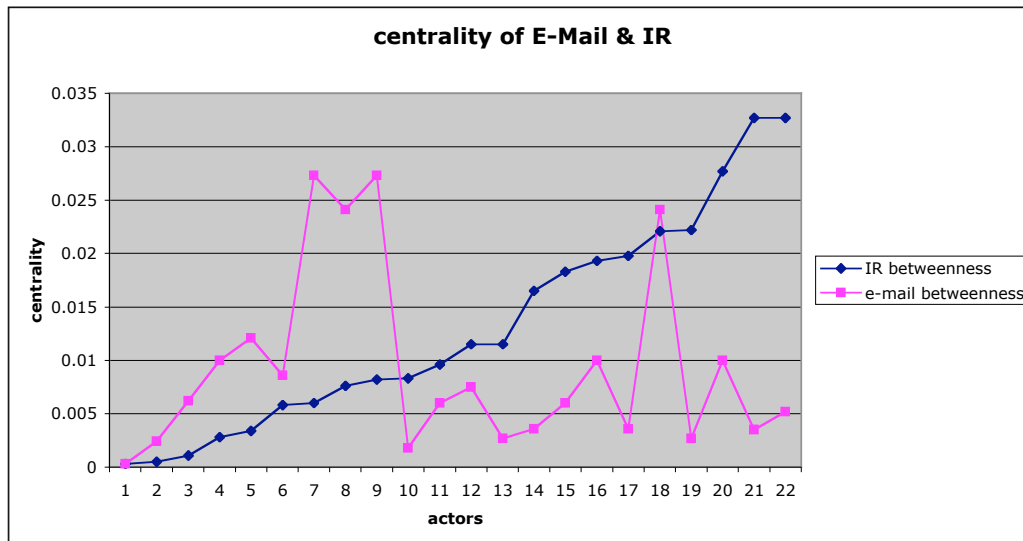


Figure 8. Actor betweenness centralities of IR (blue) and e-mail (purple) networks are different. This finding is partially supported by earlier work comparing the correlation between e-mail and face-to-face interaction (Grippa et. al 2006). There are people like actors 7 to 9, who send lots of e-mail with a continuously high e-mail betweenness, but do not talk much to the other actors, exhibiting therefore low face-to-face infrared betweenness. On the other hand, people like actors 21 and 22, who act as a true “floorwalkers”, have high infrared betweenness, but relatively low e-mail betweenness. Actor degree centralities of e-mail and infrared readings are correlated, however (Corr=0.57. adj R sq= 0.32, p=0.005). This means that the overall number of interaction partners for an actor is about the same for e-mail and face-to-face communication: an actor exchanging e-mails with many people also talked with many people, and an actor who spoke with few others face-to-face also communicated with fewer people over e-mail.

7. Discussion and Conclusions

Microscopic social network analysis can be used to complement proven psychological tests such as the FFI. It could be used, e.g. as further input to identify people suitable for certain professions, for example identifying the most agreeable candidates among potential recruits as police officers. In the long run we anticipate using microscopic social network analysis to identify optimal social communication structures and personality characteristics for more productive collaboration.

By just wearing social badges, a user will finally be able to answer question like “Do I have more of an introvert or an extrovert communication style? What personality types do I have to bring into a meeting to make it more productive? How can I change my personal communication behavior to be more efficient? What leadership styles are most effective for a certain situation?”

This paper describes first results of a project aiming to identify high-performing interaction patterns of knowledge workers by measuring social interaction at the microscopic level. The study illustrated the use of *social badges* in several work groups in a bank. Analyzing the face-to-face network is a more objective way of doing social network analysis, which permitted identification of personal characteristics of individuals such as extroversion, neuroticism, openness, and agreeability. As already noted above, further research is needed to obtain deeper insights into causality: are people with fluctuating centrality more creative because they have the fluctuating communication pattern, or is this fluctuating pattern indicative of more creative people. This work is preliminary in that our sample size of 22 team members, out of which 18 had taken the FFI test, is quite small. We therefore will want to repeat this experiment in a larger setting. We also speculate that for other nationalities, cultures, and industries our results might be different.

The long-term goal of our research is to develop a set of interventions and recommendations that can lead to better individual and organizational creativity and performance. Towards that goal, this study and its proposed methodology try to assist in obtaining insights about the relationship between attributes of individual actors such as creativity, agreeability, and openness, the overall social network structure, and organizational creativity and innovation. We hope that future research will help organizations become more innovative and productive by exploring their

hidden social structures in a virtual mirror – helping members of an organization to better understand their hidden social characteristics to improve the overall organization.

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